CONSERVATION OF TEXAS CAVES AND KARST

by William R. Elliott*

On the human time scale, caves are a nonrenewable resource.

INTRODUCTION

The perceptions of scientists, cavers, and the public about Texas caves and karst have changed dramatically over the decades, and continue to change as the state's population grows and more areas become urbanized. In this chapter I examine the conservation and restoration of caves, cave fauna, groundwater, and karst. Space does not permit a full discussion of the many cave conservation projects that have been conducted in Texas.

For many years even the most conservation-minded cavers thought only in terms of conserving individual caves. Only since about 1984, when it became apparent that rare cave creatures near Austin were threatened by land development, have we had the opportunity to conserve clusters of caves or entire karst areas. Recently these concerns have become more aligned with groundwater conservation, particularly in the Edwards Aquifer region.

CAVE CONSERVATION

Texas speleology started in 1948 with the publication of National Speleological Society Bulletin 10. That pivotal document contained descriptions of perhaps two hundred caves, but it contained little on conservation. A. T. Jackson, the University of Texas archeologist who did the original excavation of Fate Bell Shelter, wrote a brief article for the bulletin entitled "Proposed: A Seminole Canyon Park." In 1938 Jackson and a geologist had tried to persuade the National Park Service and the Texas State Parks Board to set aside Seminole Canyon as an archeological park. Jackson wrote, "For reasons not disclosed, the project was never undertaken. Today there is still no protection from vandals for irreplaceable works of art—in the form of huge murals on the walls. There is still time for the area to be given park status—if we work hard and fast. In the meantime, it is the responsibility of each visitor to see that he leaves everything in as good condition as he finds it." Jackson's idea was prophetic—in the 1970s the Texas Parks and Wildlife Department acquired portions of two ranches, finally opening Seminole Canyon State Historical Park in February, 1980. Nowadays the Department uses electronic surveillance to keep watch on the sensitive areas of the park.

In the heyday of Texas caving in the 1950s and 1960s, cavers practiced self-control and perceived themselves as the biggest threat to caves. Cave conservation consisted of admonishing each other not to break stalactites, not to write on the wall, not to leave trash, and not to bury carbide in caves. Many cavers smoked while caving. Conservation projects consisted mainly of small caving parties cleaning trash out of a favorite cave. The most important aspect of cave conservation was secrecy about cave locations. This was the most effective way to keep other cavers (usually perceived as less careful and

*12102 Grimsley Drive, Austin, Texas 78759

considerate than yourself) or high school students out of the caves.

Probably the earliest cave gating project by Texas cavers was at Cave Y (Whitten Cave), Schleicher County, in the early 1960s. With the help of concerned Texas Speleological Association (TSA) cavers, the owner filled the largest entrance with concrete and installed a heavy steel gate on the smaller one after a local high school student fell and broke his arm in the cave (Meador, 1965). Cavers are rarely allowed to enter the cave anymore. One conservation concern was that the cave contained human bone material (Bill Russell, pers. comm.).

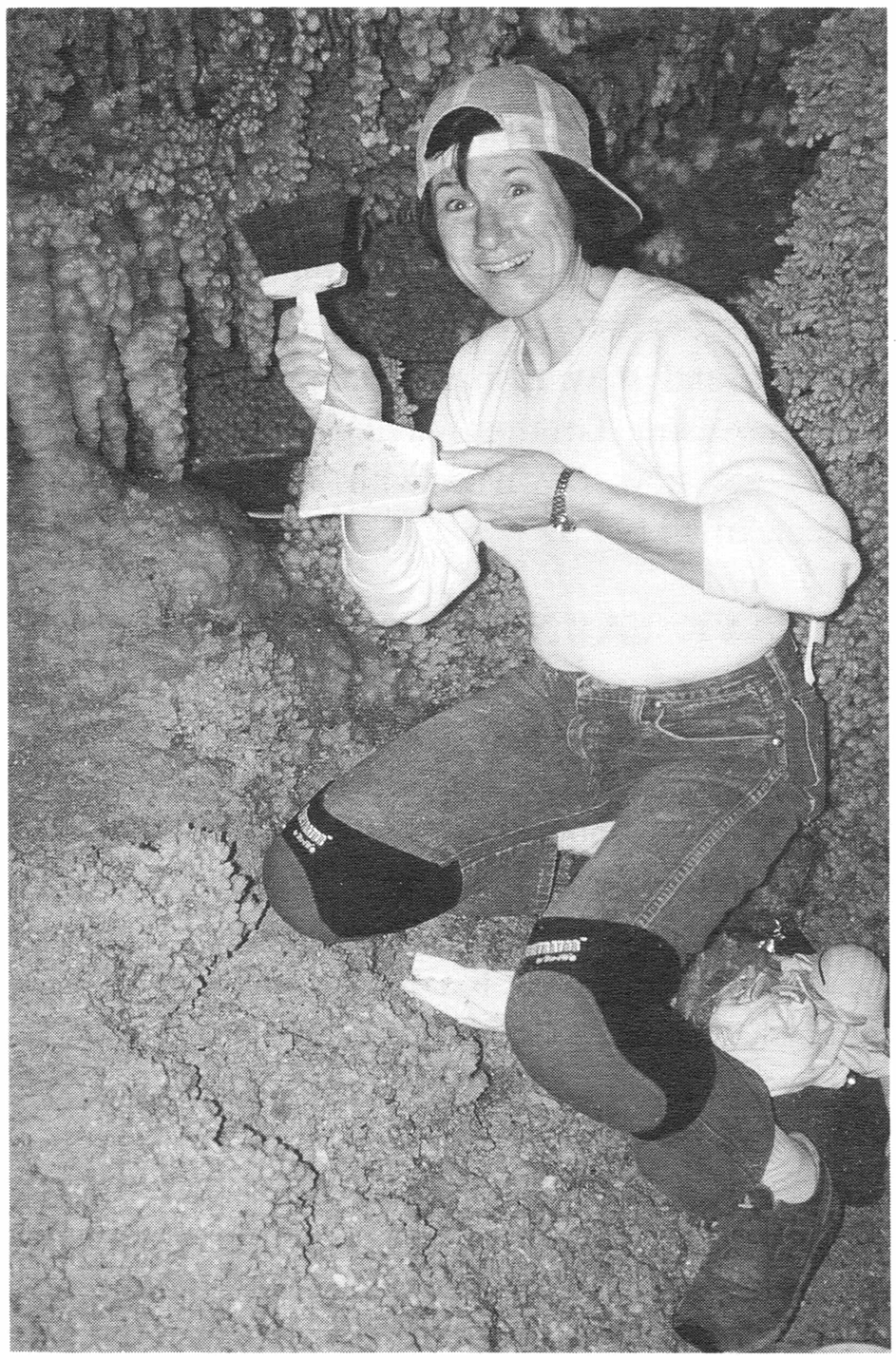
Individual cave owners sometimes place gates on their caves to keep out trespassers. One of the earliest examples was the gating of Ezell's Cave by J. T. Mostyn about 1963 (see the description of Ezell's and other caves in "Texas Wild Caves" in this volume). The entrance was covered with an iron plate to keep out intruders. The gate killed or drove off the resident bats. In 1967 the Texas blind salamander *Typhlomolge rathbuni* was placed on the endangered species list and The Nature Conservancy bought the cave with the help of the Southwest Texas Grotto to protect the salamander. The cave was regated with a bar gate, which was broken frequently by local youths. In 1970 two attempts were made to reintroduce bats into the cave to provide nutrients to the aquatic fauna, but the bats would not stay. Finally, a strong, state-of-the-art gate was built by local cavers and the entrance area was fenced and is now monitored by cave stewards.

Veni (1988) and Elliott and Reddell (1989) documented the rate of cave-filling and destruction in urban Central Texas counties. At least 5% of known Texas caves had been destroyed or filled by humans, mostly during land development. In Bexar County (San Antonio), at least 44 caves had been destroyed or filled. A notable example is Dead Deer Cave, which was an important recharge cave. Another 9 caves were severely damaged by trash dumping. In Travis County (Austin) at least 32 caves had been destroyed or filled. In Williamson County, at least 10 caves were degraded. Most of the damage occurred since 1970. Projection of the 1970-1989 destruction rate led Elliott and Reddell to conclude that no known caves would be left intact in Travis County by the end of the 21st Century, assuming that no new caves were discovered. Because of the protection of endangered species, this historical trend has been significantly slowed since 1989 in Travis and Williamson counties, and previously unknown caves are being dug open during contract karst studies faster than old ones are being destroyed. A few previously sealed caves have even been re-opened during biological survey work related to endangered species (e.g., Williams Cave, Williamson County). Veni (1993c) presented a graph showing the rates of cave discovery and cave destruction in Bexar County. The rate of discovery now exceeds the rate of destruction. Although the increased rate of discovery in several counties means new opportunities in exploration and science, it is important to remember that there still is a net degradation of caves occurring. Many of the caves are too close to pollution sources and are being invaded by pest species (see below). On the human time scale, caves are a nonrenewable resource.

Unlike the gating of Ezell's Cave, owners more typically have filled caves to avoid perceived liability. In response, several cavers formed the Texas Cave Law Coalition in 1989, and succeeded in having a bill passed to add cave owners to an existing statute that protects landowners from liability for injuries sustained in outdoor activities, such as hiking and boating (Texas Legislature, 1989). However, many landowners still mistakenly believe that owning a wild cave is a legal liability, despite the statutory protection and the fact that no one has yet been sued in Texas, to the writer's knowledge, for a cave-related injury or death.

CAVE RESTORATION AND PROTECTION

Attitudes about the commercial development of caves have changed for the better. A case in point is Longhorn Caverns, which was acquired in 1932 by the Texas State Park Board. The Civilian Conservation Corps (CCC) worked for several years to excavate 15,000 m^3 (20,000 cubic yards) of clay fill from the cave and to develop trails for the public. These excavations took place during place during The Great Depression when people needed work, but the scientific and natural values of the cave were not adequately preserved. H. M Law of Southern Methodist University led a cave survey and reported, "Bats are so numerous in some parts as to necessitate their removal before the rooms can



Joann DeLuna cleans up in Caverns of Sonora, Sutton County, before going to bed (see "Cot Cave" in Kickapoo Caverns chapter; photo by Nathan Summar).

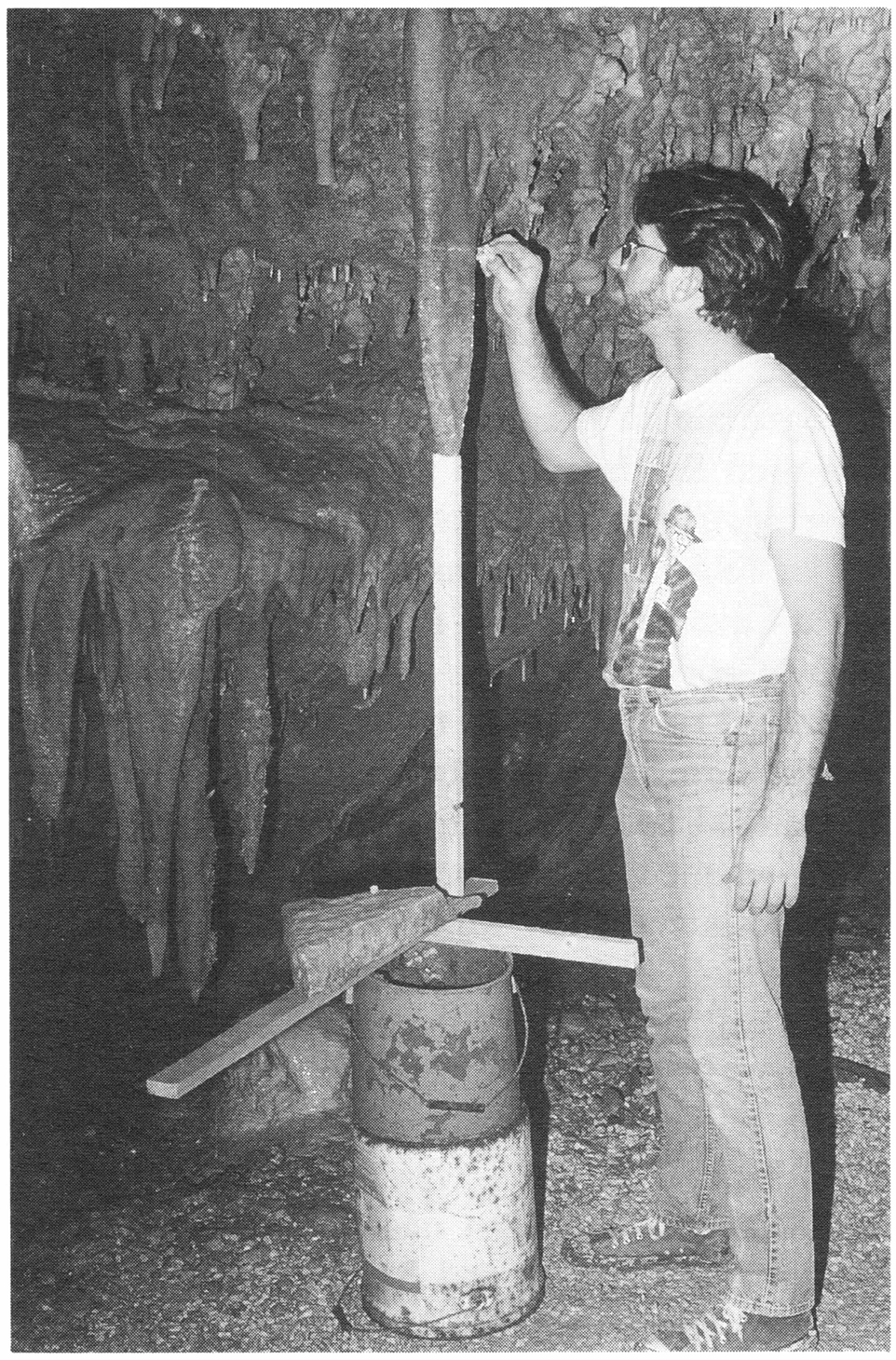
be opened to the public." (Craun, 1948). Bats no longer inhabit the cave, and the cave is nearly devoid of natural fauna except in a few areas. Much of the cave at that time consisted of low crawlways, so the CCC had to excavate much of the fill. Artificial shafts were dug to facilitate removal of the original floor deposits of mud, guano, and bone-laden clay. These were dug out or washed down to the lower levels with high-pressure hoses. The original level of the clay floor can still be seen in several passages. Semken (1961) was able to study some of the fossil bones in the remaining clay fill, but a major scientific resource probably was washed away during the development. By the 1950s one room was so covered with signatures written in lipstick that it was called " The Lipstick Room." Civil Defense supplies were also stored in the cave on the premise that it would make a good atomic bomb fallout shelter, a questionable idea at best since caves have many atmospheric and hydrologic connections to the surface. In the 1960s manager Doyle Clawson had the Lipstick Room cleaned up. In 1989 the TSA held a volunteer cleanup project with the help of manager Ronnie Waggoner, and removed the Civil Defense materials and an old photographic lab from the cave. A sinkhole that had been used for decades as a dump was cleaned up and many truckloads of trash hauled off.

The TSA has held annual, volunteer, work projects at Caverns of Sonora in 1991, 1992, and 1993, led by George Veni. The management recognized the need to rid the cave of rock, gravel, and dirt that originated from trail construction in 1960. Some of the material had washed down onto delicate areas, which required careful brushing (see photo). The labor costs for such work would have been extremely high, thus volunteers were needed and the owners worked alongside them. A short, new trail is being constructed more carefully under the direction of Jack Burch (Veni, 1992a, 1992b, 1993a, 1994).

At Natural Bridge Caverns, a new trail in the South Caverns has been under construction since the mid-1980s (Wuest and Burch, 1989). Concrete steps and trails are being placed on flowstone slopes with minimal impact and with consideration for moisture flow. Extra care is being taken in the placement of lighting. No date has been projected yet for opening this section to the public because the first goal of the developers is to build the trail correctly.

An act of vandalism at Cave Without A Name spurred cavers to try innovative techniques to restore broken speleothems. Veni (1993b) found that glueing large stalactites back together with industrial epoxy worked better when a simple lever-and-fulcrum was used to press the stalactite upwards (see photo).

In 1986 the Texas Cave Management Association (TCMA) was founded and began several projects, including a revision of the Texas Caverns Protection Act. The statute originally had been passed in the 1960s at the request of show cave owners, but was partly rescinded later when the Texas Penal Code was revised. A section relating to pollution was removed. The statute was reauthorized (1977) but retained its original weakness in permitting destruction of caves if the owner gave



Restoration of a stalactite with epoxy, fulcrum, and lever. Philip Farrington in Cave Without a Name, Kendall County (photo by George Veni).

written permission. A bill drafted by TCMA was sponsored in 1987 to strengthen the statute by adding protection for groundwater, bats, and cave fauna, and by increasing the penalties for vandalism. The bill was rejected in committee even after receiving favorable support from all who testified. The bill's chances may have been damaged by its own sponsor in the Texas House—when questioned about bat protection by a House committee, she speculated that bats probably could be written out of the bill since they probably were not natural inhabitants of caves anyway. Subsequent testimony by a biologist correcting this and several other misconceptions about bats did not sufficiently persuade the committee.

To further its goals, TCMA acquired its first cave (Whirlpool Cave, Travis County) in 1990. TCMA also manages O-9 Well and Amazing Maze Cave in West Texas for the University of Texas System. In 1993 TCMA acquired Marigold Cave in Williamson County as an endangered species preserve for the Tooth Cave ground beetle *Rhadine persephone*. TCMA's Mike Warton has gated numerous caves, some with U. S. Fish and Wildlife Service approved bat gates for the benefit of cave myotis (see photo). TCMA is involved in cave cleanups and stewardship in cooperation with the City of Austin. Grottos (caving clubs) throughout Texas are now involved with cave conservation projects of all types.

CAVE FAUNA CONSERVATION

As mentioned above, the first cave preserve in Texas was Ezell's Cave in San Marcos, established in 1970. At about the same time Tooth and Kretschmarr caves near Austin were placed under the stewardship of the Texas System of Natural Laboratories to protect the diverse invertebrate cave fauna. Gehlbach (1971) proposed that Texas biologists and conservationists begin building a system of cave preserves with a variety of natural communities. Gehlbach bemoaned the fact that few biologists were taking the time to preserve caves for research. That proposal went unheeded and Ezell's Cave and the Kretschmarr Ranch remained the only Texas cave preserves for many years.

In 1984 land development began to encroach on the rural Jollyville Plateau west of Austin, particularly the Kretschmarr Ranch. Further studies of the caves were conducted to document the rare species and numerous caves in the area (Reddell, 1984). It was hoped at that time that the developers would voluntarily set aside some of the land to preserve the more significant caves. Although the City of Austin had adopted a Comprehensive Watershed Ordinance, it was too weak and too late in coming to protect the caves. The land was considered valuable and part of it was to be developed. In 1986 the Travis Audubon Society petitioned USFWS to list six species of cave arthropods, mostly located on the Jollyville Plateau, as endangered under the federal Endangered Species Act (Chambers and Jahrsdoerfer, 1988).

Meanwhile, other conservation issues began to heat up in Austin. People became interested in the endangered birds, such as the golden cheek warbler and the black capped vireo, and rare plants, such as the bracted twistflower. The news media frequently

mentioned these species and the relentless trend of land development in the hill country west of town. These became popular causes, along with concern about water-quality degradation in the Barton Creek-Barton Springs watershed and the Colorado River, Austin's water supply.

In 1988 some of these issues came to a head. Private negotiations with the developers were stalled, so a group called Earth First! began to openly trespass to draw attention to the destruction of potential bird habitat. They then occupied some caves as a political stunt and obtained news media coverage. This action got much attention, but Earth First! did not endear itself to the caver community, although both wanted the caves protected.

Meanwhile, the USFWS listed five of the six proposed cave species as endangered: *Texella reddelli* Goodnight and Goodnight, the Bee Creek Cave harvestman; *Tartarocreagris texana* Muchmore, the Tooth Cave pseudoscorpion; *Neoleptoneta myopica* (Gertsch), the Tooth Cave spider; *Rhadine persephone* Barr, the Tooth Cave ground beetle; and *Texamaurops reddelli* Barr and Steeves, the Kretschmarr Cave mold beetle. The five species became seven due to a taxonomic split in 1993, in which two new species were described. The two new species, *Texella reyesi* and *Batrisodes texanus*, are legally protected because most of their populations are endangered and some were included in the previous definitions of *Texella reddelli* and *Texamaurops reddelli*.

As a result of the listings, a series of reconnaissance biology studies on the seven species in the Austin area were conducted, supported by the U. S. Fish and Wildlife Service (USFWS) , Texas Parks and Wildlife Department (TPWD), the City of Georgetown, numerous developers and banks, and Melvin Simon & Associates, Inc. (Elliott and Reddell, 1989; Reddell, 1991; Reddell and Elliott, 1991). Between 1989 and 1994 the number of known localities for the seven endangered cave species was increased greatly. However, most of the additional caves involve just two of the species, and most of the caves are in urbanizing areas threatened by development, quarrying, and fire ants. The studies helped increase general understanding of the biology of all the cave fauna in the area.

Land development is not the only threat to the Texas cave fauna. The red imported fire ant *Solenopsis invicta,* originally from Brazil, invaded the United States in the 1930s through the port of Mobile, Alabama. The species had moved into Texas by 1956 and is currently expanding westward. Although limited to areas south of the -12° C (10° F) minimum temperature line, the fire ant is expected to infest irrigated areas across the southwestern U.S. and eventually invade the West Coast (Vinson and Sorensen, 1986). The species has already infested most areas of the Deep South.

A strong cave gate with two locks and an animal-access hole (far end), LakeLine Cave, Williamson County (photo by William R. Elliott).

In the late 1980s fire ants began colonizing karst areas in Central Texas, and cavers began reporting infestations in cave entrances (Elliott and Reddell, 1989; Elliott, 1992b, 1993). By 1991, at least 24 of the 64 known endangered-species caves in Travis and Williamson Counties had fire ants foraging inside from nearby colonies. The temperature of Texas caves, about 18-24° C (65-75° F), is nearly optimal for fire ants, although they do not actually construct nests in caves except in some entrances where there is sufficient soil. The fire ant is extremely voracious and can severely reduce the spe-

cies diversity of the native soil fauna and any ground-nesting animals (Porter and Savignano, 1990).

Fire ants have been observed preying on young cave crickets, millipedes, pseudoscorpions, earthworms, and other cave fauna. Elliott (1993) conducted a fire ant control and ecological study in and around 12 endangered species caves. The study involved baiting of ½ to 1-hectare plots around the caves with either "Logic" (fenoxycarb) or "Amdro" (hydramethylnon). Both are low-impact pesticides formulated on corn grit with soybean oil and are very attractive to the ants. Colonies in and near cave entrances were treated with boiling water containing a small amount of detergent to aid in soil-penetration. Treatment schedules were timed so that the ants would retrieve most of the bait before sundown, when cave crickets come out to forage. The study showed that boiling water is more labor-intensive than baiting, but is significantly more effective. Boiling water avoids direct contamination of the cave environment and kills the ant colonies immediately, rather than weeks later.

In 1989 the conjunction of several issues resulted in the formulation of an ambitious regional habitat conservation plan (HCP) at the urging of the USFWS. Many such plans have been assembled by local interests in various parts of the country, and such HCPs are encouraged under the Endangered Species Act. The Balcones Canyonlands Conservation Plan (BCCP) was formulated to preserve lands in Travis County. If implemented, about 6,000 acres would go to karst preserves and much more than that for two endangered birds, rare plants, and watershed protection. Six cave species, and more than 30 rare companion species occurring in about 60 caves, would be protected. County funding for the BCCP was defeated in a bond election in the autumn of 1993, but the City of Austin has provided some support. A new funding mechanism is being sought.

The Melvin Simon Co. developed its own LakeLine Mall Habitat Conservation Plan (H. Co. Simon, 1991). Since two endangered invertebrates were on the property, the company obtained a Sec. 10(a) permit from USFWS, which would allow incidental take of *Rhadine persephone* beetles and *Texella reyesi* harvestmen while building a shopping mall. The plan, approved in February 1992, included the purchase by the company of three karst preserves in the area to mitigate the take of the two species during construction. I am currently conducting long-term management and ecological studies of these preserves and their caves, LakeLine Cave, Testudo Tube, and Temples of Thor Cave.

Actually, many more described and undescribed troglobites from the Balcones Escarpment of Central Texas may have to be considered for listing because they exist in urbanizing areas. The Balcones Escarpment is geologically highly dissected , which has resulted in intense speciation in the cave faunas. About 100 species and subspecies of rare cave and groundwater invertebrates may be endangered, including both aquatic and terrestrial forms. At least 42 of these species are known from single localities only, so they are extremely vulnerable to land development and other man-made pressures, such as fire ants. Travis County contains at least 34 rare troglobites, 22 of which occur only in that county. Based on my analysis (1991), the BCCP could select at least 60 caves that would offer protection for all rare troglobites, including the 6 endangered cave species in Travis County. The BCCP would also provide karst watershed protection for the Barton Springs salamander *Eurycea sosorum*, which is threatened by developments in the Barton Creek and nearby watersheds that contribute to the Barton Springs segment of the Edwards Aquifer. This species may be listed as endangered soon.

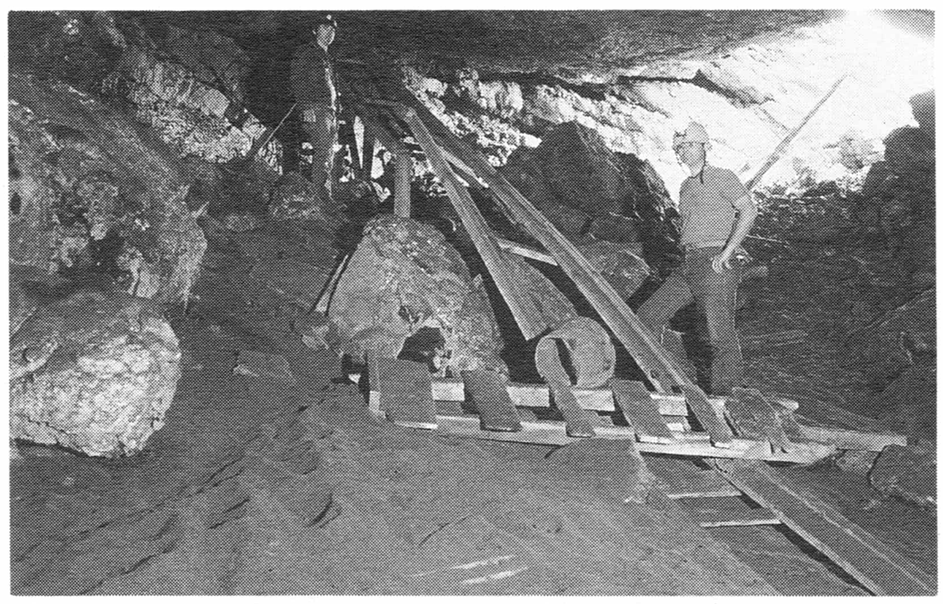
In January 1992 USFWS received a petition from a coalition of 5 conservation groups to list 9 troglobitic invertebrate species in Bexar County. The species include 5 spiders, one harvestman, and 3 beetles, a total of 11 taxa counting 4 included beetle subspecies. Cave studies are being carried out in the San Antonio area to determine the true ranges of these species.

The Williamson County commissioners court petitioned the USFWS to "delist" (remove from the endangered species list) all seven endangered cave species in Travis and Williamson counties. This petition was studied, scientific information was gathered and compared, and the petition was denied (USFWS, 1994). In March, 1994, the commissioners court sued the Secretary of the Interior to delist two of the species. This case has not gone to court as of this writing.

Bat caves present a special ecological management challenge. Bats are unquestionably ecologically and environmentally important. Mexican

free-tailed bats live in Texas caves, bridges, buildings, and other structures during the summer, but mostly in large caves (see Reddell's discussion of other bat species in "The Cave Fauna of Texas" in this volume). Davis et al. (1962) estimated that the summer populations of freetails in Texas caves reach 95.8 to 103.8 million, and that these bats eat from 6,000 to 18,000 metric tons of insects annually in Texas.

Texas has a long history of guano mining, originally for the manufacture of gun powder about the time of the Civil War, and later as fertilizer. Large freetail caves such as Bracken Bat Cave seem not



Guano mining gear in Davis Blowout Cave, Blanco County. Dale Pate on left, Joe Broberg on right (photo by William R. Elliott, 1984).

to have been adversely affected by mining, which was usually done in the winter when the bats were gone to Mexico. A common mining practice was to open a shaft in the rear of the cave to hoist out guano. Bracken has a shaft at its end, but this seems not to have affected the bat colony, which is still the largest known (20-40 million). Other mining operations probably adversely affected bats, depending on the degree of ventilation that resulted from artificial shafts and direct disturbance of the bats. Green Cave probably was affected by too much ventilation caused by an artificial shaft near the end of the cave (Rex Wahl, pers. comm.). Since acquiring the cave in 1986, the Texas Parks and Wildlife Department closed the shaft and the bat population has increased.

Beaver Creek Bat Cave and Davis Blowout Cave were guano mines as recently as the 1940s. They have been protected by ranchers. The removal of guano from some caves may have benefitted the bats by preventing some chambers from filling with deposits. The gating of freetail caves is undesirable because these bats do not tolerate gates, owing to their flight geometry and speed requirements.

One major freetail cave, Valdina Farms Sinkhole, Medina County, was ruined by a recharge dam, constructed by the Edwards Underground Water District. The cave formerly housed a unique cave salamander, *Eurycea troglodytes*, up to 4 million freetails, and a rare colony of the old man bat *Moormoops megalophylla.* None of these species were found in the cave after the cave flooded via the recharge channel (Veni, 1987).

There are only about 16 major Mexican freetail roosts in Texas, 13 of them caverns (Davis et al. 1962; Wahl, 1989.) This species will not readily inhabit other caves because it has particular requirements for large warm caverns, to be able to drop long distances from the ceiling before flying, to have adequate room to raise a large crop of young, and to incubate the rapidly developing young in an essentially tropical atmosphere. This is a tropical bat that is adapting, through migration, to the temperate zone.

In the 1910s and 1920s, Dr. Charles A.R. Campbell of San Antonio promoted the construction of numerous bat towers, structures that looked like church belfries on stilts. As the chief public health physician for the City of San Antonio, one of Campbell's jobs was to maintain quarantine camps. He theorized that bats would control mosquitoes, which would reduce malaria, still an important disease in Texas at that time. He also promoted guano as fertilizer; in 1917 he recovered 1,359 kg (2,996 lb.) of guano from a tower at Mitchell's Lake, a sewage lake near San Antonio. Campbell influenced the State Board of Health, and the state legislature passed a bill, "Protecting bats" (Texas Legislature, 1917). Bats were declared beneficial to public health, and it was a misdemeanor to kill them, punishable by a $5 to $15 fine. In his book *Bats, Mosquitoes, and Dollars,* Campbell, (1925) claimed that the bat guano from his towers contained mosquito fragments. He also claimed to have eliminated malaria in those areas. The benefit of the towers was questioned after Storer (1926) demonstrated that the Mitchell Lake tower, which contained Mexican freetails, contained no mosquito fragments in the guano. Freetails generally feed on

moths, flying ants, beetles, leafhoppers, and true bugs (Schmidly, 1991).

The benign attitude toward bats was reversed by a rabies scare in 1956, when George Menzies, a Texas Department of Health rabies researcher, died of rabies. In 1959 a mining engineer died of rabies; he, like Menzies, insisted he had not been bitten by a bat or any animal and had simply gone into Frio Bat Cave (Constantine, 1967). In the two cases, however, there was a skin lesion or a bleeding scratch that could have been infected. Later studies by Constantine on animals caged in Frio Cave demonstrated that rabies could be contracted by the "aerosol route," that is by inhalation of the virus contained in bat saliva and urine aerosols. The transmission was more effective when ventilation of the cave was lowest and many bats were present, as shown by carbon dioxide and ammonia measurements. Ever since those studies many public health people have assumed that humans are at a high risk of contracting rabies by merely entering a bat cave.

As a result of the rabies scare, the legislature unanimously rescinded the bat protection law (Texas Legislature, 1957), and the public attitude toward bats hardened. Campbell's bat towers were even torn down. (Only one Texas bat tower remains; it is on private land near Comfort and is marked with a state historical plaque.) However, at least two considerations seemed to have been overlooked. First, Constantine's caged animals probably were exposed to ammonia vapors for up to 30 days. I have measured ammonia in Bracken Bat Cave at 55 ppm, which is hazardous to humans, and 195 ppm was detected in Frio by Constantine. Such ammonia concentrations should cause severe lung tissue scalding, transforming the alveoli into open sores. The ammonia exposure also should have severely weakened some of the animals, making them more susceptible to infections. Second, other possible routes of exposure were not eliminated in the case of Menzies. As a bat rabies researcher, he handled rabid animals and virus in the field and in the laboratory. One source of virus was an experimental, live rabies vaccine that was administered to Menzies by his own physician when Menzies reported that he thought he had rabies (Bobby Davis, pers. comm.). Thus, Menzies may have contracted rabies by any of three routes: inhalation in the cave, skin lesion in the field or laboratory, or treatment.

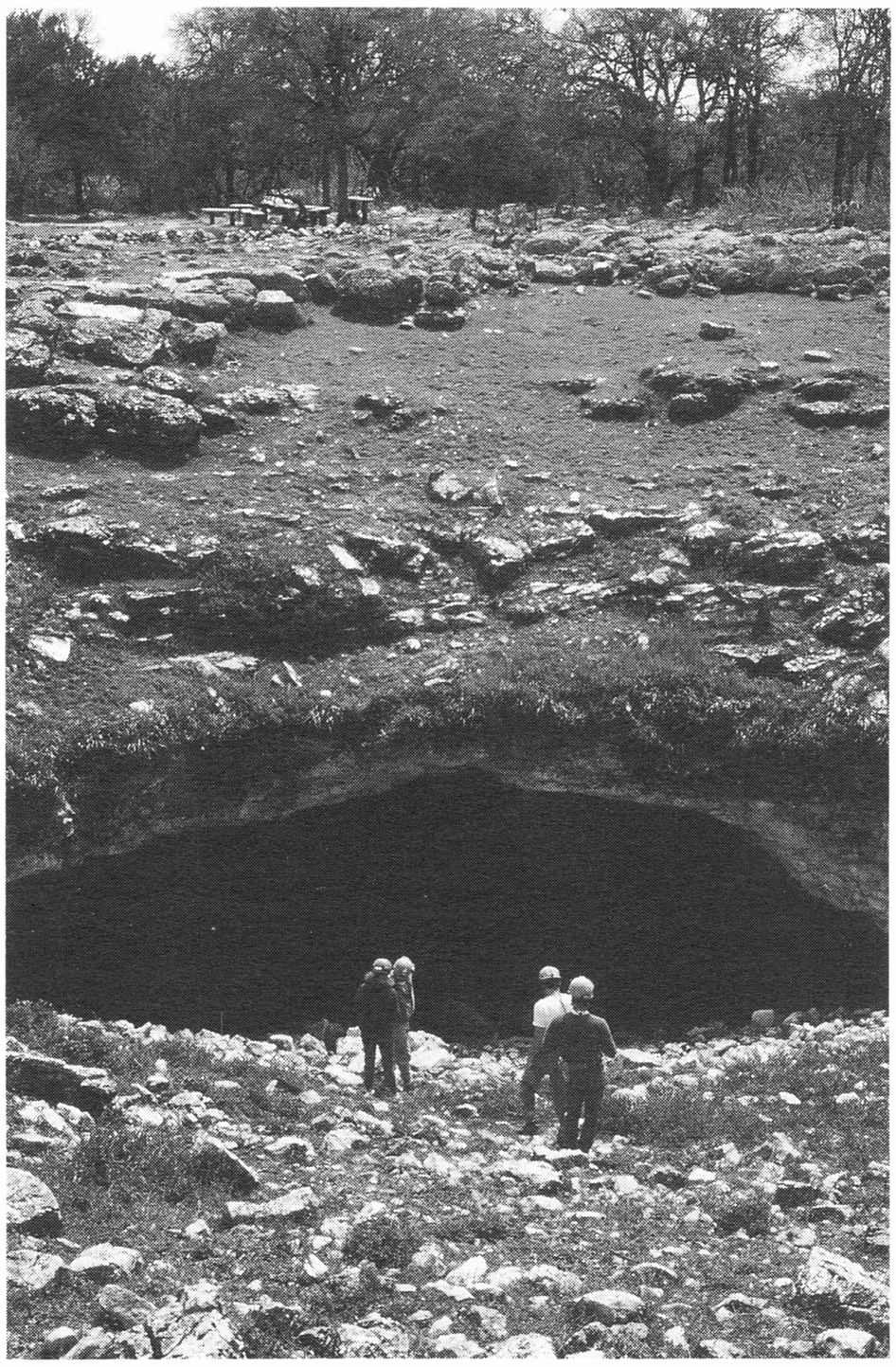
Certainly, many cavers and biologists have visited bat caves over many years, and none has died of rabies, to the writer's knowledge. However, exposure time is brief in most cases. Few of these people had received rabies vaccine until recent years. In actual practice the risk to humans of contracting rabies by the "aerosol route" is low rather than high. However, the risk of ammonia-related illness or histoplasmosis may be rather high in some of the caves. Properly fit-tested, air-purifying respirators with ammonia cartridges and perhaps HEPA filters are needed for entering bat caves with large colonies.

Unfortunately, imagined public health concerns overshadowed the ecological benefits of bats, even

A bat gate for cave myotis at Beck Horse Cave, Williamson County. The bars are about 15 cm (5¾ in.) apart (photo by William R. Elliott).

though scientists like Constantine pointed out their benefits. However, it is fortunate that one of Constantine's recommendations (1967) was not followed: to ventilate freetail bat caves in order to reduce airborne virus concentrations and the incidence of rabies in the bats. It is known that pregnant freetails prefer the warm temperatures of the nursery colonies, created partly by an incubator effect and partly by the structure of the caves they inhabit (Herreid, 1963, 1967). It is now known that bat rabies is but one (or more) strain of rabies, as determined by monoclonal antibody studies, and that it is rarely transmitted to other species (Keith Clark, Texas Department of Health, pers. comm.). Even though a few people have died of bat rabies, it has little public health significance.

A new attitude toward cave life was evident in the 1980s when the Texas Parks and Wildlife Department (TPWD) began a program of acquiring ecological preserves, many containing significant caves. In two purchases (1984 and 1987) TPWD acquired Colorado Bend State Park, San Saba County. The park contains numerous caves, one of which, Gorman Cave, is a large and important *Myotis velifer* (cave myotis) cave. In 1985 TPWD purchased the Devil's Sinkhole, Edwards County, a major freetail cave and historic site that also contains significant crustacean species in its lakes. In 1986 TPWD acquired Kickapoo Caverns State Natural Area, which contains Green Cave, an important freetail bat and cave swallow cave, and numerous smaller caves. In 1988 TPWD purchased Devil's River State Park, Val Verde County, which contains Fawcett's Cave, an important *M. velifer* cave. In 1991 TPWD purchased Kendall Tunnel, an abandoned railroad tunnel in Kendall County, now called "Old Tunnel Wildlife Management Area," to protect thousands of freetail bats (Bigony, 1991).



Bracken Bat Cave, Comal County (photo by George Veni).

In 1986, Bat Conservation International's (BCI) founder, Merlin Tuttle, moved his organization from Milwaukee to Austin. Tuttle's public lectures and publicity about the ecological benefits of bats created high interest in bat conservation. A local chapter of BCI was formed in Austin, which began sponsoring bat census studies and educational trips to Bracken Bat Cave to observe the evening flight. A large colony of Mexican free-tailed bats living under the Congress Avenue bridge in Austin began to receive positive publicity, whereas previous news reports on the colony were very negative. By 1991 several hotels and restaurants near the bridge claimed that the bridge colony actually attracted tourists to watch the evening flight. Part of BCI's program includes educational bat flight watches and control of access at Bracken Bat Cave.

In 1990 the Texas Nature Conservancy (TNC) bought James River Bat Cave, Mason County, and renamed the new preserve "Eckert James River Bat Cave." The cave has been a popular study site for biologists for many years and is now available for groups to view the evening flight of freetails. TNC announced its plans in 1991 for a "Texas Hill Country Bioreserve" system, which will involve purchases of critical habitats and watersheds in the Edwards Plateau and Balcones Escarpment. TNC has stated that it recognizes private landownership as the best means of protection, but that it will raise a large fund over three years to purchase and protect bat caves if they become threatened through property sales (Jim Fries, pers. comm.). Groundwater protection is another major goal of this program.

Many significant bat caves and tunnels remain in private ownership. A significant new freetail colony took up residence in an abandoned section of the Huber Limestone Mine near Marble Falls, Burnet County. The population, estimated in 1989 at about 4 million (Wahl, 1989) is protected by the mine owners.

Although the large freetail colonies in Texas are few and vulnerable to destruction, the smaller bat caves harboring *Myotis velifer*, *Mormoops mega-*

lophylla, *Plecotus townsendii*, and other species, have already suffered from human pressure. Most of the large freetail caves are relatively inaccessible to the public and have such oppressive atmospheres that few people venture inside. *M. velifer* and other bat caves are smaller, more numerous, and more inviting. Several examples illustrate the vulnerability of small bat caves:

1) In 1961 an entire colony of *M. velifer* was killed or driven off from Chinaberry Cave (Bat Cave), Williamson County, by an unidentified intruder using a .22 caliber rifle with rat-shot (James Pope, pers. comm.).

2) In 1973 the San Antonio River Authority built a flood-control dam 60 m downstream from Bear Cave, Bexar County, which was a bat roost (probably for *M. velifer)*. The cave soon was completely flooded and washed out. In 1984, a local developer filled the cave with large boulders, sand, and gravel, out of fear of liability because an overweight person got stuck in the entrance and had to be rescued. About 20,000-100,000 bats were roosting in the cave when it was filled. Floodwaters reopened the cave within a year. The cave is now recognized by state officials as an important aquifer recharge feature, but the situation continues to endanger bats that repopulate it (Veni 1988, pers. comm.; K. Menking, pers. comm.).

3) Numerous bats have been killed in Walkup Cave (Beasley Cave), Hardeman County. Brown (1987) reported that locals shotgunned the bats. In 1983 he caught a group of a dozen high school students spraying the roosting bats with gasoline and setting them on fire. The bat colony may have moved to a nearby cave, Lady's Descent, because of such harassment (Butch Fralia, pers. comm.). Walkup Cave was an important hibernaculum for *M. velifer*, *Eptesicus fuscus pallidus*, and *Plecotus townsendii pallescens*.

4) In the late 1980s the Austin Chapter of BCI noted several small caves in the Austin area that probably were once inhabited by *M. velifer*. Ceiling stains and guano deposits often indicated sizeable former colonies. *M. velifer* may be less loyal to its cave roosts than freetails and seems to move from site to site readily. Whether this behavior is caused more by natural ecological factors or by human disturbance is unclear. *M. velifer* can tolerate occasional humans in large caves where it can flee to alternate roosts. Such is the case in Fawcett's Cave (Val Verde County), Gorman Cave (San Saba County), and Powell's Cave (Menard County). However, repeated disturbances will drive them off.

Sometimes a bat cave can be recolonized. *M. velifer* returned to two Williamson County caves: Mural Cave in 1987 and Beck Horse Cave in 1991 (see photo). All that was done was to clear vegetation that partially blocked entrances (Elliott, 1992a). Powell's Cave was recolonized by *M. velifer* in 1989 after a mapping project by the Texas Speleological Association excavated the entrance, which had slumped (Elliott, 1992a). No bats had inhabited the cave before it was opened by cavers in the 1950s (Pete Lindsely, pers. comm.). Thus, *M. velifer* will voluntarily recolonize a cave, although transplanted bats will not stay, as happened at Ezell's Cave.

GROUNDWATER CONSERVATION

The Edwards Aquifer is the subject of major environmental and political issues. It is a karst aquifer that stretches from Del Rio to north of Austin along the margin of the Edwards Plateau, and provides drinking water to about 1.5 million people in the San Antonio area. As pumping begins to exceed natural recharge and water levels decline, several rare species and the human economy are threatened. *Stygobromus pecki* (Comal Springs amphipod) is one such species. Water rationing in San Antonio and other cities may soon become commonplace. In addition, the Comal and San Marcos rivers, which originate from large karst springs, are important in maintaining the Guadalupe River ecosystem and its endangered species, including the important San Antonio Bay estuary on the Texas coast. The bay supports a multi-million-dollar fishing and shrimping industry and also contains endangered species.

The State of Texas did not limit the use of groundwater by landowners until 1991, when the State Attorney General issued an opinion that the Texas Water Code, which gives the State the authority to regulate groundwater usage, is constitutional. Previously, this aspect of the Code had not been enforced because of court rulings. The legal confusion had contributed not only to a lack of effective regional groundwater planning but to blatant waste.

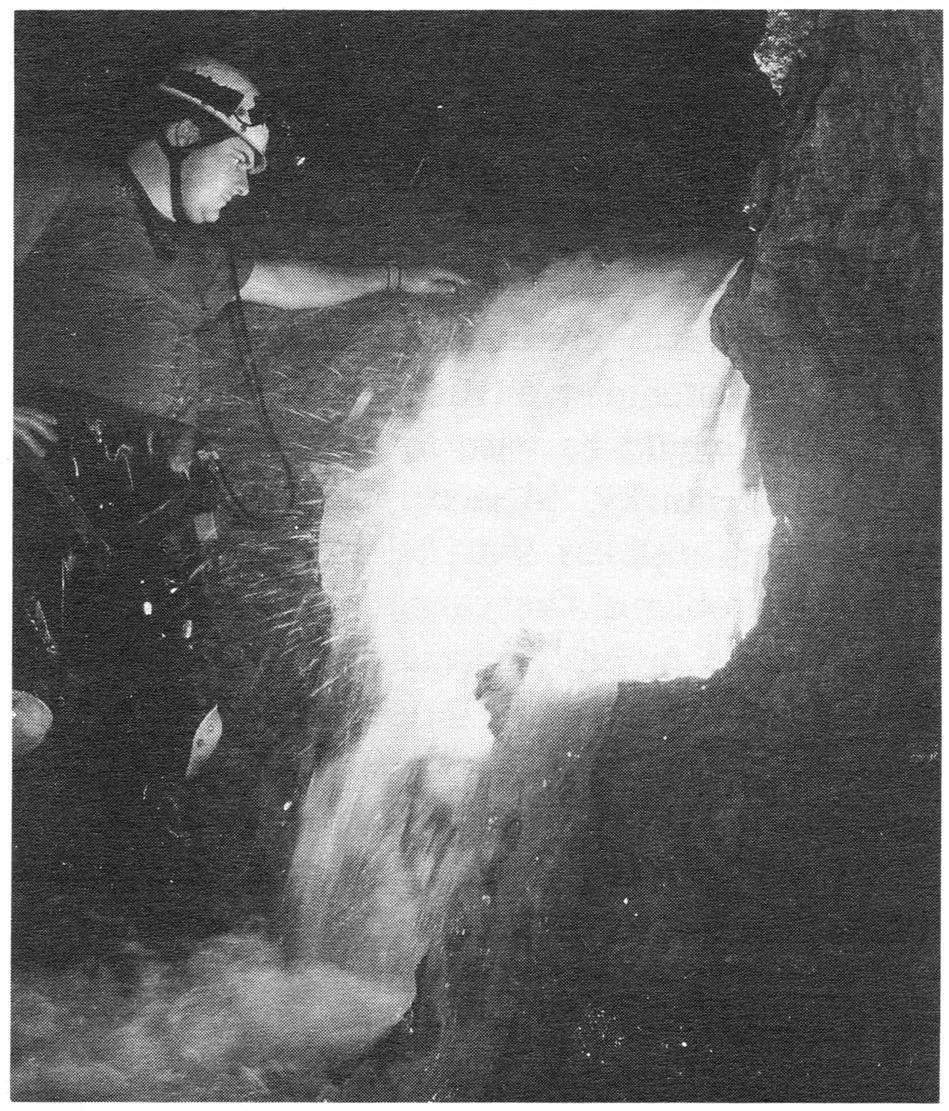
The issue boiled over in 1991 when an extremely

high-volume water well was drilled for the Living Waters Artesian Springs catfish farm near the Medina River in Bexar County (Swanson, 1991). The record-breaking well, drilled with an oil rig, was 76 cm (30 in.) in diameter, 500 m (1600 ft.) deep, and gushed 163,000 m^3 (43,000,000 gal.) a day, more water than several small cities combined and over 25% of the City of San Antonio's daily pumpage. There ensued a series of legal maneuvers by the Texas Water Commission, Edwards Underground Water District, San Antonio River Authority, U.S. Environmental Protection Agency, and the USFWS to regulate the farm's water usage. In April 1991, the USFWS announced that it would assume that Comal Springs would go dry in 1992 and would institute regional controls under the Endangered Species Act if necessary.

Because of a lawsuit by the San Antonio River Authority and the Edwards Underground Water District, the catfish farm shut in its well in late November, 1991. The level of the Edwards Aquifer then rose about two ft. in two weeks. The level had not generally risen in 1991, despite the fact that it was the wettest year on record. Obviously the catfish farm was having a large effect on regional water supplies (Glenn Longley, pers. comm.).

A lawsuit by the Sierra Club against the U. S. Secretary of the Interior recently resulted in a decision requiring the USFWS to identify springflow levels from the Edwards Aquifer where "take" begins to occur. The taking or killing of endangered species that are dependent on the aquifer would be prohibited under the U. S. Endangered Species Act. The judgement requires USFWS to notify all cities and persons withdrawing water of minimum springflow determinations. Continued withdrawals would be subject to regulation by the Service.

The conduit-flow nature of the Aquifer has supported the use of dramatically large wells to withdraw water. Conversely, conduits are also utilized to more effectively recharge the Aquifer, as in the case of Valdina Farms Sinkhole. However, such use of caves can harm important or rare species and quickly introduce contaminants into the regional water supply. Fortunately, the public is becoming more aware of the need to preserve karst watersheds to maintain both the quantity and quality of groundwater. Unfortunately, existing state rules are often inappropriate or inadequate for karst aquifers. Concerns about water supplies and endangered species will increasingly influence the extent to which groundwater is regulated in Texas.



Joe Ivy at The Waterfall, Sorcerer's Cave, Terrell County (photo by George Veni).

KARST CONSERVATION

The word "karst" has been used increasingly by environmental engineers and scientists, managers, activists, and the news media in Central Texas. The word is used, but few understand how karst really works. We have a tendency to conserve cave entrances and not karst areas. Small karst preserves are being created, but some are only a few acres in area and are covered with juniper and fire ants. To truly conserve a cave, the cave's ecological and hydrogeological connections must be taken into account. In many Central Texas caves the major energy inputs are raccoons, bats, cave crickets, harvestmen, and plant detritus, yet few of the preserves have sufficient area and long-term management plans to ensure that these inputs are not degraded. How large an area is needed to insure that raccoons will utilize the caves? If fire ants are not managed, will they eventually decimate cave crickets and other species upon which the rare, cave-adapted

species depend? How harmful are street runoff and residual pesticides to cave creatures and aquifers? If we monitor the health of blind species in the caves and the aquifers, will we have a natural advance-warning system for the public health, or are drinking water standards enough? Drinking water standards already are being violated at some wells in the San Antonio area (Rice, 1994; Roddy, 1992).

Texans would be wise to look to other states, such as Kentucky, Missouri, and Arkansas, and avoid their mistakes that led to significant karst pollution problems. One cannot dump chicken processing waste or city sewage directly into a cave stream without adversely affecting someone, often miles away. We have our own myths about karst aquifers in Texas. They are the same myths that afflict people in other states: that karst groundwater "cleans" itself while traveling underground, that springs are pure, that you cannot spoil your drinking water if most of it recharges miles away in another county and if your own area contributes little recharge.

Besides the connection to drinking water, there are many reasons for conserving caves and karst. As demonstrated in the preceding chapters of this volume by nationally recognized scientists, our caves are important repositories of natural history and human prehistory. We should have more respect.

There are reasons to be hopeful. Support for long-term ecological studies and management of a few areas have developed in the last three years. A need still exists for detailed hydrogeologic studies to scientifically delineate boundaries for karst preserves through dye-tracing studies and other techniques. Incentives are needed for landowners to conserve significant caves and surface environments, rather than consider them as dumping grounds or economic and legal liabilities. Significant archeological caves on private land are not adequately protected by law. Significant biological caves should not be ruined in the name of water conservation, as were Valdina Farms Sinkhole and Bear Cave.

The history of state legislation in this area is not encouraging. Education of the public on karst species and resources should be improved, but the scientists who are most knowledgeable have not been adequately utilized to that end. Opposition to endangered species by political groups is often based on myths about governmental control of private land use. There are many examples in Central Texas of residential developments being allowed to proceed as long as adequate studies and planning are done to set aside greenbelts for water and wildlife (e.g., Welch, 1994). Incentives exist for private landowners to comply with and support groundwater protection and endangered species, but are poorly developed.

SUMMARY AND CONCLUSIONS

Texas cavers have come far in changing their perception of cave conservation problems. Thirty or forty years ago cavers were concerned about broken stalactites and carbide dumping. Scientists were concerned mostly about the resources of their own disciplines—archeological and paleontological sites or more glamorous species, like blind salamanders. Today cavers are still concerned about broken formations, but they also are concerned about the outright destruction of caves, endangered species, maintaining healthy bat colonies, and their own water supplies. Very few cavers smoke in caves anymore. Cavers still protect caves with secrecy, but in urban areas that contain endangered cave species they have found it is more effective to disclose cave locations to the USFWS so that the caves can be protected, or at least gated. Scientists and conservationists now see the connectedness of karst resources and are more apt to speak out for conservation of the whole rather than the part.

In my youth Texans commonly believed that most Texas caves were connected to Longhorn Caverns, which in turn was connected to Carlsbad Caverns. That myth has faded, and today the average person in Central Texas who reads the newspaper knows that caves are formed by groundwater and that bats do not get in your hair and suck your blood. However, we still have much to do in educating decision makers on how karst actually works and that caves are multifaceted resources that deserve study and respect. Scientists and cavers should continue to join together, as they did in the days of A. T. Jackson concerning Seminole Canyon, to protect irreplaceable resources and to dispel ignorance. Many Central Texas teachers, from first grade to high school, take up the subject of caves for a week or two. It is an excellent subject to teach the basics of earth sciences, biology, ecology, and

water resources. Let us hope that the next generation will have a better fund of knowledge on which to base decisions for the use of the karst resources of Texas.

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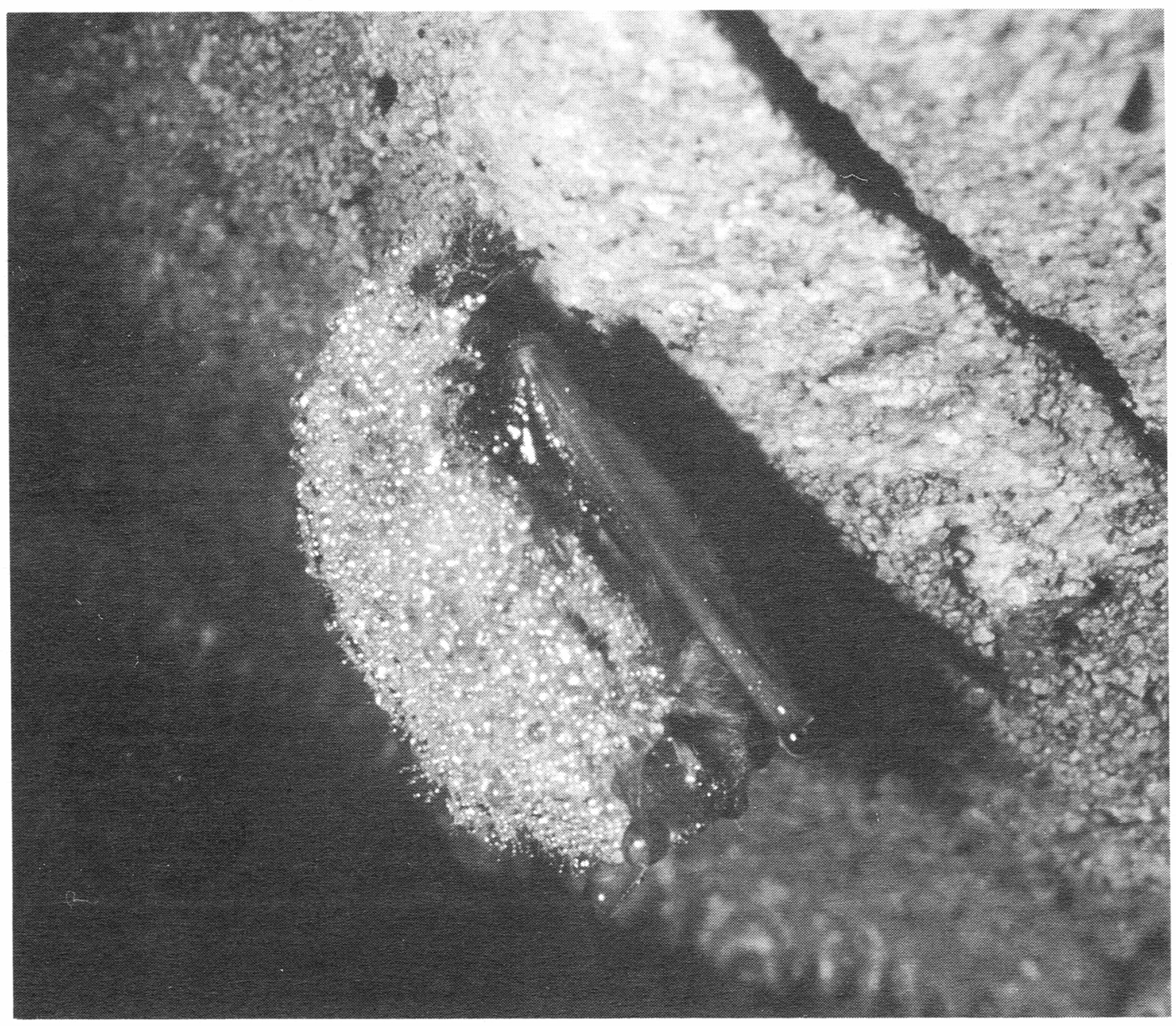

An eastern pipistrelle, Pipistrellus subflavus, *hibernating in Thor Cave, Williamson County (photo by William R. Elliott).*

(Renamed in 2003 as the tri-colored bat, *Perimyotis subflavus*.)