STATUS OF *TROGLOGLANIS PATTERSONI* EIGENMANN, THE TOOTHLESS BLINDCAT

by

Glenn Longley and Henry Karnei, Jr.

Aquatic Station
Southwest Texas State University
San Marcos, Texas 78666

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Project Leader

James E. Johnson
Endangered Species Biologist
U. S. Fish and Wildlife Service
P. O. Box 1306
Albuquerque, New Mexico 87103

ABSTRACT

Twenty-six specimens of *Trogloglanis pattersoni* Eigenmann were collected during this study. New evidence about ecological relationships is presented including current status, distribution, feeding habits, parasitism, and population levels. The study area was the Central Pool of the Edwards Aquifer in Bexar County, Texas.

This report is submitted in fulfillment of Contract No. 14-16-0002-77-035 by Glenn Longley and Henry Karnei, Jr. under the sponsorship of the U. S. Fish and Wildlife Service. The report covers the period from March 1, 1977 to May 31, 1978.

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ACKNOWLEDGEMENTS

Dr. D. G. Huffman, of the Aquatic Station, Southwest Texas State University, examined specimens for parasites. We wish to extend sincere appreciation to Mr. Richard D. Reeves, U.S.G.S. in San Antonio, for his assistance and encouragement during this study. The City Water Board and Mr. Ozzie A. Brynie cooperated by allowing us to sample a city water well. We appreciate the assistance of Mr. Richard Verstraeten and his brothers in making their wells and irrigation facilities available to us.

We would like to give special thanks to Gail Lindholm for illustrating the fishes for us.

The cooperation of Southwest Texas State University is gratefully acknowledged.

INTRODUCTION

Trogloglanis pattersoni Eigenmann, 1919 is commonly referred to as the toothless blindcat. This species is classified as indicated below:

Phylum	-	Chordata
Class	-	Osteichthyes
Order	-	Siluriformes
Family	-	Ictaluridae

This fish is presently protected under the State of Texas nongame rule 127.70.12.001-.006 under the authority of Sections 43.021 through 43.030 and Sections 67.001 through 67.005, Texas Parks and Wildlife Code. A permit is required to take this fish.

From the study of distribution patterns, population estimates, and general condition of this unique ecosystem, we are convinced that this species is not endangered. There is considerable evidence that the nearby occurrence of the "Bad Water Zone" is required for its existence.

BACKGROUND

ORIGINAL DISCOVERY AND DESCRIPTION

In 1919 C. H. Eigenmann described a new blind catfish from San Antonio, Texas. The specimen had been obtained from a well belonging to George W. Brackenridge. No date of collection was indicated in the original description (Eigenmann, 1919). Mr. Brackenridge gave the specimen to Professor J. T. Patterson of the University of Texas who sent it to Eigenmann for determination. The holotype is catalogued as No. 15240 Indiana University Museum. Eigenmann named the new fish *Trogloglanis pattersoni* (Figure 1). The generic name *Trogloglanis* is derived from (G)*Troglo* = Cave, (G)*glanis* = catfish, originally from Glanis, the name of a river. The specific or trivial name, *pattersoni*, honors Professor J. T. Patterson. This original description was very brief and was based on one specimen.

The second known specimen was caught in June, 1934 by Josef Boecke in a ditch fed by an artesian well on his farm 4.42 km east and 2.0 km north of the Alamo in San Antonio. It was an immature male, 68.3 mm in standard length. This specimen is deposited in the Witte Memorial Museum, San Antonio, Texas (Accession No. 34. 20.7.G). A much more complete description based on this specimen was included in a paper comparing the blind catfishes from Texas (Hubbs and Bailey, 1947).

The last known *T. pattersoni* collected prior to this study was caught by Mr. John E. Werler from a 1280 m deep well on the O. R. Mitchell ranch, Von Ormy, Texas, 16.43 km southwest of San Antonio. The date of collection was unknown but the specimen was received at Tulane University in 1955 (Suttkus, 1961). This specimen is in the Tulane University Museum collection No. TU10808. Suttkus provides additional descriptive information particularly regarding osteology.

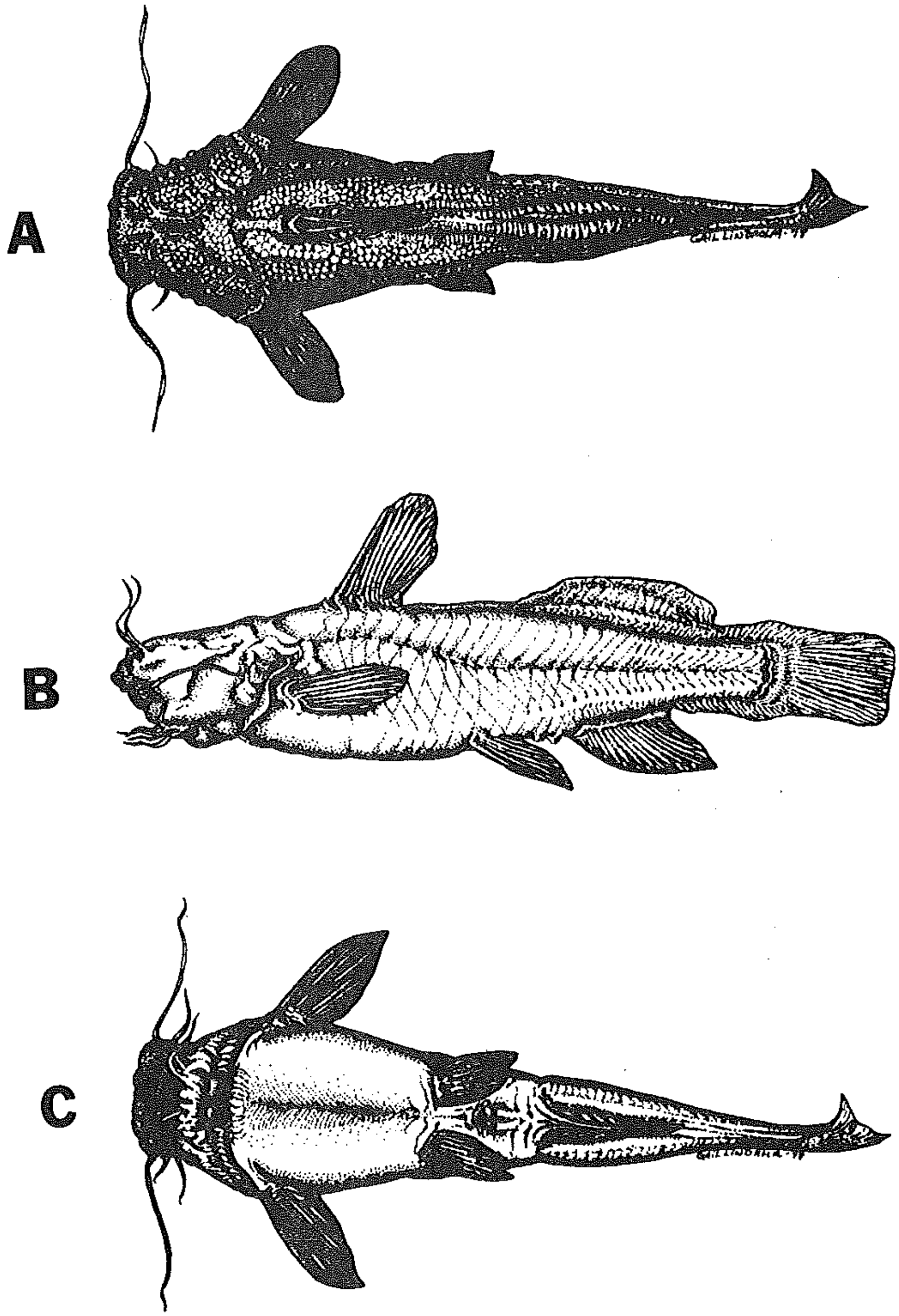


Figure 1. *Trogloglanis pattersoni* Eigenmann, standard length 87.2 mm A = Dorsal view, B = Lateral view, and C = Ventral view

TAXONOMIC PROBLEMS

The three papers mentioned contributed to the description of *T. pattersoni* and they also included proposals regarding the taxonomic relationships of this species to known surface forms. Eigenmann (1919) concluded that *T. pattersoni* was most related to the Madtoms genus *Noturus* (formerly *Schilbeodes*). He reasoned that the position of the dorsal and ventral fins, as well as the adipose fin indicate this relationship. A comparison of the two genera is illustrated in Figure 2.

Hubbs and Bailey, (1947) and Suttkus (1961) agree that *T. pattersoni* is most probably derived from an ancestor of the bullhead genus *Ictalurus* (formerly *Ameiurus*). Hubbs and Bailey reasoned that since the venoin pore in the pectoral axil is lacking and the adipose fin, although large, is separated from the procurrent caudal rays, the derivation from *Ictalurus* is more plausible. Suttkus gave more evidence of the relationship to *Ictalurus* by comparing the shapes of the dermethmoid bone of the skull. In Figure 3 the genus *Ictalurus* is compared with *T. pattersoni*. The monotypic genus *Trogloglanis* is very highly differentiated from other members of the family Ictaluridae. The highly specialized, toothless mouth has undergone more change than other external morphological features. Since there is a lack of fossil evidence linking this form to surface forms it may be premature to try to establish relationships with epigean genera. The relationships will be understood much better after physiological and biochemical characters are studied. In hypogean populations genetic drift is often an important factor in causing rapid morphological change in relatively

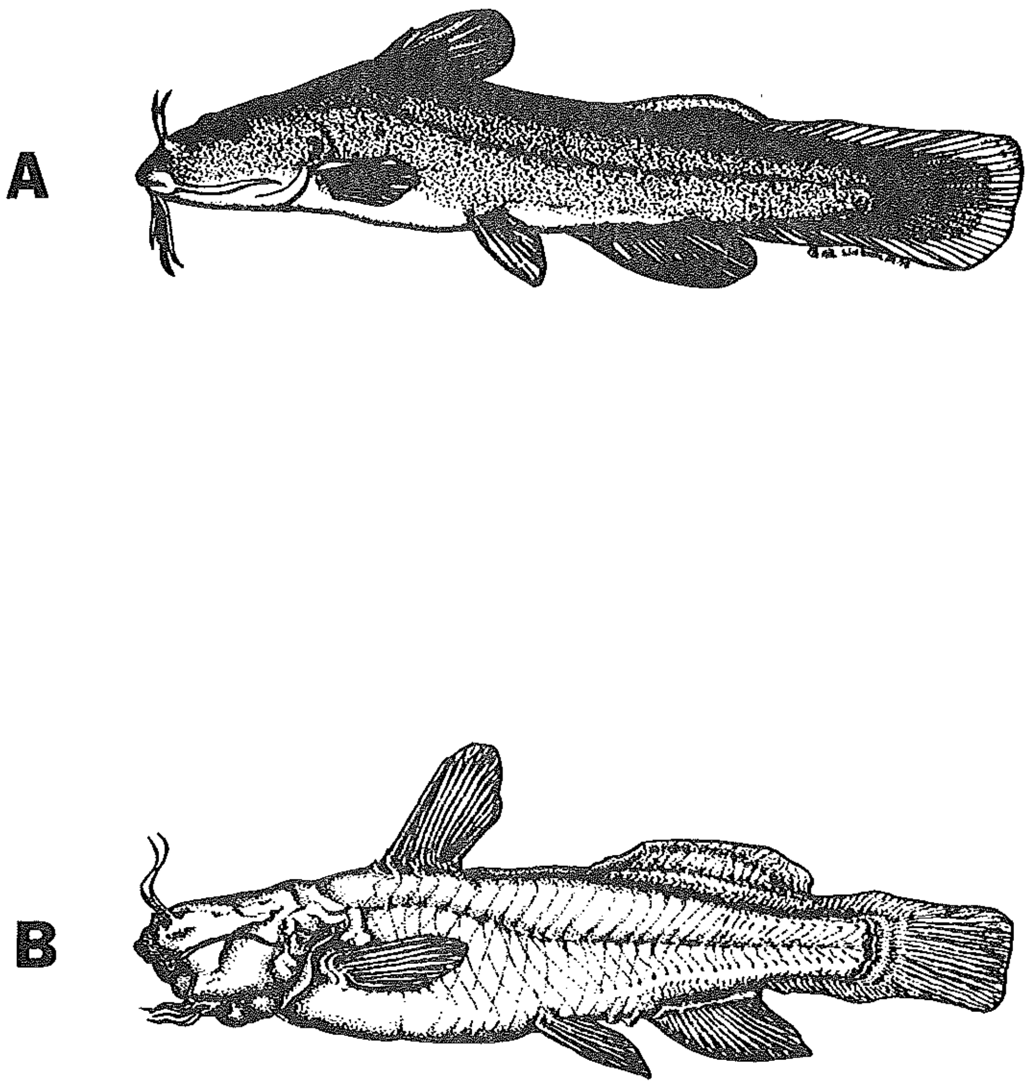


Figure 2. A comparison between the stonecat, *Noturus flavus* (A) and the toothless blindcat, *Trogloglanis pattersoni* (B)

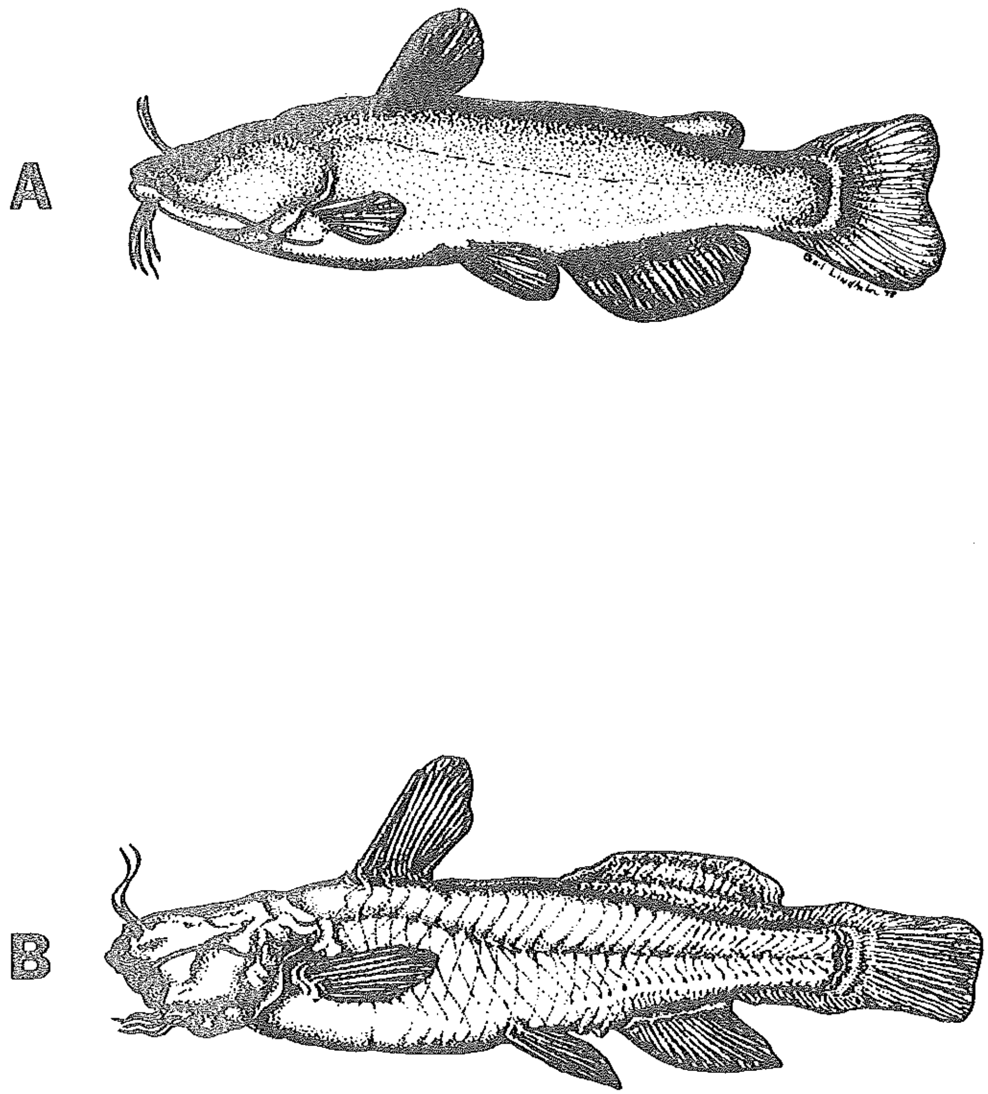


Figure 3. A comparison between the black bullhead, (A) *Ictalurus melas* and the toothless blindcat, (B) *Trogloglanis pattersoni*

short periods of time. This effect is mainly due to relatively small breeding populations. Before definite relationships are proposed complement fixation studies, electrophoretic studies and DNA studies should be completed.

In a revision of the catfish genus *Noturus* and an analysis of higher groups in the Ictaluridae, Taylor (1969) reviewed the probable relationships of this fish to other Ictalurids. Taylor's proposed phylogeny of the Ictaluridae is shown in Figure 4.

SIGNIFICANCE (BIOLOGICAL OR ECOLOGICAL)

Trogloglanis pattersoni is the most highly specialized Ictalurid catfish known. It represents one of the two troglobitic catfish known in North America. This form has no external indication of eyes. *T. pattersoni* has a highly specialized mouth (Figure 5) and there is no pigment in the skin. These attributes, along with others related to existence in caves of great depths, make this fish a very interesting subject of study.

This fish probably occupies the trophic level just below the top carnivore in this system, *Satan eurystomus*. The shape of the digestive tract, materials found in the digestive tract, and mouth character would tend to indicate a herbivorous type existence. It may be possible that this form feeds on fungal growths and dead or dying organisms in the aquifer.

Since the air bladder is absent, *T. pattersoni* is able to withstand great hydrostatic pressure. Adipose tissue has replaced the air bladder for adding bouyancy. These modifications are interesting to biologists. From a practical standpoint it may be possible to note changes in chlorinated hydrocarbon concentrations in the

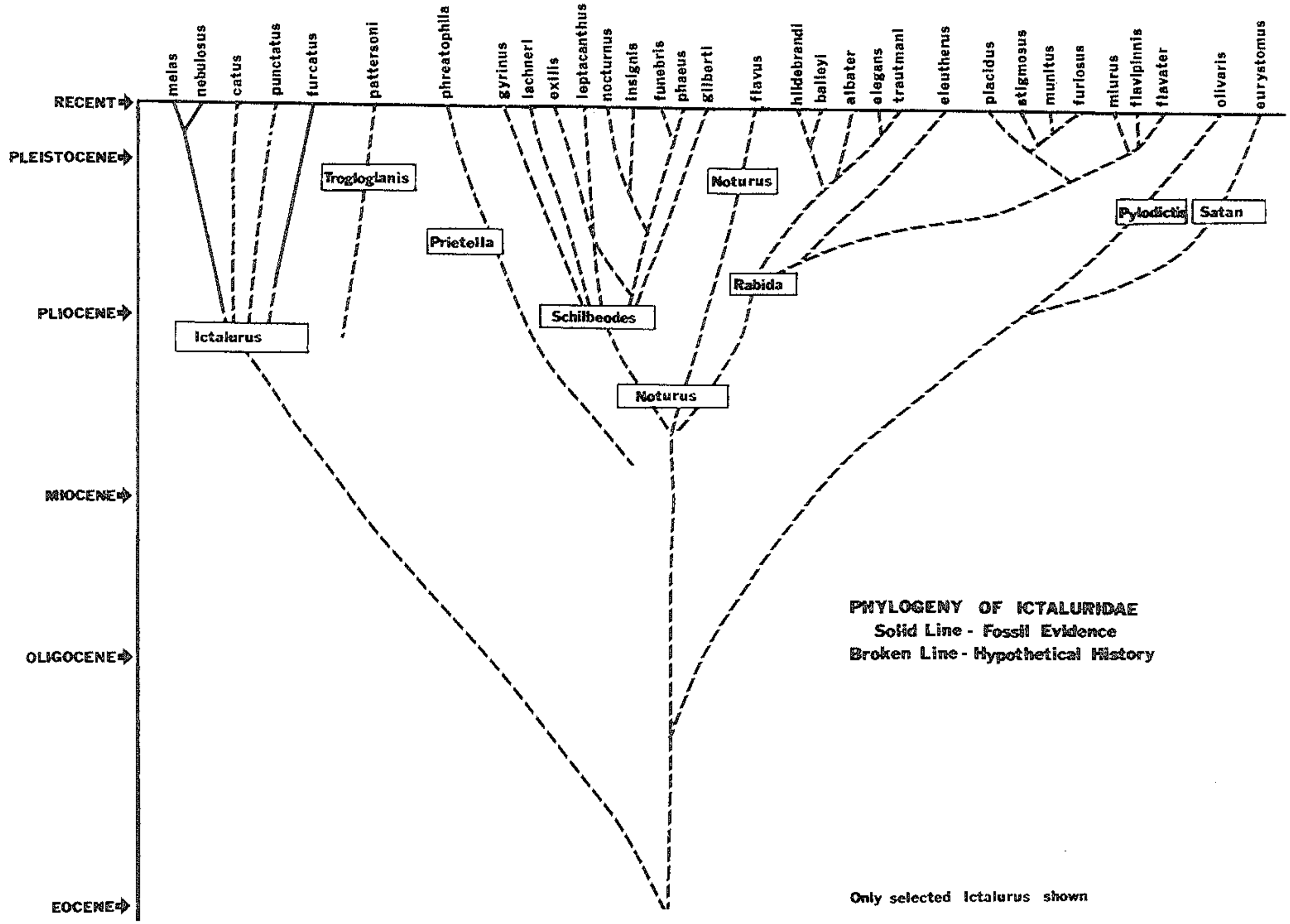


Figure 4. Phylogeny of the Ictaluridae (Taylor, 1969)

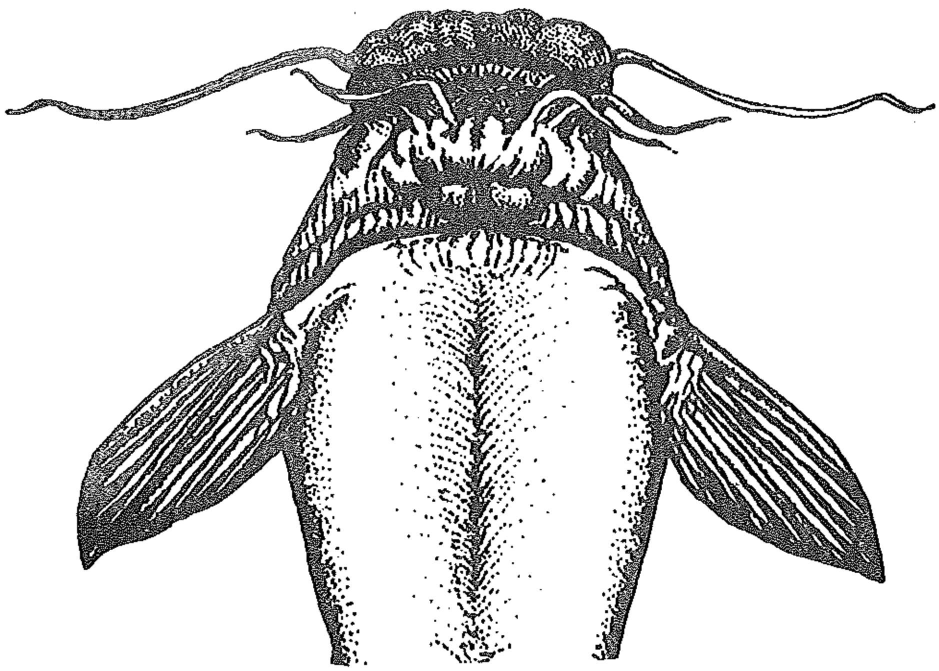


Figure 5. Mouth structure of *Trogloglanis pattersoni*

aquifer by sampling the extra fatty tissue of these fish. One would expect "biological" magnification to concentrate pollutants up the food chain.

DATE FIRST LISTED

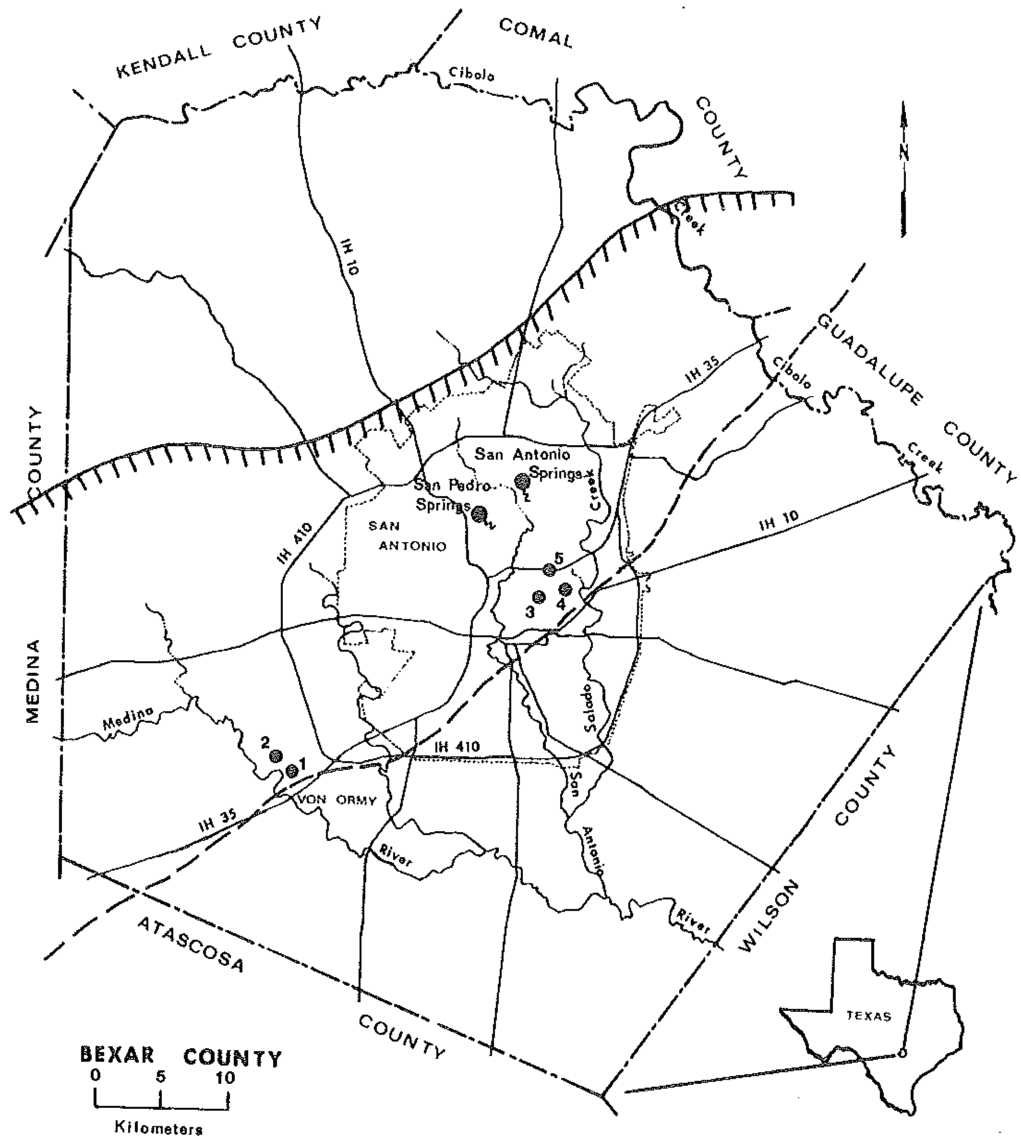
This species is not currently listed as threatened or endangered by the U. S. Fish and Wildlife Service. It was listed as "status - undetermined" in the "Redbook", officially titled, Threatened Wildlife of the United States (U. S. Department of the Interior, 1973c). Texas Parks and Wildlife Department employees have suggested it for listing. The Texas Organization for Endangered Species (T.O.E.S.) has listed it as threatened (T.O.E.S., 1975). The T.O.E.S. reference also indicates that the toothless blindcat is listed in the Red Data Book of the International Union for the Conservation of Nature. Texas Parks and Wildlife Department protects this species under its nongame rules.

DISTINGUISHING CHARACTERISTICS

GENERAL CHARACTERISTICS

The maximum total length for a specimen recovered during this study was 103.8 mm. The maximum standard length was 87.2 mm. The maximum weight in formalin was 16.21 grams. The largest specimen was taken from the artesian City Water Board well at the Artesia Pump Station in San Antonio (Location 3 in Figure 6). The type specimen had a total length of 85 mm (Eigenmann, 1919). It was 82% as large as our largest specimen. The following description appeared in his paper:

Head similar to that of a tadpole, as broad as long; mouth



1 O. R. Mitchell Well
2 Verstraeten Well
3 Artesia Well
4 G. W. Brackenridge Well
5 Josef Boecke Well

KEY
Artesian Well
Spring
Balcones Escarpment
Bad water zone

Figure 6. Collection locations of *Trogloglanis pattersoni*

inferior; teeth?; adipose fin long and low, rounded posteriorly, connected at its base with the accessory caudal rays; no external evidence of eyes; distance between origin of dorsal and tip of snout half as great as origin of dorsal from the end of the adipose; distance between snout and origin of ventrals 1 1/7 in the distance between origin of ventrals and base of middle caudal rays; pectoral spine strong and pointed, about two thirds as long as the longest ray, about equal to the length of the head behind the posterior nares, smooth in front, its posterior margin with seven straight teeth, less than half the width of the spine; caudal truncate, with numerous accessory rays; dorsal spine equal to the pectoral spine; base of adipose fin equal to the predorsal area; anal but slightly rounded, its highest ray equal to the length of the head. Nasal barbel reaching very nearly to end of opercle, maxillary barbel to the pectoral spine, mental barbels a little beyond the edge of the gill opening.

The fish appear light pink when alive except for the mouth. The mouth is very reddish. The only living specimens were those obtained from the Artesia Pump Station well and they lived for a short while. Death was probably due to the battering by water that forced them through pumps and pipes before entering the nets.

A list of morphological measurements obtained during this study are compared with measurements made by previous workers in Appendix 1.

SPECIFIC CHARACTERISTICS

Hubbs and Bailey (1947) give a very detailed description of the second specimen of *T. pattersoni* which was an immature male, 68.3 mm in standard length:

Though well developed, especially on the head, the lateral line system is much less conspicuous than in *Satan eurystomus*. Between a slender tube at the front of the lateral line and the uppermost pore of the opercular series, but at a distinctly higher level, are 2 similar tubules. The more posterior of the 10 or 11 small operculomandibular pores are at the tips of minute tubes. The anteriormost pore on the mandible is well separated from its fellow of the other side.

There is one similar pore behind the eye position, another above and slightly behind this, 5 or 6 in the infraorbital series, 2 interorbitals, 2 nasals, 1 prenasal, and 1 more at the front base of each nasal barbel. All these pores are very minute. Most of them open in small tubules. No supratemporal canal or pores are visible. The lateral line is developed to near the posterior end of the adipose fin, but is much interrupted posteriorly. Anteriorly, it consists of an irregularly lobate dermal keel, with mere traces of open tubes and pores.

The nostrils are of moderate size. The diameter of the anterior is about 1.0 mm. It is notably larger than in *S. eurystomus*.

There are at least 8 branchiostegal rays. The gill-rakers on the outer arch number 4 + 15 = 19. They are slender, but very short. The longest is about one-seventh as long as the distance between the posterior nostrils.

The very delicate jaws as well as the bones of the palate are toothless.

The dorsal fin is high and somewhat pointed, with 1 long, well-developed spine and 5 branched rays. The anal, more or less semicircular in outline, has 4 unbranched and 11 branched rays. The outer ray is smooth. The caudal fin is weakly truncate, not convex posteriorly as shown in Eigenmann's figure (1919: 398. Fig. 1). In addition to the 17 principal caudal rays there are 13 procurrent rays above, of which 1 is segmented, and 15 procurrent rays below, of which 3 are segmented. Each pectoral fin has 9 branched rays and a single strong spine, which is smooth along its anterior edge and bears 8 or 9 prominent serrations posteriorly. The pelvic fin of the right side has 1 simple ray on its outer edge, which is smooth, and 7 branched rays.

The intestine is rather thin-walled and is somewhat more coiled than it is in *S. eurystomus*. The outer edge of the testis bears a few weak, lobulate projections, rather than the fine fringe that is usually developed in the Ameiuridae. No air bladder could be found. The body cavity is largely filled with adipose tissue.

Lines joining the insertions of the pectoral fins with the point of union of the broadly connected branchiostegal membranes intersect at an angle of 108°; those joining the pectoral insertions with the tip of the snout, at an angle of 68°. The angle formed by the edges of the shoulder girdle, as seen from below, is about 110°. The gular groove is obsolete. The angle formed by the lines joining the insertions of the pectorals and the corners of the mouth is 34°; by the dorsal and ventral contours of the head, just behind the barbels, 24°; and by the muzzle, in lateral profile, 46°.

The most outstanding characteristic is the unique sucker mouth shown in different views of head, Figure 7.

In the key to the genera of Ictaluridae (Blair, et al., 1968) *Trogloglanis* is distinguished by the following characters; eyes absent, body without pigment, jaw teeth absent, jaws paper thin, lower jaw much shortened and turned into mouth.

SEXUAL DIMORPHISM

This species does not have reliable external characters that can be used for the determination of sex.

CHARACTERISTICS FOR IDENTIFICATION OF PARTS

In North America there are only two troglobitic catfish. Hubbs and Bailey (1947) include in their paper a very exhaustive comparison of *T. pattersoni* with *S. eurystomus*. This emphasizes the differences between the two genera. The lack of eyes and pigment easily separate these forms from epigean forms.

DISTRIBUTION

FORMER KNOWN DISTRIBUTION

George W. Brackenridge Well

Eigenmann (1919) secured the type specimen from an artesian well on the land of George W. Brackenridge. Mr. Brackenridge held extensive areas of land around the turn of the century. In 1883 he bought the San Antonio Water Works Company from LaCoste and Associates (Baker, 1978). The old pumphouse, now used as office space, still stands in Brackenridge Park, not far from the San Antonio Zoological Gardens. Wells on the zoo property were sampled but short periods of time. This effect is mainly due to relatively small breeding populations. Before definite relationships are proposed complement fixation studies, electrophoretic studies and DNA studies should be completed.

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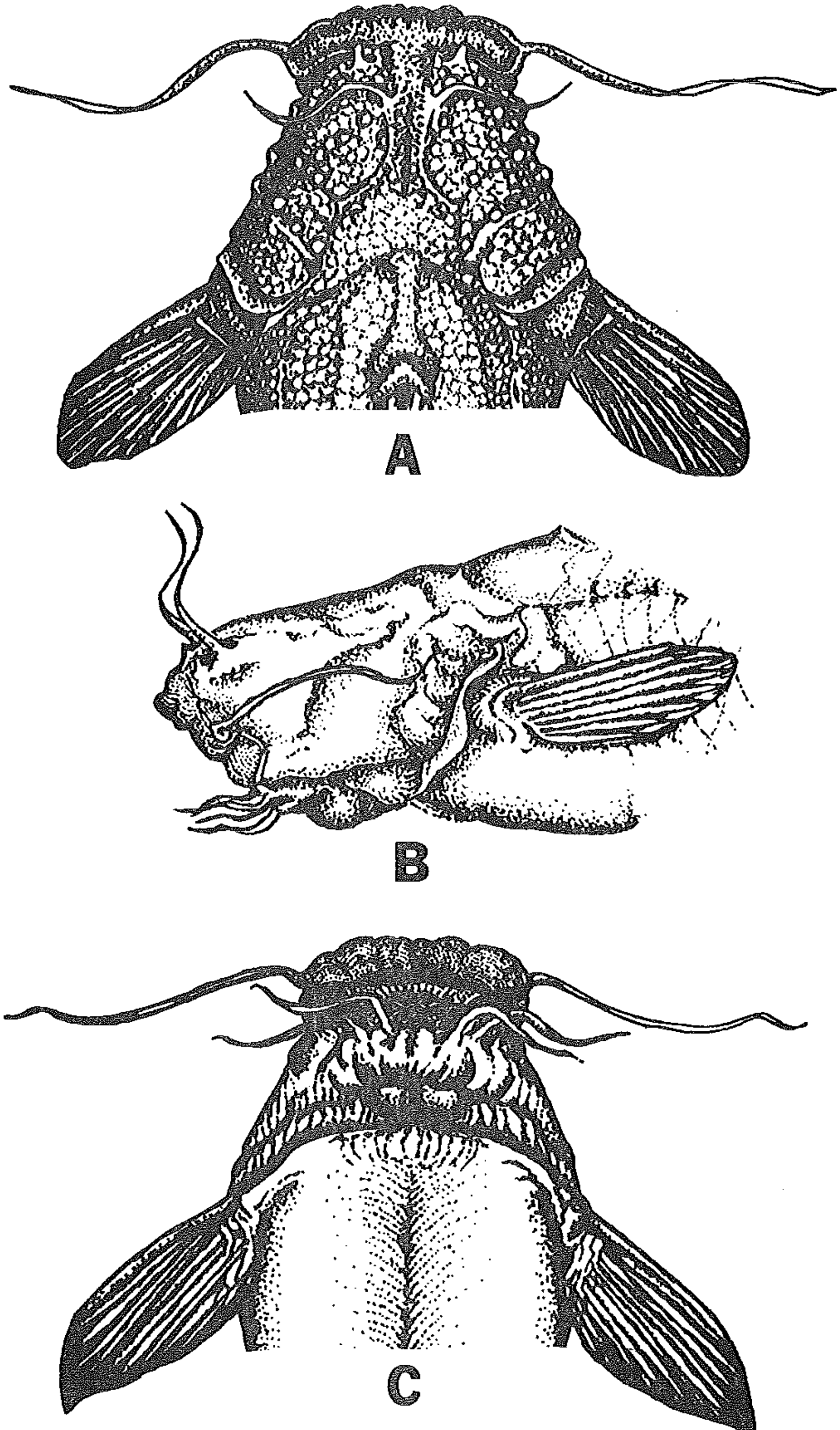

Figure 7. Head region of *Trogloglanis pattersoni*
A = Dorsal view, B = Lateral view, and C = Ventral view

they did not produce *T. pattersoni*. They did produce cave invertebrates. The original description did not indicate which of G. W. Brackenridge's wells produced the fish but discussions with "old Belgium farmers" have indicated that the well was one located near Salado Creek south of IH 35 (Number 4, Figure 6). Mr. Brackenridge originally owned large parcels of land near the present Coliseum and Belgium Lane roads. This area was known as "Belgium Lane Farms". Brackenridge owned four wells in the area and water from these wells was used for irrigation. One of the four wells at the intersection of Belgium Lane and KONO Road is still in existence. It is owned by the Verstraeten Brothers, Inc. of San Antonio. The area is no longer used for agriculture. Residences have been built in the area and the well is in poor state of repair. Sampling was not possible and it is our understanding this 308 m well is destined to be capped soon. This well is probably the type locality according to statements made to us by early residents.

Josef Boecke Well (Figure 6 - Well No. 5)

Hubbs and Bailey (1947) list the Josef Boecke well as the collection location for the second known specimen of *T. pattersoni*. They listed the location as 4.43 km east and 2.02 km north of the Alamo in San Antonio. The area is now in the right of way of IH 35 in San Antonio. The well was covered by highway construction. The well was 308 m deep.

O. R. Mitchell Well (Figure 6 - Well No. 1)

An additional specimen of *T. pattersoni* was collected from a well on the O. R. Mitchell Ranch in 1955 (Suttkus, 1961).

This individual was collected by Mr. John Werler from the artesian well (582 m deep) on the ranch located approximately 22.5 km southwest of San Antonio near Von Ormy. This is U.S.G.S. Well No. AY-68-43-601.

Other

Two other locations have been mentioned as locations that produced blind fish (Hubbs and Bailey, 1947). The references did not indicate which of the two known species from the San Antonio area were present. The locations were:

(1) Alamo Dressed Beef Company - This business could not be located. City and county records were checked and this business was not listed.

(2) Mrs. R. P. Persyn referred to blind catfish in a newspaper article supposedly included in the San Antonio Light of September 7, 1929. This issue of the paper was checked and no article was found. There evidently was an incorrect reference given for the date of the article. There is a Persyn well mentioned in the U.S.G.S. well records (AY-68-44-501) but this may not have been the same well.

(3) El Patio Foods - A 430 m deep artesian well located at 2600 Southwest Military Drive, San Antonio produced the catfish, *S. eurystomus* (Suttkus, 1961). Interviews with employees of the El Patio Foods plant indicated "about fifty" catfish were found when the water tower was drained in 1964. They further stated that "two types of catfish were present, one with a sucker-type mouth and the other with a flathead catfish type mouth". None of the fish were preserved and therefore we were unable to confirm

this sighting as *T. pattersoni*. It is very probable that the "sucker-type mouth" fish were *T. pattersoni*.

PRESENT KNOWN DISTRIBUTION

O. R. Mitchell Well (Figure 6 - Well No. 1)

From March 23, 1977 to June 30, 1977 three specimens of *T. pattersoni* were collected at this location. The depth of this well is 582 m with a reported flow of 315 liters $sec.^{-1}$ Our request for permission to sample during 1978 was denied by Mr. Turner, the O. R. Mitchell Ranch foreman.

Verstraeten Well (Figure 6 - Well No. 2)

Netting of the artesian well on the Verstraeten Brothers Farm began March 16, 1977 and is continuing. One *T. pattersoni* was collected from this well. The well is located approximately 0.8 km northwest of the O. R. Mitchell well. The well is 513 m deep with a reported flow of 315.4 liters $sec.^{-1}$ This well was the most productive well for invertebrates. This may have been due in part to the type of net and placement of the net. The net was 4.6 meters long and was placed on a 41 cm pipe that was located approximately 3.2 m under the surface of an irrigation reservoir. The net had to be placed on the pipe utilizing SCUBA. A float to the surface allowed us to pull the end of the net to the surface and remove organisms contained. Due to the location of the net completely under water the organisms trapped were buffeted less than those in the nets on other wells.

Artesia Well (Figure 6 - Well No. 3)

Sampling of the San Antonio City Water Board Well No. 4 (CWB number) at the Artesia Pump Station began February 22, 1978 and is continuing. This well is located approximately 3.2 km southwest of the probable type locality (Figure 6 - Well No. 4). There are at present five artesian wells at the Artesia Pump Station. The well being sampled is 402 m deep and has a flow of 244 liters sec^{-1}. Twenty-two specimens of *T. pattersoni* were collected from this well during our study.

HOW COMPLETELY IS THE DISTRIBUTION KNOWN?

Distribution of *T. pattersoni* seems to parallel that of *S. eurystomus*. Both fishes are limited to artesian wells over 305 meters deep in an area paralleling IH 35 from southwest Bexar County in the Von Ormy area to central eastern Bexar County in the Coliseum area (Figure 6). The chief waterbearing stratum of the region is the Edwards Limestone Formation of Lower Cretaceous age (Livingston, Sayre, and White, 1936). Like other formations in this area, the Edwards Limestone dips toward the coast. In the southern part of Bexar County, it lies 914 meters below the surface (Figure 8). In northern Bexar County, it lies at the surface on the Edwards Plateau. In the northern city limits of San Antonio, the top of the formation lies 61 to 122 meters below the surface. The artesian wells samples in north and northwestern Bexar County did not produce *T. pattersoni*, although invertebrate fauna were found.

The Balcones Fault Zone and the interface between fresh and saline water, the "Bad-Water Zone", also parallels IH 35 (Figure 6).

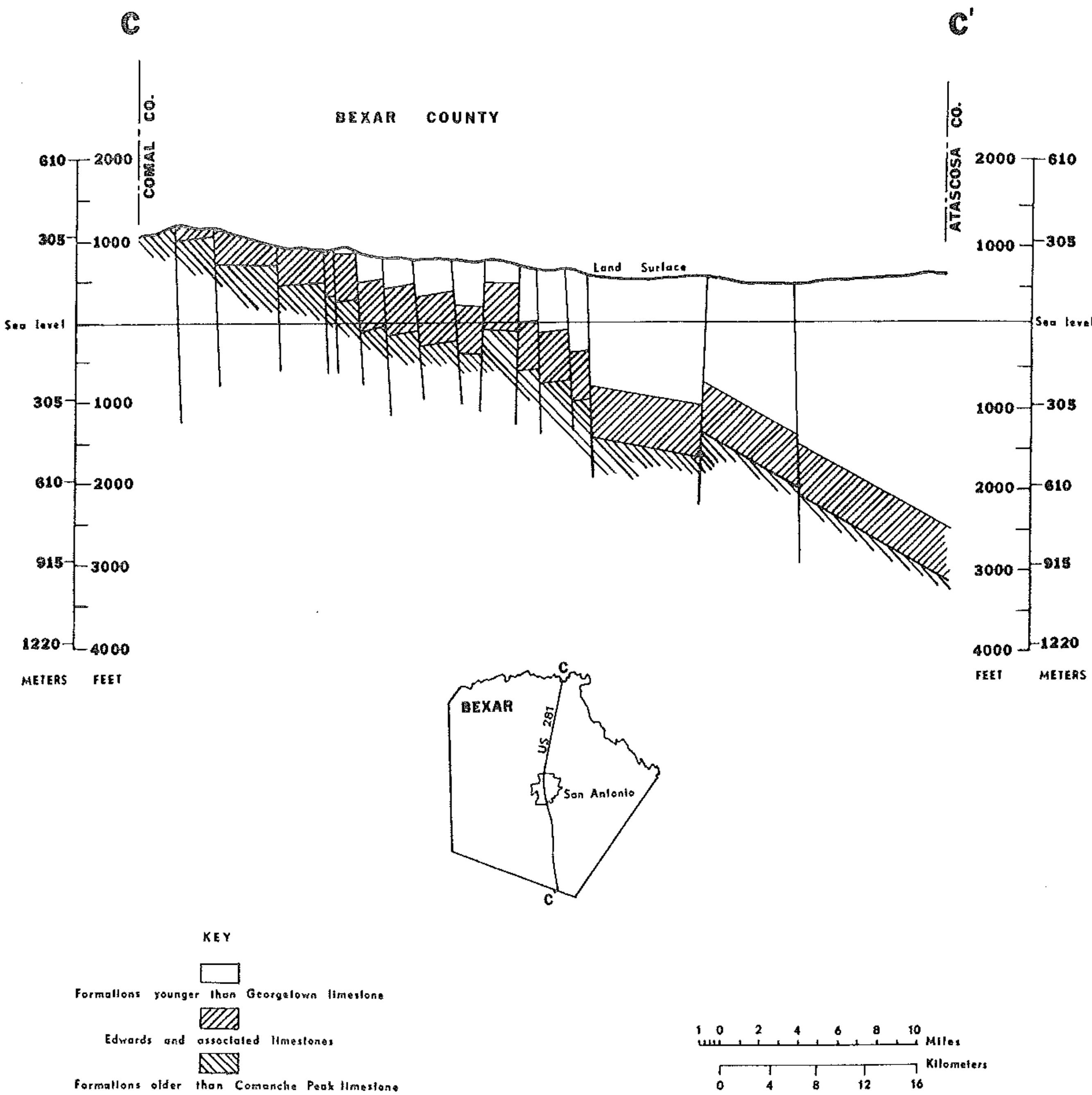

Figure 8. Geologic cross-section of Bexar County (modified from Petitt and George, 1956a)

This area is highly faulted with numerous caverns and fissures providing natural habitats for the fish (Figure 9).

Water temperature is different between northern and southern Bexar County (Figure 10). In northern Bexar County where the Edwards Limestone is exposed to the surface, the temperature is near 24°C. In southern Bexar County the temperature is near 27°C. All the locations producing *T. pattersoni* have a water temperature of 27°C. Temperature can be detected by cutaneous senses of the fish. Fish tend to remain in a temperature preferendum and the temperature of the water may contribute to orientation on long or short range movements (Lagler et al., 1962). Some bony fishes can detect temperature changes of 0.03°C if the rate of heat change is rapid (Lagler et al., 1962). It is possible that temperature is important in limiting the distribution of the blindcats to the deep artesian wells in southern Bexar County.

Further sampling of artesian wells in Medina, Uvalde, and Kinney Counties is needed to determine the range of these troglobitic fish.

HABITAT

This troglobitic fish is probably restricted to the San Antonio pool of the Edwards Aquifer (Figure 11). The only source of these fish has been from artesian wells in the southern part of Bexar County. Numerous caves exist in northern Bexar County and many have been explored. Numerous collections of cave aquatic invertebrates have been made but no troglobitic fish have ever been recorded from the caves in the northern part of the area.

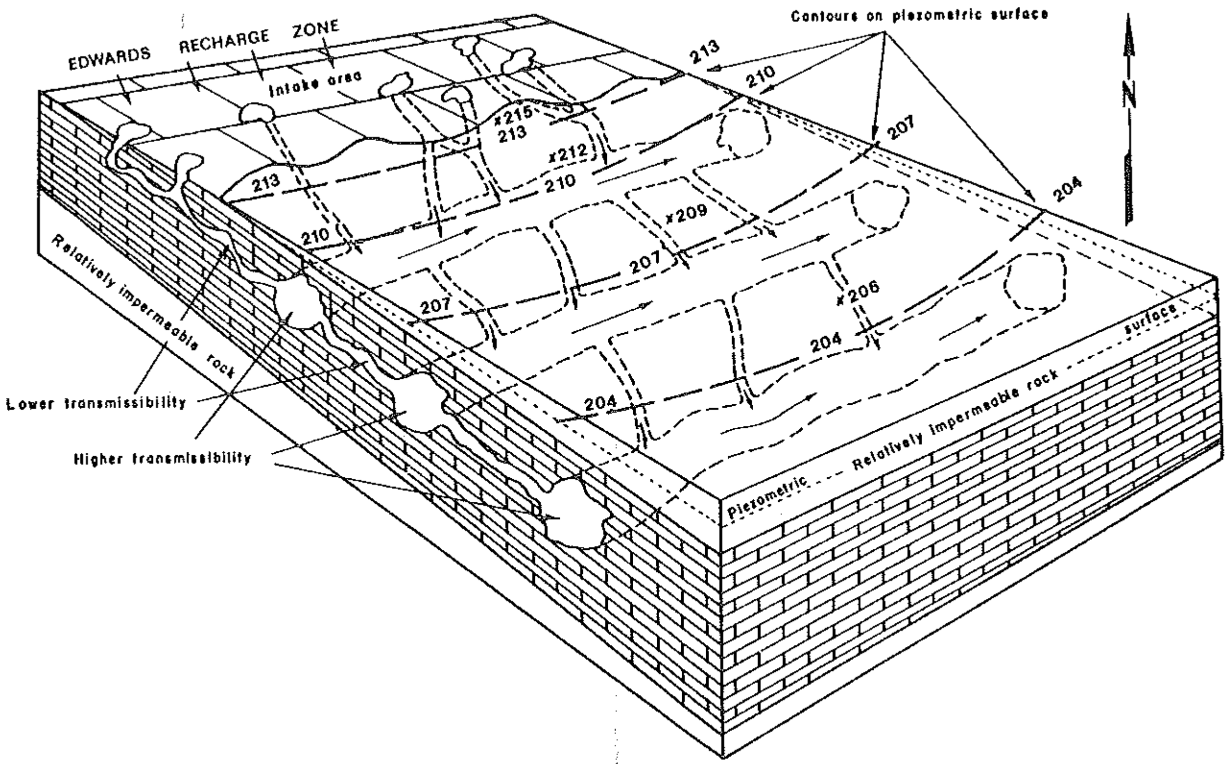

Figure 9. Hypothetical diagram showing how water in the cavernous Edwards may flow (adapted from Arnow, 1959)

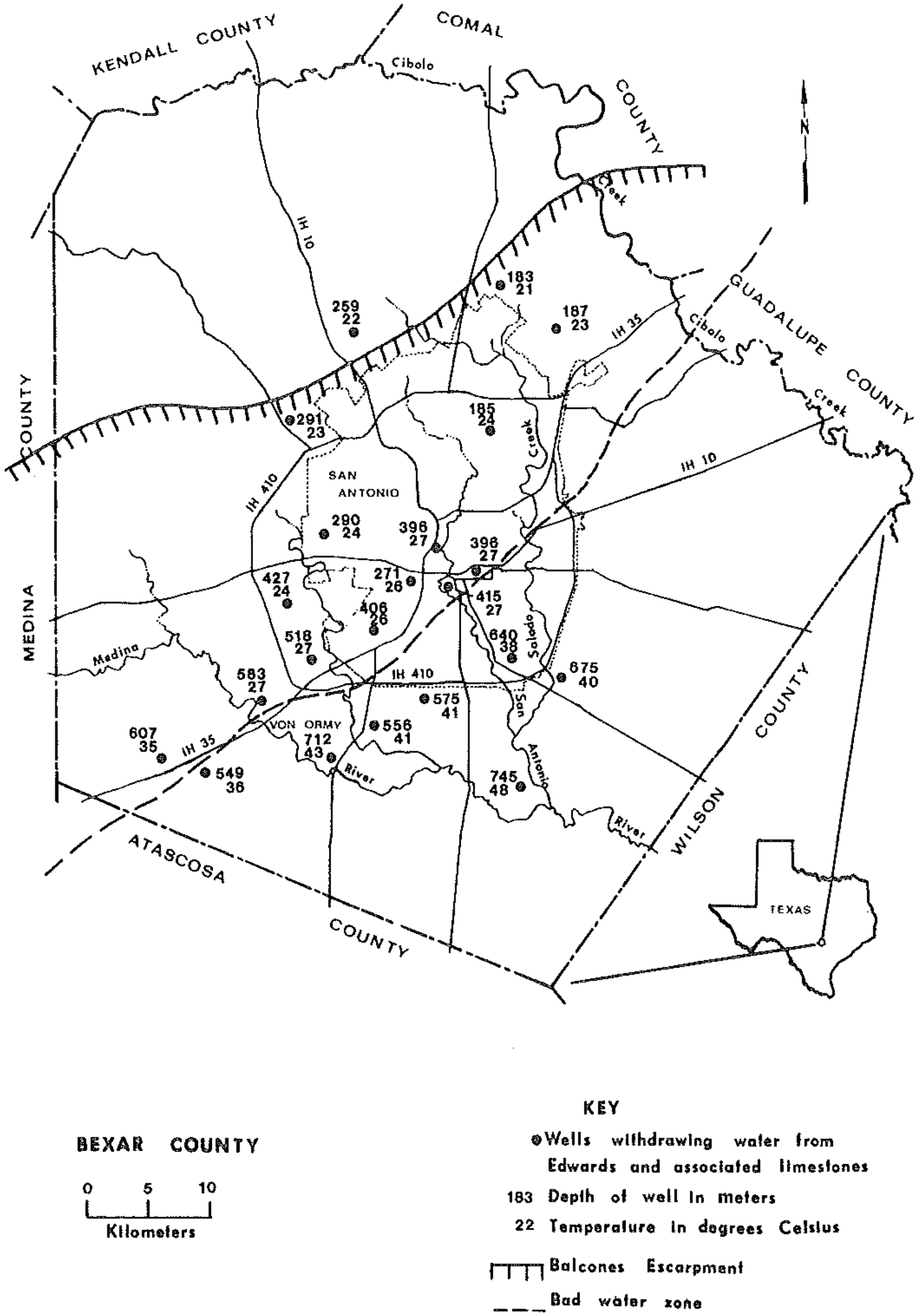

Figure 10. Water temperature and depth of selected wells in the study area (adapted from Petitt and George 1956a)

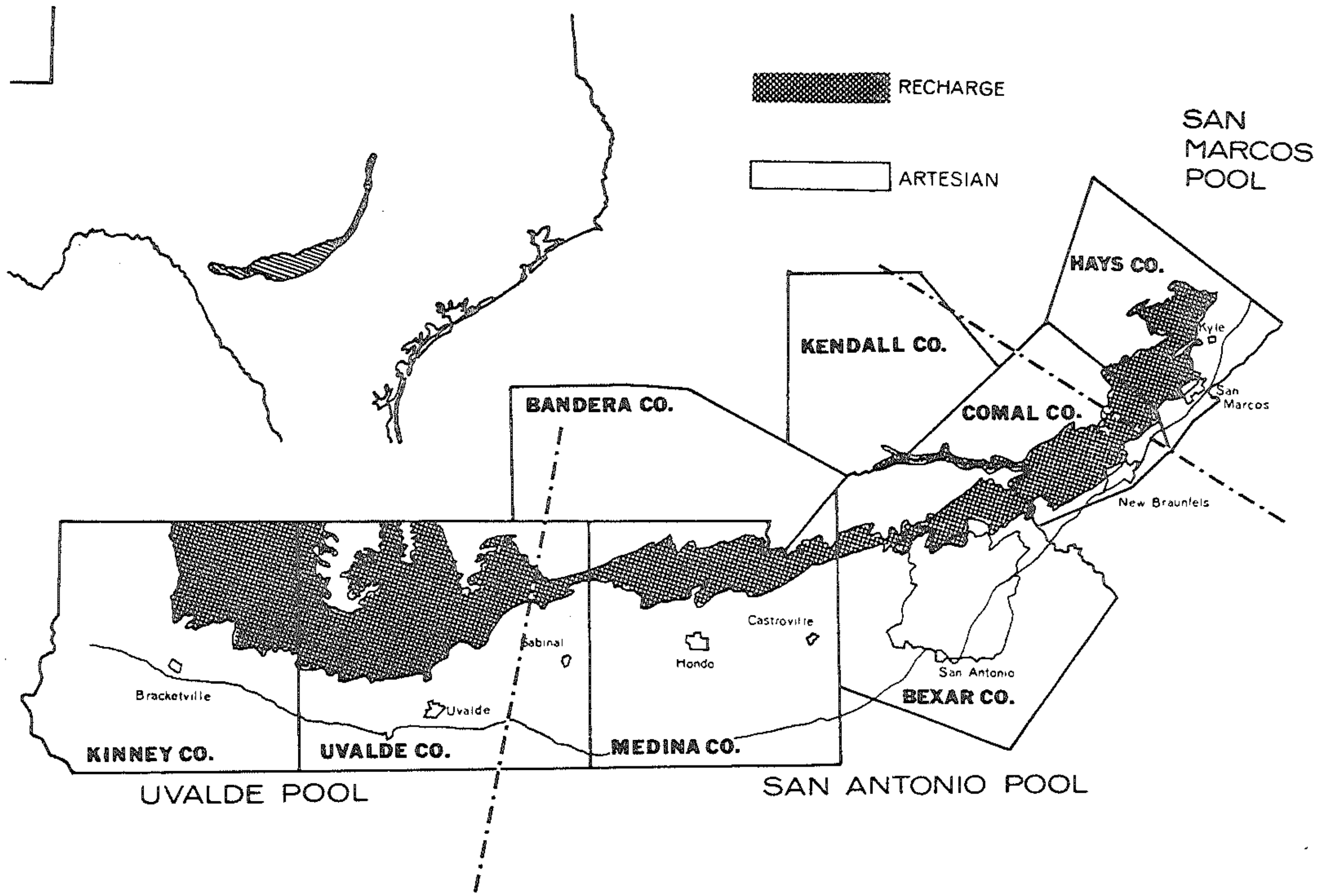

Figure 11. Edwards Aquifer (Longley, 1978)

Many wells penetrate caverns in the San Antonio area (Pettit and George 1956a; ____, 1956b; ____, 1956c; ____, 1956d and Livingston, 1947). The density of wells in the San Antonio area is very great. Many of these wells are utilized by the City of San Antonio. It is estimated that in 1975 wells and springs in Bexar County discharged 3.19×10^8 m^3 of water from the Edwards Aquifer. Only 13.82% of this was from springs (Rappmund, 1976). In reviewing various publications concerned with the hydrology of the Bexar County area, it was noted that the well logs of a large percentage of the wells in the San Antonio area included some cavernous areas. It was often noted in well logs that at the point where a large cavern or numerous crevices occurred in the Edwards, this depth turned out to be the bottom of the well and source of water (Pettit and George, 1956b). An indication of the water level contours in the San Antonio area is given in Figure 12.

The U.S.G.S. and Texas Water agencies have done much work on the chemical quality of the Edwards Aquifer in the San Antonio area (Garza, 1962; Reeves, et al., 1972; Reeves, 1976; and Pearson and Rettman, 1976). Chemical analyses done during this study are shown in Appendix 2. An interesting thesis prepared at the University of Texas discussed the sources of nitrate in Edwards Aquifer water (Brownning, 1977). In general these publications delineate the position of the "Bad Water Line" and give insight into the geochemistry of the area. Figure 13 shows the concentration of dissolved solids, sulfates and chlorides from selected wells in and adjacent to the study area.

Other publications give insight into how the water movement

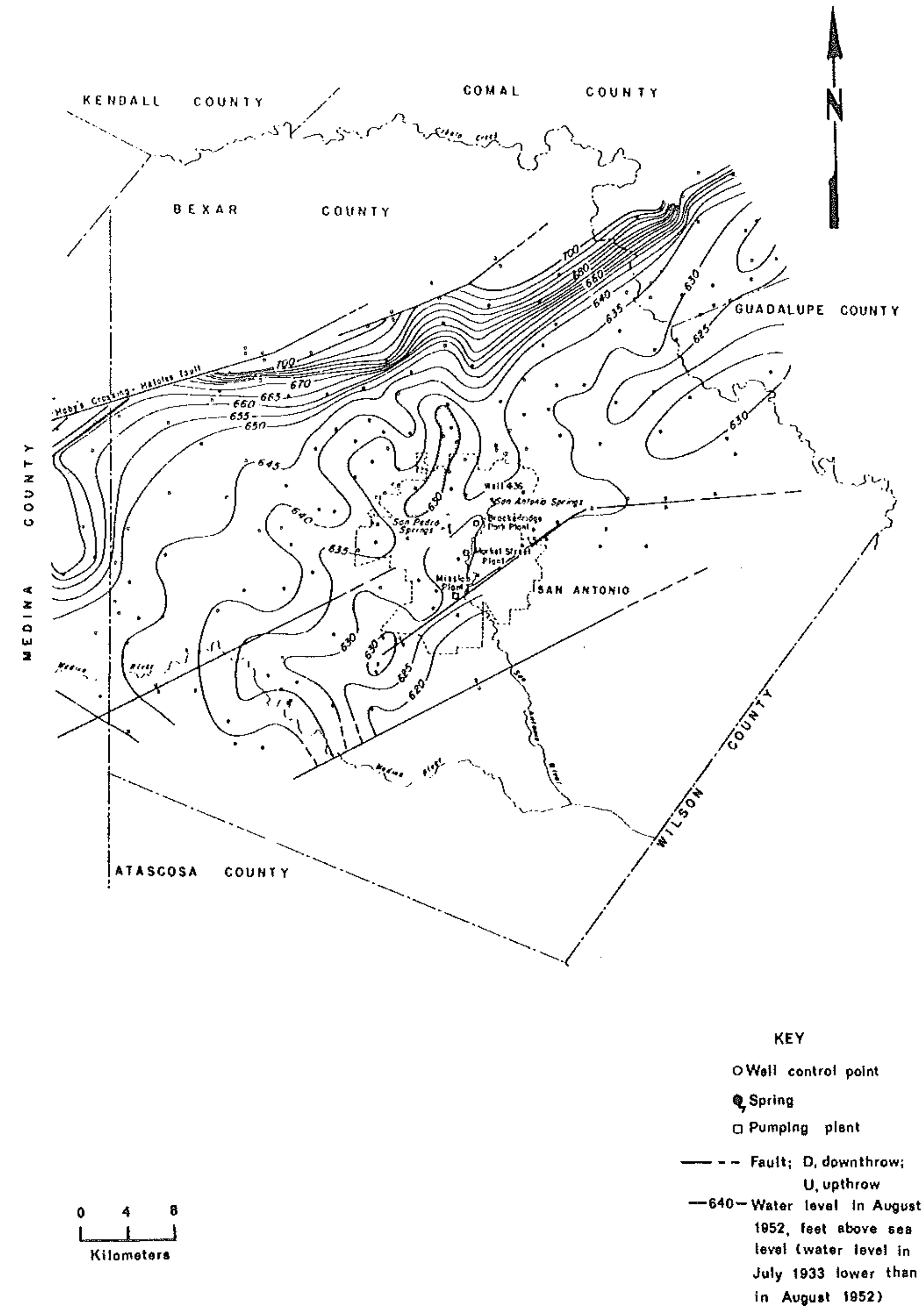

Figure 12. Water level contours in Bexar County (modified from Lang, 1954)

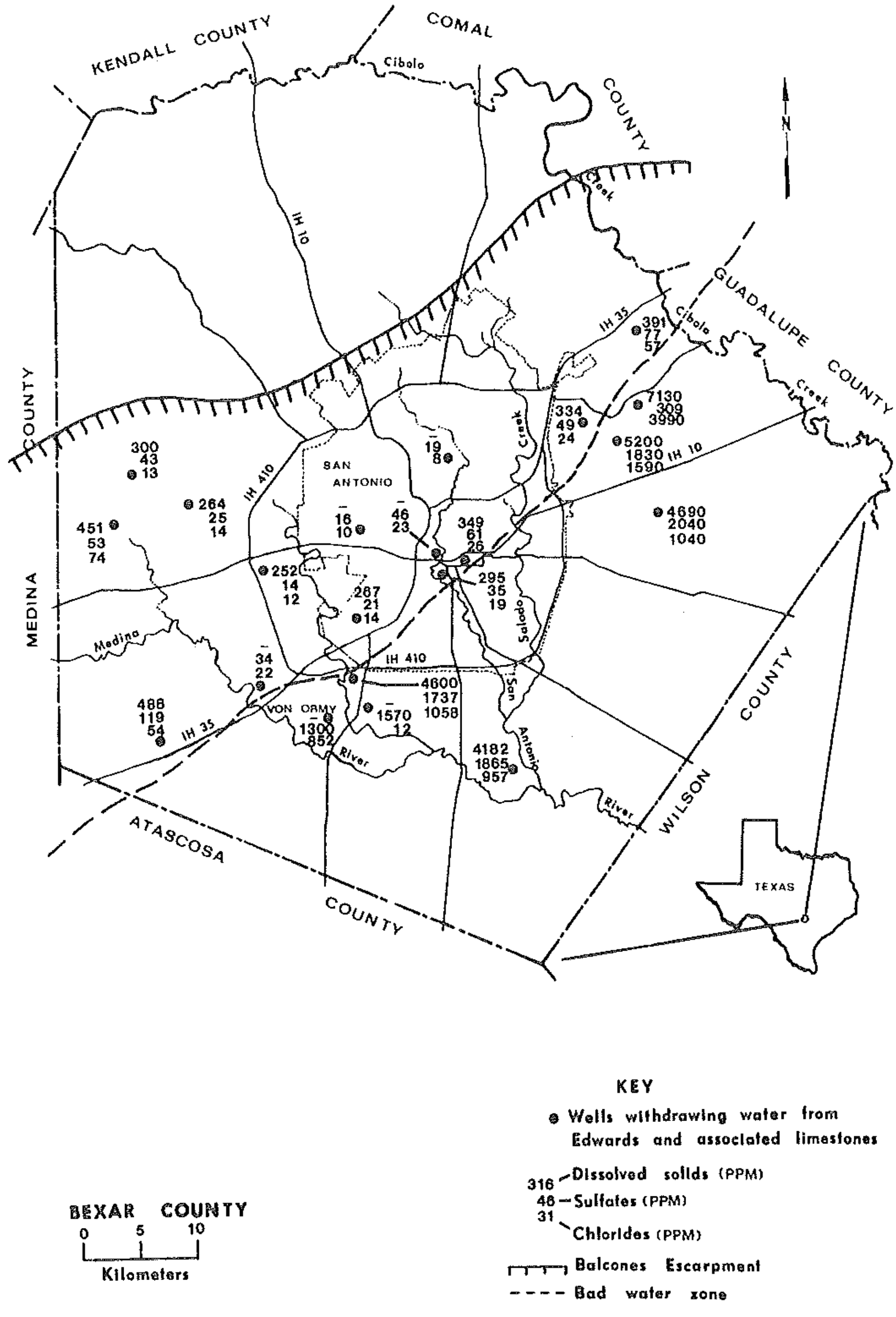

Figure 13. Concentrations of dissolved solids, sulfates, and chlorides in selected wells (modified from Pettit and George 1956a)

occurs within the Edwards Aquifer in the area of San Antonio (Pearson, et al., 1975; Pearson and Rettman, 1976; Maclay and Small, 1976; Abbott, 1977, and Puente, 1976). In general, the movement in the aquifer is from the west to the east or northeast. There are also numerous publications which discuss the hydrology of the aquifer specifically. These often include water levels, recharge, discharge, amounts of precipitation and other hydrologic parameters (Puente, 1974; Garza, 1966; Rettman, 1969; Follett, 1956; Lang, 1954; Rappmund, 1975; Maclay and Rettman, 1973; Rappmund, 1977; Knowles and Klemt, 1975 and Sieh, 1975). Some interesting insight into the water situation in Bexar County may be noted from projections for San Antonio Springs flow (Figure 14). Interesting hydrologic models have been devised for predictive purposes based on increased population and therefore increased water usage (Figure 15). These models show that the average water level in the aquifer will continue to drop in the future without additional recharge. An attempt has been made to identify some of the water resource planning problems in the metropolitan area of San Antonio (Garner and Shih, 1973). It should be obvious that the habitat of *T. pattersoni* is unique and that increased pumping may have some effect on the habitat. The great depths and the considerable distance from the recharge zone at which these fish exist protect them from rapid changes in their habitat. There is a tremendous capability for dilution of toxic materials that might penetrate to the aquifer. It would seem that organic pollution would possibly stimulate the energy flow up the food chain if toxic materials were absent. The circumstances that the fish live in now near the "Bad

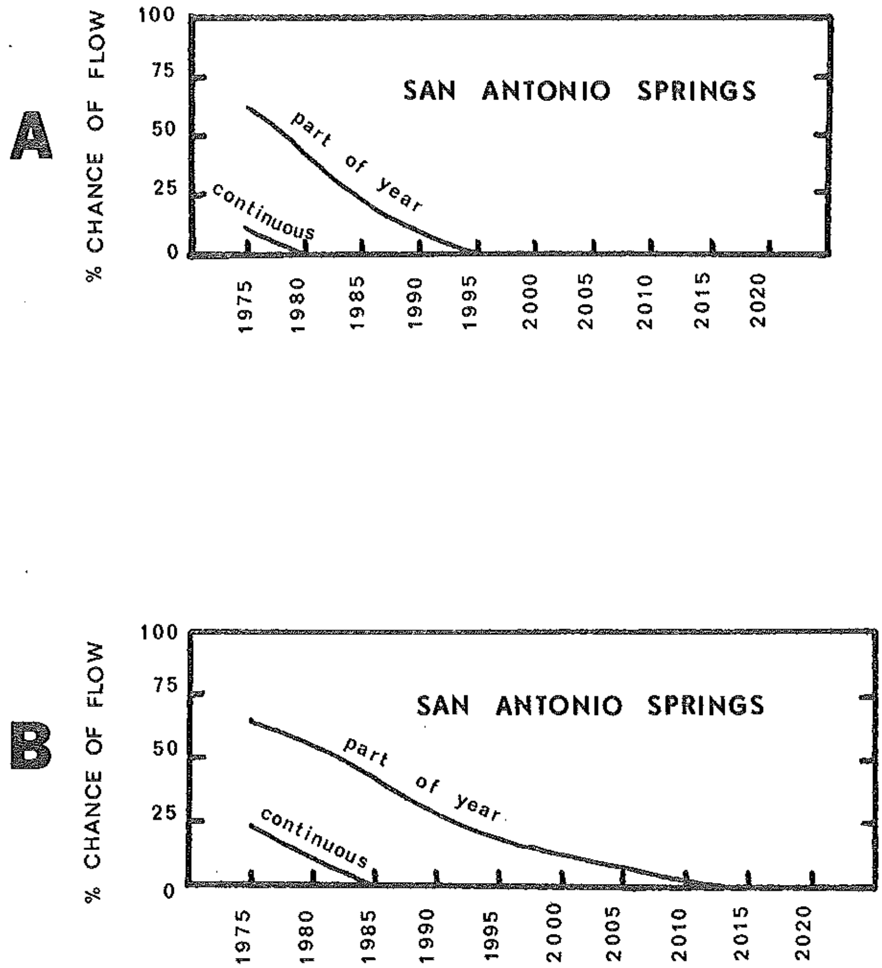

Figure 14. Projected flow of San Antonio Springs; A = High population increase, B = Low population increase (U.S.D.I., 1973a and U.S.D.I., 1973b)

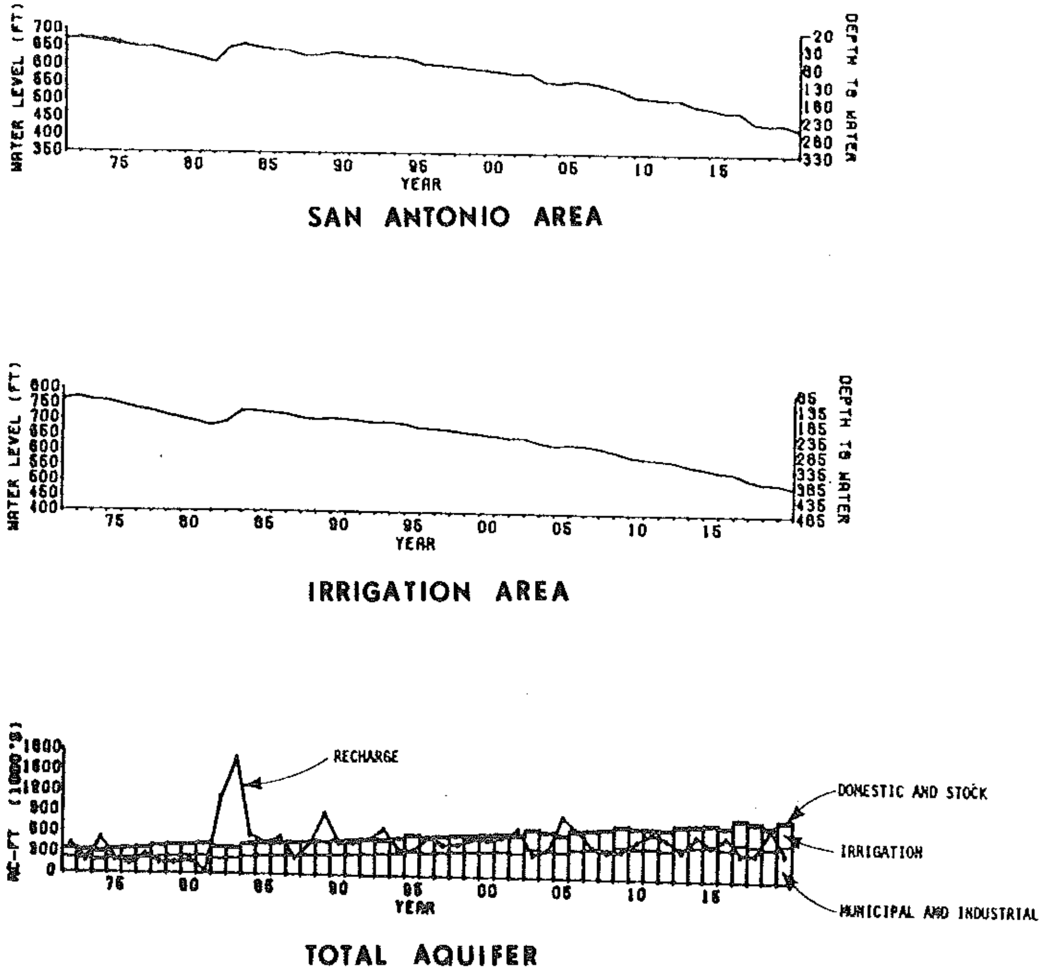

Figure 15. Hydrologic models (Seaward, et al., 1974)

Water Zone," would seem to imply they may be dependent on organic matter from this area.

ESSENTIAL HABITAT

The fish are probably restricted to an area of approximately 103,600 hectares. The numbers of fish collected during this study would indicate a very healthy population. If we were able to collect from all the wells in the area assumed to contain fish, the numbers would be overwhelming. The habitat of the fish is the sole source of drinking water for the City of San Antonio. The federal and state regulations that govern this water supply should protect it sufficiently for the fish to continue to exist. The fish will never be easy to obtain by those interested in them. The locations where they may be caught, in specially constructed nets, are difficult to gain access to. They also have the disadvantage of being collectable only when there is a need for water such as during the irrigation season. The city has only one well where piping from the well will allow collecting and this is only possible when there is excess water. San Antonio and San Pedro Springs, the two major natural outlets from the aquifer, stopped flowing during the period of 1950 to 1973. They are flowing at present, but due to the nature of their outlets and their location in highly public areas it has been impossible to sample them. The major San Antonio Spring ("Blue Hole" at Incarnate Word College) is a large cavernous opening. The senior author of this report used SCUBA to clean out parts of an old water system and debris from the opening in June, 1977. Penetration some 8 to 9 meters deep allowed the observation of two side passages off of the main passage. Most of the flow is coming from a large fissure in the south passage. Surface fish were abundant in all parts of the cave and it would have been impossible to net exclusively subterranean organisms. The surface forms caught in the net would probably have eaten all the subterranean forms. This spring is not far from historic collecting sites (Figure 6).

Where this fish gets into surface waters, its chance for survival is slight. The blind, pink fish are easy prey for eyed surface predators such as other fish and birds. At present, only one location is probably receiving many fish that survive. The large well on the O.R. Mitchell ranch is run much of the year to keep large ponds filled. The foreman, Mr. Turner, was never completely candid about how much or when water was flowing from the well into ponds. It was our impression that some outlets from the well distribution system were open most of the time. Some pipes leading from the well flow into the ponds under the surface of the water. All attempts to contact the owner were futile. The foreman seems to be in complete control of all activities on the ranch. He has stated on several occasions that he doesn't want people requesting permission to sample outlets from the well.

NUTRITIONAL NEEDS AND FEEDING HABITS

Many troglobites have been observed to live for prolonged periods without food. The blind fish, *Amblyopsis spelaeus*, from Mammoth Cave remained alive for two years without food (Vandel, 1965). Other cave vertebrates have been known to withstand prolonged periods without food (Longley, 1978 and Vandel, 1965). The nutritional factor is very important in the distribution of most troglobites. Richness of cave fauna is usually related to an abundance of food.

The catfishes would appear to be preadapted to subterranean existance since surface forms have highly adapted sensory structures and habits of feeding on the dark bottom areas in lakes and streams. Physical stimuli are detected by cutaneous and acoustical receptors for heat, flow or touch. Chemical stimuli are received by the organs of taste and smell. If *T. pattersoni* has evolved from an Ictalurid ancestral type, the methods for sensing food should be similar. Observations of behavior and recordings of nerve discharges show various species of *Ictalurus* to be highly sensitive to touch on the head region (Lagler, et al., 1962). Bullheads have concentrated on nocturnal feeding and have developed elaborate systems of olfaction and gustation. Lagler, et al. (1962) estimated that bullheads contain more than 100,000 taste buds over their entire body. The taste buds are composed of two types of sensory cells. These sensory cells have short, hair-like extensions (cilia) which come in contact with the water. Microscopic examination revealed that the epidermis of *T. pattersoni* is heavily covered with these hair like extensions.

The barbels have neuroreceptors that function for taste and touch. In *Ictalurus*, the tips of the barbels are composed of a series of free nerve endings. When the tip comes in contact with an object it is simultaneously felt and tasted. *T. pattersoni* has a total of eight barbels; two nasal, two maxillary and two pair of mental barbels. In addition to the barbels, *T. pattersoni* has an inferior suctorial mouth with a fleshy modification of the lips (Figure 5). The lips are mobile and plicate. With the well developed barbels surrounding the mouth, *T. pattersoni* probably locates food sucked from soft bottom materials.

Catfish have a well developed olfactory system. The sensory structures for olfaction are located in the nasal cavities. As the fish swim water passes through the nasal cavities. In *T. pattersoni* the anterior nostril has a posterior flap to facilitate the passage of water. Water enters the anterior nostril and exits the posterior nostril. Typically the sense of smell is more acute than taste in most fish. Lagler, et al. (1962) reported that when the nasal apparatus of bullheads was plugged they were unable to detect food.

T. pattersoni probably uses its lateral line system to aid in the detection of food. The lateral line system senses disturbances such as vibrations from moving objects. The lateral line in *T. pattersoni* extends nearly to the posterior end of the adipose fin and forms a dermal keel anteriorly.

The stomach contents of *T. pattersoni* failed to reveal what the catfish are foraging on. Internal anatomy did pose an interesting question. The intestine of *T. pattersoni* is coiled and very thin walled (Figure 16). A coiled intestine in fishes usually indicates herbivorous feeding (Lagler, et al., 1962). Loricarid catfishes exhibit coiled intestines and are mostly herbivores. The stomach contents of one *T. pattersoni* did contain what appeared to be partially digested fungus. In nearly all of the wells sampled during this study, a fungus was found in the samples. The fungus is identical to that obtained from the artesian well in San Marcos (Longley, 1978). The abundance of troglobitic invertebrate fauna

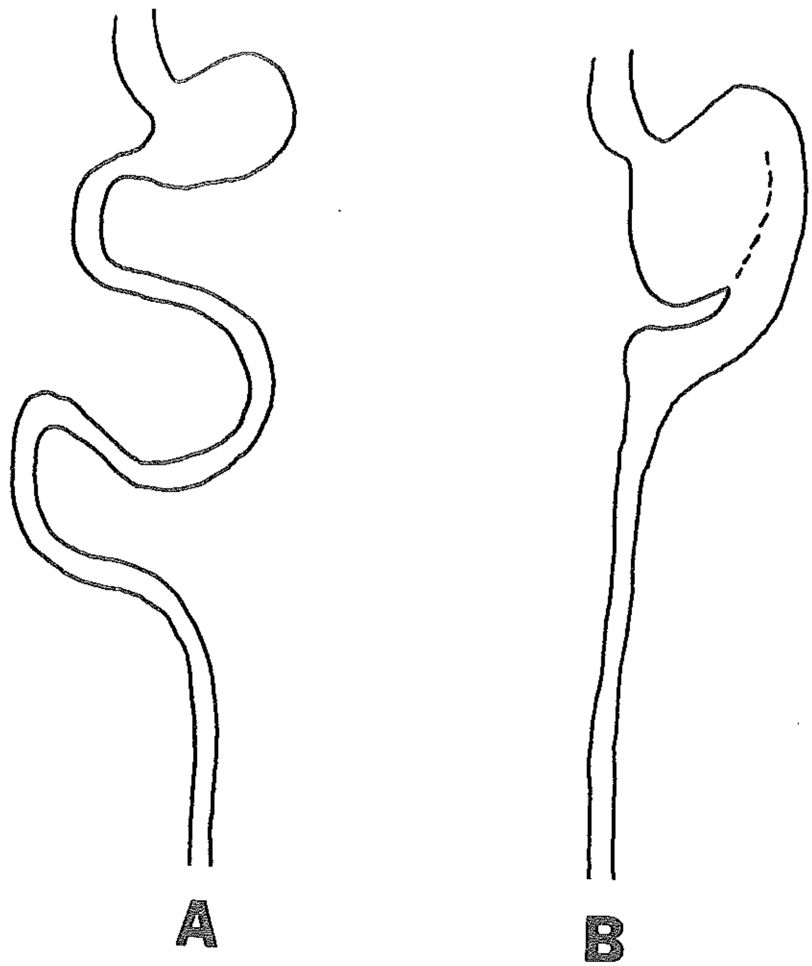

Figure 16. Comparison of the intestines of *Trogloglanis pattersoni* (A) and *Satan eurystomus* (B)

could be an additional food source (Table 1). *T. pattersoni* may be a scavenger utilizing dead or dying invertebrates in the sediments. Several of the amphipods and the gastropods would live on or in the sediments. It may be that sufficient numbers of these forms exist for adequate nutrition. When more gut contents are examined it will probably be found that these fish are omnivorous.

REPRODUCTION AND DEVELOPMENT

There are no definitive external indications of sexual dimorphism found while studying the specimens collected. There was a difference noted on the male and female that were dissected. The female had a tubercle on either side of the genital pore. The male did not show this feature. We did notice these structures on several other fish but did not dissect the other fish due to limited numbers of good specimens. Histological work will be necessary to determine if these fish contain active gametes.

The specimens collected ranged from 46.6 mm to 103.8 mm in total length. At the present time nothing is known about the life history of these fish at sizes below 46.6 mm total length. No estimate of longivity was possible. Many troglobites have longer life spans than their epigean relatives. Appendix 1 summarizes the information about change in morphology with size.

POPULATION LEVEL

NATURAL POPULATION ESTIMATES

An estimate of population size of *T. pattersoni* was based on

Table 1. Relative abundance of troglobitic aquatic invertebrates from artesian wells in Bexar County, Texas (Karnei, 1978)

Species	Per Cent of Total Organisms
Palaemonetes antrorum (Shrimp)	51.56
Gastropod 1 (Probably new genus)	24.40
Amphipods (=8 species)	15.73
Cirolanides texensis (Isopod)	7.55
Monadella texana (Thermosbaenacean)	0.13
Gastropod 2 (Probable new genus)	0.13
Gastropod 3 (Probable new genus)	0.09
Stenascellidae (New species of isopod)	0.04
Crustacea (New)	0.04

collections from the Artesia Pump Station (Appendix 3). One assumption made is that the catfish are randomly exposed to the artesian wells at the pump station and are not "clumped" due to the velocity of water escaping the wells. Population estimates can be related to the volume of flow as indicated by Longley, 1978. Average flow of the well sampled at Artesia Pump Station is 2.1×10^4 m^3/day. The sampling period extended for 68 days with 1.4×10^6 m^3 of water sampled. Based on the average flow rate, 1 toothless blindcat comes out of the artesian well with every 6.5×10^4 m^3 of water (1/3.09 days). If flow rate remained constant at 2.1×10^4 m^3/day, then approximately 118 *T. pattersoni* would leave this artesian well each year. Due to the great amount of water pressure issuing from a 41 centimeter pipe, the flow rate of well number 5 (Figure 4) had to be restricted so that a sampling net could be attached. If the well was allowed to flow entirely open, the average flow would be 2.7×10^4 m^3/day. Of the five wells at the pump station, three are flowing artesian wells having a combined flow rate of 8.2×10^4 m^3/day. Using the restricted flow rate estimate of 1 fish every 65×10^4 m^3 (a conservative estimate), then 457 fish would be lost from the population in one year at this one location. One must consider that there are great numbers of wells in the distribution area that are not being sampled. Some of these have even greater flow rates.

POPULATION ESTIMATES

Natural population estimates were based on the assumption of continuous artesian flow in one year from the wells at the Artesia

Pump Station (Well No. 3, Figure 6). Actual population losses are calculated from pumped flow records for the period 1950 to 1977. Discharge records from the Artesia Pump Station indicated that 2.12×10^8 m^3 of water was produced from the entire field in the 28 year span of operation. Utilizing the artesian flow estimate of 1 catfish every 6.5×10^4 m^3, then 3,256 *T. pattersoni* have been lost from the population in 28 years at this location alone.

In 1977, 6.4×10^6 m^3 of water was pumped from the Artesia Pump Station. Net loss of fish is estimated to be 98 *T. pattersoni* at this location for 1977.

Based on the population estimates, there appears to be a large population of *T. pattersoni* in the San Antonio pool of the Edwards Aquifer. There is no way of knowing completely the total loss of *T. pattersoni* because most water utility stations are closed systems. A closed system involves a direct connection from the artesian well to the distribution reservoir. There is no way to place a sampling device on these wells. The water is chlorinated between the well and the reservoir, thereby killing all organisms coming from the subterranean ecosystem. This probably accounts for the buildup of organic deposits on the bottoms of many water distribution reservoirs in the area. Bexar Metropolitan Water District, Bexar County, and the City Water Board have several pump stations located within the study area. Most of these wells are over 305 meters deep and have flow rates over 315 liters sec^{-1}. Since *T. pattersoni* is distributed from the Von Ormy area to the Coliseum area, these wells probably produce the catfish.

PARASITISM AND PREDATION

DISEASE AND PARASITES

Two freshly caught fish were examined for evidence of external and internal parasites. One 72.0 mm male and one 81.8 mm female (standard length) were examined. Both fish appeared to be mature adults. Dr. David G. Huffman, Southwest Texas State University did not find evidence of external or internal parasites.

PREDATION

Living in the same habitat with *T. pattersoni* is *S. eurystomus* (Longley and Karnei, 1978). The morphology of *S. eurystomus* would seem to indicate its position as the top carnivore in this area of the Edwards Aquifer. The widemouth with teeth would indicate a carnivorous feeding habit. *S. eurystomus* is also larger than the *T. pattersoni*. *T. pattersoni* probably is food for *S. eurystomus*. When *T. pattersoni* reaches surface waters via springs or wells, it is easy prey for predaceous fish or birds.

REASONS FOR CURRENT STATUS

Texas Parks and Wildlife personnel have suggested this form should be considered for inclusion on federal lists. The reasoning probably stems from the paucity of specimens of this species in scientific collections. The fish does have a very restricted habitat but this is apparently the only significant reason for concern with its status. The fish is currently protected under state non-game law, although the need for this protection is highly questionable. The inaccessibility of the habitat of this fish protects it well.

CONSERVATION AND RECOVERY

At present no specific efforts are being made to conserve this fish. If any danger exists for the survival of *T. pattersoni*, it would probably stem from the large quantities of water being withdrawn from the Edwards Aquifer in the San Antonio area without adequate provision for additional recharge. The high volume of flow from wells may somehow decrease the numbers of fish below the number adequate to sustain a healthy breeding population.

Studies will continue at Southwest Texas State University Aquatic Station and, if sufficient numbers of living specimens are obtained, spawning studies will be attempted.

LITERATURE CITED

Abbott, P. L. 1977. Effect of Balcones Fault on ground-water movement, south central Texas. Tex. J. Sci. 29:5-14.

Arnow, T. 1959. Ground-water of Bexar County, Texas. Texas Board of Water Engineers Bull. 5911. 52 pp.

Baker, T. L. 1978. An interesting history -- how San Antonio water planners can guarantee adequate supply for a fast-growing city. Water 60:12-15.

Blair, W. F., A. P. Blair, P. Brodkorb, F. R. Cagle, and G. A. Moore. 1968. Vertebrates of the United States. (2nd ed.) McGraw-Hill Book Co., New York. 616 pp.

Browning, L. A. 1977. Source of nitrate in water of the Edwards Aquifer, south central Texas. M. A. Thesis, University of Texas, Austin. 89 pp.

Eigenmann, C. H. 1919. *Trogloglanis pattersoni* a new blind fish from San Antonio, Texas. Proc. Amer. Phil. Soc. 58:397-400.

Follett, C. R. 1956. Records of water level measurements in Bexar County, Texas Board of Water Engineers Bull. 5606. 60 pp.

Garner, J. K. and C. S. Shih. 1973. Identification of water resources planning problems in the metropolitan area of greater San Antonio and its associated counties. Texas Water Resources Institute TR-49. Texas A & M University. 152 pp.

Garza, S. 1962. Chemical analyses of water from observation wells in the Edwards and associated limestones, San Antonio area, Texas. Edwards Underground Water District Bull. 1. n.p.

Garza, S. 1966. Ground-water resources of the San Antonio area, Texas. (a progress report on studies, 1960-64) Texas Water Development Board Report 34. 31 pp.

Hubbs, C. L. and R. M. Bailey. 1947. Blind catfishes from artesian waters of Texas. Occas. Pap. No. 499 Mus. Zool., Univ. Mich. 499:1-15.

Karnei, H. 1978. Survey of the subterranean fauna, Bexar County, Texas. M. S. Thesis (In preparation). Southwest Texas State University, San Marcos, Texas.

Knowles, T. and W. B. Kelmt. 1975. Mathematical simulations of the Edwards Aquifer. Water for Texas. 5:3-6.

Lagler, K. F., J. E. Bardach and R. R. Miller. 1962. Ichthyology. John Wiley and Sons., New York. 545 pp.

Lang, J. W. 1954. Ground-water resources of the San Antonio area, Texas, a progress report of current studies. Texas Board of Water Engineers Bull. 5412. 30 pp.

Livingston, P. A., A. N. Sayre and W. N. White. 1936. Water Resources of the Edwards Limestone in the San Antonio Area, Texas. U. S. Geol. Surv., Water-Supply Paper, 773-B: 59-113 pp.

Livingston, P. 1947. Ground-water resources of Bexar County, Texas. Texas Board of Water Engineers. 234 pp.

Longley, G. 1978. Status of *Thphlomolge (=Eurycea) rathbuni*, the Texas Blind Salamander. End. Species Report 2. U. S. Fish and Wildlife Service. 45 pp.

Longley, G. and H. Karnei. 1978. Status of *Satan eurystomus* Eigenmann, the widemouth blindcat. Contract No. 14-16-0002-77-035. U. S. Fish and Wildlife Service. 48 pp.

Maclay, R. W. and P. L. Rettman. 1973. Regional specific yield of the Edwards and associated limestones in the San Antonio, Texas area. U. S. Geological Survey (open file report). 10 pp.

Maclay, R. W. and T. A. Small. 1976. Progress report on geology of the Edwards Aquifer, San Antonio area, Texas, and preliminary interpretation of borehole geophysical and laboratory data on carbonate rocks. U. S. Dept. of the Interior, Geological Survey. (Open File Report 76-627). 65 pp.

Pearson, F. J., Jr., P. L. Rettman, and T. A. Wyerman. 1975. Environmental tritium in the Edwards Aquifer, central Texas 1963-71. U. S. Dept. of the Interior (Open File Report 74-362). 32 pp.

Pearson, F. J., Jr. and P. L. Rettman. 1976. Geochemical and isotopic analyses of waters associated with the Edwards Limestone aquifer, central Texas. U. S. Geological Survey Report. 35 pp.

Pettit, B. M. and W. O. George. 1956a. Ground-water resources of the San Antonio area, Texas, a progress report on current studies. Texas Board of Water Engineers Bull. 5608. Vol. 1. 80 pp.

Pettit, B. M. and W. O. George. 1956b. Ground-water resources of the San Antonio area, Texas. Texas Board of Water Engineers Bull. 5608. Vol. 2, pt. 1. 252 pp.

Pettit, B. M. and W. O. George. 1956c. Ground-water resources of the San Antonio area, Texas. Texas Board of Water Engineers Bull. 5608. Vol. 2, pt. 2. 285 pp.

Pettit, B. M. and W. O. George. 1956d. Ground-water resources of the San Antonio area, Texas. Texas Board of Water Engineers Bull. 5608. Vol. 2, pt. 3. 225 pp.

Puente, C. 1974. Records of precipitation, water levels, and ground-water recharge to the Edwards and associated limestones, San Antonio area, Texas 1972-73. Edwards Underground Water District. 12 pp.

Puente, C. 1976. Statistical analysis of water-level, spring flow, and stream flow data for the Edwards Aquifer in south central Texas. Edwards Underground Water District. 58 pp.

Rappmund, R. A. 1975. Ground-water discharge from the Edwards and associated limestones, San Antonio area, Texas. 1976. Edwards Underground Water District Bull. 34. 8 pp.

Rappmund, R. A. 1976. Ground-water discharge from the Edwards and associated limestones, San Antonio area, Texas (1976). Edwards Underground Water District Bull. 35. 7 pp.

Rappmund, R. A. 1977. Ground-water discharge from the Edwards and associated limestones, San Antonio area, Texas (1976). Edwards Underground Water District Bull. 36. 8 pp.

Reeves, R. D., J. Rawson, and J. F. Blakey. 1972. Chemical and bacteriological quality of water at selected sites in the San Antonio area, Texas, August 1968-April 1972. U. S. Geological Survey Report. 30 pp.

Reeves, R. D. 1976. Chemical and bacteriological quality of water at selected sites in the San Antonio area, Texas, August 1968-January 1975. U. S. Dept. of the Interior, U. S. Geological Survey. 122 pp.

Rettman, P. 1969. Records of wells and springs, San Antonio area, Texas. Edwards Underground Water District. 28 pp.

Seward, L. B., T. R. Knowles and W. B. Klemt. 1974. Ground-water models for Texas. Paper presented at Water for Texas Conf., Texas A & M University, Sept. 19-20. 29 pp.

Sieh, T. W. 1975. Edwards (Balcones fault zone) Aquifer test well drilling investigation. Texas Water Development Board, Water Availability Division. 117 pp.

Suttkus, R. D. 1961. Additional information about blind catfishes from Texas. Southwest Nat. 6:55-64.

Taylor, W. R. 1969. A revision of the catfish genus *Noturus* Rafinesque, with an analysis of higher groups in the Ictaluridae. U. S. National Museum Bull. 282. Smithsonian Institution Press, Washington. 315 pp.

Texas Organization for Endangered Species. 1975. T.O.E.S. watch-list of endangered, threatened, and peripheral vertebrates of Texas. Temple, Texas. Publ. 1. 12 pp.

U. S. Dept. of the Interior. 1973a. Memorandum: Performance of Edwards Aquifer when subjected to a rapid increase in well discharge. Bureau of Reclamation (Southwest Region). Loose leaf. n.p.

U. S. Dept. of the Interior. 1973b. Memorandum: Edwards Aquifer when subjected to increasing well discharge. Bureau of Reclamation (Southwest Region). Loose leaf. n.p.

U. S. Dept. of the Interior. 1973c. Threatened Wildlife of the United States. Fish. and Wildl. Resource Pub. 114. 289 pp.

Vandel, A. 1965. Biospeleology, the biology of cavernicolous animals. (Transl. from French). Pergamon Press, New York. 524 pp.

Appendix 1. Proportional measurements of *Trogloglanis pattersoni** (expressed as thousandths of the standard length)

Measurement	1	2	3	4	5	6	7	8	9	10	11	12	13	14
	Specimen Numbers**													
Total length (mm)	46.6	62.1	68.0	71.0	76.0	76.0	74.7	74.0	81.0	80.9	78.4	81.7	81.0	84.2
Standard length (mm)	38.7	51.1	54.3	58.6	62.0	62.0	63.1	63.2	65.3	65.8	65.8	66.8	66.9	68.0
Wet Weight in Formalin (g)	0.82	2.68	2.64	4.27	4.15	3.71	5.06	4.20	7.16	7.06	7.05	5.28	6.02	4.50
Body depth below dorsal origin	207	196	184	227	194	190	223	226	240	260	243	208	217	172
Body depth above anal origin to top of adipose	178	204	201	208	177	165	208	212	228	228	231	235	200	190
Caudal peduncle depth (overall)	129	143	129	116	129	131	124	117	138	137	149	132	120	116
Caudal peduncle depth (muscle mass only)	85	82	72	85	81	79	79	79	84	84	76	75	76	79
Caudal peduncle length	168	176	184	150	179	160	166	158	172	157	182	163	167	162
Predorsal length	310	339	337	341	323	323	333	345	338	350	334	344	345	329
Length to adipose origin	618	636	608	614	661	661	618	617	609	602	600	611	631	676
Dorsal base	106	135	147	121	129	129	141	101	121	126	131	112	135	107
Interdorsal distance	150	180	180	157	210	215	177	100	153	163	155	193	188	174
Adipose fin, basal length	240	266	313	273	242	277	301	316	268	277	269	308	299	306
Adipose fin, length to tip	310	315	331	329	261	303	317	322	303	312	342	332	311	318
Adipose notch to caudal base	114	112	129	119	113	105	116	90	113	123	114	112	90	103
Anal origin to caudal base	388	386	383	319	350	355	361	328	352	343	347	344	374	338
Anal base	186	211	208	188	177	184	193	153	184	178	169	187	191	176
Pelvic insertion to anal origin	103	114	99	106	129	110	109	160	107	99	122	135	120	124
Length to pelvic insertion	566	536	552	573	565	550	552	549	582	603	565	598	546	574
Anus to anal origin	52	59	68	51	81	65	59	71	46	35	58	64	60	88
Dorsal fin height	178	239	287	235	258	289	255	189	240	286	254	277	257	221
Dorsal spine length	--	162	217	123	176	161	174	117	168	172	173	195	167	118
Longest dorsal ray	--	184	249	174	191	223	206	--	161	179	198	--	202	--
Adipose fin vertical height	65	78	74	73	66	66	79	60	83	73	88	62	75	44

Appendix 1 (Cont.)

Measurement	Specimen Numbers**													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Caudal fin length														
To upper angle.	248	245	285	232	210	242	182	--	282	260	223	--	239	--
To end of shortest ray.	230	180	210	191	182	192	158	--	230	205	175	--	181	--
To lower angle.	238	217	271	242	231	223	206	--	271	242	226	--	236	--
Anal fin, depressed length.	245	274	300	268	269	285	266	209	253	281	261	241	299	250
Longest anal ray.	--	180	225	154	194	194	171	--	168	167	155	152	224	--
Pelvic fin length	109	166	180	137	132	153	143	111	145	176	123	151	139	116
Pectoral fin length	155	229	227	247	231	242	201	141	231	237	213	251	232	206
Pectoral spine length	116	157	153	138	142	139	174	--	150	160	147	142	164	96
Length first pectoral branched ray beyond tip of spine	--	166	221	142	165	195	182	--	199	119	99	--	194	--
Between pectoral insertions	186	227	184	222	210	210	219	158	233	234	217	210	209	210
Between pelvic insertions	41	37	37	43	44	45	32	32	46	38	32	34	45	32
Head length	271	274	273	270	269	271	261	275	299	299	281	262	269	263
Head width.	271	294	285	273	260	263	279	272	273	271	277	271	266	281
Head depth at occiput	163	155	147	188	166	148	190	158	172	167	185	145	161	135
Head depth at end of first third of projection of head length.	140	117	120	169	142	131	158	--	155	143	167	--	149	--
Mouth Width														
Gape, exterior.	--	166	166	--	162	176	162	--	168	184	167	--	175	--
Least interior width.	--	98	81	--	79	85	95	--	77	93	68	--	82	--
At base of maxillary barbels, behind upper lip. . . .	--	176	175	--	163	173	164	--	208	193	175	--	179	--
Snout tip to mandible tip	98	104	116	--	118	106	111	--	175	122	120	--	105	--
Snout tip to front of gill opening.	155	174	171	184	205	161	174	--	201	191	179	--	254	--
Front of gill opening to line joining pectoral insertions.	103	98	105	109	97	113	81	--	110	137	125	--	149	--

Appendix 1 (Cont.)

Measurement	Specimen Numbers**													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Length of barbels														
Nasal	--	135	217	159	131	158	143	--	247	160	214	--	136	--
Maxillary	--	139	166	--	98	145	124	--	168	182	160	--	120	--
Outer mental	--	94	147	--	79	98	71	--	103	94	106	--	75	--
Inner mental	--	88	83	--	65	98	60	--	86	79	103	--	54	--
Distance between posterior nostrils	--	76	81	77	66	65	79	60	84	76	82	59	73	71
Snout to posterior nostrils	--	78	74	67	82	82	73	78	75	97	76	89	75	74
Dorsal origin to occiput	145	137	133	162	105	129	143	--	139	143	164	169	145	110
Dorsal origin to caudal base	695	728	700	674	719	697	718	657	698	669	699	674	710	704

*For paired structures measurements were taken on both sides and averaged.

**Specimens held by the following:
Southwest Texas State University--Nos. 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, and 28
Witte Memorial Museum--No. 15
Tulane University--No. 16

Appendix 1

Measurement	Specimen Numbers**													
	15	16	17	18	19	20	21	22	23	24	25	26	27	28
Total length (mm)	--	--	81.5	84.1	84.1	86.4	88.5	87.2	87.2	89.1	94.0	93.3	96.0	103.8
Standard length (mm)	68.3	68.6	69.3	70.5	71.3	72.0	72.8	72.8	73.4	75.0	78.1	78.2	81.8	87.2
Wet Weight in Formalin (g)	--	--	4.18	6.84	6.57	8.33	7.93	6.75	8.31	7.47	11.15	11.72	11.16	16.21
Body depth below dorsal origin	220	208	209	214	209	228	213	214	210	183	228	251	227	229
Body depth above anal origin to top of adipose	223	250	157	211	194	208	209	207	204	177	224	220	200	212
Caudal peduncle depth (overall)	127	141	101	142	122	135	124	130	127	129	137	128	133	123
Caudal peduncle depth (muscle mass only)	83	--	75	70	77	79	82	71	83	71	78	84	73	75
Caudal peduncle length	194	179	185	173	164	165	187	181	166	183	163	202	174	169
Predorsal length	319	355	332	326	344	333	345	360	319	307	328	355	345	335
Length to adipose origin	599	639	577	638	631	646	611	684	620	589	640	678	601	657
Dorsal base	110	115	92	128	126	117	114	129	123	120	122	123	122	117
Interdorsal distance	189	183	157	210	199	201	172	196	198	200	227	271	183	242
Adipose fin, basal length	307	316	264	295	261	264	234	272	286	309	250	317	306	239
Adipose fin, length to tip	328	329	--	312	294	307	269	290	327	311	294	324	318	286
Adipose notch to caudal base	115	119	101	99	119	104	147	113	114	99	132	127	103	115
Anal origin to caudal base	376	339	384	360	362	336	343	387	342	384	335	340	348	327
Anal base	196	179	202	187	180	167	168	225	177	197	175	179	164	161
Pelvic insertion to anal origin	162	167	137	126	128	113	137	110	129	107	125	161	136	109
Length to pelvic insertion	502	523	538	572	564	581	547	536	549	547	561	607	575	584
Anus to anal origin	63	62	65	55	58	56	69	66	60	55	51	55	49	61
Dorsal fin height	257	--	206	227	229	264	261	223	232	251	227	230	259	229
Dorsal spine length	175	--	159	142	181	153	183	165	161	173	140	157	165	157
Longest dorsal ray	225	--	--	170	184	194	209	209	204	153	151	238	218	153
Adipose fin vertical height	86	80	--	85	62	75	69	56	68	79	74	92	79	64

Appendix 1

Measurement	Specimen Numbers**													
	15	16	17	18	19	20	21	22	23	24	25	26	27	28
Caudal fin length														
To upper angle.	244	247	--	184	184	222	234	220	215	200	213	236	196	204
To end of shortest ray.	212	220	--	170	168	183	196	202	151	184	178	196	158	183
To lower angle.	242	246	--	189	178	222	238	216	204	197	220	221	187	218
Anal fin, depressed length.	254	246	274	255	254	238	261	298	240	239	243	249	222	255
Longest anal ray.	169	196	--	153	97	156	192	196	113	173	138	173	159	157
Pelvic fin length	149	155	130	135	137	133	165	150	135	131	127	148	137	132
Pectoral fin length	219	231	188	201	184	232	254	224	185	207	186	243	214	200
Pectoral spine length	174	--	144	128	142	153	162	147	124	149	114	150	141	120
Length first pectoral branched ray beyond tip of spine	45	224	--	186	153	101	103	202	161	177	90	215	171	108
Between pectoral insertions	255	266	237	270	219	211	216	220	208	213	218	247	230	213
Between pelvic insertions	33	39	66	31	36	35	41	41	37	37	32	34	37	33
Head length	271	307	270	258	266	275	275	276	256	251	252	319	270	243
Head width.	266	281	267	267	273	278	253	254	244	273	256	269	256	258
Head depth at occiput	174	186	144	170	161	154	165	144	159	167	157	177	160	161
Head depth at end of first third of projection of head length	132	--	111	128	123	128	151	137	121	147	141	142	134	164
Mouth Width														
Gape, exterior.	131	--	--	142	151	181	173	151	144	148	151	137	189	163
Least interior width.	81	--	--	74	67	78	69	69	94	77	70	102	76	57
At base of maxillary barbels, behind upper lip. . . .	139	--	--	163	154	182	188	157	150	163	153	147	191	170
Snout tip to mandible tip	49	--	--	79	104	118	147	96	105	120	108	39	134	116
Snout tip to front of gill opening.	129	--	--	247	170	165	179	162	159	243	156	172	230	169
Front of gill opening to line joining pectoral insertions.	78	--	--	99	136	115	113	120	112	93	122	111	147	103

Appendix 1

Measurement	Specimen Numbers**													
	15	16	17	18	19	20	21	22	23	24	25	26	27	28
Length of barbels														
Nasal	210	196	--	199	118	181	201	148	139	136	129	223	153	200
Maxillary	202	176	--	156	98	167	177	93	172	113	141	125	137	161
Outer mental	145	100	--	123	74	104	96	52	98	75	90	94	71	112
Inner mental	137	74	--	111	--	76	69	45	65	67	77	70	55	87
Distance between posterior nostrils	61	72	--	61	70	74	81	76	72	67	70	75	71	71
Snout to posterior nostrils	58	83	--	71	77	82	77	76	68	76	64	100	98	67
Dorsal origin to occiput	--	64	146	149	137	142	168	148	140	127	138	123	156	163
Dorsal origin to caudal base	--	686	670	709	683	697	687	694	734	727	720	731	697	712

*For paired structures measurements were taken on both sides and averaged.

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Witte Memorial Museum--No. 15
Tulane University--No. 16

Appendix 2. Physicochemical analyses of wells sampled during the study period

Parameter		Well #1* 20 VI 77	Well #2* 20 VI 77	Well #3* 24 III 72
Depth	(m)	582.0	513.0	402.0
pH		7.3	7.3	7.3
Specific Conductance	(µmhos)	467.0	482.0	465.0
Water Temperature	(^{o}C)	27.0	27.0	27.0
Sodium Adsorption Ratio		0.3	0.3	-
Percent sodium		8.0	8.0	-
Dissolved (ug/l)				
Arsenic		1.0	1.0	-
Barium		0.0	0.0	-
Cadmium		0.0	0.0	-
Chromium		10.0	10.0	-
Copper		0.0	0.0	-
Iron		10.0	10.0	-
Lead		1.0	0.0	-
Manganese		0.0	0.0	-
Mercury		0.0	0.0	-
Selenium		1.0	1.0	-
Silver		0.0	0.0	-
Zinc		0.0	0.0	-
Dissolved (mg/l)				
Calcium		65.0	66.0	-
Chloride		18.0	19.0	15.0
Fluoride		0.3	0.3	-
Magnesium		16.0	17.0	-
Oxygen		5.1	4.3	4.9
Potassium		1.1	1.2	-
Silica		12.0	12.0	-
Sodium		8.7	10.0	-
Sulfate		23.0	30.0	23.0
Organic-N		0.04	0.01	-
Dissolved (mg/l)				
Kjeldahl-N		0.05	0.05	-
NH_3-N		0.01	0.04	-
NO_2-N		0.00	0.00	-
NO_3-N		1.3	1.2	-
Phosphorus-P		0.00	0.00	-
Organic-Carbon		0.5	0.3	-

Appendix 2. (Cont.)

Parameter	Well #1* 20 VI 77	Well #2* 20 VI 77	Well #3* 24 III 72
Total (mg/l)			
Organic-Carbon	4.8	0.3	-
Organic-N	0.03	0.01	-
Nitrogen-N	0.75	0.46	-
NO_2-N	0.01	0.01	-
NO_3-N	0.70	0.43	-
NH_3-N	0.01	0.01	-
Nitrogen-NO_3	3.3	2.0	-
Kjeldahl-N	0.04	0.02	-
Phosphorus-P	0.02	0.02	-
Bicarbonate	240.0	240.0	244.0
Carbonate	0.0	0.0	-
Noncarbonate hardness	31.0	38.0	-
Hardness	230.0	230.0	236.0
Detergents-MBAS	0.0	0.0	-

*See Figure 6

Appendix 3. Numbers of *Trogloglanis pattersoni* collected during this study

Date	No. used in Appendix 1	O. R. Mitchell Well	Artesia Well No. 4	Verstraeten Well
4 IV 77	26	1		
7 IV 77	8	1		
17 IV 77	12	1		
18 I 78	14			1
24 II 78	18		1	
27 II 78	24,27		2	
3 III 78	5,6,7,13		4	
5 III 78	3,17		2	
8 III 78	2		1	
11 III 78	22		1	
13 III 78	11,19,23		3	
19 III 78	20		1	
20 III 78	28		1	
21 III 78	9		1	
23 III 78	25		1	
25 III 78	4		1	
29 III 78	10		1	
31 III 78	1		1	
26 IV 78	21		1	