STATUS OF *TROGLOGLANIS PATTERSONI* EIGENMANN, THE TOOTHLESS BLINDCAT

AND

STATUS OF *SATAN EURYSTOMUS* HUBBS AND BAILEY, THE WIDEMOUTH BLINDCAT

PREPARED FOR THE
FISH AND WILDLIFE SERVICE
ALBUQUERQUE, NEW MEXICO

BY

GLENN LONGLEY
HENRY KARNEI, JR.

U.S. FISH AND WILDLIFE SERVICE
ALBUQUERQUE, NEW MEXICO
1979

ENDANGERED SPECIES REPORT 5

STATUS OF *SATAN EURYSTOMUS* HUBBS AND BAILEY,

THE WIDEMOUTH BLINDCAT

by

Glenn Longley and Henry Karnei, Jr.

Aquatic Station
Southwest Texas State University
San Marcos, Texas 78666

Contract #14-16-0002-77-035

June 30, 1978

Project Leader

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

ABSTRACT

Fourteen specimens of *Satan eurystomus* Hubbs and Bailey have been 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.

CONTENTS

FIGURES

TABLE

APPENDICES

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 fish for us.

The cooperation of Southwest Texas State University is gratefully acknowledged.

INTRODUCTION

Satan eurystomus Hubbs and Bailey, 1947 is commonly referred to as the widemouth 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 it requires the nearby occurrence of the "Bad Water Zone" for its existence.

BACKGROUND

ORIGINAL DISCOVERY AND DESCRIPTION

In 1938 Carl L. Hubbs visited the Witte Memorial Museum at San Antonio, Texas. The director of the Museum, Mrs. Ellen S. Quillin, allowed him to examine two blind catfishes. They were both apparently in the family Ictaluridae. One was the previously described, highly specialized *Trogloglanis pattersoni* (Eigenmann, 1919), and the other was a new form to be designated *Satan eurystomus* Hubbs and Bailey, 1947

(Figure 1). In the original description the authors noted that other blind catfishes had been captured and reported but none were preserved. Other sites listed as sources of blind catfishes in the paper were (1) an artesian well of the Alamo Dressed Beef Company (the specimen was given a number by the Witte Memorial Museum and then lost), (2) Mrs. R. P. Persyn referred to a blind catfish in the September 7, 1929 San Antonio Light newspaper and (3) Mr. Josef Boecke indicated that he had seen about twenty blind, pink catfish in his irrigation ditches fed by his 305 meter deep artesian well west of San Antonio.

The holotype (Witte Memorial Museum, San Antonio, Texas, Accession No. 31.P.16.5) was collected from a 381 meter deep artesian well near San Antonio, Texas. Mr. William Kempin had given the specimen to the Museum. It was an immature male with a standard length of 68.7 mm (Appendix 1). In the paper (Hubbs and Bailey, 1947) the authors compared this new genus to the previously described *Trogloglanis pattersoni*.

Suttkus (1961) gave additional information about *S. eurystomus*. He obtained one specimen from Mr. John E. Werler in 1955. The specimen was taken from the nearby 610 meter deep well on the O. R. Mitchell Ranch, Von Ormy, Bexar County, Texas. He obtained another specimen (U.S.N.M. No. 195830) from Dr. Bruce B. Collette. It came from the El Patio Foods Plant at 2600 S. W. Military Drive, San Antonio, Bexar County, Texas. The fish was taken about June 1, 1960 from a newly drilled well (427 meters deep). The San Antonio news reported that about a dozen blind catfish and some freshwater shrimp came out of the well during the initial flow. The latter specimen had been held in the San Antonio Zoo for a period of time before the U. S. National Museum obtained it.

Clark Hubbs (in Lundelius and Slaughter, 1971) reviewed the available

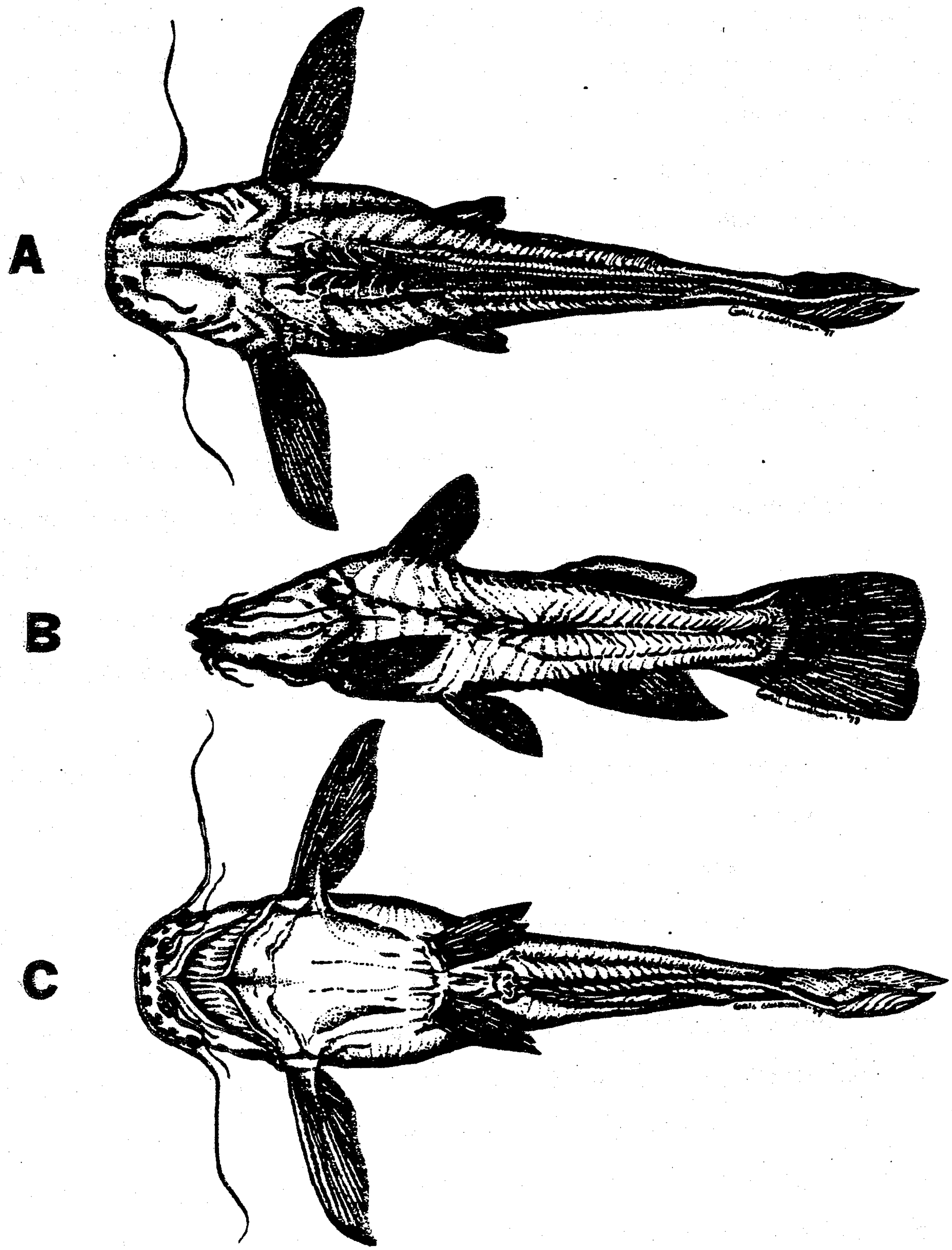


Figure 1. *Satan eurystomus* Hubbs and Bailey, standard length 97.1 mm
A = Dorsal view, B = Lateral view, and C = Ventral view

information on Texas cave fishes. At least 200 fishes are known to inhabit Texas inland waters and only two, *Satan eurystomus* and *Trogloglanis pattersoni*, are troglobitic. Seven surface fishes have been found in Texas caves and two of these (29%) are catfishes. Longley (1977) in a report to the Edwards Underground Water District, noted the presence of Yellow Bullheads (*Ictalurus natalis*) in Valdina Sinkhole, a cave system in Medina County. The cave system occurs in the Edwards formation, therefore the fish are in the Edwards Aquifer.

TAXONOMIC PROBLEMS

Prior to this study only three specimens were ever examined by the scientific community. To obtain a better understanding of the taxonomic relationships of this species there is much about life history, morphology at different life stages, sexual dimorphism, genetics and physiological differences that still needs to be investigated. Hubbs and Bailey (1947) and Suttkus (1961) have indicated they consider this species to be most closely related to the epigean *Pylodictis olivaris*, the flathead catfish. Based on external morphological similarities this would seem to be the most probable relationship (Figure 2). One should keep in mind that changes in relatively small breeding populations caused by genetic drift, can effect major morphological changes in relatively short periods of time. 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. He agreed with previous workers that *S. eurystomus* is most similar to *Pylodictis* and constructed a

A

B

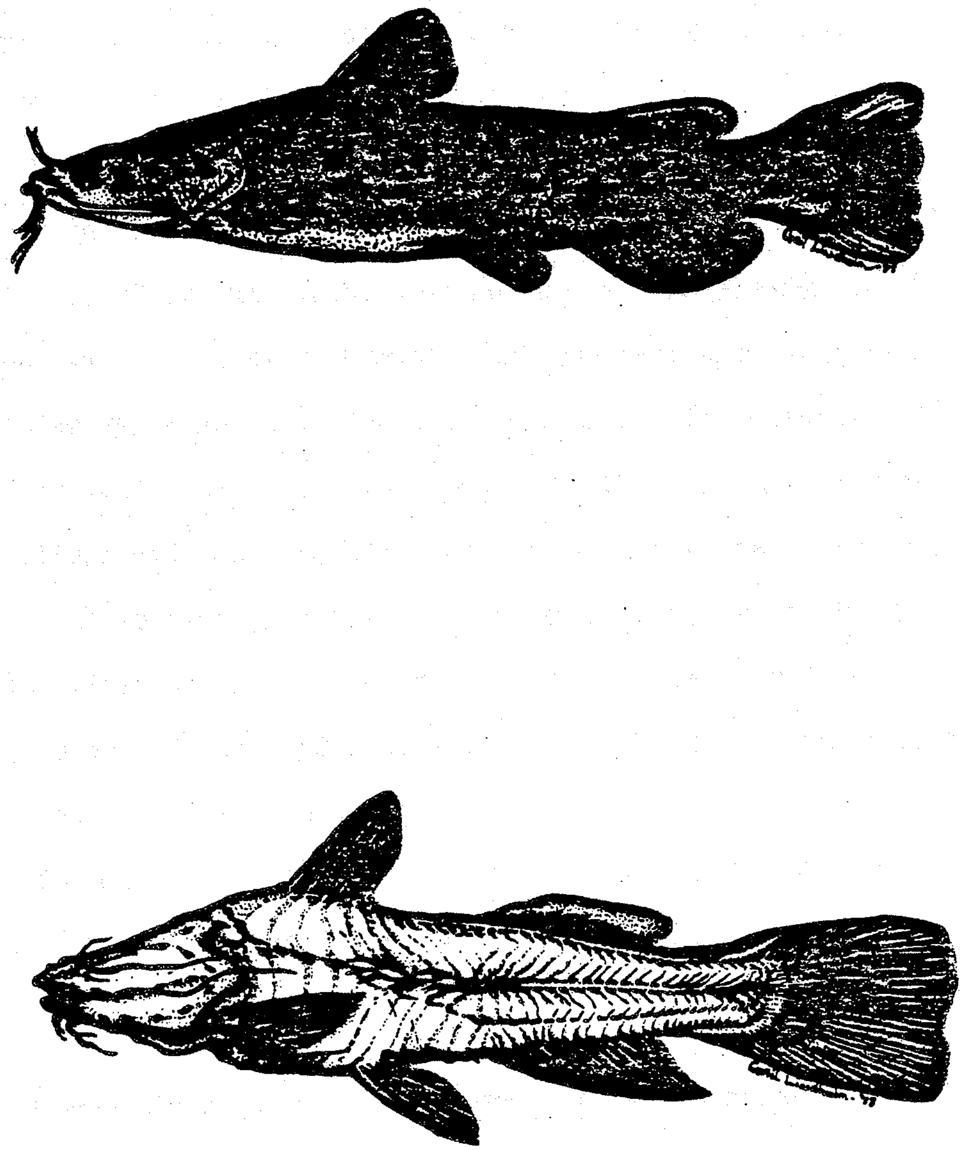


Figure 2. A comparison between the flathead catfish, *Pylodictis olivaris* (A) and the widemouth blindcat, *Satan eurystomus* (B)

phylogeny of the Ictaluridae (Figure 3).

SIGNIFICANCE (BIOLOGICAL OR ECOLOGICAL)

Satan eurystomus is of considerable scientific interest since it represents one of the two known troglobitic catfish inhabiting subterranean waters in North America. The eyes are completely absent, at least externally. This fish is probably the top carnivore in a section of the Edwards Aquifer in southern Bexar County, Texas. This has some interesting implications for determining water quality changes. One would expect pollutants such as pesticides and heavy metals to be concentrated up the food chain by "biological magnification." It is possible that in the future small changes in water quality may be determined by periodic sampling of fatty tissues of this fish.

Another feature of this fish that is particularly interesting is the adaptation for living at great depth (near 610 meters) in some locations. The fish, unlike its surface relatives, does not have an air bladder, but has replaced it with generous accumulations of fat in the area where the air bladder would occur.

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). It has been suggested for listing by Texas Parks and Wildlife Department employees. 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 widemouth blindcat is listed in the Red Data Book of the International Union

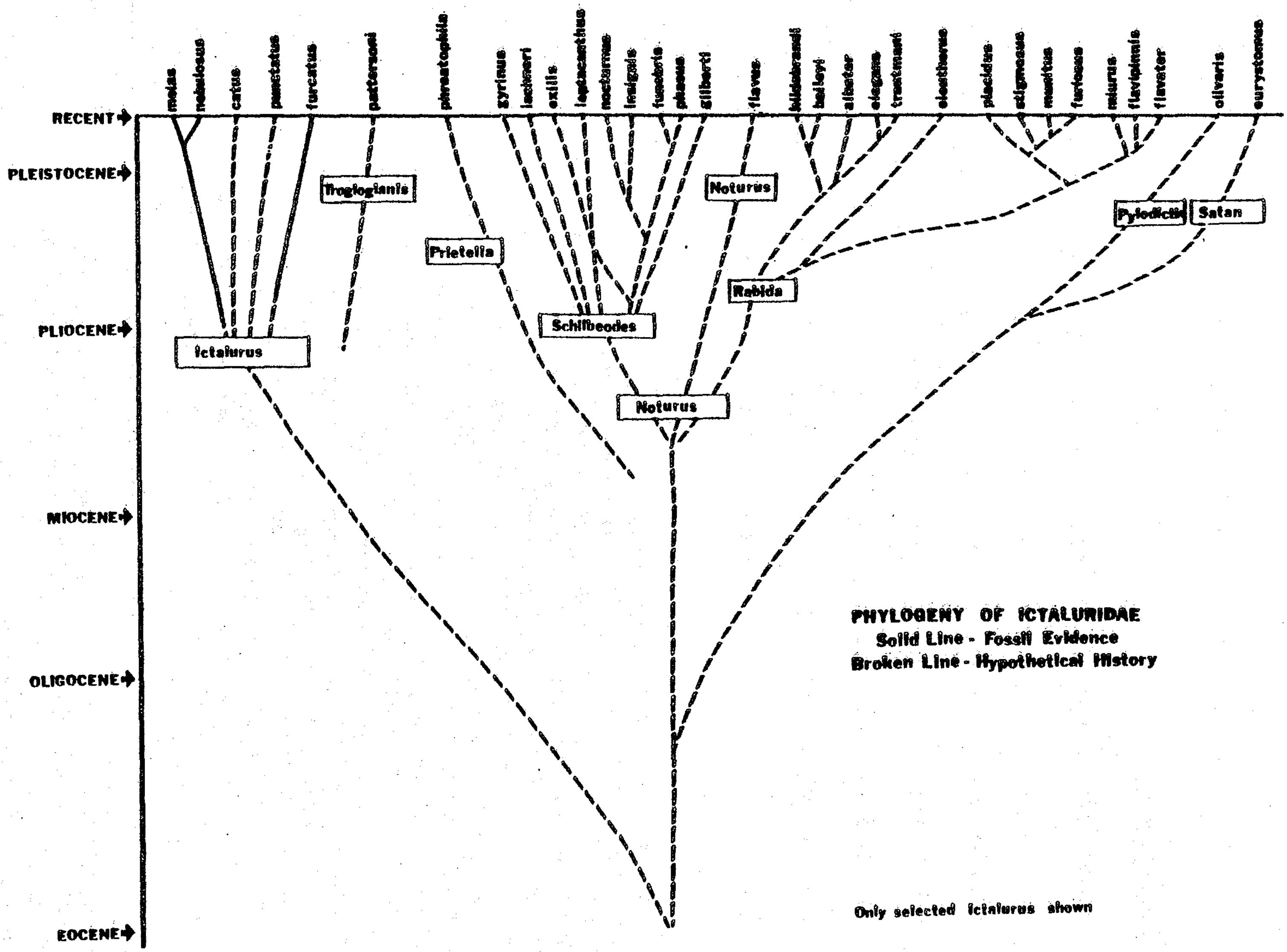


Figure 3. Phylogeny of the Ictaluridae (Taylor, 1969)

for the Conservation of Nature.

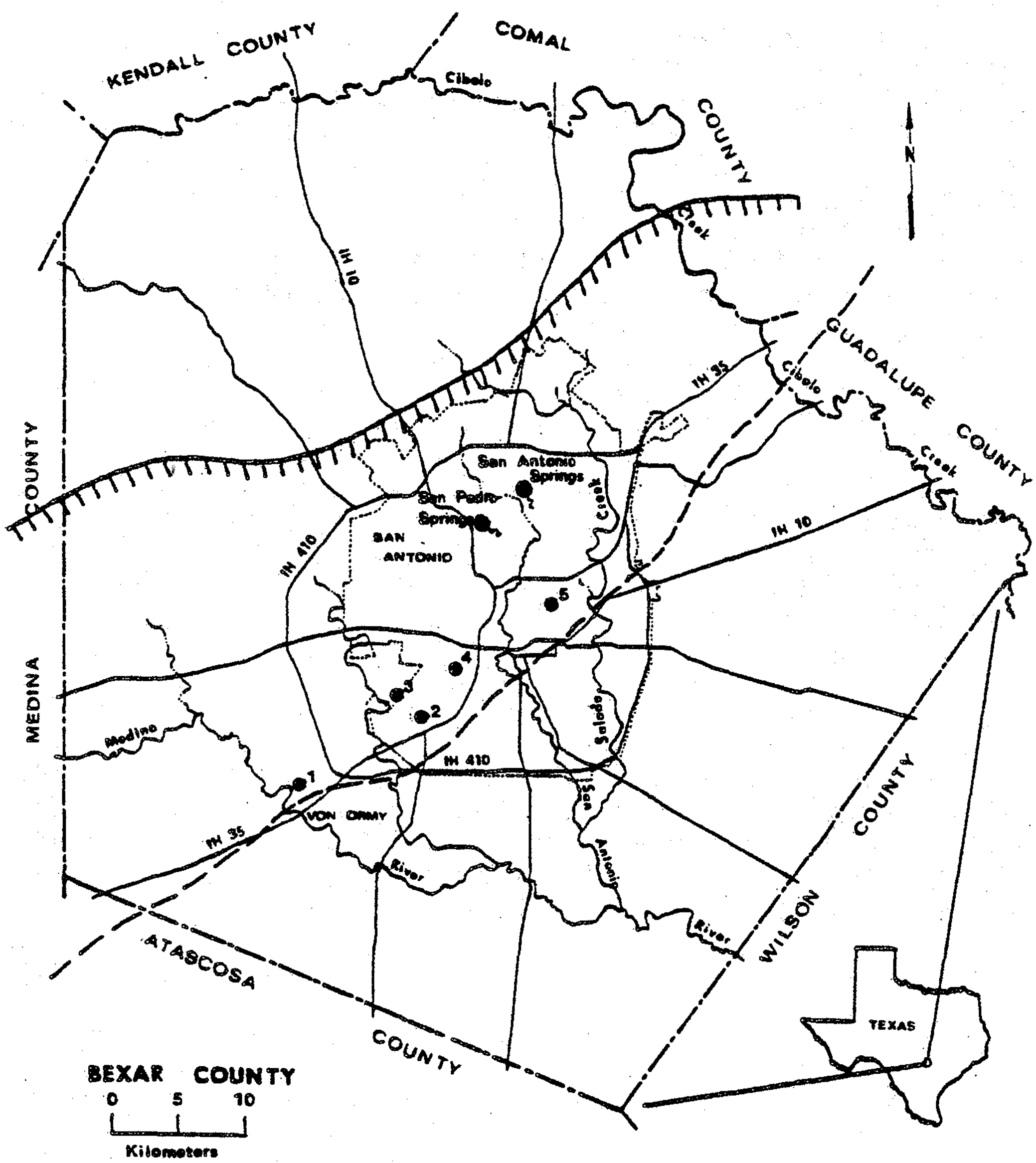
Texas Parks and Wildlife has determined that this species should be afforded protection under its nongame rules.

DISTINGUISHING CHARACTERISTICS

GENERAL CHARACTERISTICS

The maximum total length for a specimen recovered during this study was 136.9 mm. The maximum standard length was 113.6 mm. The maximum weight in formalin was 27.38 grams. The largest specimen was taken from the artesian City Water Board well at the Artesia Pump Station in San Antonio (location 5 in Figure 4). The holotype specimen was an immature male 68.7 mm in standard length (Hubbs and Bailey, 1947). It was 60% as large as our largest specimen. The following description appeared in their paper:

> In common with most other blind, subterranean fishes, the lateral line canals and pores of the head are excessively developed. Two large pores open just behind the head, at the origin of the lateral line. The upper, more anterior one is almost level with the 2 pores comprising the straight part of the lateral line on the posterior part of the head. There are 12 large operculomandibular pores. The anteriormost pore on the mandible opens close to its fellow of the opposite side in a median transversely oval pit. A pore lies behind the eye position. Another is situated above and behind this pore. Of the 5 or 6 pores in the infraorbital series, the anterior 3 or 4 form a nearly horizontal line behind the anterior nostril. On each side there are 1 interorbital, 2 nasals, and 1 prenasal. No supratemporal canal or pores are visible. The lateral line extends to below dorsal or to below interdorsal space. It has 3 elongate pores in a short anterior tube, and behind this 5 to 9 short separated sections of tube, each with a pore on either side. Sense organs in the form of low cones are conspicuous particularly on the head and anterior trunk regions.
>
> The nostrils are minute. The diameter of the anterior one is about 0.4 mm., only two-fifths the size of that in *T. pattersoni*.
>
> There are 10 branchiostegal rays. The gillrakers on the outer arch number 4 + 15 = 19. They are slender and



1 O. R. Mitchell Well
2 El Patio Foods Well
3 William Kempin Well
4 Bexar Metropolitan Well
5 Artesia Well

KEY
Artesian Well
Spring
Balcones Escarpment
Bad water zone

Figure 4. Collection locations of *Satan eurystomus*

moderately long. The longest is about one-third as long as the distance between the posterior nostrils.

The premaxillaries bear a well-developed patch of villiform teeth which form a transverse band without backward projecting processes. The length of the band is 9 percent of the width; there is no separation or constriction at the midline. The palate is toothless.

The first dorsal fin is high and somewhat pointed, with 1 rather weak spine and 7 branched rays (counting the last 2 elements as 1 ray). The anal is long and low, with 6 unbranched and 14 branched rays. Along the front margin of the anal fin the anterior rays bear several weak antrorse spinules per segment. Except for the marginal principal rays the caudal fin is mutilated distally, but the form of the remaining part of the fin suggests that it may have been slightly emarginate. There are 17 principal caudal rays; 13 procurrent rays above, of which at least 5 are segmented; and 16 procurrent rays below, of which at least 4 are segmented. Each pectoral fin has 10 branched rays and a single spine, which is smooth along its anterior edge and bears 8 to 10 serrations posteriorly. Each pelvic fin has 9 branched rays and 1 simple ray on its outer edge, which bears spinules like those at the front of the anal fin.

The intestine is relatively thick-walled and rather short, with one extra coil about one-third as wide as the mouth. The outer edge of the testis is finely fringed, as is usual in the family. No trace of an air bladder could be found. The body cavity is largely filled with adipose tissue.

The fish appear light pink when alive. One small specimen has been photographed extensively, including a super-8 mm motion picture of its swimming activity in an aquarium. The films may be viewed by contacting the Aquatic Station, Southwest Texas State University. A list of morphological measurements obtained during this study are compared with measurements made by previous workers in Appendix 1. The head region of *S. eurystomus* is covered with numerous lateral line pores (Figure 5). These pores contain sensory receptors that no doubt have increased in number as an adaptive response to the subterranean habitat.

SPECIFIC CHARACTERISTICS

In the key to the genera of Ictaluridae (Blair, W. F., Blair, A. P., Brodkorb, P., Cagle, F. R., and G. A. Moore, 1968) *Satan* is distinguished

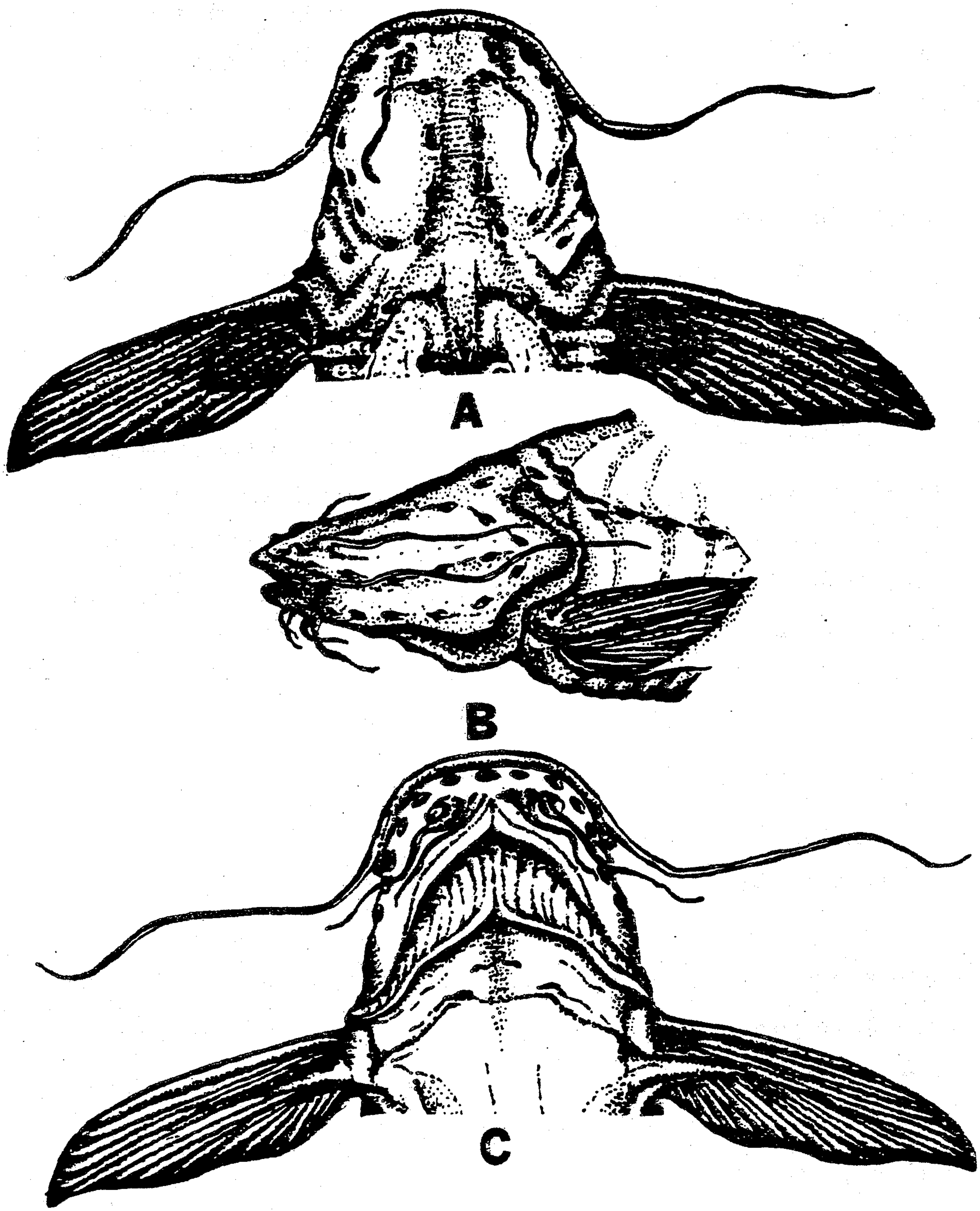


Figure 5. Head region of *Satan eurystomus* A = dorsal view, B = lateral view, and C = ventral view

by the following characters; eyes absent, body without pigment, jaw teeth well developed, jaws strong, lower jaw normal and slightly shorter than upper and mouth not inverted (Figure 1). This is a monotypic genus (Figure 3).

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. The head regions are easily distinguished based on structure of the mouth (Figure 6). In addition to the specific characteristics mentioned previously the absence of an air bladder would separate these forms from their similar surface relatives.

DISTRIBUTION

FORMER KNOWN DISTRIBUTION

William Kempin Well (Figure 4 - Well No. 3)

Hubbs and Bailey (1947) secured the type specimen from the Witte Memorial Museum at San Antonio, Texas, in 1938. Mrs. Ellen Quillin received the blind catfish from William Kempin. According to several of the "Old Belgium Farmers," location of the Kempin artesian well (381 meters deep) was in southwest San Antonio near the East Kelly Air Force Base. Presently this area is under development and has become a residential area. No evidence of the well site could be found.

El Patio Foods Well (Figure 4 - Well No. 2)

Approximately 2.4 kilometers south-southeast from that location,

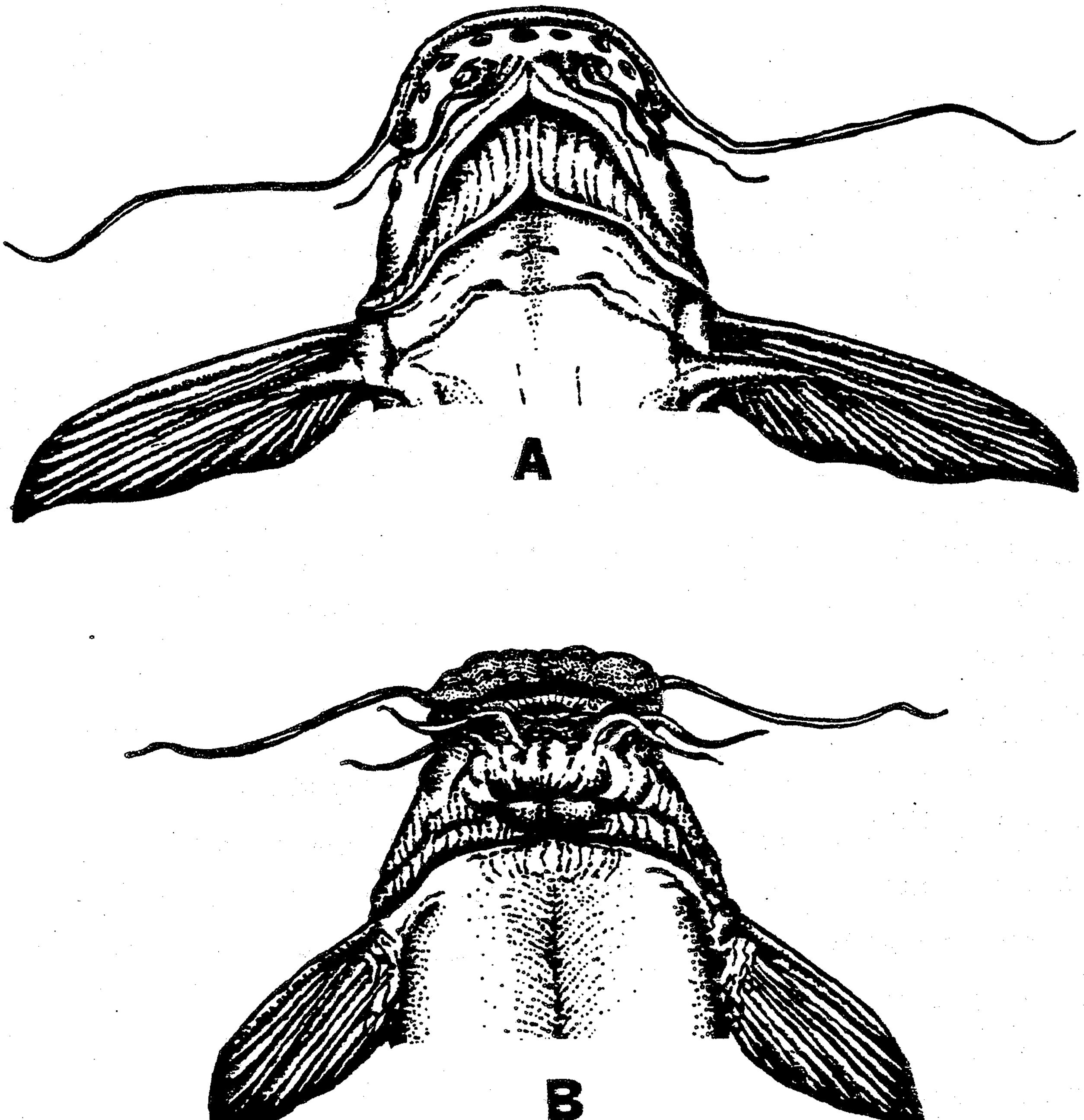


Figure 6. Comparison of the mouth structure of *Satan eurystomus* (A) and *Trogloglanis pattersoni* (B) (ventral view)

the second *S. eurystomus* was collected (Suttkus, 1961). Suttkus lists the artesian well (427 meters deep) at the El Patio Foods Plant, 2600 Southwest Military Drive, San Antonio, Texas, as the location. The specimen was collected on June 1, 1960. Patio Foods closed the well due to infiltration of Edwards oil and sulfur from the "Bad Water Zone" in 1964. At the present time this well is capped.

<u>O. R. Mitchell Well</u> (Figure 4 - Well No. 1)

An additional specimen of *S. eurystomus* was collected on the O. R. Mitchell Ranch in 1955 (Suttkus, 1961). The blind catfish was collected by Mr. John Werler from the artesian well (582 meters deep) on the ranch located approximately 22.5 kilometers southwest of San Antonio in the Von Ormy Area (U.S.G.S. No. AY-68-43-601).

<u>Bexar Metropolitan Water District Well</u> (Figure 4 - Well No. 4)

Mr. Walker, manager of the Bexar Metropolitan Water District, collected a specimen of *S. eurystomus* from an artesian well owned by the water district in 1953. He reported that "three blind catfish came out of a 15 centimeter irrigation well on approximately the 500 block of Carlisle in southwest Bexar County." These fish survived for two days before they died. Unfortunately only one fish was preserved. It is in the possession of Mr. Walker. The depth of the well is unavailable. The well has been capped.

<u>Other</u>

Three other locations have been mentioned as locations that possibly produced this fish (Hubbs and Bailey, 1947). The references were to blind catfish and may have been made regarding either of the species found in the area. The locations are as follows:

(1) Alamo Dressed Beef Company - This business could not be located. Bexar County and City of San Antonio records were checked and no reference could be found regarding this company. Well records were checked and none were listed under this name. Several other sources were checked that should have mentioned such a business but no reference could be found to it. As a result we do not know where this locality was or whether the fish were *S. eurystomus*.

(2) Mrs. R. P. Persyn referred to catfish in a newspaper article. We assume that this catfish came from a Persyn Well but we checked the newspaper files including the San Antonio Light on September 7, 1929 and were unable to find any article including information by Mrs. Persyn. It is probable that the article appeared on another date and a mistake was made in the reference to it. We also talked with several Persyns currently living in the San Antonio area. None of them knew of a Mrs. R. P. Persyn or where she may have lived. 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) Josef Boecke is said to have sighted "about twenty blind, pink catfishes" in his irrigation ditches. His farm was near the present location of Interstate 35 and the Coliseum, slightly north and east of the Artesia Pump Station, (Well 5 - Figure 4). We cannot be sure whether his sightings included both species of catfish known to occur in the area.

PRESENT KNOWN DISTRIBUTION

<u>O. R. Mitchell Ranch - Von Ormy</u>

From March 23, 1977 to June 30, 1977 three specimens of *S. eurystomus* and three specimens of *T. pattersoni* were collected at this location. One 3.8 cm specimen of *S. eurystomus* was caught alive. The specimen lived in the waters from the SWTSU, Aquatic Station artesian well at San Marcos for 164 days before it died. The depth of the artesian well is 582 meters with a reported flow of 315 liters sec^{-1}. Request for permission to sample in 1978 was denied by Mr. Turner, the O. R. Mitchell Ranch Foreman.

Artesia Pump Station, City Water Board - San Antonio

Sampling of the City Water Board Artesia Pump Station well began February 22, 1978 and is continuing. Artesia Pump Station is located approximately 3.2 kilometers southwest of the historical location for *T. pattersoni* near the Joe Freeman Coliseum on Coliseum Road and Aniol Roads (Figure 4). Well Number 4 of the five artesian wells at the pump station is being sampled. The well is 402 meters deep and the flow is 244 liter sec^{-1}. Eleven specimens of *S. eurystomus* have been collected at this location during this study.

HOW COMPLETELY IS THE DISTRIBUTION KNOWN?

Distribution of *S. eurystomus* seems to parallel that of *T. pattersoni*. 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 4). 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 7). In northern Bexar County, it lies at the surface on the Edwards Plateau. In the northern city limits of San Antonio, the

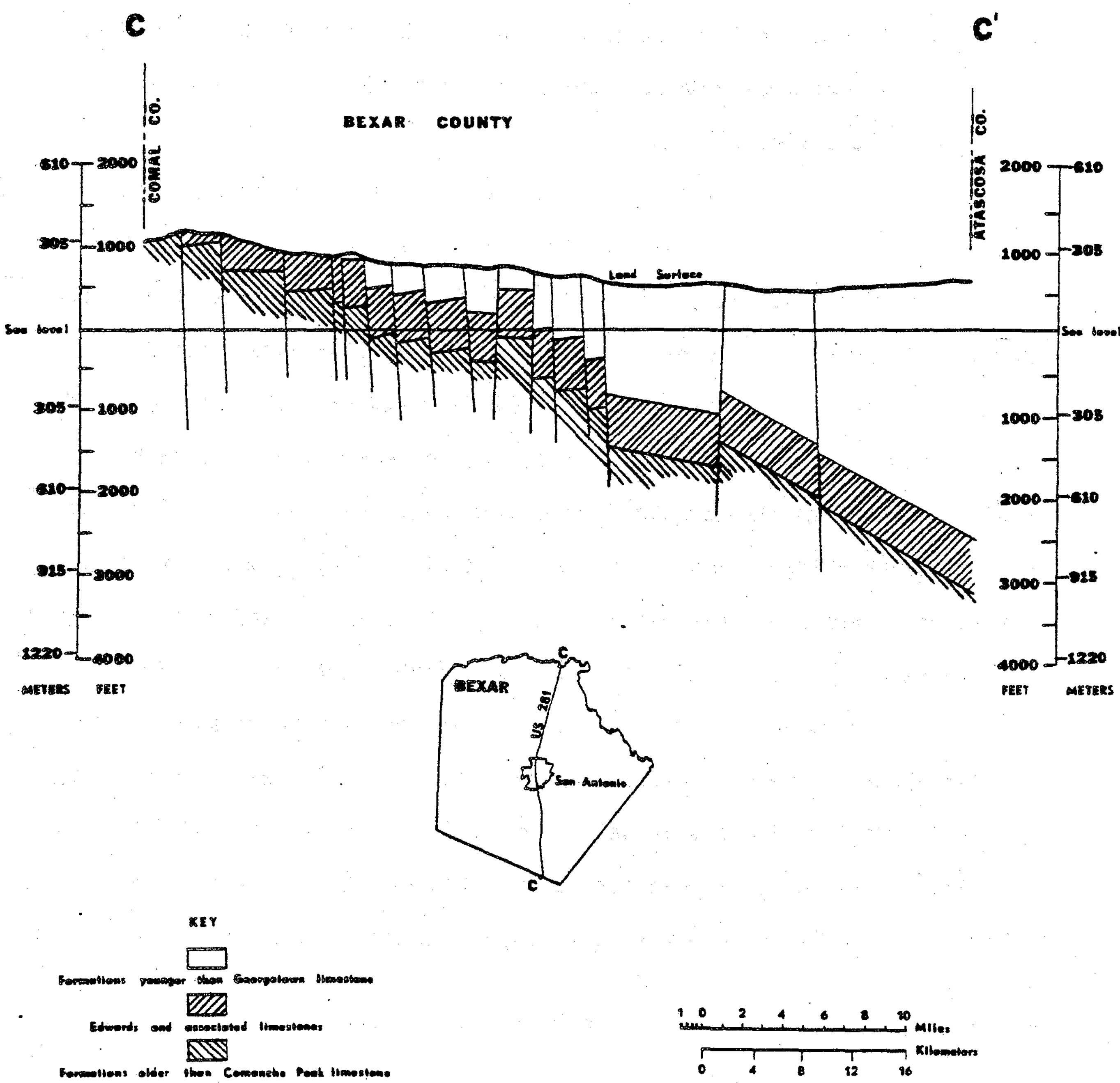


Figure 7. Geologic cross-section of Bexar County (modified from Petitt and George, 1956a)

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 *S. eurystomus*, 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 4). This area is highly faulted with numerous caverns and fissures providing natural habitats for the fish (Figure 8).

Water temperature is different between northern and southern Bexar County (Figure 9). 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 *S. eurystomus* 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. It should be noted that one of these fish was kept at San Marcos for 164 days in well water having a temperature of 22°C.

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 10). The only source of these fish has been from artesian wells in the southern part of Bexar County. Numerous

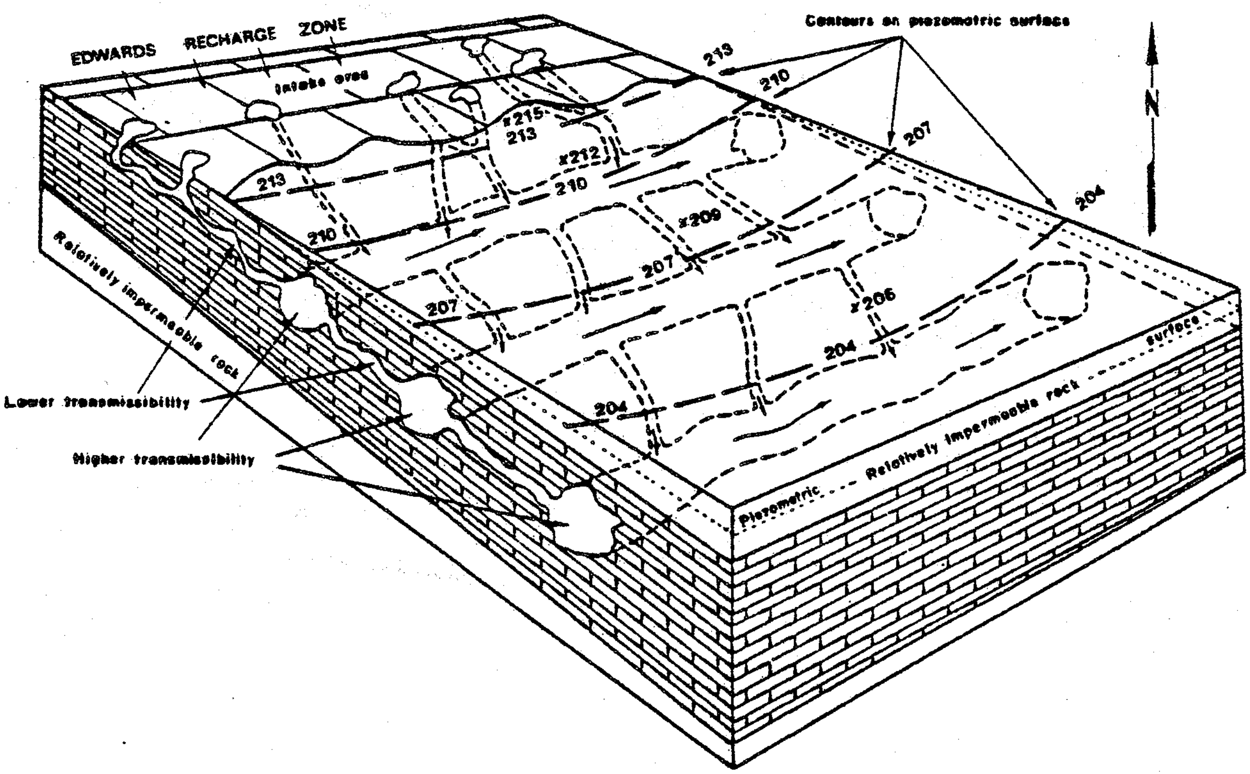


Figure 8. Hypothetical diagram showing how water in the cavernous Edwards may flow (adapted from Arnow, 1959)

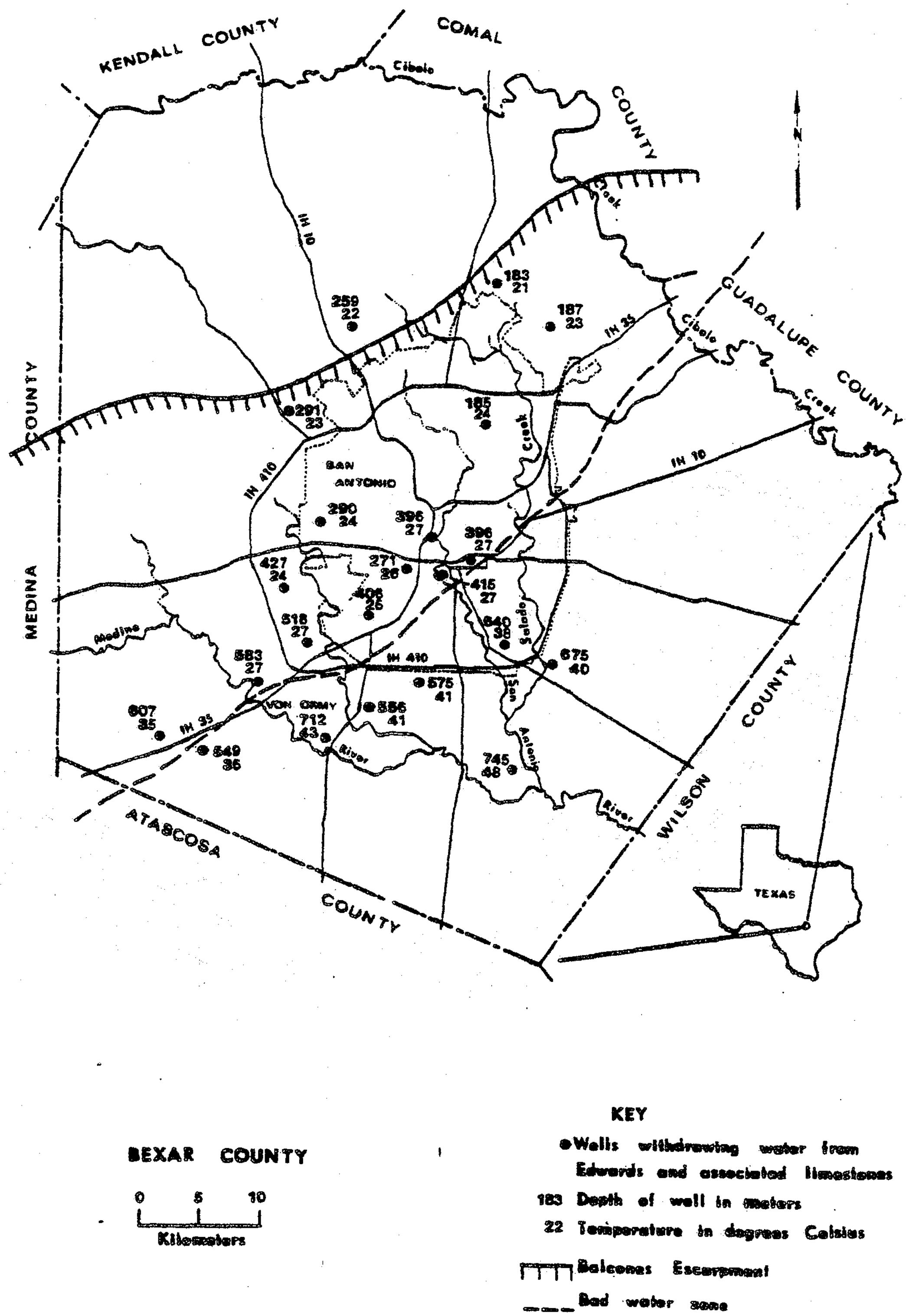


Figure 9. Water temperature and depth of selected wells in the study area (adapted from Petitt and George 1956a)

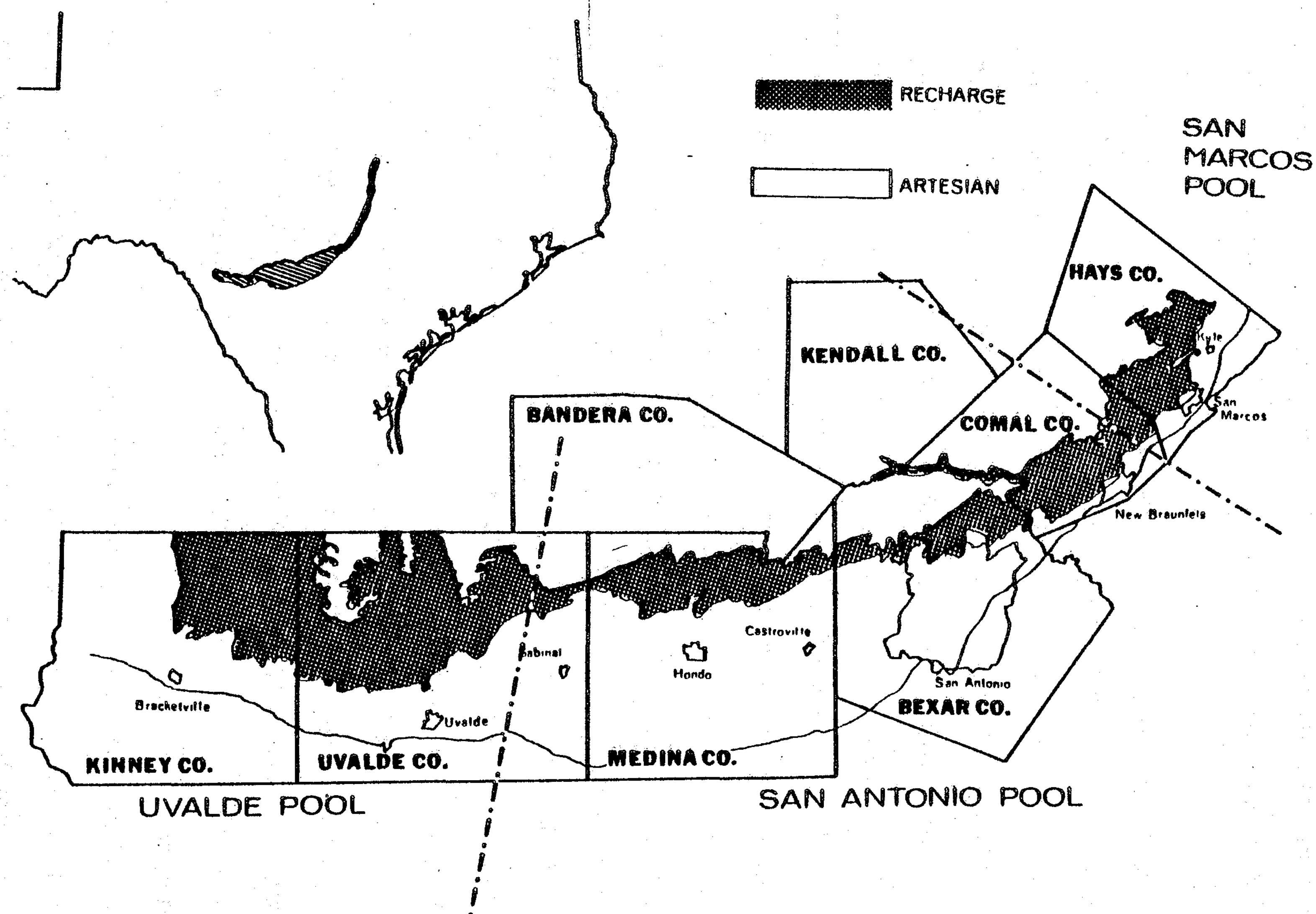


Figure 10. Edwards Aquifer (Longley, 1978)

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.

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 11.

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 (Browning, 1977). In general these publications delineate the position of the "Bad Water Line" and give insight into the geochemistry of the area. Figure 12 shows the concentration of dissolved solids, sulfates and chlorides from selected

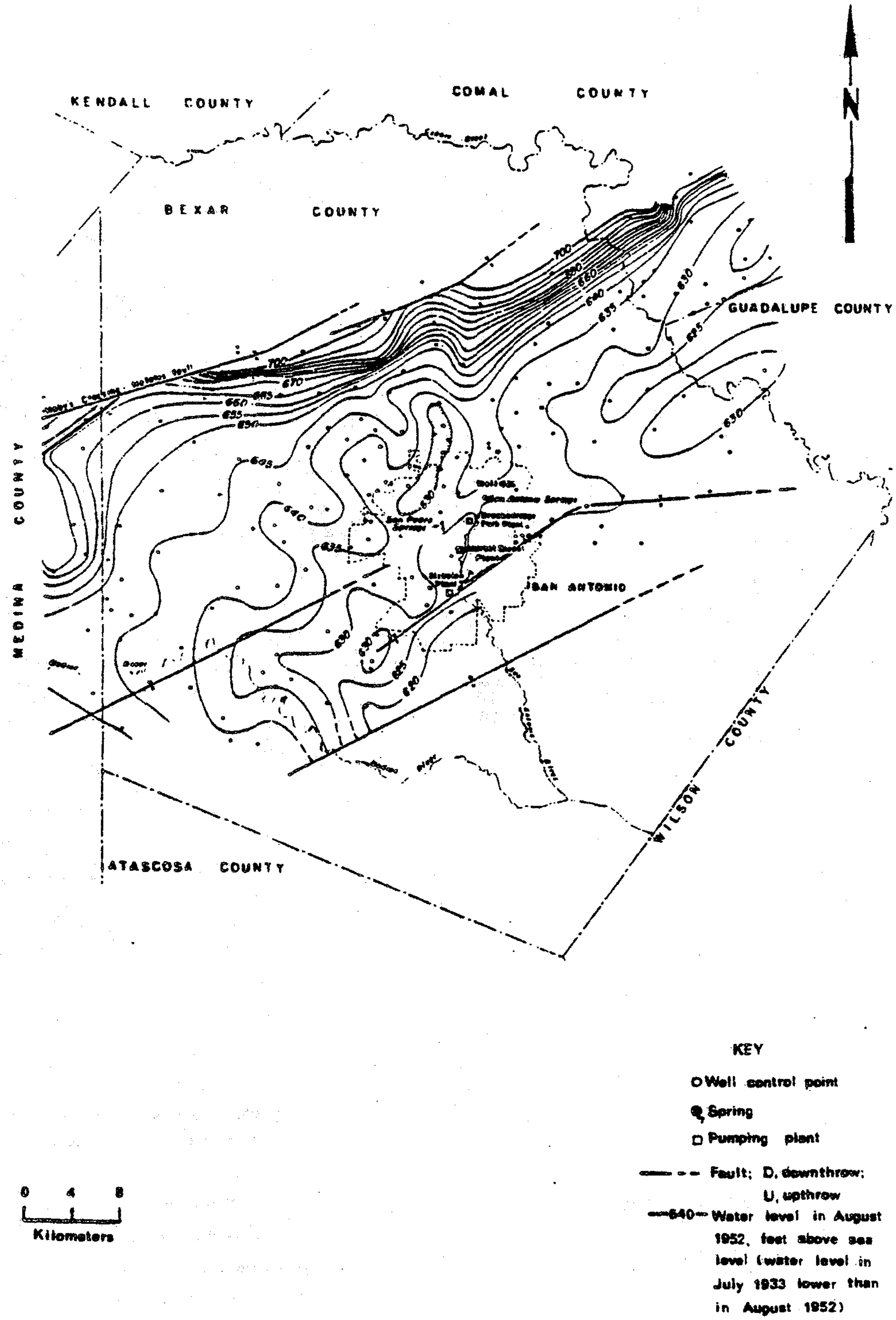


Figure 11. Water level contours in Bexar County (modified from Lang, 1954)

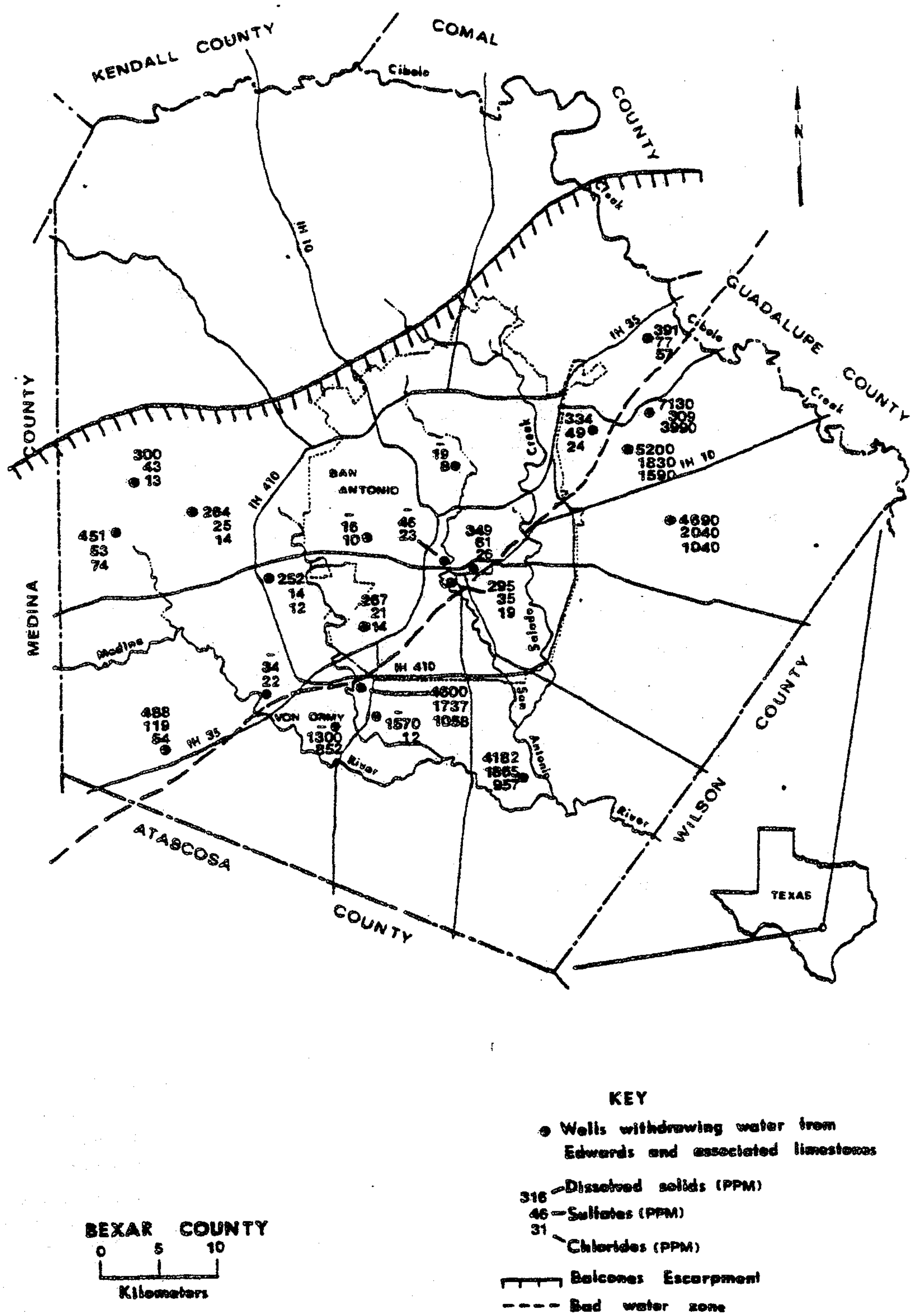
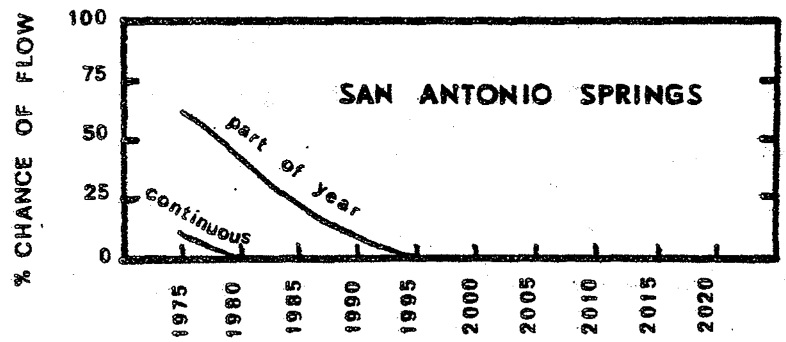


Figure 12. Concentrations of dissolved solids, sulfates, and chlorides in selected wells (modified from Pettit and George 1956a)

wells in and adjacent to the study area.

Other publications give insight into how the water movement 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 13). Interesting hydrologic models have been devised for predictive purposes based on increased population and therefore increased water usage (Figure 14). These models point out 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 *S. eurystomus* is unique and that increased pumping may have some effect on the habitat. Due to the great depths at which these fish exist and the considerable distance from the recharge zone it is unlikely that any rapid changes will occur 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. The circumstances that the fish live in now near the "Bad Water

A



B

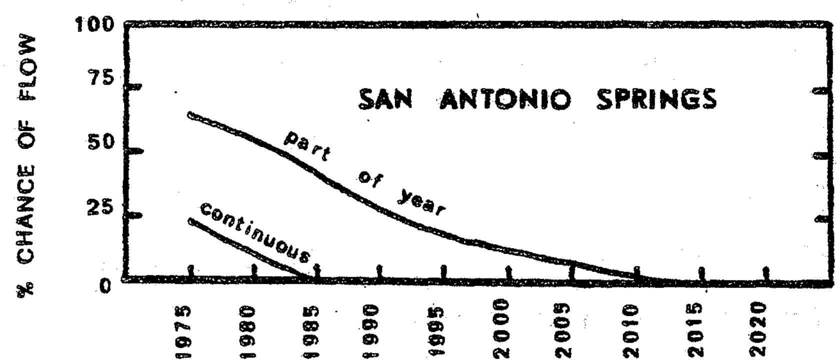


Figure 13. Projected flow of San Antonio Springs; A = High population increase, B = Low population increase (U.S.D.I., 1973a and U.S.D.I., 1973b)

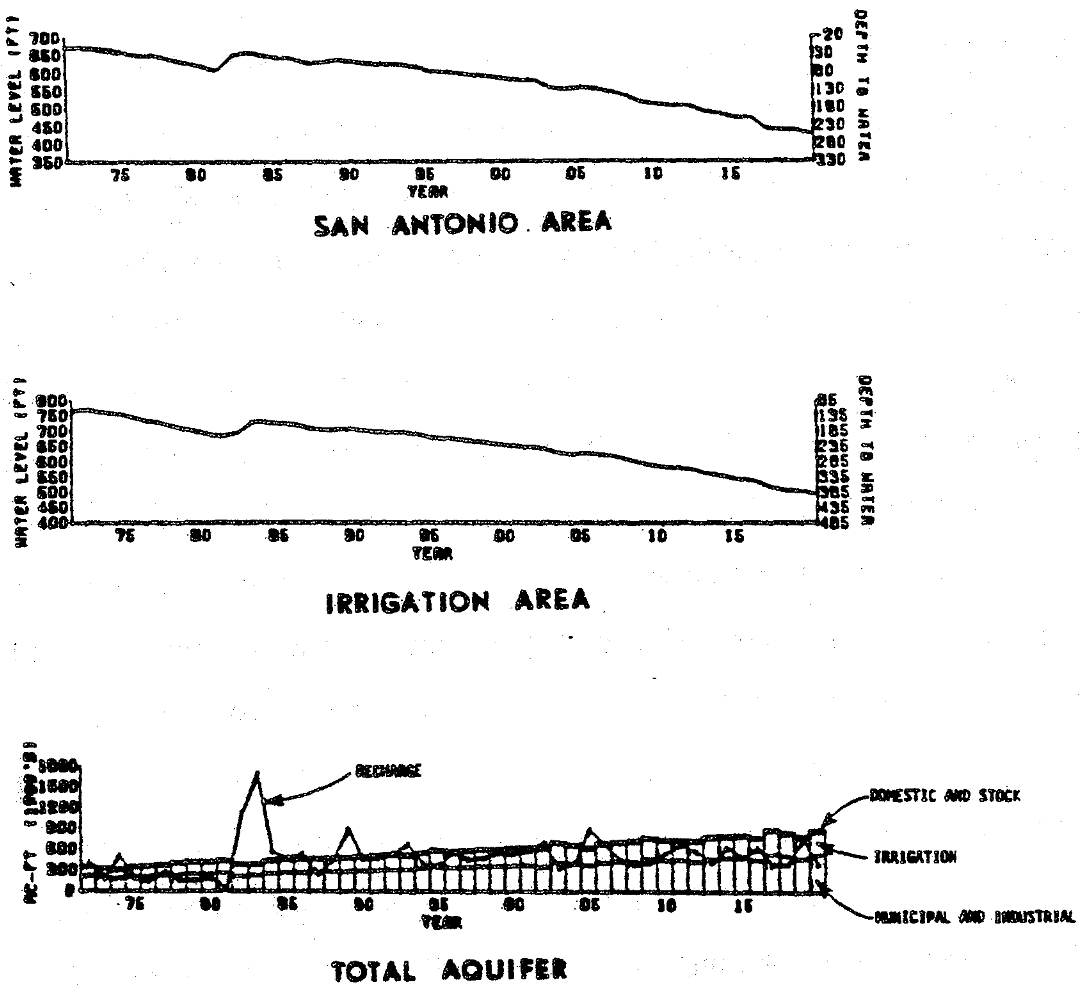


Figure 14. Hydrologic models (Seaward, et al., 1974)

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 easily obtained 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 4).

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. The large well on the O. R. Mitchell ranch is run much of the year to keep some 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. The owner is very old and all attempts to contact him 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.

Catfish have several ways of detecting food. 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.

Pylodictis olivaris is widely distributed in Texas waters. The eyes of *P. olivaris* are very reduced compared to other catfish. In addition to the reduced eyes, *P. olivaris* has well developed acoustico-lateralis and cutaneous senses.

This acoustico-lateralis system informs the fish of localized and distant disturbances such as vibrations from a moving object. The receptor unit of the lateral line system is the neuromast (Vandel, 1965). This is an area composed of sensory tissues made of pyriform cells. Each cell has a hairlike extension at its apex which reaches into a fluid-filled cupula located in the hypodermis. Neuromasts have a continuous discharge that act as a sonor source. In contrast to *T. pattersoni*, the lateral line of *S. eurystomus* is excessively developed especially in the head region (Figure 5). The pores are as large or larger than the posterior nostrils in *S. eurystomus* The acoustico-lateralis system of *S. eurystomus* likely plays a major role in the detection of food in its ecosystem.

Olfactory senses in *S. eurystomus* are not as well developed as in *T. pattersoni* and the posterior nostrils are minute when compared to *T. pattersoni*. Olfactory detection of food by *S. eurystomus* is probably secondary to the lateral line system.

The epidermis of *S. eurystomus* (Figure 1) does not contain the cilia-like taste buds of *T. pattersoni*. The sense of taste is probably secondary for the detection of food.

Cutaneous receptors of *S. eurystomus* are quite evident. The nasal and maxillary barbels are much larger than those of *T. pattersoni*. Barbels have neuroreceptors that function both for taste and touch stimuli. 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 tasted and touched simultaneously before ingestion. Figure 6 illustrates the differences in barbel size between *S. eurystomus* and *T. pattersoni*.

Satan eurystomus probably obtains the majority of its food by using its highly developed acoustico-lateralis system and the large barbels.

The stomach contents of *S. eurystomus* yielded partly decomposed decapods, isopods and amphipods. The numbers of shrimp from the Verstraeten well (Longley and Karnei, 1978) may indicate the food availability of invertebrates in this unique system. For the period March 23, 1977 to October 27, 1977, 1,129 *Palaemonetes antrorum* (shrimp) were collected from this well. Numbers of invertebrates could not be related to flow because the well was used for irrigation and flow was not constant. The numbers appear only slightly less than those from a well at San Marcos (Longley, 1978). *Satan eurystomus* is probably an opportunistic predator feeding on any organism that it can get in its wide mouth. This probably includes *T. pattersoni*. The relative abundance of troglobitic invertebrate fauna trapped from the artesian wells in Bexar County is illustrated in Table 1.

The internal and external anatomy of *S. eurystomus* implies that the catfish is a carnivore. The intestine is straight and thick-walled as exhibited by most top predators (Figure 15). The mouth is transverse and has well-developed teeth in villiform bands on both jaws. The jaws are strong in contrast to *T. pattersoni* which has thin jaws (Figure 6). The

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

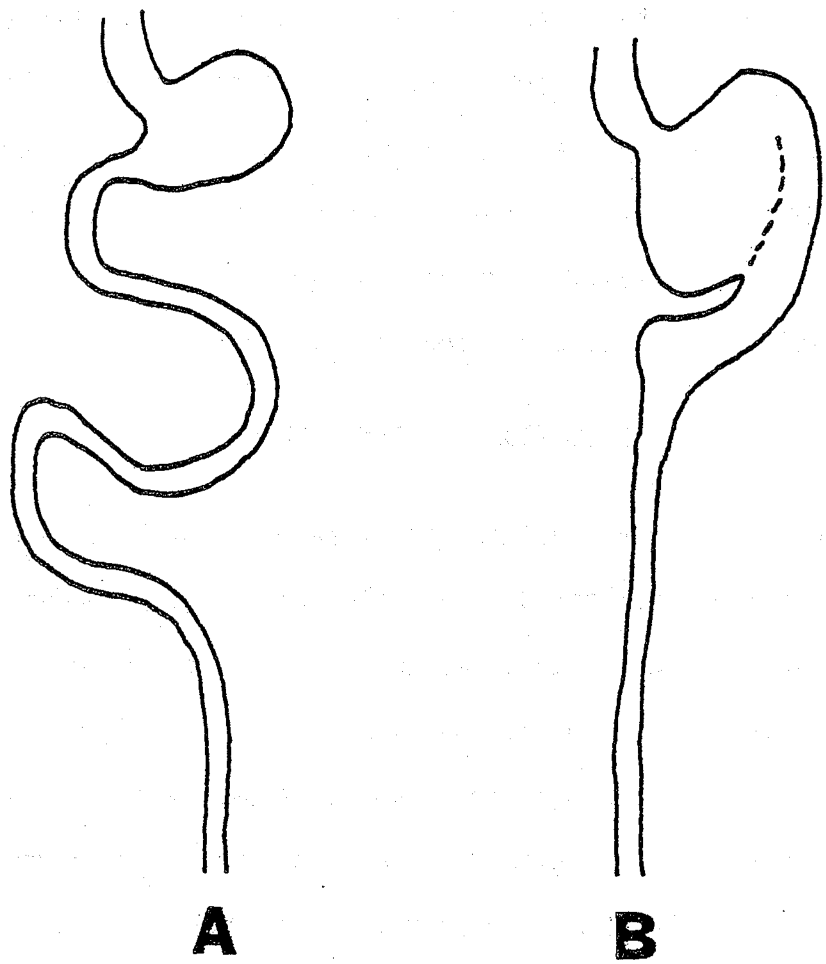


Figure 15. Comparison of the intestines of *Trogloglanis pattersoni* (A) and *Satan eurystomus* (B)

stomach is well defined when compared to T. *pattersoni*.

If S. *eurystomus* is the top carnivore in the San Antonio pool of the aquifer, it will be interesting to see if T. *pattersoni* is an additional food source. The size of S. *eurystomus* when compared to T. *pattersoni*, the presence of teeth and the wide transverse mouth suggest that T. *pattersoni* could easily be captured by S. *eurystomus*. Further analysis of the stomach contents of S. *eurystomus* will clarify this point.

Usually the top carnivore in an ecosystem has lower population numbers than the herbivores or the lower members of the food chain. Population estimates will clarify this point. At the time of this report, the ratio of T. *pattersoni* to S. *eurystomus* is 2:1.

REPRODUCTION AND DEVELOPMENT

There were no external indications of sexual dimorphism found while studying the specimens collected. One male and one female were dissected. Their gonads were similar to those of the surface form P. *olivaris* which were used for comparison. Due to the limited numbers of good specimens no attempt was made at this time to establish a sex ratio in the individuals sampled. Histological work will need to be done before it can be determined at what stage these fish contain active gametes.

At the present time nothing is known about the life history of these fish. No estimate of longivity is possible. Many troglobites have longer life spans than their surface relatives.

Appendix 1 summarizes the information about change in morphology with size.

POPULATION LEVEL

NATURAL POPULATION ESTIMATES

An estimate of population size of *S. eurystomus* was based on 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 widemouth catfish comes out of the artesian well with every 1.3×10^5 m^3 of water (1/6.2 days). If flow rate remained constant at 2.1×10^4 m^3/day, then approximately 59 *S. eurystomus* 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 1.3×10^5 m^3 (a conservative estimate), then 229 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. 5, Figure 4). 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 1.3×10^5 m^3, then 1,628 *S. eurystomus* 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 49 *S. eurystomus* at this location for 1977.

Based on the population estimates, there appears to be a large population of *S. eurystomus* in the San Antonio pool of the Edwards Aquifer. There is no way of knowing completely the total loss of *S. eurystomus* 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 *S. eurystomus* 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 the evidence of external and internal parasites. One 113.6 mm male and one 107.2 mm female (standard length) were examined. Both fish appeared to be mature adults. No external parasites were evident but internal parasites were found. The following observations were made by Dr. David G. Huffman, Southwest Texas State University:

1) No evidence of protozoans were found (further analysis is needed).
2) Common intestinal flora (Spirochaetes) were observed.
3) Four nematodes (unidentifiable at present) were collected.

PREDATION

In its subterranean habitat, *S. eurystomus* is the top carnivore. Breeder and Gresser (1941) compared the blind subterranean population of the Mexican characins to their sighted counterpart of the surface waters. When the eyed and blind fish were placed in an aquarium, the surface individuals attempted to school while the blind characins wandered aimlessly. As a result, the sighted individuals became upset and attacked and killed the sightless fish. When *S. eurystomus* reaches surface waters via springs or wells, it is easy prey for predaceous fish or birds. The pink coloration of the fish would probably attract surface predators, including 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 very well.

CONSERVATION AND RECOVERY

At present no specific efforts are being made to conserve this fish. If any danger exists for the survival of *S. eurystomus*, 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 Faults 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.

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.

Breeder, C. M. and E. B. Gresser. 1941. Correlations between structural eye defects and behavior in the Mexican blind Characin. Zoologica 26:123.

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. Klemt. 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. 1977. Preliminary report of biological investigation; Valdina farms sinkhole-Medina County, Texas. Edwards Underground Water District. 16 pp.

Longley, G. 1978. Status of *Typhlomolge* (=*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 *Trogloglanis pattersoni* Eigenmann, the toothless blindcat. Contract No. 14-16-0002-77-035. U. S. Fish and Wildlife Service (in preparation).

Lundelius, E. L. and B. H. Slaughter. 1971. Natural History of Texas caves. Gulf Nat. Hist. Dallas. 174 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 1974. 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. 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. Biospeology, the biology of cavernicolous animals. (Transl. from French). Pergamon Press, New York. 524 pp.

Appendix 1. Proportional measurements of *Satan eurystomus*[a] (expressed as thousandths of the standard length)

Measurement	Specimen Numbers**															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Total length (mm)	40.8	72.1	74.4	--	89.0	--	--	108.7	106.2	111.4	118.3	120.0	120.4	131.0	136.9	134.3
Standard length (mm)	31.2	60.9	63.5	68.7	74.1	77.3	88.0	89.5	92.0	94.4	97.1	100.0	103.0	107.2	111.4	113.6
Wet Weight in Formalin (g)	0.287	2.88	2.44	--	6.56	--	--	9.80	8.84	14.94	18.52	15.47	13.53	22.34	20.54	27.38
Body depth below dorsal origin	160	184	159	201	197	196	168	202	185	224	229	207	194	191	191	218
Body depth above anal origin to top of adipose	137	161	143	174	166	168	189	162	152	180	181	163	165	197	165	194
Caudal peduncle depth (overall)	96	99	106	104	109	112	88	101	84	107	113	101	107	112	112	112
Caudal peduncle depth (muscle mass only)	64	77	79	83	84	--	--	67	--	79	77	68	83	76	63	79
Caudal peduncle length	224	156	170	154	162	144	161	144	152	157	154	143	146	151	152	151
Predorsal length	321	363	331	343	370	367	339	364	326	339	350	365	347	373	388	366
Length to adipose origin	577	611	646	524	578	640	616	573	586	575	629	645	621	644	636	655
Dorsal base	122	126	110	133	134	124	126	112	113	132	115	120	126	121	123	133
Interdorsal distance	128	151	174	44	134	89	165	66	155	136	166	116	167	165	163	192
Adipose fin, basal length	298	259	220	371	344	283	262	281	273	309	258	310	243	269	277	273
Adipose fin, length to tip	346	283	271	381	364	292	288	321	--	360	285	350	262	284	283	278
Adipose notch to caudal base	112	107	129	127	124	122	115	112	124	114	126	100	124	121	111	97
Anal origin to caudal base	401	365	378	485	386	377	373	378	424	368	381	335	393	383	368	361
Anal base	189	218	244	234	233	249	216	238	266	217	237	200	252	234	213	222
Pelvic insertion to anal origin	128	115	134	163	127	142	168	123	124	143	133	149	136	119	133	133
Length to pelvic insertion	513	535	501	475	518	508	468	536	522	535	515	519	515	580	537	512
Anus to anal origin	61	59	57	45	40	58	51	69	47	53	62	78	66	57	60	63
Dorsal fin height	208	227	--	266	228	261	259	210	--	249	207	228	223	205	221	203
Dorsal spine length	89	--	--	105	93	128	186	--	80	117	101	120	85	149	69	60
Longest dorsal ray	--	--	--	245	211	239	221	--	--	251	165	190	175	170	171	167
Adipose fin vertical height	46	49	47	60	58	65	47	56	--	53	60	59	81	66	72	68

Appendix 1 (Cont.)

Measurement	Specimen Numbers**															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Caudal fin length																
To upper angle.	234	204	230	245	252	271	210	232	--	220	237	226	208	215	228	222
To end of shortest ray.	189	186	184	--	94	213	174	192	--	177	188	160	174	163	182	132
To lower angle.	218	220	222	238	263	254	202	223	--	219	221	198	165	201	219	148
Anal fin, depressed length.	256	289	285	284	293	284	291	299	--	267	288	268	311	289	307	277
Longest anal ray.	--	--	--	167	166	177	162	--	--	201	134	170	136	159	123	115
Pelvic fin length	122	158	154	136	182	183	173	159	--	162	160	171	169	160	200	158
Pectoral fin length	227	202	236	228	220	222	220	179	--	233	196	216	214	213	267	220
Pectoral spine length	157	--	101	105	97	--	--	--	--	118	85	77	97	73	76	77
Length first pectoral branched ray beyond tip of spine.	--	--	--	123	194	219	224	--	--	181	125	171	136	145	188	141
Between pectoral insertions	186	184	150	224	186	239	221	197	170	212	216	191	209	188	198	218
Between pelvic insertions	29	33	39	28	33	24	27	38	41	42	38	40	39	37	41	47
Head length	253	276	268	309	317	342	316	279	250	266	270	260	272	266	294	273
Head width.	269	225	228	225	256	244	229	249	239	255	228	191	252	224	233	231
Head depth at occiput	160	148	120	182	148	184	153	168	148	160	141	149	117	119	173	187
Head depth at end of first third of projection of head length	--	117	80	94	101	--	--	121	109	108	73	72	78	84	128	119
Mouth Width																
Gape, exterior.	154	177	163	159	197	--	--	188	152	180	168	142	180	163	184	161
Least interior width.	103	138	150	120	152	--	--	175	147	164	144	133	155	151	131	156
At base of maxillary barbels, behind upper lip	--	179	173	154	148	--	--	198	--	175	187	141	196	185	180	145
Snout tip to mandible tip	--	51	39	8	47	--	--	42	43	65	51	28	49	30	47	52
Snout tip to front of gill opening.	250	151	157	104	130	--	--	149	122	126	156	111	105	112	127	149
Front of gill opening to line joining pectoral insertions	--	179	126	146	148	--	--	184	175	178	127	136	218	177	200	146

Appendix 1 (Cont.)

Measurement	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
	Specimen Numbers**															
Length of barbels																
Nasal	--	--	--	86	119	84	57	--	--	--	82	--	49	82	40	--
Maxillary	--	296	--	329	323	433	381	--	152	286	423	330	381	438	522	260
Outer mental	--	82	--	142	198	157	181	--	--	128	174	141	97	186	206	--
Inner mental	--	75	--	88	128	107	107	--	--	71	80	81	73	86	84	--
Distance between posterior nostrils	--	--	--	81	88	89	78	--	--	83	86	--	82	65	87	--
Snout to posterior nostrils	--	--	--	78	81	84	76	--	--	64	71	--	56	67	63	--
Mandibular tooth patch, length	--	16	16	9	18	--	--	17	15	21	16	19	26	19	18	21
Premaxillary tooth patch																
Length	--	20	16	11	18	10	9	20	16	18	21	20	16	29	17	20
Width	--	126	129	126	135	131	126	132	120	127	127	131	136	127	126	128
Dorsal origin to occiput	80	192	151	--	146	78	77	190	151	162	178	174	161	187	203	180
Dorsal origin to caudal base	689	722	665	--	641	667	671	670	715	673	669	668	659	669	678	674

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

**Specimens held by the following:
Southwest Texas State University--Nos. 1, 2, 3, 5, 8, 9, 10, 11, 13, 14, 15, and 16
Witte Memorial Museum--No. 4
Tulane University--No. 6
United States National Museum--No. 7
Bexar Metropolitan Water District--No. 12

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

Parameter	Well #1* 20 VI 77	Well #5* 24 III 72
Depth (m)	582.0	402.0
pH	7.3	7.3
Specific Conductance (μmhos)	467.0	465.0
Water temperature (°C)	27.0	27.0
Sodium Adsorption Ratio	0.3	-
Percent sodium	8.0	-
Dissolved (ug/l)		
Arsenic	1.0	-
Barium	0.0	-
Cadium	0.0	-
Chromium	10.0	-
Copper	0.0	-
Iron	10.0	-
Lead	1.0	-
Manganese	0.0	-
Mercury	0.0	-
Selenium	1.0	-
Silver	0.0	-
Zinc	0.0	-
Dissolved (mg/l)		
Calcium	65.0	-
Chloride	18.0	15.0
Fluoride	0.3	-
Magnesium	16.0	-
Oxygen	5.1	4.9
Potassium	1.1	-
Silica	12.0	-
Sodium	8.7	-
Sulfate	23.0	23.0

Appendix 2. (Cont.)

Parameter	Well #1* 20 VI 77	Well #5* 24 III 72
Dissolved (mg/l)		
Organic - N	0.04	-
Kjeldahl - N	0.05	-
NH_3 - N	0.01	-
NO_2 - N	0.00	-
NO_3 - N	1.3	-
Phosphorus - P	0.00	-
Organic - Carbon	0.5	
Total (mg/l)		
Organic - Carbon	4.8	-
Organic - N	0.03	-
Nitrogen - N	0.75	-
NO_2 - N	0.01	-
NO_3 - N	0.70	-
NH_3 - N	0.01	-
Nitrogen - NO_3	3.3	-
Kjeldahl - N	0.04	-
Phosphorus - P	0.02	-
Bicarbonate	240.0	244.0
Carbonate	0.0	-
Noncarbonate Hardness	31.0	-
Hardness	230.0	236.0
Detergents - MBAS	0.0	-

* See Figure 4

Appendix 3. Numbers of *Satan eurystomus* collected during this study

Date	No. used in Appendix 1	O. R. Mitchell Well	Artesia Well No. 4
24 III 77	(head only)	1	
5 IV 77	5	1	
31 V 77	1	1*	
6 III 78	10		1
8 III 78	(badly decomposed)		1
17 III 78	9		1
19 III 78	16		1
27 III 78	15		1
5 IV 78	8		1
27 IV 78	14		1
30 IV 78	11		1
11 V 78	13, 2		2
22 V 78	3		1

* Caught alive and kept for 164 days in well chamber at San Marcos.