STATUS OF *TYPHLOMOLGE* (= *EURYCEA*) *RATHBUNI*,

THE TEXAS BLIND SALAMANDER

BY

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ABBREVIATIONS AND SYMBOLS

ABBREVIATIONS

cm	--	centimeter
ft	--	feet
FWS	--	U. S. Fish and Wildlife Service
ha	--	hectare
m	--	meter
m^2	--	square meter
m^3	--	cubic meter
mm	--	millimeter
SEM	--	scanning electron microscope
sp	--	species
TOES	--	Texas Organization for Endangered Species
USNM	--	United States National Museum
VPC	--	Vernon's Penal Code (Texas Law)
X	--	times (magnification)

SYMBOLS

K_b	--	Buda formation
K_{dr}	--	Del Rio clay
K_{ed}	--	Edwards group
K_{gt}	--	Georgetown formation
N_m	--	magnetic north
N_t	--	true north

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INTRODUCTION

Eurycea (formerly *Typhlomolge*) *rathbuni* (Stejneger), 1896 is commonly referred to as the Texas Blind Salamander. This species may be classified as indicated below:

Phylum	-	Chordata
Class	-	Amphibia
Order	-	Caudata
Family	-	Plethodontidae

This salamander is presently considered to be endangered primarily because it had apparently been declining in one location, Ezell's Cave on the southwest side of San Marcos, Texas.

Research during the last three years has convinced me that this species is not endangered.

BACKGROUND

ORIGINAL DISCOVERY AND DESCRIPTION

In 1895 a well was completed by the U. S. Department of the Interior at the old Federal Fish Hatchery in San Marcos, Texas. The well penetrated a cavern at 58 meters (m) (DeCook and Doyel, 1955). This cavern was the major source of water for this artesian well from which numerous blind salamanders were expelled. Salamanders were sent to Leonhard Stejneger, Curator of Reptiles and Amphibians at the U. S. National Museum. The original description was done by Stejneger (1896). He named the blind salamander Typhlomolge rathbuni after the type specimen No. 22686, USNM. Norman (1900) described the behavior of these salamanders and Emerson (1905) described the general anatomy in a paper that included much detail about the various systems, but excluded a description of the male urogenital system. Eigenmann (1909) described the 'degenerative evolution' of this salamander and included line drawings from the dorsal and lateral views (Figure 1) and a detailed description of eye development. Uhlenhuth (1921) described the distribution and habits of the blind salamander including detailed descriptions of the known localities. Hilton (1945) described the skeleton of the blind salamander and Dundee (1957) described the induced partial metamorphosis in this form.

A thesis prepared at the University of Texas (Potter, 1963) included a description of a salamander from a gravel company excavation in the then dry bed of the Blanco River 3.3 miles northeast of the Hays County Courthouse, San Marcos. This specimen was similar to the salamanders known from other locations in the San Marcos area, but it exhibited considerable morphological variation from other forms. It was different since it had a broad, stocky body and moderately short, thick limbs. In the thesis it was described as a new species, Typhlomolge robusta (Potter, 1963). The thesis was never published and only one specimen remains according to Floyd Potter, Texas Parks and Wildlife Department (personal communication). This specimen is in the personal collection of Potter at his ranch near Lampasas, Texas.

TAXONOMIC PROBLEMS

A new troglobitic salamander, Eurycea tridentifera, was described from the waters of Honey Creek Cave, Comal County, Texas (Mitchell and Reddell, 1965). While comparing the new species with other neotenic salamanders of the Edwards Plateau, the authors discovered a continuum of characters

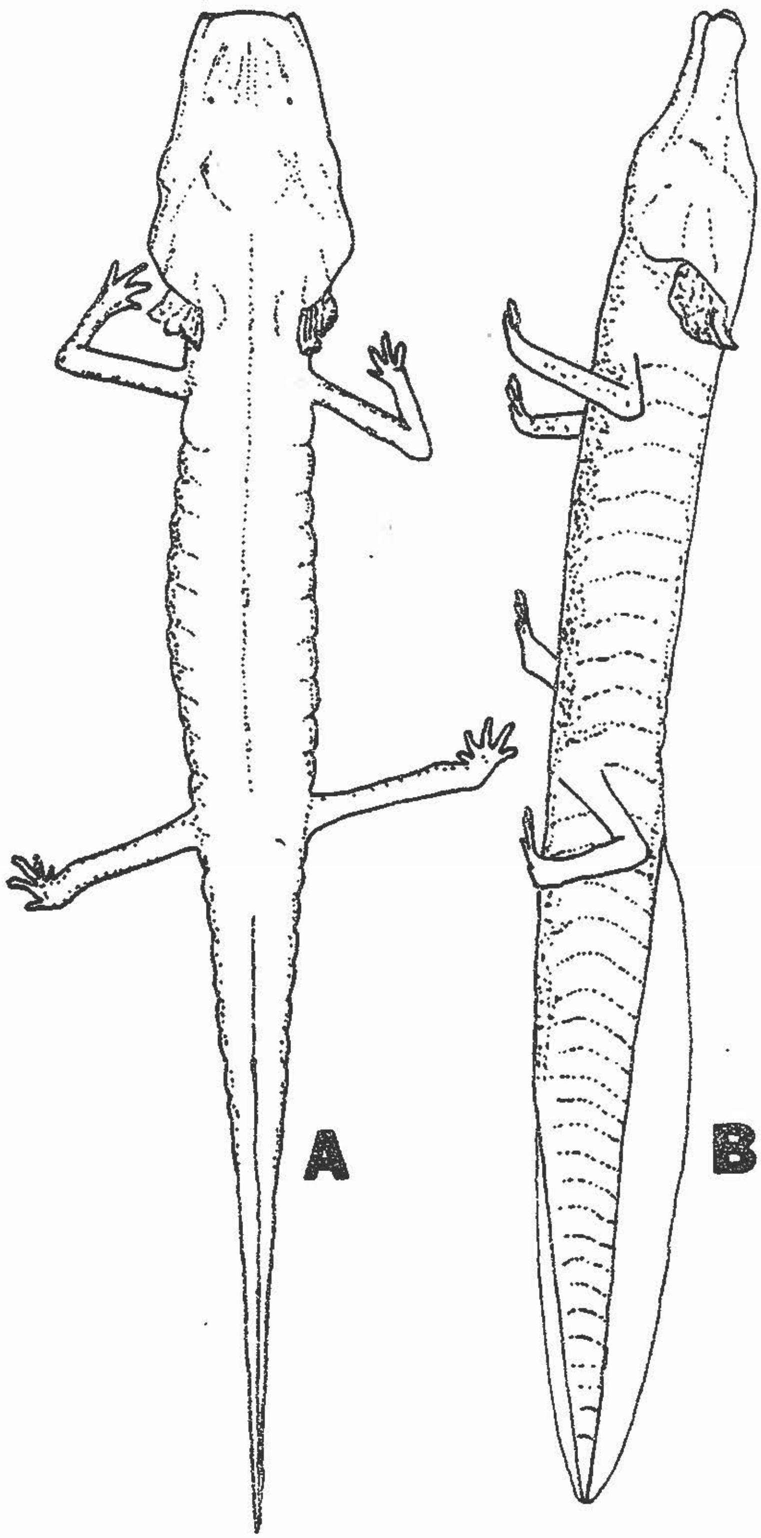

Figure 1. *Eurycea* (=*Typhlomolge*) *rathbuni* 8.8 cm
(Eigenmann, 1909) A=Dorsal, B=Lateral

between Eurycea and Typhlomolge (Figures 2, 3, and 4). This discovery appears to have closed the gap in the differences between the two genera. As a result they proposed removal of Typhlomolge to the genus Eurycea. In a study of the osteology and evolution of the plethodontid salamanders Wake (1966) compared Eurycea and Typhlomolge and stated that both forms developed from the same ancestor, a "Pro-Eurycea." He suggested the retention of the genus Typhlomolge. Brandon in his articles of 1971 a and b and 1973 preserved the name of the genus Typhlomolge in preference to Eurycea rathbuni and Eurycea tridentifera. In a later paper, Mitchell and Smith (1971) found no apparent distinction between the two genera from the point of view of osteology. In a study of North American cave salamanders Monique Clerque-Gazeau (1975) used the name Eurycea rathbuni in preference to Typhlomolge rathbuni. I have observed these salamanders at considerable length and have compared my observations of the young of Eurycea rathbuni and Eurycea nana, the San Marcos dwarf salamander. I consider the use of the genus Eurycea more appropriate. This view is due to several factors which I will include later in describing the larval stages of Eurycea rathbuni.

Eurycea rathbuni is of considerable scientific interest due to its uniqueness. This form is the most advanced troglobitic salamander known in the world today. It shows many adaptations toward total life in a cave that are of interest to all students of zoology and speleology. It is the top carnivore in a portion of the Edwards Aquifer sometimes referred to as the Purgatory Creek system (properly referred to as the San Marcos pool of the Edwards Aquifer). The salamander helps to maintain proper population levels of various aquatic troglobites including beetles, isopods, copepods, ostracods, amphipods, shrimp and snails, and therefore is important in maintaining ecological stability.

I feel that this species may be of considerable value in gauging water quality changes in the Edwards Aquifer. The Edwards Aquifer is the sole drinking water supply for San Antonio, Texas, and several of the smaller cities on the Balcones Escarpment. The increase in the human population density above the recharge zone of the Aquifer poses a threat to the quality of the water. Probably the best means of monitoring the quality of the water will be to monitor the species diversity of its delicate troglobitic biota in the same manner that surface water systems are commonly monitored.

Eurycea rathbuni was first listed as an endangered species in the Federal Register, Vol. 32, No. 48, March 11, 1967: 4001 (U.S. Department of the Interior, 1974). This species is also listed as endangered by the International Union for the Conservation of Nature (TOES, 1975) and the State of Texas (Non-game and Endangered Species Article No. 913a: VPC State of Texas). The Texas Organization for Endangered Species (TOES) agreed in 1976 to change the status of this species to threatened.

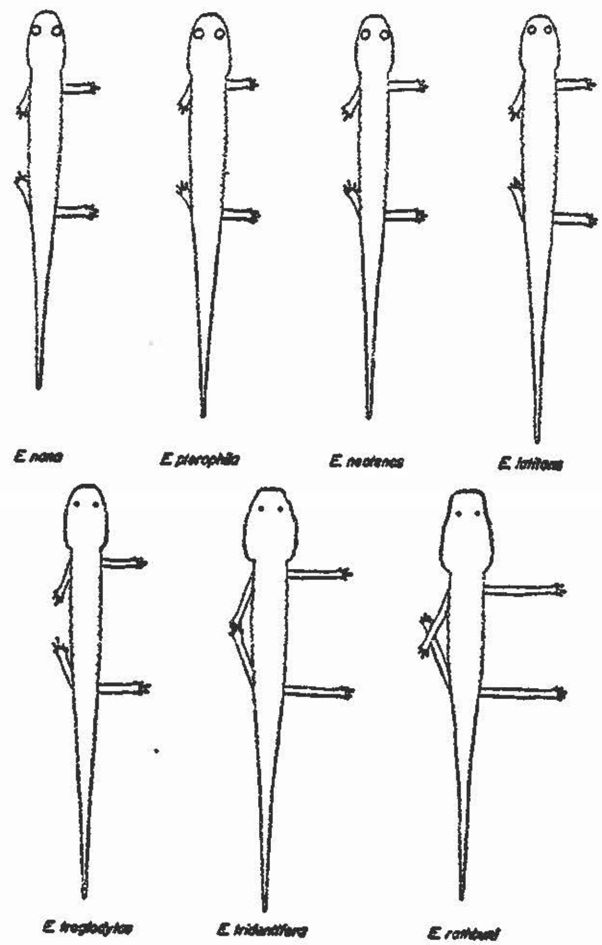

Figure 2. Dorsal views of the neotenic salamanders of the Edwards Plateau, note gradation in body proportions (from Mitchell and Reddell, 1965)

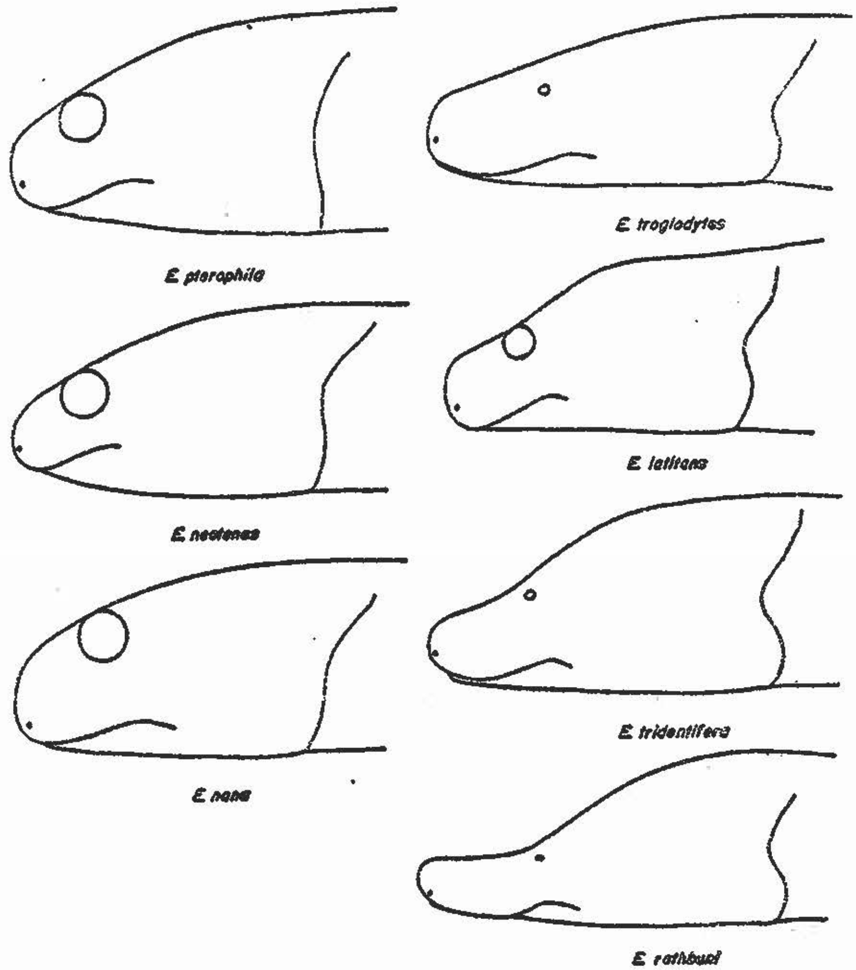

Figure 3. Lateral views of heads of neotenic salamanders of the Edwards Plateau (from Mitchell and Reddell, 1965)

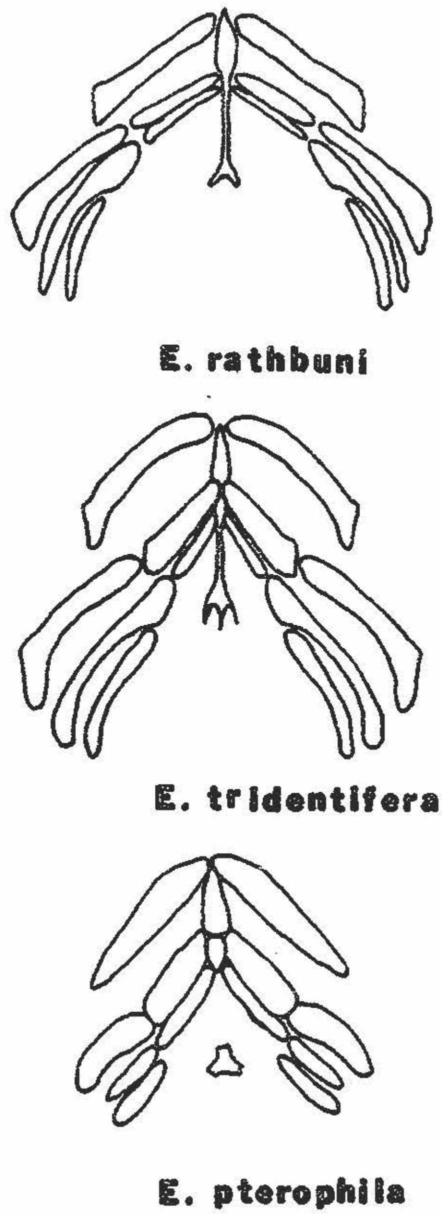

Figure 4. Hyobranchia of three Edwards Plateau *Eurycea* (from Mitchell and Reddell, 1965)

DISTINGUISHING CHARACTERISTICS

The maximum total length noted for specimens recovered in this study was 12 cm for two specimens from the Artesian Well located at the Aquatic Station, Southwest Texas State University. This well was formerly owned by the U.S. Dept. of Interior. Uhlenhuth (1921) reported catching one 12 cm specimen from the well in Wonder (Beaver) Cave (Appendix I). The following description of *Eurycea* (=*Typhlomolge*) *rathbuni* was provided by Stejneger (1896):

> Head excessively large and broad, the distance from tip of snout to base of upper gill-branch but slightly less than distance between axilla and groin, its width equal to one half the latter distance; snout very much depressed, broad, truncated, nearly square anteriorly; nostrils widely separated at the corners of the truncated snout, their distance greater than that between the eyes, which are deeply hidden under the skin and only visible as two small dark spots; mouth comparatively small, with strongly developed labial lobes; body short and slender, the distance between axilla and groin being but slightly greater than length of head and only one half the length of the tail, its width being much less than that of the head and even less than that of the snout; limbs excessively slender and long, of nearly even length, about one-fifth of total length; fingers overlapping knee and toes overlapping elbow when adpressed to the sides of the body; fingers four, toes five, short, slender, free, with rounded tips, their relative length variable; tail comparatively long, nearly one-half the total length, much compressed, finned below and particularly strongly above, the end pointed.
>
> Skin smooth; a very strongly marked gular fold; a well marked vertebral groove; eleven costal grooves. Teeth on intermaxillaries and mandible small; the vomero-palatine teeth large, decreasing in size at both ends. Gill branches long and slender, the middle one longer; fimbriae long and slender, not bushy. Color nearly white, semi-transparent, the upper surfaces densely sprinkled with minute pale gray dots.
>
> Dimensions - Total length, 102 mm; from snout to anus, 53; from snout to gular fold, 16; from snout to beginning of upper gill branch, 22; width of head, 13; width of snout, 9; distance between nostrils, 7; distance between eyes, 6;

distance between axilla and groin, 25; fore limb, 20; hind limb, 20; longest finger, 2.3; longest toe, 2.5; width of limbs, 1.7; tail, 11.

I have noticed the following characteristics in the juveniles. The surface of skin is covered with many small pigmented cells (probably melanocytes), occurring in patterns (Figure 5). The eyes are more prominent in the juveniles; the head is noticeably dorso-ventrally flattened, even in very small juveniles. The gills are simple at first. A list of morphological measurements obtained during this study is included in Appendix II for comparison of growth stages. Very good color photographs of this species occur in each of the following references: Mohr and Poulson, 1966; Conant, 1975, and Zahl, 1972.

In the book, _Vertebrates of the United States_, the salamander is placed in the genus _Eurycea_ (Blair, W. F., Blair, A. P., Brodkorb, P., Cagle, F. R., and G. A. Moore, 1968). Their key to _Eurycea_ distinguishes _Eurycea rathbuni_ with the following characters: adults with gills, in central Texas, eyes reduced and diameter 1/10th of head width or less, appressed limbs meeting or overlapping, appressed limbs overlapping 5-6 intercostal folds. Williams (1975) in his _Key to the Herps of Texas_ uses the following sequence to identify _Eurycea rathbuni_ from other Plethodontid salamanders: Toes 5-4, tongue free at sides and back only, eyes lacking; body with little or no dark pigments; troglobitic, legs overlap when adpressed; and snout elongated. No keys have been written for distinguishing juveniles. This species does not have reliable external characters that can be utilized to determine sex.

Eurycea rathbuni is unique in having no concentration of pigment in structures internally or externally. The blood is the only substance giving color to this species, gills appear red in living specimens. A pair of small black dots appear deep beneath the skin on the dorsal surface of the head. An electron micrograph (Figure 6) shows the distribution of neurogemmae (chemical sense organs) on the surface of the skin. These structures are similar to neuromasts which are receptor organs of the lateral-line system (Vandel, 1965).

Figure 5. Juvenile *Eurycea rathbuni* (Juvenile *Eurycea nana* shown for comparison)

Figure 6. Head region of juvenile Eurycea rathbuni (SEM 550 X)

DISTRIBUTION

FORMER KNOWN DISTRIBUTION

In a paper on the distribution of Eurycea rathbuni, Uhlenhuth (1921) noted that the type locality (the Artesian Well) and three other localities, i.e., Frank Johnson's Well, Ezell's Cave and Wonder (Beaver) Cave (Figure 7, Appendix I) are the only known sources of this salamander. He used diagrams to illustrate water levels and proposed connections between the sources and illustrated each of the localities. Uhlenhuth referred to the system where the salamander lives as the "Purgatory Creek System." Purgatory Creek is a surface stream in the San Marcos River watershed and drains an area to the west of the river. His reason for referring to the subterranean system by the same name was probably due to the occurrence of the salamander in a well (Johnson's Well) located in this creek bed, and the supposition that much recharge must occur where the surface stream crosses the fault zone.

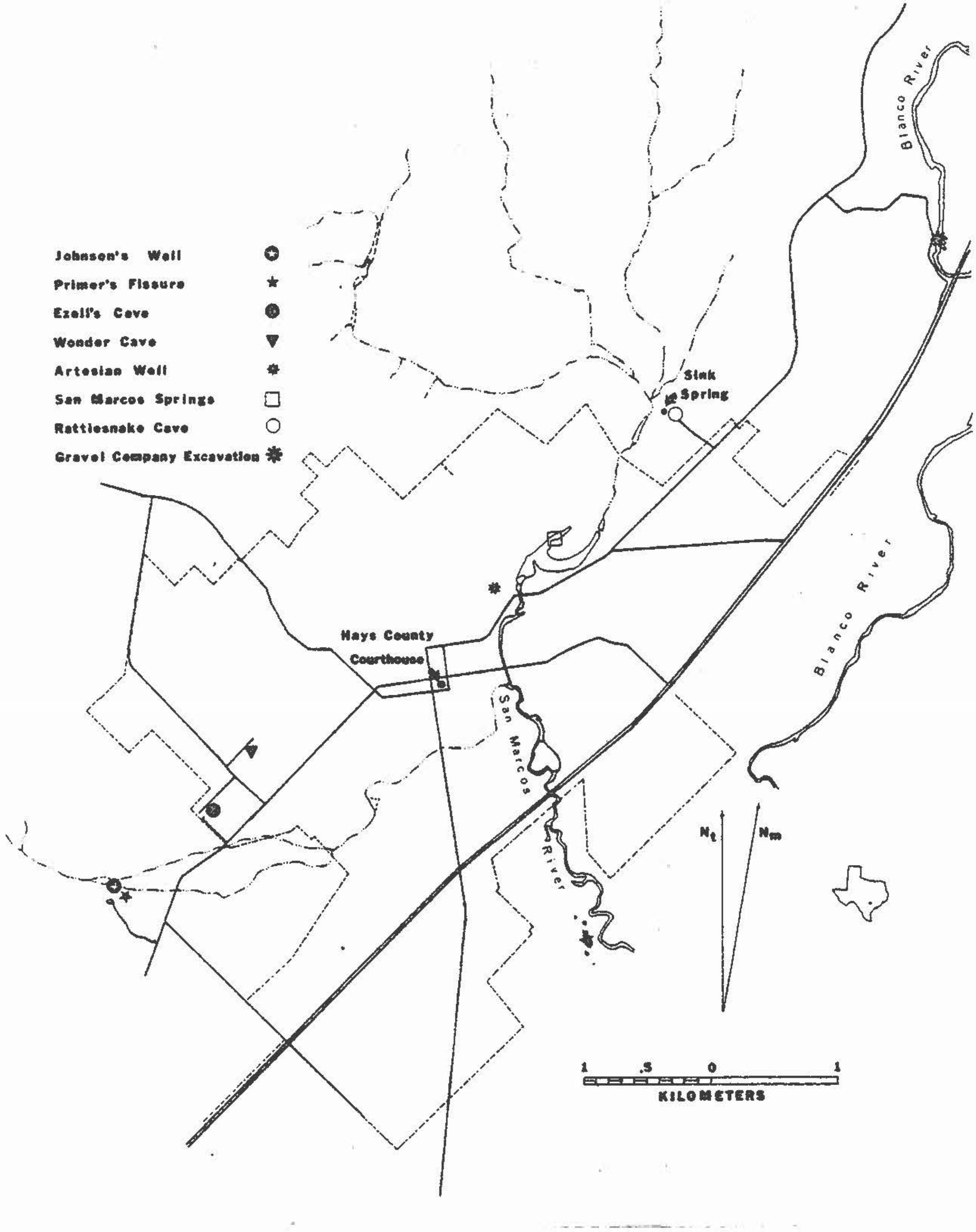

Figure 7. Locations of troglobitic <u>Eurycea</u> in the San Marcos area.

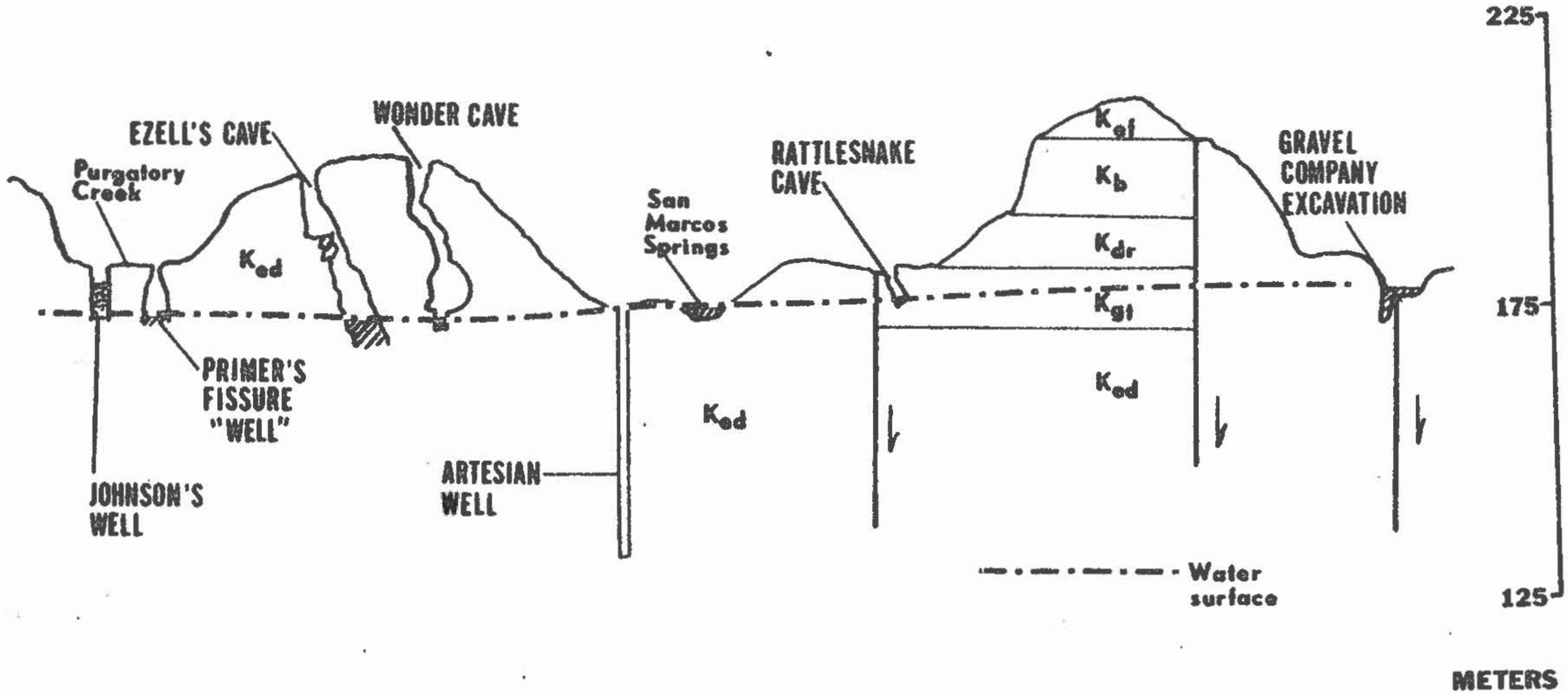

Figure 8. Section N60W approximately parallel to the San Marcos Springs Fault, adapted from Russell, 1976

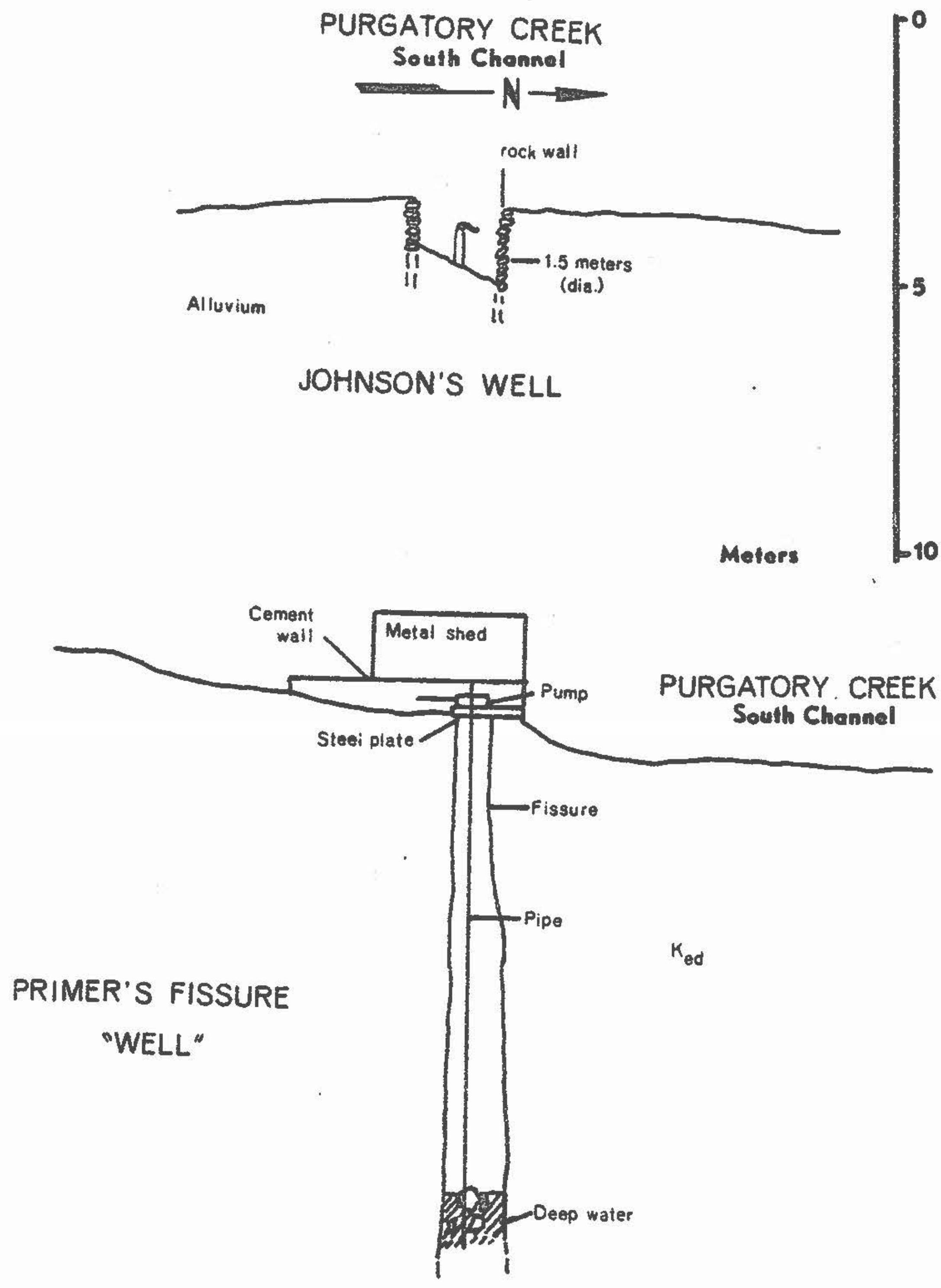

Figure 9. Comparison of Frank Johnson's Well to Primer's fissure "Well" (Russell, 1976)

The status and distribution of *Eurycea rathbuni* was recently reviewed in a report for the Soil Conservation Service (Longley, 1975). The known distribution had not changed from the time of Uhlenhuth's (1921) paper. All known collections prior to November 24, 1975 were listed as having been made in one of the four locations: Artesian Well, Frank Johnson's Well, Wonder (Beaver) Cave or Ezell's Cave. All the locations occur within Hays County, Texas, in or near San Marcos (Figure 8).

One problem concerns the location of Frank Johnson's Well. In recent years, a natural fissure located on the Ben Primer property, has been referred to as Johnson's Well. This natural fissure (cave) has a pump on a pipe that descends to water level in the fissure. The opening has been modified with cement so as to appear like the top of a well. This site was not dug. This fissure is located on the side of Purgatory Creek a short distance below what I consider to be Johnson's Well (Figure 9). For a number of years persons have descended into the fissure on Dr. Primer's property by removing the pump and descending the natural chimney to water. For some time numerous specimens of *Eurycea rathbuni* were obtained from this "well." Specimens were removed from Primer's fissure in 1972 by R. W. Mitchell for the National Geographic Society (Zahl, 1972). On April 24, 1974 Floyd Potter, Texas Parks and Wildlife Department, entered this fissure and observed two *Eurycea rathbuni*. During the period from 1917 (when Uhlenhuth visited the well) to 1951 (the earliest date R. W. Mitchell collected from Primer's fissure), Frank Johnson's Well, located in the stream bed of Purgatory Creek, filled with sediment and collectors were redirected to what I now call Primer's fissure. Unfortunately, at some time during this period of 35 years, investigators began to call Primer's "Well" the Frank Johnson Well. Since the two locations are approximately 184 meters apart, it is possible that the two openings enter the same cavern. The original description of Johnson's Well indicated that it was a dug well which opened into a cave at a depth of 8.8 meters (Uhlenhuth, 1921).

PRESENT KNOWN DISTRIBUTION

Artesian Well

I have sampled the Artesian Well on the Southwest Texas State University campus continuously since 1973 (Figure 7). During this time thirty-two salamanders have been obtained.

San Marcos Springs

I began netting one of the largest springs (Pipe Spring) November 24, 1975. The first day yielded 4 Eurycea rathbuni. Since that time salamanders have been obtained almost every time the net was removed for a total of 101.

Wonder Cave (Beaver Cave) (Figure 7, Appendix I)

During January, 1977, I visited the well in Wonder Cave but was unable to view any subterranean organisms. The bottom of the well has been cemented and the pool of water is used as a wishing well by tourists. It contains many corroding coins which may inhibit the presence of aquatic forms. Lights in the cave are left on continuously during the day. No recent records could be located of sightings of Eurycea rathbuni in this cave.

Ezell's Cave (Figure 7, Appendix I)

The caretaker of this cave observed a salamander approximately 9 cm long in the pool during December 1976. This is the most recent sighting of a salamander in this cave. I arranged for 8 small Eurycea rathbuni from San Marcos Springs to be placed in Ezell's Cave on November 23, 1976. The history of Ezell's Cave is best obtained from an article by W. K. Davis in the Natural History of Texas Caves (Lundelius and Slaughter, 1971). The cave is owned by the Nature Conservancy and excursions into the cave are limited to protect the delicate fauna of the cave. The cave was designated as a Natural Landmark by the National Park Service in 1971. Until recently, this was the only known area with easy access to a pool of subterranean water where Eurycea rathbuni commonly occurs. The reason for purchase of this cave by the Nature Conservancy was to protect the aquatic and terrestrial fauna from uncontrolled collecting. For a time the population of salamanders in this cave appeared to have dwindled and the reason given was that in efforts to protect the cave from vandals and collectors, bats were excluded. This supposedly eliminated the source of organic matter that was at the base of the food chain in the cave. The original placement of the Texas Blind Salamander, Eurycea (=Typhlomolge) rathbuni on the various endangered species lists, including the U. S. Government's, was based on observations of populations in the one pool of Ezell's Cave. Little consideration was given to numbers of salamanders from other sources in the area such as Primer's fissure and the Artesian Well.

Rattlesnake Cave (Figure 7, Appendix I)

During February and March, 1975 spelunkers reported seeing *Eurycea rathbuni* in this cave located on the property of Dr. Nilon Tallant (Russell, 1976). They reported seeing several salamanders on each visit to this cave after having left bait in the water of the cave. On November 29, 1976, I visited the pool of water in Rattlesnake Cave and after observing the pool for a short time a salamander (approximately 9 cm long) was seen walking across a submerged ledge in the rear of the pool. The salamander was *Eurycea rathbuni*. These sightings, in a cave located only 103.6 meters east of Sink Spring (Natural Well) extend the known range further east and north along the Balcones Escarpment, if the salamanders in the Blanco River excavation (Potter, 1963) are considered as a separate species.

Blanco River Gravel Quarry

This site is located approximately 182 meters northwest of the Interstate Highway 35 bridge over the Blanco River. The specimens from this site were collected by McBride B. Wilson, Hays County Gravel Company, on July 23, 1951. The salamanders were discovered while excavating with heavy equipment in the then dry bed of the Blanco River. Several salamanders were sighted. Two salamanders were caught and presented to Dr. C. S. Smith at Southwest Texas State University. After the death of Dr. Smith in 1952 one of the specimens was lost. The other was used by Potter (1963) to describe a species called *Typhlomolge robusta*.

Other

Unconfirmed locations where owners claim to have seen or obtained blind salamanders include the following:

1) Helmer Hageman Property on Spring Road, San Marcos, Texas - Salamanders reported from a dug well that penetrates a cavern (near Rattlesnake Cave).

2) Cave called locally - Devil's Kitchen, said to be located to the north of San Marcos approximately 1/2 the distance to the Blanco River along the old Austin Highway (old U.S. 81).

It is my opinion that *Eurycea rathbuni* is distributed throughout the Edwards Aquifer in the San Marcos area (Figure 10). It is probable that several other locations

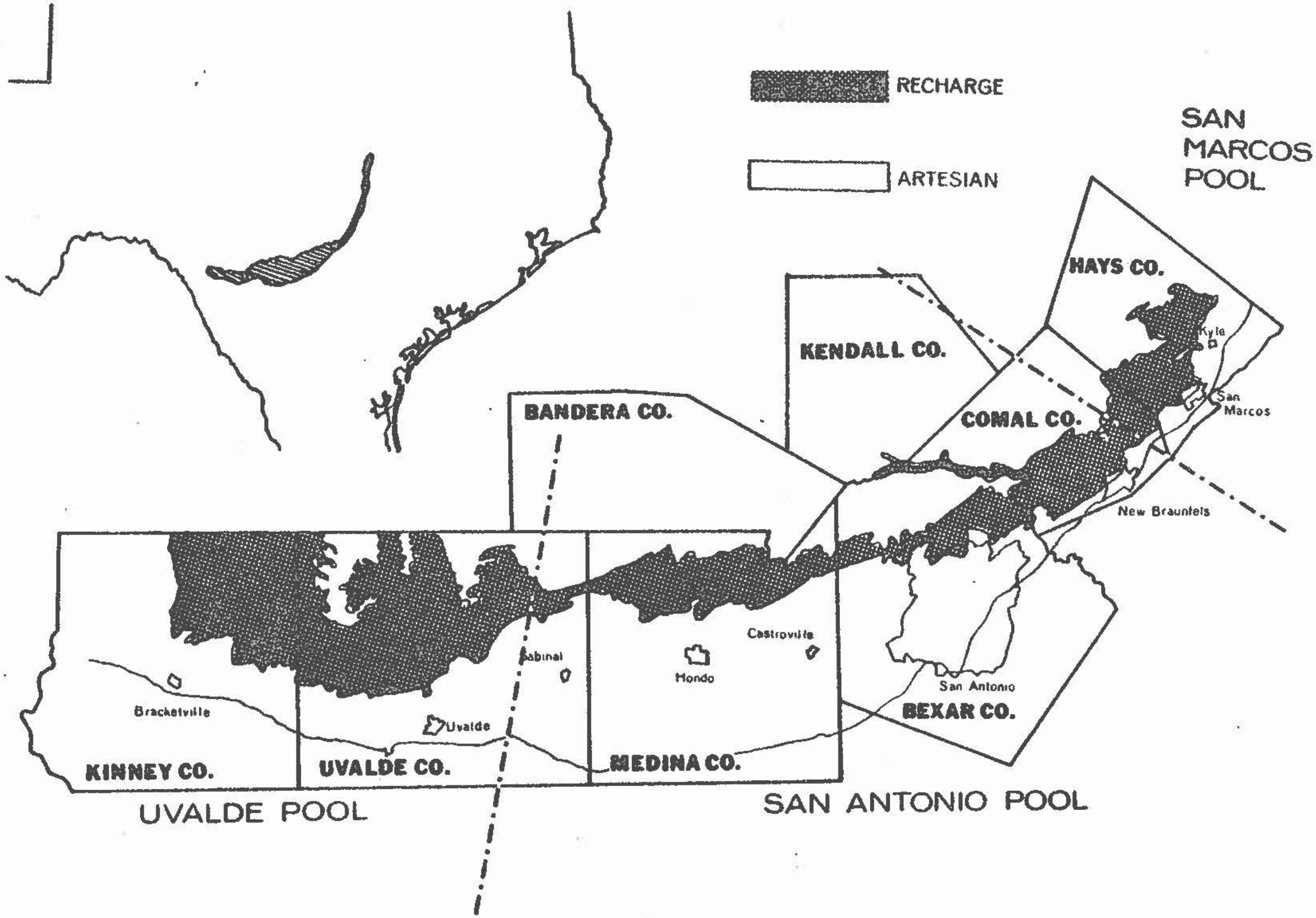

Figure 10. Edwards Aquifer

will be found in this area that will contain these salamanders. Numerous caves located in the upper San Marcos River watershed open into the flood plain of various creeks. Several have been noted in the Sink Creek drainage with trees and other debris washed into their openings. There is little doubt that many of these caves lead to water. Each of these is a source of organic matter for the subterranean food chains. I have serious doubts that the previous over-collecting of Ezell's Cave had any major effect on the total population of *Eurycea rathbuni*. The present known distribution is greater than known in the past. I do not consider the population of *Eurycea rathbuni* to be in danger of extinction in any portion of its known range. I cannot say with certainty that this species is likely to become endangered throughout a significant portion of its range within the predictable future. I propose that this species be removed from the endangered species list.

The only danger that I can predict for this species would be the possible buildup of toxic materials in the aquifer from recharge by heavily populated areas over the recharge zone. I do not feel, however, that this will be allowed to happen to our water supply, the Edwards Aquifer. The U. S. Environmental Protection Agency has recently been given new enforcement powers to control drinking water quality. The Edwards Underground Reservoir has been determined to be the principle source of drinking water for an area near San Antonio, Texas (Fed. Reg. Dec. 16, 1975, Vol. 40, No. 242, pp. 58344-58345). This regulation is pursuant to Sect. 1424(e) of the Safe Drinking Water Act (P.L. 93-523). Under the authority vested by this act, I expect stringent control to be exercised by the Federal Government of activities over the recharge zone of the aquifer. In addition to the federal regulation, the State of Texas Water Quality Board Order No. 75-0128-20 is designed to protect the waters of the Edwards Aquifer from contamination.

If the salamanders need any degree of protection it is where they occur in caves with easy access to the surface, such as Ezell's Cave or Rattlesnake Cave. I would suggest that in these very restricted areas in the total range of the salamanders, they may be considered as threatened in the accessible areas of the cave. These localities consist of two pools of water not having a total surface area greater than 138 m^2. Most of this is in Ezell's Cave. Those salamanders thrust out of wells and springs will be lost to predation by surface forms if not captured and salvaged. Considering the population length distribution in salamanders collected from the Artesian Well and San Marcos Springs (Appendix II), the population is expanding as denoted by an abundance of juveniles.

HABITAT

This neotenic salamander is aquatic throughout life and lives in the water-filled cavernous areas in the San Marcos Pool of the Edwards Aquifer (Figure 10). My observations indicate that this salamander travels along ledges and occasionally swims for a moment in deep pools then spreads its legs rigidly and settles gently to the bottom. The adults and juveniles apparently occupy the same areas. In my studies I have caught all life stages in nets on the same spring and well. The subterranean water temperature of this region is a relatively constant 21°C, and the water quality excellent (Longley, 1975).

I kept one small (3 cm) Eurycea rathbuni alive for about a month in an aquarium in which the temperature varied between 19°C and 24°C and Uhlenhuth (1921) was able to keep this species in aquaria for more than one year. These forms are possibly stenothermal but little investigation has been directed toward determining critical temperature minima and maxima for different life stages.

ESSENTIAL HABITAT

The salamander is probably restricted to an area of approximately 10,342 hectares (ha) in size. Much of this area is directly beneath the city of San Marcos. Since this area is relatively small, one could expect the population of salamanders to be more vulnerable to localized changes in their habitat. With proper enforcement of regulations controlling polluted water recharge, the salamanders should not be adversely affected. Collecting these salamanders poses no threat to their existence. The area in caves where they are vulnerable to capture is extremely small in relation to their total range. Those specimens entering surface waters from springs and wells are rapidly utilized as food by predaceous fish. No confirmed reports have indicated their presence in surface waters outside of enclosures (nets). It is known that a number of wells in the San Marcos area penetrate the caverns containing water (DeCook and Doyle, 1955). Many of these wells have the type pumps on them that would immediately kill any subterranean organism. Most modern well systems in this area have submersable pumps with screens to protect the pumps from sand and gravel. It is likely that many salamanders are killed on these screens. The numbers and size structure of salamanders coming from the Artesian Well and San Marcos Springs indicate a healthy, expanding population, free from any threat of extinction.

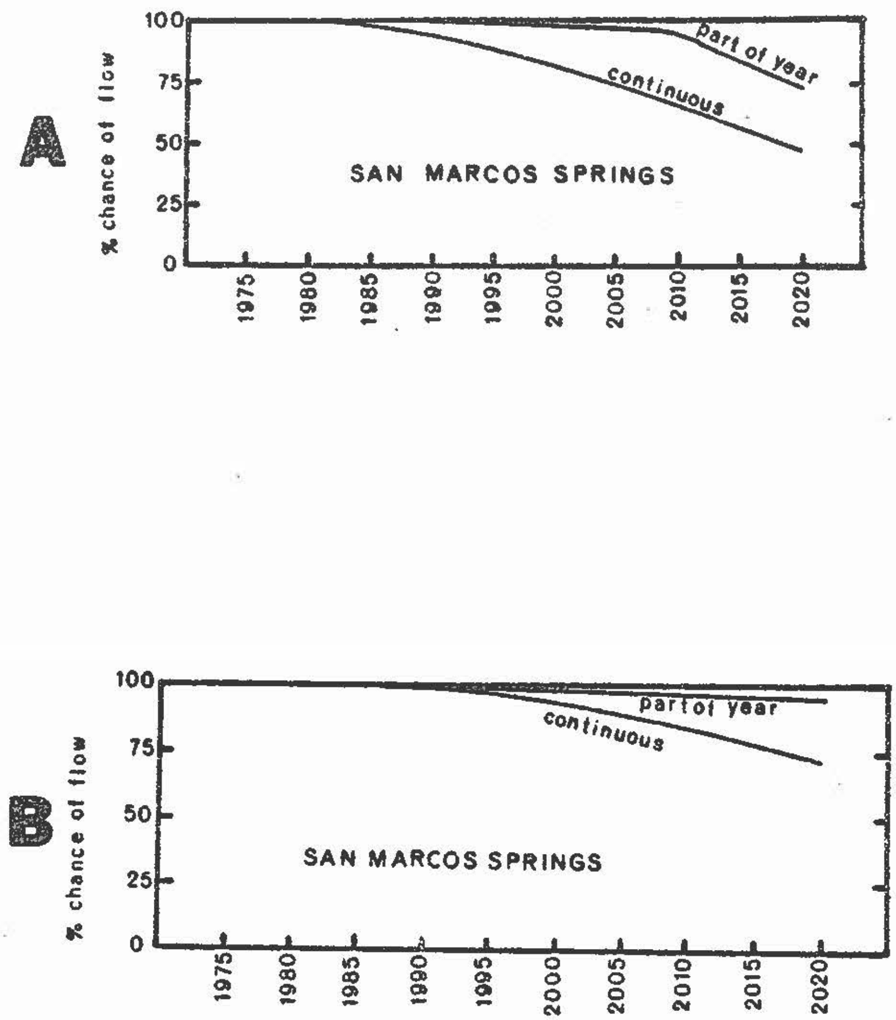

Figure 11. Projected high (A) and low (B) flows from San Marcos Springs, considering continuous and intermittent groundwater pumping.

Table 1. Abundance of cave invertebrate fauna trapped from the flowing Artesian Well, Southwest Texas State University, adapted from Longley, 1975.

Species	Maximum Size (mm)	Number of Days Counted	Organisms Per Day (average)	Range of Numbers Organisms/Day
Sphalloplana mohri (Planarian)	16.3	365	0.002	0 - 1
Horatia micra (Snail)	1.5	93	4.90	1 - 14
Monadella texana (Thermosbaenacean)	1.8	68	0.22	0 - 3
Lirceolus smithii (Isopod)	3.7	101	0.98	0 - 3
Cirolanides texensis (Isopod)	11.5	240	0.05	0 - 2
Copepods	1.6	-		-
Amphipods (=9 species)	13.6	93	8.18	4 - 15
Palaemonetes antrorum (Shrimp)	13.3	92	37.59	17 - 54
Haideoporus texanus (Dytiscid beetle)	3.6	328	0.02	0 - 1

It has been projected that as early as 1985 San Marcos Springs could become intermittent (Figure 11). This condition would not have a drastic effect on subterranean populations. A summary of the groundwater hydrology for the area is contained in a report about the Upper San Marcos River Watershed (Longley, 1975). When the human population of this area becomes very large, groundwater levels will continue to decline. Then some adjacent water bearing strata will contribute greater quantities of water to this area. Some of the adjacent aquifers contain water of poorer quality. Some of these waters, especially to the south, are high in salts or sulfur compounds. If these waters are brought into this area by decreased head in the Edwards Aquifer it is possible that at some point there would be considerable effect on the subterranean fauna. I would like to stress that this unfortunate possibility should be many years in the future.

NUTRITIONAL NEEDS AND FEEDING HABITS

In my observations of the feeding of both adults and juveniles of *Eurycea rathbuni*, one factor is most notable. The salamanders feed on any small organism with which they come in contact. Two papers that may offer insight into feeding behavior appear in the International Journal of Speleology (Culver 1973, 1975). One discusses interaction between competition and predation in cave communities and the other the feeding behavior of a cave salamander.

Counts have been made of various organisms coming out of the Artesian Well for more than 1-1/2 years. I have not summarized all the information for this report but the species and other preliminary data are included so that food availability can be considered (Table 1). The largest form is a blind shrimp *Palaemonetes antrorum*. This form and some of the larger amphipods are the primary food of the larger salamanders. Captive salamanders feed on these organisms. The salamanders probe the water using lateral movements of the head. When anything living is encountered the mouth quickly opens and the food item is immediately sucked into the mouth. The numerous sharp teeth prevent any chance of escape.

There appears to be no food selectivity. Young salamanders feed well on copepods. One juvenile was observed to eat 14 copepods at one feeding. Stomach contents of most of the captured salamanders have been examined. The small snails, *Horatia micra*, are easily recognizable when the digested remains of other forms are not. Several specimens examined had snails in their gut, including one very small (2.81 cm) salamander. Since snails do not move about rapidly, the salamanders must be able to sense very small amounts of movement or utilize some chemosensory structure.

A

B

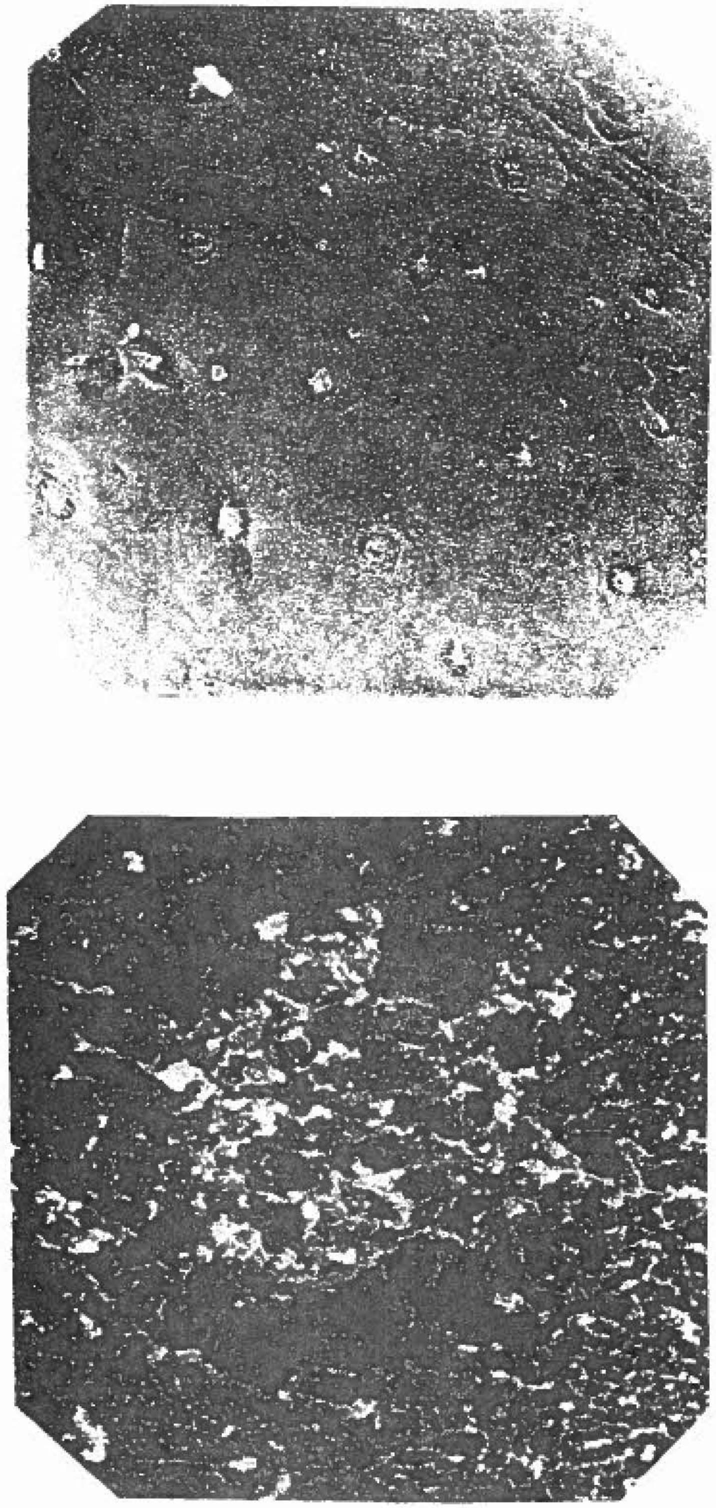

Figure 12 Dorsal Neurogemmae of juvenile *Eurycea rathbuni* (SEM); A = 300 X, B = 5000 X

Specialized neurogemmae are found distributed over the surface of these salamanders. The neurogemmae are related to the neuromast receptor organs of the lateral line system in fish (Vandel, 1965). Electron micrographs of the surface of Eurycea rathbuni illustrate the abundance of these organs (Figure 12). My observations would indicate that these salamanders are opportunistic in their feeding. I am unsure at this time exactly how food items are detected, but several hypotheses have been suggested. Two papers, Norman (1900) and Eigenmann (1909) suggest that these salamanders are very sensitive to vibrations of the water around them. This is a logical conclusion if the sensory structures so abundant on the salamander surface are mechanoreceptors. It is just as logical to consider an olfactory sense as a possible mode of food detection. The receptors mentioned previously may have chemosensory function. This point has not yet been clarified.

No diel cycle has been noted in feeding behavior. This I plan to investigate with some of the salamanders in the holding chamber of the Artesian Well. Biorhythms are important regulatory mechanisms and it will be interesting to discover if these rhythms persist in subterranean forms in the absence of surface stimuli.

REPRODUCTION AND DEVELOPMENT

There is no external indication of sexual dimorphism. The only description of the female Eurycea rathbuni reproductive system was done by Emerson (1905) in her paper on the general anatomy. Emerson did not have males available and no literature could be found in which the male reproductive system is described. In an 8.99 cm specimen I observed paired testes, unlobed, and having a length of 9.1 mm. The presence of unlobed testes would indicate that the male is sexually active all year. This is expected since there are no well developed seasonal changes in the subterranean habitat. Unfortunately this also eliminates one of the few means available for aging salamanders (Porter, 1972). Porter notes references that indicate testes of Plethodontidae are irregularly lobed. He describes the direct relationship between number of lobes and age of the salamander. He indicates that each lobe of such multiple-lobed testes represents a center of spermatogenesis and is swollen due to this activity. Sever (1974) discusses the occurrence of multiple testes in the genus Eurycea. He concludes that multiple testes are probably not useful above the tribe level as a tool for aging. He did not examine Eurycea rathbuni, and no method has been devised to age these salamanders.

In salamanders less than 3cm long it is very difficult to differentiate the sex of the animal from viewing the gonads. Histological work will be necessary to determine exactly when these salamanders contain active gametes. During my study, a gravid female (10.4 cm long) appeared to be near death. The female was killed and dissected. Examination of the ovaries revealed 22 developed eggs in the right ovary and 17 developed eggs in the left ovary. The exact number of undeveloped eggs was not determined, but there appeared to be approximately the same number of undeveloped eggs. No study has revealed the length of time these forms are sexually active. Two papers on reproduction and larval development of two other species may give some insight into characteristics of the group (Ireland, 1974 and 1976). Ireland's work was done on two transforming plethodontids, Eurycea longicauda melanopleura and Eurycea multiplicata griseogaster. Unfortunately, comparisons of these forms may be of little use since they are surface, transforming species affected by seasonal changes.

Juveniles have been found at all times during the year. Several of these have been less than 1 cm long and still appear to have yolk sac. This stage would be comparable to Necturus maculosus larvae between 49 and 97 days of age (Goin and Goin, 1971). Eggs were found September 15, 1975, in the net on the Artesian Well. These eggs were not positively identified as those of the salamander, but this possibility exists.

At present nothing is known about the breeding behavior of Eurycea rathbuni. I have fifteen moderate to large salamanders in captivity in the holding chamber of the well and it is possible that I may try to devise a means whereby they can be furnished with abundant food and allowed to come in contact. It is my hope that this may permit breeding to take place and more information be made available on this aspect of their life history. It is improbable that any care of eggs or young occurs. It is probable that the fertilization in these forms is accomplished as in other Eurycea (Goin and Goin, 1971). During courtship the male deposits several spermatophores and the female picks them up with the lips of her cloaca. In the cloaca the gelatinous cap of the spermatophore dissolves allowing the sperm to migrate to the female spermatheca. It is possible that the male forces the spermatophore into the female cloaca. This process may be a possible mechanism that in the subterranean environment would allow mating to occur less often. The female may store sperm from a mating until she is prepared to ovulate. Another possibility is that enough sperm may be stored during one mating to fertilize several different groups of eggs.

Appendix II summarizes the information about change in morphology with size. The small juveniles appear to have a greater density of pigmented spots in their dorsal surface than do the larger forms. It is possible that the number of pigmented cells (probably melanophores) stay constant without stimulation from light and therefore are almost unnoticeable on the mature specimens. In the juveniles the eyes are much nearer the surface and appear larger in relation to the size of the head (Figure 5).

POPULATION LEVEL

POPULATION RECORDS

More localities are known at this time than in the past and one of these, San Marcos Springs, has yielded large numbers of specimens. Historically, reference has been made to the occurrence of these salamanders in the four localities mentioned in the distribution section. All population records prior to this study have been based on observations at the following localities.

Johnson's Well

Many references are made to the collection of salamanders from this location. The last published record of collections from this locality is by Uhlenhuth (1921). He notes that five salamanders were trapped in 1916 and eight in 1917. Those collections after 1917 may not be from Johnson's Well.

Primer's Fissure, "Well"

The earliest collections that I could verify as having been made from this location were those of R. W. Mitchell in 1951 (personal communication). Many of the "Johnson's Well" collections that have been referred to in publications before 1976 are in fact records from Primer's Fissure, "Well."

Ezell's Cave

Most estimates of population size were based on observations in Ezell's Cave. Ezell's Cave was the only known location within the range providing easy access to a pool of subterranean water. During September, 1967, the Nature Conservancy purchased Ezell's Cave and began measures designed to protect the fauna of the cave. A decline in numbers of salamanders was noted in the pool of this cave during the years prior to 1967. This apparent decline was based on the observations of mid size to large salamanders.

Small salamanders have apparently never been reported from the exposed pool in Ezell's Cave. I contend that the juveniles were there all the time, but due to their size they were not noticed. As I mentioned previously, the caretaker noticed an approximately 9 cm salamander in the pool during December, 1976.

Wonder (Beaver) Cave

No recent published records could be found that list this cave as a collecting locality. Staff at the cave indicated that there have been no sightings in recent years.

Artesian Well

Since October, 1973, continuous sampling of the Artesian Well on the Southwest Texas State University campus yielded 14 salamanders in 1975 and 17 salamanders in 1976.

San Marcos Springs

On November 24, 1975, an intermittent sampling program was initiated on one of the large San Marcos Springs (Pipe Spring). The spring chosen is one which has been covered and diverted into the show area of Aquarena via a 73.6 cm pipe. Sampling of this spring has not been continuous but has been done when time would allow. Thirty *Eurycea rathbuni* were captured by the end of 1975. These collections were the first time *Eurycea rathbuni* had been obtained from these springs. Sixty-eight were collected in 1976. No collecting was done at this spring for 6 months during 1976.

Rattlesnake Cave

On November 29, 1976, I entered a small cave at the end of Spring Road on the north side of San Marcos. This cave was located on the property of Dr. Nilon Tallant. While in the cave I observed a *Eurycea rathbuni* walking on a shelf in the back of a pool. I would estimate the salamander to be 9 cm long. This observation of *Eurycea rathbuni* in Rattlesnake Cave is the northernmost verified sighting along the Balcones Escarpment. The cave is located 91 meters from the center of Sink Springs on bearing 105°E. During 1976 several spelunkers reported seeing blind salamanders in this cave.

POPULATION ESTIMATES

An attempt was made to estimate the total population based on my collections from San Marcos Springs and the Artesian Well (Appendix III). If one assumes the salamanders are randomly exposed to the well and spring openings, then one can make population projections related to volume of flow. Based on an average flow rate of 1380.42 m^3/day from the Artesian Well, my calculations indicate that 1 salamander comes out of the Artesian Well with every 29,463 m^3 of water (1 salamander every 21.34 days). If one used the same volume of water per salamander from San Marcos Springs this would mean an estimated 13 salamanders leave the springs each day (4,745/year) with an average flow rate of 393,915 m^3/day. The size of the population necessary to support this loss each year would necessarily be large. My collections on Pipe Spring completely support this estimate. I have no way of knowing the percentage of the strata in this region of the aquifer consisting of caverns supporting salamanders. Geological studies indicate that the Edwards limestone of the aquifer is penetrated by many caverns (Grimshaw, 1976).

At the present time 15 salamanders are in captivity. These moderate to large salamanders are being held in darkness in a distribution chamber of the Artesian Well. One of the salamanders was caught in the net on the Artesian Well June 26, 1975, and is still in a jar in the chamber. The jars holding the salamanders have minnow seine netting over their mouths so that a good exchange of fresh water occurs. The salamanders are fed monthly with organisms coming from the well. The longest period they have been held in captivity is nearly 31 months (this study). Salamanders have been held up to a year in aquaria by Uhlenhuth (1921). No more than a few salamanders were held at any one time.

PARASITISM AND PREDATION

DISEASE AND PARASITES

Salamanders caught during my studies have been examined internally for parasites. The following discoveries have been made with the assistance of Dr. David G. Huffman, Southwest Texas State University:

(new sp.?) = 1) *Capillaria* sp., eggs in feces (Nematoda)
2) *Hexamita* sp., in gut (Mastigophora, Protista)

3) Neoechinorhynchus (cylindratus?) - gravid females, in gut and body cavities (Acanthocephala)

(new sp.?) = 4) Digenetic Trematode - with eggs, in gut

PREDATION

In its subterranean habitat, Eurycea rathbuni is the top predator. When this salamander is brought to the surface via springs and wells it is easy prey for various fish and other nekton. Some reports of the occurrence of surface fish in the caves of the area occur periodically. These are usually sunfish that have probably washed into some of the larger recharge openings. It is not expected that these forms survive. No records of cave adapted fish occur in this portion of the Edwards Aquifer. In the San Antonio region two species of cave adapted blindcats do occur in the Edwards Aquifer, Satan eurystomus and Trogloglanis pattersoni (Suttkus, 1961; Hubbs and Bailey, 1947; Eigenmann, 1919; and Hubbs, in Lundelius and Slaughter, 1971).

REASONS FOR CURRENT STATUS

Persons familiar with only one source of salamanders (Ezell's Cave) noticed a decline in numbers in the area that is exposed to non-scuba-equipped spelunkers. This decline may be attributed to collecting. Other contributing factors involved were:

1) Loss of bat population
2) Decrease in input of organic matter
3) The toxic effect of carbide left by spelunkers, that may have formed toxic materials which tended to cause the salamanders to move out of the immediate area.

Changes in this small area may not reflect significant changes in the overall population. Due to the present known population sizes and age structure a healthy, expanding population is indicated. The inaccessibility of much of the potential habitat shields these forms from most threats.

CONSERVATION AND RECOVERY

The Nature Conservancy has purchased and protected Ezell's Cave (Davis, in Lundelius and Slaughter, 1971). In attempting to meet the requirements of my Federal Scientific Collecting Permit FWS #PRT-8-239-C, I placed 9 salamanders caught in surface nets back in the aquifer via Ezell's Cave. I have not placed more salamanders back in the subterranean waters for several reasons:

1) There is limited access to Ezell's Cave
2) No other such location was known to me until recently
3) There are questions that arise regarding the advisability of such activity (such as what impact to the resident population will the introduced numbers pose?)
4) Will such introductions cause any disturbance of localized gene pools?
5) The necessity of reintroducing forms from the wells and springs

My ideas regarding conservation of this species closely parallel many of those expressed by Ehrenfeld (1976). He lists some of the usual reasons given for assigning value to a species such as *Eurycea rathbuni*:

(He uses the Houston Toad, *Bufo houstonensis* as an example)

1) Recreational and esthetic values
2) Undiscovered and undeveloped values
3) Ecosystem stabilization values
4) Examples of survival
5) Environmental baseline and monitoring values
6) Scientific research values
7) Teaching values
8) Habitat reconstruction values
9) Conservation value: Avoidance of irreversible change

In his article he also discusses the use of formal priority rankings and non-economic values.

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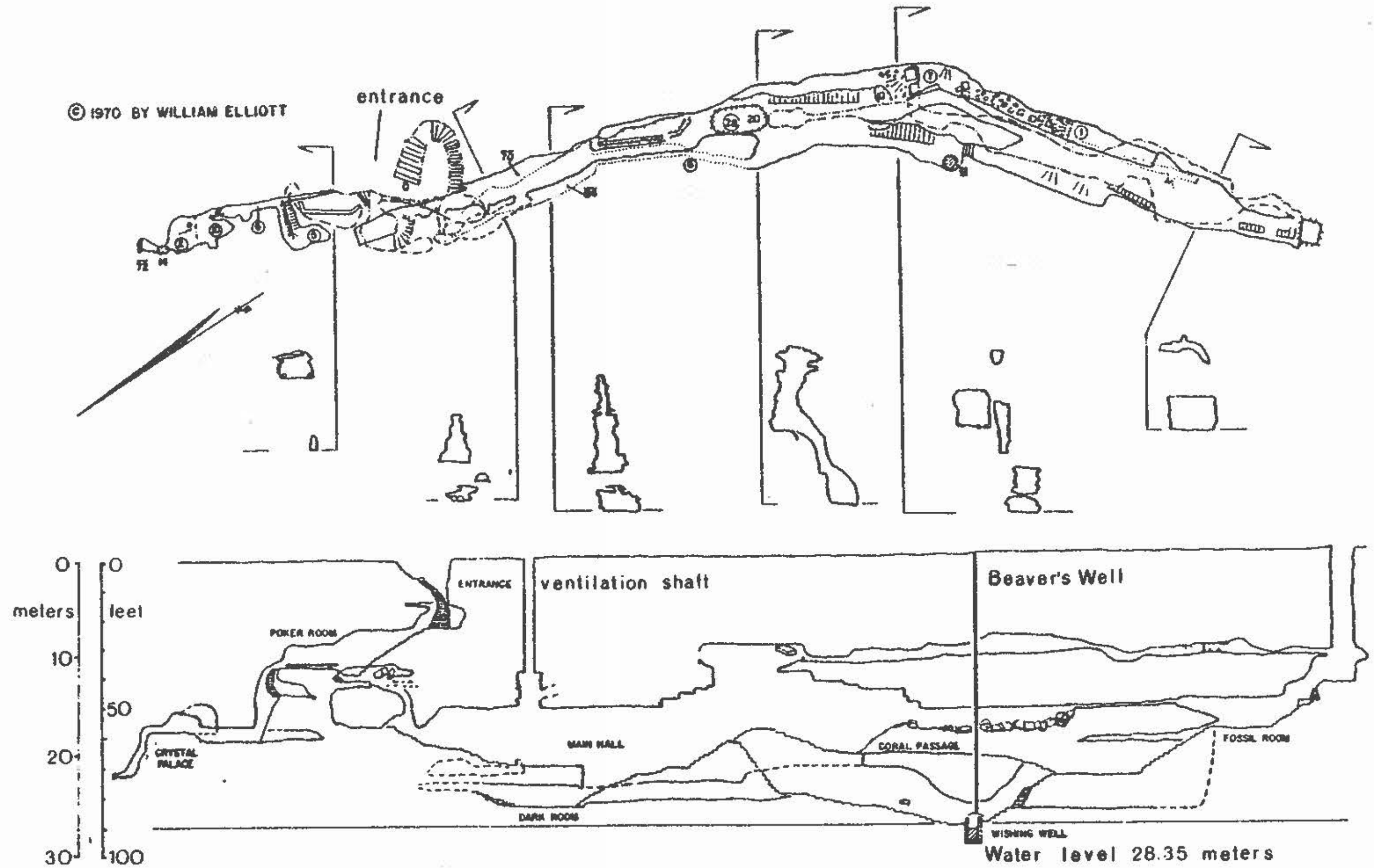
Appendix I. Caves in which *Eurycea rathbuni* is known to occur. A = Wonder Cave, B = Ezell's Cave, C = Rattlesnake Cave.

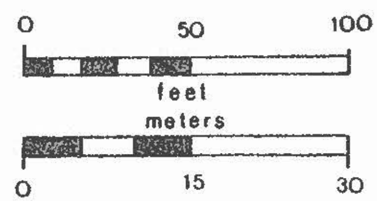


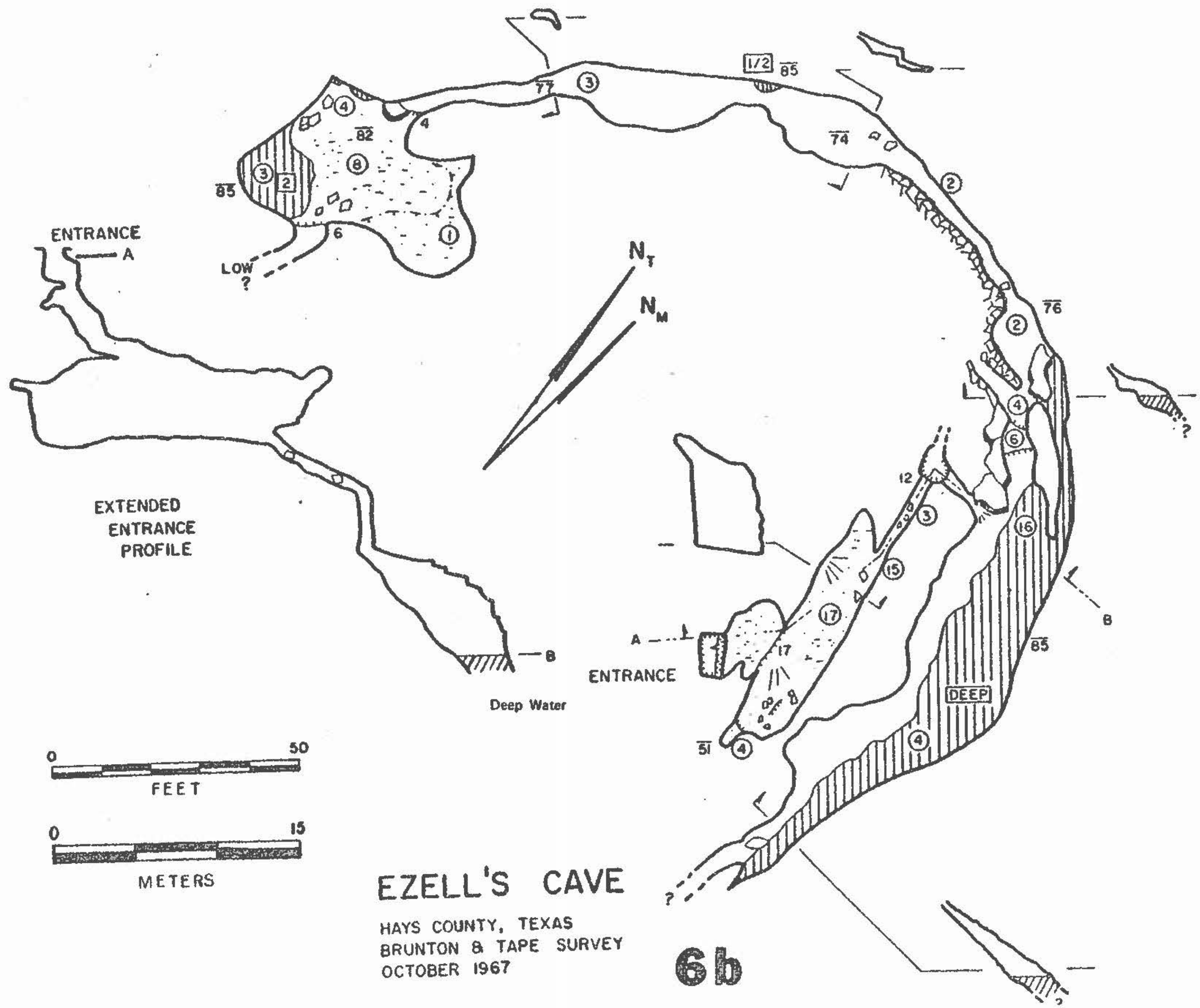
WONDER CAVE (BEAVER CAVE)

HAYS COUNTY, TEXAS

BRUNTON AND TAPE SURVEY, JULY, AUGUST 1970 BY
W. ELLIOTT, V. ELLIOTT, B. HARRISON,
R. McMILLAN, AND M. WALSH
DRAFTED BY WILLIAM ELLIOTT

6A

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EZELL'S CAVE
HAYS COUNTY, TEXAS
BRUNTON & TAPE SURVEY
OCTOBER 1967
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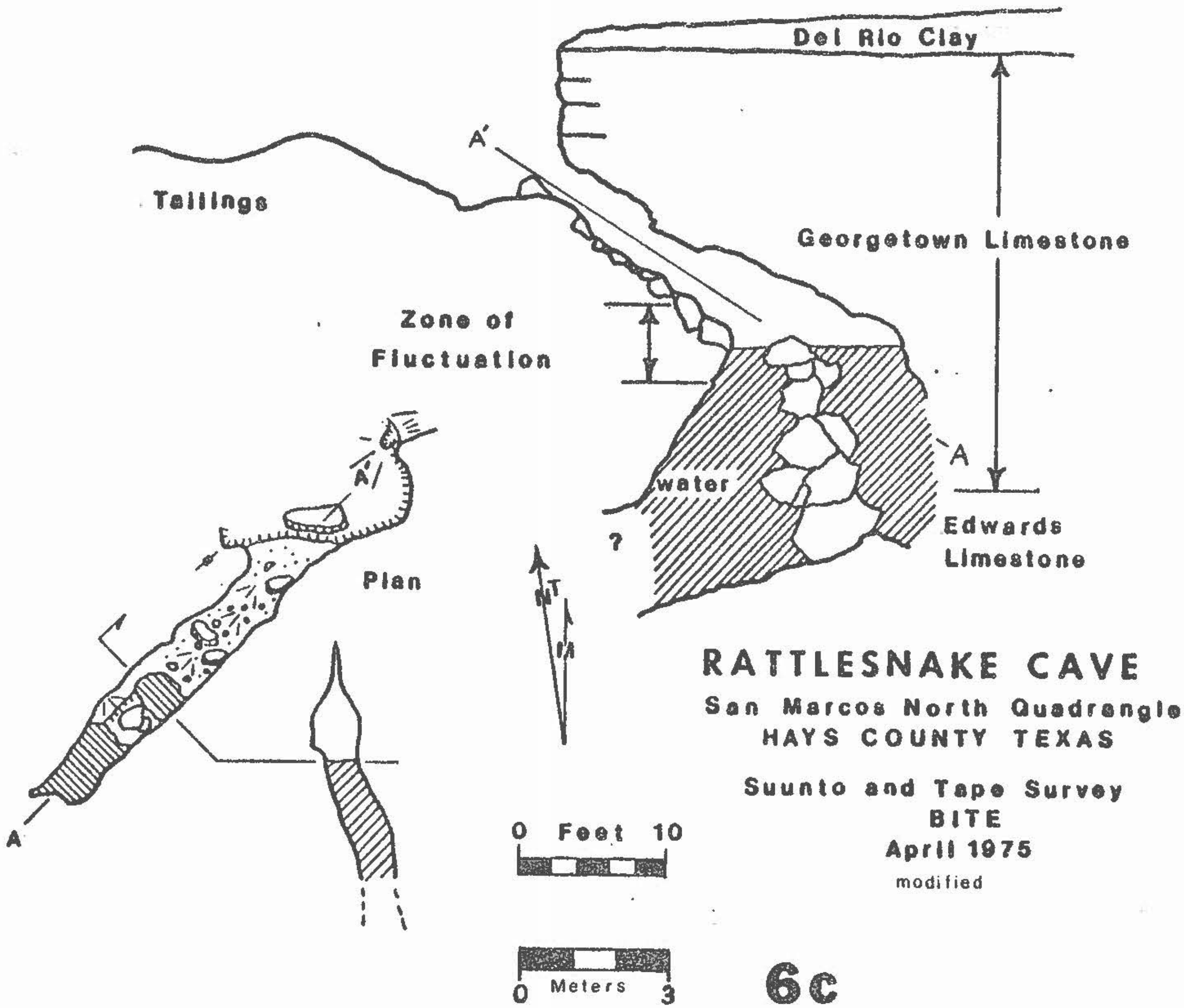
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RATTLESNAKE CAVE
San Marcos North Quadrangle
HAYS COUNTY TEXAS
Suunto and Tape Survey
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Appendix II. Measurements (cm) of <u>Eurycea rathbuni</u> at different sizes; S = sex, ToL = total length, SVL = snout-vent length, AGL = axilla-groin length, TaL = tail length, FL = forelimb length, HL = hindlimb length and IoW = inter-orbital width

Date Collected	Location*	SWT#	S	ToL	SVL	AGL	TaL	FL	HL	IoW
14 IV 76	Well	**	F	11.25	5.80	2.90	5.35	2.10	2.40	.75
26 VIII 76	Well	**	?	9.50	5.60	2.65	3.90	1.60	1.60	.55
27 I 76	Spring	A-1	M	8.99	4.74	2.19	4.25	1.76	1.76	.42
15 IX 76	Well	**	?	8.60	4.90	2.50	3.70	1.60	1.60	.55
4 II 76	Spring	A-3	M	7.85	4.14	2.11	3.71	1.52	1.52	.38
7 X 75	Well	**	?	7.30	4.50	2.00	2.80	1.40	1.50	.40
5 I 77	Well	**	?	7.20	4.10	1.90	3.10	1.30	1.30	.55
13 IX 75	Well	**	?	6.70	4.00	1.90	2.70	1.35	1.35	.50
16 XII 76	Well	**	?	6.10	3.30	1.60	2.80	1.50	1.50	.45
17 I 76	Spring	A-2	M	6.01	3.74	1.89	2.37	1.15	1.17	.30
11 VIII 76	Well	**	?	5.20	3.20	1.50	2.00	1.10	1.15	.35
16 VII 76	Well	**	?	5.10	3.10	1.50	2.00	.80	.90	.40
22 XII 76	Well	**	?	5.00	3.10	1.40	1.90	1.15	1.20	.30
4 III 76	Spring	A-77	M	3.31	2.02	.98	1.29	.64	.75	.14
22 II 76	Spring	A-70	M	3.30	1.86	.77	1.44	.57	.62	.14
5 XII 75	Spring	A-15	M	3.08	1.63	.85	1.45	.60	.67	.13
23 XII 75	Spring	A-35	M	3.07	1.73	.86	1.34	.54	.60	.16
22 III 76	Spring	A-80	F	2.99	1.72	.75	1.27	.52	.55	.15
19 III 76	Spring	A-78	M	2.97	1.69	.79	1.28	.50	.54	.13
6 IV 76	Spring	A-82	M	2.90	1.79	.84	1.11	.49	.52	.15
21 I 76	Spring	A-48	?	2.90	1.74	.73	1.16	.50	.57	.12
8 II 76	Spring	A-62	?	2.81	1.74	.80	1.07	.52	.60	.14
31 XII 75	Spring	A-39	?	2.76	1.62	.72	1.14	.51	.57	.13
25 I 76	Spring	A-52	?	2.67	1.63	.81	1.04	.49	.52	.13
5 XII 75	Spring	A-18	?	2.65	1.84	.98	.81	–	–	.13
8 II 76	Spring	A-63	?	2.63	1.61	.76	1.02	.47	.54	.12
9 XII 75	Well	A-26	?	2.60	1.50	.77	1.10	.45	.52	.12
29 II 76	Spring	A-76	?	2.60	1.54	.67	1.06	.45	.49	.12
20 II 76	Spring	A-68	?	2.53	1.71	.76	.82	.46	.46	.11
20 I 76	Well	A-47	?	2.52	1.48	.68	1.04	.46	.49	.11
27 II 76	Spring	A-73	?	2.50	1.51	.72	.99	.40	.47	.12
18 I 76	Spring	A-46	?	2.49	1.63	.60	.86	.46	.52	.12
8 XI 74	Well	A-7	?	–	1.62	.65	–	.67	.67	.18
7 XII 75	Spring	A-19	?	2.49	1.50	.70	.99	.45	.49	.12
29 I 76	Spring	A-57	M	2.43	1.52	.67	.91	.41	.45	.10
19 III 76	Spring	A-79	?	2.36	1.33	.62	1.03	.38	.42	.12
5 XII 75	Spring	A-17	?	2.32	1.33	.60	.99	.39	.41	.13
21 I 76	Spring	A-50	?	2.25	1.50	.69	.75	–	–	.13
21 I 76	Spring	A-49	?	2.25	1.35	.67	.90	.41	.47	.13
16 II 76	Spring	A-67	?	2.22	1.39	.63	.83	.43	.43	.09

Appendix II (Continued)

Date Collected	Location*	SWT#	S	ToL	SVL	AGL	TaL	FL	HL	IoW
25 III 76	Spring	A-81	?	-	1.33	.65	-	-	-	.10
27 I 76	Spring	A-55	?	2.22	1.32	.52	.90	.41	.45	.12
31 XII 75	Spring	A-38	?	2.21	1.40	.71	.81	.38	.39	.11
27 I 76	Spring	A-54	?	2.16	1.28	.61	.88	.32	.37	.11
27 II 76	Spring	A-72	?	2.15	1.34	.73	.81	.32	.36	.11
27 II 76	Spring	A-75	?	2.14	1.30	.62	.84	.39	.40	.10
9 XII 75	Spring	A-30	?	2.10	1.15	.55	.95	.36	.36	.10
7 XII 75	Spring	A-20	?	2.06	1.22	.57	.84	.38	.38	.11
2 II 76	Spring	A-58	?	2.03	1.21	.62	.82	.34	.38	.10
25 I 76	Spring	A-53	?	1.90	1.16	.54	.74	.37	.38	.10
9 XII 75	Spring	A-29	?	1.86	1.15	.52	.71	.36	.37	.11
29 XI 75	Spring	A-13	?	1.86	1.10	.46	.76	.36	.29	.10
31 XII 75	Spring	A-37	?	1.79	1.16	.52	.63	-	-	-
19 IV 76	Spring	A-85	?	1.78	1.23	.56	.55	-	-	-
16 XII 75	Spring	A-31	?	1.78	1.07	.51	.71	.33	.32	.09
17 I 76	Spring	A-45	?	1.75	-	-	-	-	-	-
9 XII 75	Spring	A-28	?	1.70	1.03	.50	.67	.38	-	-
4 II 76	Spring	A-4	?	1.67	1.02	.45	.65	.27	.29	.09
27 XI 75	Spring	A-12	?	1.61	.98	.53	.63	.18	.18	.10
17 I 76	Spring	A-44	?	1.60	1.00	.54	.60	-	-	.08
29 XII 75	Spring	A-36	?	1.60	.97	.49	.63	.24	.26	.09
7 XII 75	Spring	A-23	?	1.58	.89	.41	.69	.24	.27	.08
7 XII 75	Spring	A-25	?	1.58	-	-	-	-	-	-
16 II 76	Spring	A-65	?	1.54	.94	.42	.60	.31	-	.09
2 II 76	Spring	A-59	?	1.53	.98	.39	.55	.26	.28	.07
19 XI 76	Spring	A-92	?	1.47	.87	.39	.60	.25	.24	.08
22 XII 75	Well	A-32	?	1.46	.84	.44	.62	.26	.18	.08
28 IX 76	Well	A-87	?	1.46	.87	.41	.59	.18	.16	.08
27 I 76	Spring	A-56	?	1.44	.90	.44	.54	.25	.23	.09
21 I 76	Spring	A-51	?	1.44	.83	.39	.61	.28	.25	.09
3 I 76	Well	A-41	?	1.43	.82	.39	.61	.22	.20	.10
27 XI 76	Spring	A-94	?	-	.82	-	-	-	-	.09
3 I 76	Well	A-40	?	1.42	.86	.47	.56	.21	.21	.05
7 XII 75	Spring	A-21	?	1.41	.98	.42	.43	.26	.24	.07
27 XI 76	Spring	A-93	?	1.40	.86	.39	-	.24	.26	.10
2 X 76	Well	A-88	?	1.38	.85	.41	-	.21	.19	.08
20 II 76	Spring	A-69	?	1.38	.82	.32	.56	.22	.22	.06
30 XI 76	Spring	A-95	?	1.37	.80	.40	.57	.25	.26	.09
9 XII 75	Spring	A-27	?	1.37	-	-	-	-	-	.08
19 I 77	Spring	A-89	?	1.36	.81	.41	.55	.22	.19	.09
3 VI 76	Spring	A-86	?	1.36	.81	.30	.55	.17	.17	.09
25 II 76	Well	A-71	?	1.35	.85	.37	.50	.20	.17	.08

Appendix II (Continued)

Date Collected	Location*	SWT#	S	ToL	SVL	AGL	TaL	FL	HL	IoW
8 IV 76	Spring	A-83	?	1.32	.79	.38	.53	-	-	.08
23 XII 75	Spring	A-34	?	1.32	-	-	-	-	-	-
19 I 77	Spring	A-90	?	1.31	.88	.41	.43	.21	.15	.09
19 VIII 75	Well	A-10	?	1.31	.83	.36	.48	.17	.10	.09
7 XII 75	Spring	A-22	?	1.31	.81	.37	.50	.21	.21	.08
30 XI 76	Spring	A-96	?	1.30	.81	.37	.49	.25	.25	.10
27 XI 75	Spring	A-11	?	1.28	.89	.47	.39	.24	.21	.07
2 II 76	Spring	A-61	?	1.26	.88	.37	.38	.26	.22	.09
29 XI 75	Spring	A-14	?	1.25	-	-	-	-	-	.07
2 VII 75	Well	A-8	?	1.24	.84	.39	.60	.12	.11	.10
2 II 76	Spring	A-60	?	1.24	.80	.36	.44	.23	.22	.10
17 I 76	Spring	A-43	?	1.23	-	-	-	-	-	-
30 XI 76	Spring	A-97	?	1.21	.77	.38	.44	.23	.24	.08
25 I 77	Spring	A-91	?	1.20	.74	.32	.46	.18	.18	.09
8 II 76	Spring	A-64	?	1.19	.79	.34	.40	.20	.20	.09
7 XII 75	Spring	A-24	?	1.14	.82	-	.32	-	-	-
17 I 76	Spring	A-42	?	1.13	-	-	-	-	-	-
30 XI 76	Spring	A-98	?	1.10	.83	.43	.27	-	-	.06
27 II 76	Spring	A-74	?	1.10	-	-	-	-	-	.07
4 II 76	Spring	A-5	?	1.09	.82	.43	.27	.05	.01	.04
3 I 74	Well	A-6	?	1.04	.76	.28	.28	.17	.18	.08
16 II 76	Spring	A-66	?	.95	-	-	-	.15	-	-
23 XII 75	Spring	A-33	?	.93	-	-	-	-	-	.08
19 IV 76	Spring	A-84	?	.92	-	-	-	-	-	-
29 XI 75	Spring	A-16	?	.86	-	-	-	-	-	-

* Spring = San Marcos Springs (Pipe Spring)
Well = Artesian Well

** Measurements were made on living specimens and may be slightly off since an attempt was made not to harm the salamanders.

Appendix III. Numbers of *Eurycea rathbuni* collected

Date	SWTSU Artesian Well	Pipe Spring San Marcos Springs
21 II 75	1	
26 VI 75	1	
12 VII 75	1	
5 VIII 75	1	
11 VIII 75	1	
21 VIII 75		
13 IX 75	1	
25 IX 75	1	
7 X 75	1	
12 X 75	1	
19 XI 75	1	
24 XI 75		4
27 XI 75		1
29 XI 75	1	3
5 XII 75		3
7 XII 75		7
9 XII 75	1	4
16 XII 75		1
22 XII 75	1	
23 XII 75		3
29 XII 75		1
31 XII 75		3
3 I 76	1	
6 I 76		1
17 I 76		5
18 I 76		1
20 I 76	1	
21 I 76		4
25 I 76		3
27 I 76		4
29 I 76		3
2 II 76		4
4 II 76		2
8 II 76		3
16 II 76		3
20 II 76		2
22 II 76		1
25 II 76	1	
27 II 76		4
29 II 76		1
4 III 76		1
6 III 76	1	
19 III 76		2
22 III 76		1
25 III 76		1
6 IV 76		1

Appendix III (Continued)

Date	SWTSU Artesian Well	Pipe Spring San Marcos Springs
8 IV 76		1
14 IV 76	1	
19 IV 76		2
3 VI 76		1
14 VI 76	1	
2 VII 76	1	
16 VII 76	1	
21 VII 76	1	
11 VIII 76	1	
26 VIII 76	1	
15 IX 76	1	
28 IX 76	1	
2 X 76	1	
18 X 76	1	
19 XI 76		3
23 XI 76		8
27 XI 76		2
30 XI 76		4
16 XII 76	1	
22 XII 76	1	
5 I 77	1	
19 I 77		2
25 I 77		1
TOTALS	32	101