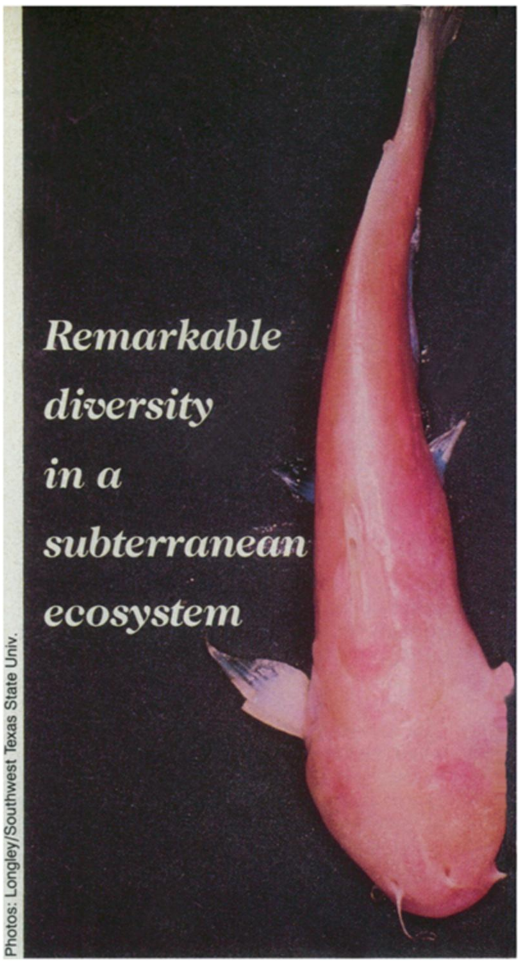
Saving Hades' CREATURES



Photos: Longley/Southwest Texas State Univ.

By ELIZABETH PENNISI

Oh, how biologist Glenn Longley might wish for the days of ancient Rome, when gods and goddesses ruled the Earth. Then, the woodland nymph Arethusa handily escaped the advances of an unwanted suitor by becoming a fountain that plunged into a deep cavern and flowed through the bowels of Hades. The Trojan hero Aeneas descended to the gloomy river Styx, where he marveled at Cerberus, the three-headed dog with snakes curled round each neck, and Hydra, the multi-headed monster.

But lacking magical powers, Longley, of Southwest Texas State University in San Marcos, can never explore his Hades, a watery realm that lies as deep as 2,000 feet beneath south-central Texas. Part of the Edwards Aquifer, this 282-kilometer-long underworld supports creatures that, while not as terrifying as those Aeneas and Arethusa witnessed, are nonetheless astounding.

"Many of the forms have not been found in any other areas," Longley says. "It's possibly the world's most unique groundwater ecosystem."

"I was aware that organisms lived in caves, and I was aware of aquatic organisms, but I didn't have any idea that such an extensive community could exist so deep underground," Longley adds.

Nor did many other people – scientists included – he later discovered. "I think that some of the people who get the most amazed are the geologists, those that know something about aquifers," says Longley. Indeed, two paleontologists, when told about the existence of catfish, salamanders, and a host of invertebrates isolated in this deep reservoir, at first thought it was a hoax – that somehow these creatures must be sneaking into the aquifer's water as it reaches the surface. But the number of organisms now caught and catalogued and the degree of adaptation in each species have convinced even skeptics.

"It's irrefutable," Longley says.

Like the ghostly shades who wandered about Hades, the aquifer's fauna bear memories of the past. Many are relics of species that lived millions of years ago.

The surprising diversity of these subterranean organisms – at least 40 species, not counting microorganisms – speaks to a healthy history for their underworld. But the rapid urbanization of the land above and an increased demand for water threaten that well-being, so much so that environmentalists have already begun to take legal action to protect the aquifer and its springs.

"More and more people are realizing that the groundwater resources are limited and that there is deterioration," says John R. Holsinger, a biologist at Old Dominion University in Norfolk, Va., who has worked with Longley. "Many of the species are rare and presently endangered. I think if something isn't done in that part of Texas, a number of those species will disappear."

The aquifer's denizens have not always been so appreciated, however. No photographer, artist, or biologist has ever – or will ever – explore this world firsthand. Instead, these creatures made themselves known as unexpected, and perhaps unwanted, intruders in supposedly pure water supplies. Even after the first sightings, decades passed before someone realized that these bizarre creatures heralded the existence of an extraordinary ecosystem.

In 1895, the U.S. Fish Commission drilled a hole in the hard Texas soil to get water for a new fish hatchery. Up came not just water, but also a most unusual salamander and several pale invertebrates. Ten years later, a tiny snail emerged, and in 1940, four more crustaceans. However, even after the Fish Commission's well became part of the Southwest Texas State University campus, no one really kept tabs on the potential significance of these surfacing organisms.

Nor was this well the only egress for these creatures. At the turn of the century, George W. Brackenridge was shocked when a strange fish popped out of his 308-meter-deep well in San Antonio. Light pink, with red lips and no eyes whatsoever, this fish represented the first sighting of the toothless blind catfish, or blindcat. Twenty years later, another blindcat appeared in a ditch beside a well just a few miles from the Alamo. Then a third emerged from a 1,280-meter-deep well dug about 16 kilometers from San Antonio.

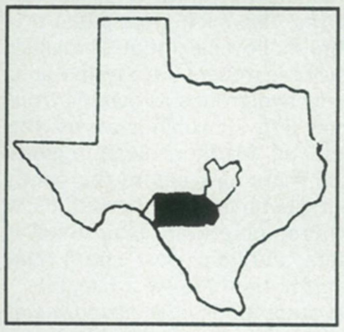
Some specimens went undocumented. Employees at a food-processing plant in San Antonio recall 50 catfish discovered in the plant's water tower when it was drained in 1964. That tower stored water from a 430-meter-deep artesian well. None of these fish was preserved.

Not until after 1976, when Longley decided to do an all-out search, did a sense of the aquifer as an ecosystem begin to take shape. He had noticed a few white invertebrates wiggling in spillways from the campus well. On a whim, he fashioned a trap from a coat hanger and his wife's pantyhose and pulled it over the well outflow pipe. "I was just amazed at the amount of material that came out," he recalls.

Longley started keeping a net over that well, continuously gathering whatever animals came up. From 1976 to 1981, he periodically trapped organisms from 22 other wells ranging in depth from 59 meters to 610 meters. In addition, he netted local springs in his quest for exotic specimens.

He collected an aquatic worm known as a planarian, other types of snails, two one-eyed crustaceans called copepods, another tiny crustacean called an ostracod, a beetle, seven more kinds of amphipods, and a cave invertebrate called a thermosbaenacean. Each animal bore the typical cave-dweller look – no pigmentation or functioning eyes. Yet many were quite distinctive.

"But you would expect that in a biological community that started out as a marine system and became a freshwater



Lacking skin pigment, the toothless blind catfish (far left) looks pink because of its blood vessels. A Texas blind salamander (top left), an amphipod (top right), and a water beetle (bottom left) are just three more of the many animals found in the San Antonio section (black area on map) of the Edwards Aquifer in Texas.

system," Longley says.

Over hundreds of millions of years, ancient seas flooded and later receded from this part of Texas, depositing the aquifer's limestone. Then groundwater nibbled away this carbonate rock, creating a karst, an irregular formation pitted like Swiss cheese with sinks and underground caverns. About 10 million years ago, the Earth ruptured, creating a fault zone that lifted some karst to form the Edwards Plateau to the north and west of the fault. Marine sediments then buried a 130-meter-thick karst layer on the opposite side of the fault zone.

"It has confined a large amount of karst area, and that's a little unusual," Longley explains. "It's kind of a quirk in the way the geological system developed."

The aquifer underlies the junction of a coastal plain and a limestone plateau. "It's kind of a crossroads of different areas that had different fauna," says Holsinger. "You've got two entirely different groundwater environments that impinge on each other. That's got to have a tremendous effect on the diversity." Also, the Texas climate is amenable to both temperate and tropical species.

In the aquifer, water now seeps along, sometimes traveling several thousand feet per day, says Longley. Where the aquifer lies close to the surface, near the fault zone, numerous caves and conduits channel surface water downward to recharge this water table. That water carries organic material that provides nutrients to some underground communities.

But the deep artesian section of the aquifer, where these exotic creatures reside, lacks such an input. At San Antonio, the closest seepage into the aquifer is 17 miles away, notes Longley. Over time, some water makes its way into these remote reservoirs, but "you're not getting any organic matter transmitted," he adds.

The existence of so many species seems to defy logic. True, they have had many, many millennia to evolve in this stable habitat. But what provides their food?

Slowly, Longley and various collaborators have pieced together the unusual food chain in these deeply buried artesian waters. Longley had noticed that when new wells are drilled through to the aquifer, a slimy discharge filled with organic matter, particularly mats of colonial bacteria and fungal filaments, sometimes gushes forth. Also, during droughts, some "bad-water" wells ooze oil, another possible food source for fungi or microbes.

Longley suspects that, could he see into the aquifer, he would find gunk-lined walls, where microbes devour fossil material contained in the solidified sediment. "In some of the deeper areas, the system almost has to be driven by fossil organic matter," says Longley. "There may be things that are similar to the biology that's going on in the deep-sea vents."

However scant or unusual their primary food source, the aquifer's inhabitants have learned to use it well. The toothless blindcat evolved paper-thin jaws that shifted to the underside of its head. Thus this fish can scarf microbial or fungal goop off ledges or cavern floors. In contrast, the widemouth blindcat most likely eats anything – including small toothless blindcats, says Longley. Instead of an air bladder – an internal bubble that many fish use to stabilize themselves at particular water levels – both species of blindcats possess a fatty blob that helps keep them buoyant while withstanding the great pressures of living so deep in the Earth.

The blind salamanders, too, bear little resemblance to surface relatives, looking more like long-legged tadpoles with gills.

These vertebrates exist in different parts of the aquifer. Two salamanders that wander about the San Marcos region, for example, appear to be absent under San Antonio, which instead has two species of blindcats. Blind shrimp, on the other hand, show up almost everywhere, perhaps expanding their range during wet eras, when high water or geologic shifts make migration possible.

"The smaller the organisms, the more dispersed they tend to be," Longley says.

He thinks that at times during the aquifer's long history, geologic barriers may have isolated small groups of organisms and made it possible for them to evolve along separate lines. Later, continued geologic activity might have created channels reconnecting these "island" pools.

The aquifer's amphipods – a group of side-swimming crustaceans – illustrate well the effect of this geologic activity on the evolution of these organisms. They belong to five families, eight genera, and 12 species, most of which periodically come into contact with one another. Holsinger and Longley collected all but one species out of a single well. "That's the greatest diversity of amphipods of any single environment known — freshwater, surface, or marine," Longley says.

In cave or subterranean environments, food tends to be in short supply and very monotonous, so the diversity of amphipod species is "totally unprecedented," Holsinger adds.

Differences in their body structure, particularly their mouth parts, suggest that many species of the aquifer's amphipods coexist by feeding, moving, and behaving so as not to compete too much for the resources at hand. Some float; some swim; some walk along the bottom; some cling to walls. One seems to munch on decaying debris in mud at the bottoms of pools. Another appears to filter food from water; a third gums soft, pulpy substances, Longley says.

The scientists trace four origins for these crustaceans. For each type, the retreat into the aquifer may have enabled it to escape extinction because of a changing climate or changing salinity of the water.

One group comes from a freshwater ancestor typically associated with groundwater in temperate regions throughout the world. These amphipods probably emigrated from parts of North America not covered by shallow seas.

This array of snail shells, averaging 2 millimeters in size, also reflects the aquifer's diversity. The mollusks were known first from a few shells found drifting in rivers. Then during the 1970s and 1980s, researchers collected a more extensive sampling from caves, streams, and artesian wells. The snails probably live in tiny cracks between rocks in the aquifer.

About 80 percent seem to have saltwater origins. Two such groups hail primarily from shallow marine and brackish waters; the researchers have pinpointed one of these two groups as coming from the Sea of Tethys, which covered the Caribbean and Mediterranean regions millions of years ago, before the continents shifted to their present positions. A third group's amphipod ancestors lived in deep waters, and its closest extant relatives cluster in the Indo-West Pacific.

Not just amphipods bear memories of lands far away. The closest cousins of one invertebrate, an isopod, seem to come from the Caribbean or Mexico. The water beetle bears little resemblance to similar American beetles, seeming instead to be derived from those native to Eurasia. The other known thermosbaenaceans live in the Mediterranean and the West Indies.

"We call them relics," says Holsinger. "[They] offer strong evidence for the stranding of organisms from marine [environments] and also corroborate the theory of continental drift."

Protected as they are from the vagaries of climate, these organisms live almost as they did millions of years ago. But given their specialized nature, they also need the stability offered by this remote place, a stability that increased demand for water may disrupt, Longley says. Water utilities drilling more wells and draining this ancient watershed will spell trouble for both these creatures and the human communities tapping this water source.

"This is an extremely unique ecosystem," says Holsinger. "I'd like to see some real rigid conservation, and if they don't start protecting the water, water supplies will dwindle." □