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CENOTES (ANCHIALINE CAVES) ON COZUMEL ISLAND, QUINTANA ROO, MÉXICO

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Abstract: Cozumel Island is a Caribbean locale having karst as the main component of its surface. Known caves are steep-sided, water-filled sinkholes (cenotes), and almost all of them are considered to be anchialine caves because they have seawater connections. In order to identify the location of as many cenotes as possible on the island, we based our study initially on aerial photographs. This was followed by visits to each site for field verification and collection of physical data and biological specimens. We explored several cenotes to record physical data such as temperature, salinity, dissolved oxygen, depth, pH, light, and to collect the animals living there. As a result, we report on eighteen cenotes on Cozumel Island, their location and fauna. Physical data from three cenotes showed that the freshwater is very thin at the top of the water table. Most of the systems are marine water-filled. Varying degrees of connection exist between these sinkholes and the ocean. In addition, other water bodies were found not to be cenotes, but aguadas (shallow water basins).

Introduction

In México about 20 percent of the land consists of karst, and by 1981 about 1024 caves were known around the country (Reddell, 1981). Particularly on the Yucatán Peninsula, the underlying rock is exclusively calcareous. In that region, cenotes are the main water bodies. Gaona-Vizcayno et al. (1980) defined them as subterranean water bodies with some connection to the surface. Hall (1936) classified the cenotes on the peninsula into four types: cenotes-cántaro (surface connection narrower than the diameter of the water body), cenotes-cilíndricos (vertical walls), cenotes-aguadas (shallow water basins), and grutas (horizontal entrance with dry sections).

The topography of Cozumel Island is mainly karstic, and it has all four kinds of cenotes. When these conduits have sea connections, we know them as anchialine caves. The local people use the freshwater from these holes to satisfy their basic water necessities. Some cenotes on Cozumel Island have been previously reported, such as Cueva Rancho Santa Rita (Reddell, 1977), Cueva Quebrada Parque de Chankanaab (Bowman, 1987; Holsinger, 1992), Cenote Xkan-ha and Cenote Aerolito (Kensley, 1988). On Cozumel, we also find shallow sediment-floored bodies of superficial water called aguadas. Cozumel Island is covered by tropical forest, so the shallow water bodies (aguadas) and the deep holes (cenotes) are not always easily found. Inaccessibility is the main reason that few cenotes have been previously catalogued.

This work aimed to identify the cenotes and aguadas on Cozumel Island, their geographic location, fauna, and some physical qualities. We also conducted surveys to obtain vertical profiles of physical data in two deeper holes (Tres Potrillos and Xkan-ha), and one from the Quebrada System (a horizontal cenote).

Study Area

Cozumel Island lies between 20°16′12″ and 20°35′15″ N latitude, and between 87°01′48″ and 86°43′48″ W longitude, and has an area of 482 km^2. The Island is off the northeastern tip of the Yucatán Peninsula, in the Mexican part of the Caribbean Sea, and its main freshwater sources are the cenotes and subterranean water conduits (Fig. 1).

Cozumel is part of the East Maya Plate with sedimentary rocks formed on a wide platform. Wurl and Giese (2005) report that core drillings indicate that the island is formed from reef sediment with a thickness of 100 m or more, which dates from the Oligocene and Quaternary Epochs. A karstic aquifer has been developed in these limestone beds.

Materials and Methods

We analyzed aerial photographs taken during the dry season (Feb. 9, 2000) at 1:75,000 from Instituto Nacional de Estadística Geografía e Informatica: Sistema Nacional de Fotografía Aérea (INEGI SINFA), and identified bodies of surface water. In addition, we reviewed the literature of species descriptions from Cozumel, and we listed the cenotes reported. Subsequently, we made several visits during 2005 to those places to corroborate their geographic

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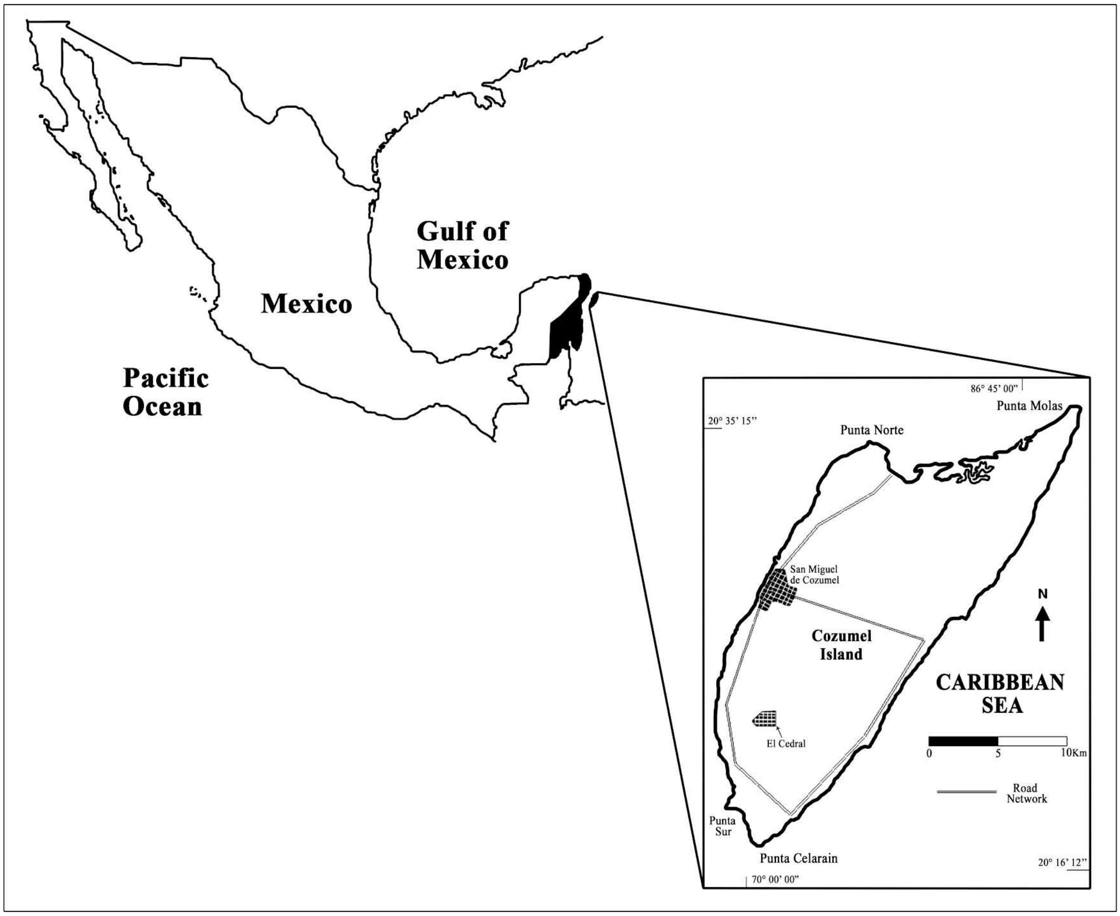

Figure 1. Index maps to the state of Quintana Roo and Cozumel Island.

locations and examine the main features. Geographic positions were registered using a Garmin Global Positioning System (GPS Summit 12 channels) using the NAD 27 Map Datum, and all positions were rounded to the closest 5 seconds. We obtained maps for three large cenotes from the literature, and then we explored them in order to corroborate the map surveys of these sinkholes. We also recorded physical data using a Hydrolab DataSonde 5 to measure temperature, salinity, dissolved oxygen, depth, light, and pH, and collected animals living there. All the cenotes were plotted on a map and listed.

Results

We registered 18 cenotes, most of them having salt water in their deeper layers, which are listed in Table 1, including their geographic locations and fauna. We also registered 250 shallow water bodies (cenotes-aguadas), from which only the larger are shown on Figure 2. The main water bodies are close to the coast, and others that lie in the inner part of the island are difficult to identify because the tropical forest is very dense. During our explorations, we found freshwater fish and turtles as the main fauna in almost all the aguadas. In most of the cenotes, however, we recorded salt or brackish water at deeper levels. As examples, we show here vertical and horizontal profiles from three cenotes: Tres Potrillos, Xkan-ha, and Cenote Km 1 (Quebrada System) (Figs. 3 and 4 respectively). During the analyses we found light penetration to occur only in the superficial water (2–3 m) of the vertical cenotes, and also to a very shallow depth (3 m) of the horizontal system. The halocline appears on the graphs, and dissolved oxygen was recorded at very low concentrations (Figs. 3 and 4). Only the Quebrada and Aerolito Systems have direct sea connections from where we collected crustaceans, echinoderms, worms, and mainly marine species of fish.

Discussion

This study deals with several water bearing features around Cozumel Island. Other authors have reported previously on different features on the island (Yañez-Mendoza, 1999; Bowman 1987; Kensley, 1988; Reddell, 1977, 1981). Here, we report the precise location of these features, the physical parameters of three of them, and

Table 1. Cenotes on Cozumel Island.

Cenote[a]	Latitude (°N)	Longitude (°W)	Length (m)	Depth (m)	Fauna	Reference
(a) Rancho San Miguel Cenote	20° 30′ 40″	86° 53′ 55″	8.0	3.0	Freshwater fish	
(b) Rancho San Miguel 1	20° 30′ 15″	86° 53′ 55″	9.0	2.0	Freshwater fish	
(c) Cenote del Dr. Villanueva	20° 30′ 20″	86° 53′ 10″	12.0	4.0	Cave crustaceans	
(d) Cenote Bambu	20° 29′ 35″	86° 52′ 30″	61.0	51.8	Freshwater fish, turtles, snakes	
(e) Universidad de Quintana Roo	20° 29′ 30″	86° 56′ 45″	15.0	1.5	Freshwater fish, land crabs, turtles	
(f) Cenote Chu-ha (San Francisco)	20° 29′ 25″	86° 57′ 20″	38.1	18.3	Freshwater fish	Milhollin, 1996
(g) Aerolito[a]	20° 28′ 00″	86° 58′ 45″	18.3	7.0	Cave crustaceans, marine fish, Cave echinoderms, cave worms	Kensley, 1988; Mejía-Ortíz et al., 2006, in press
(h) Xkan-ha	20° 27′ 55″	86° 57′ 15″	80.0	35.0	Cave crustaceans, freshwater fish, turtles	Kensley, 1988; Mejía-Ortíz et al., 2006
(i) Tres Potrillos	20° 27′ 05″	86° 59′ 15″	94.0	38.1	Cave crustaceans, freshwater fish	Yañez-Mendoza, 1999; Mejía-Ortíz et al., 2006
(j) Km 1 (Quebrada System)[b]	20° 26′ 40″	86° 59′ 45″	6.0	5.0	Cave crustaceans, freshwater fish	Bowman, 1987; Holsinger, 1992; Sternberg and Shotte, 2004; Mejía-Ortíz et al., 2006
(k) RokaBomba (Quebrada System)[b]	20° 26′ 40″	86° 59′ 40″	2.0	5.0	Cave crustaceans, freshwater fish	Bowman, 1987; Holsinger, 1992; Sternberg and Shotte, 2004; Mejía-Ortíz et al., 2006
(l) Cilpa (Quebrada System)[b]	20° 26′ 45″	86° 59′ 20″	2.0	4.0	Marine crustaceans, freshwater fish	Bowman, 1987; Holsinger, 1992; Sternberg and Shotte, 2004; Mejía-Ortíz et al., 2006
(m) Cenote Cocodrilo[b]	20° 23′ 00″	87° 01′ 10″	2493.0	17.4	Cave crustaceans	Mejía-Ortíz et al., 2006
(n) San Andrés El Cedral	20° 22′ 50″	87° 00′ 30″	15.0	4.0	Freshwater fish, crustaceans	
(o) Rancho Juvencio El Cedral	20° 21′ 20″	86° 59′ 55″	8.0	3.0	Freshwater fish, crustaceans	
(p) Cenote 1, Rancho El Chino El Cedral	20° 20′ 20″	86° 59′ 40″	12.0	5.0	Freshwater fish, turtles	
(q) Cenote 2, Rancho el Chino El Cedral	20° 19′ 10″	86° 56′ 05″	3.0	1.0	Freshwater fish, turtles	
(r) Cenote 3, Rancho el Chino El Cedral	20° 21′ 20″	86° 55′ 20″	5.0	1.5	Freshwater fish, turtles	

[a] Letters in front of each cenote corresponds to location on Figure 2.
[b] Denotes sea connection.

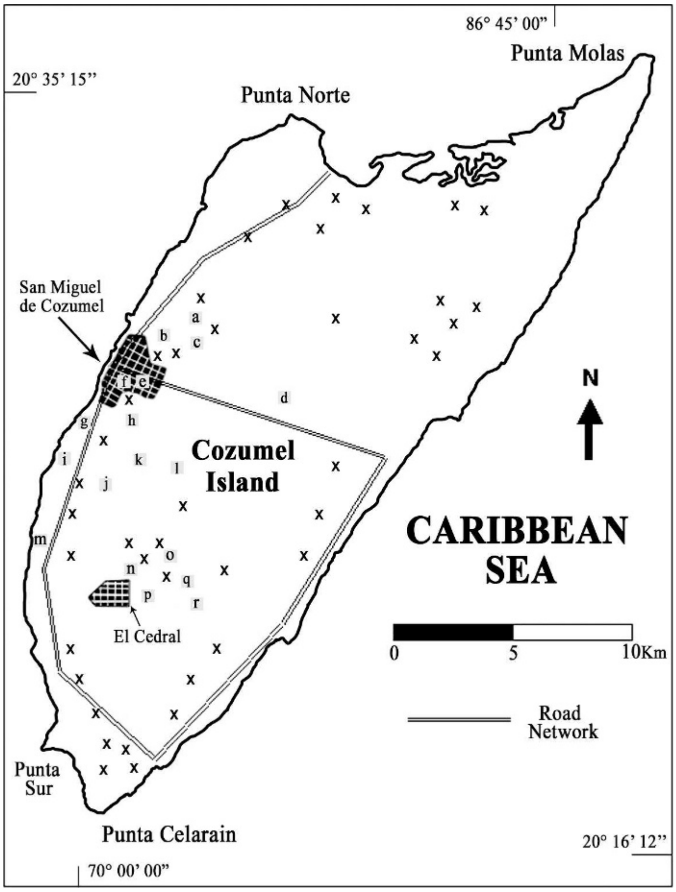

Figure 2. On Cozumel Island, crosses locate the largest aguadas (shallow water bodies), and letters keyed to Table 1 locate cenotes.

a record of other features not previously reported. We also found a significant number of aguadas. It is evident that the dense tropical forest makes the cenote entrances difficult to find. Despite the fact that the road network correlates somewhat with the previously known cenotes, our approach resulted in identification of the biggest sinkholes on the west side of the island. The island is mainly composed of limestone (Wurl and Giese, 2005), and the formation of all the cenotes is due to carbonate dissolution. We have insufficient data to suggest a pattern of distribution of these systems on the island.

At some sites, the freshwater table is shallow and superficial. This is important, because the human population of the island has been increasing during the past 5 years, with a consequent increase in water demand. At the same time, this increase in population also increases residual waste and contamination that could percolate into subterranean environments. This situation could cause a loss of water quality and also damage underground biodiversity. This could be the reason we found several species living only in the brackish water in almost all of the cenotes.

In the physical analyses, we found that the ground water of Cozumel has several zones. In the Aerolito and Quebrada horizontal systems, the mixing flow to the sea is important. Conversely, in the Tres Potrillos and Xkan-ha vertical holes, stratification with few mixing periods during the year was found. The halocline and thermocline are clearly defined in these systems.

Although freshwater fish are important in the cenotes of Cozumel, they live in the superficial water layer (Schmitter-Soto, 1999). We report a species richness from each sinkhole mainly composed of crustaceans, including species specialized to cave life. These species have slight relationships with species from other places. For example, during the recent explorations, we recorded three cenotes inhabited by members of the genus *Procaris*, but they all are probably different species (Mejía-Ortíz et al., 2006). These species are interesting because they are phylogeneticaly related to organisms from the Bahamas and Hawaii. Until now, these animals have not been recorded on the Yucatán Peninsula (Sternberg and Shotte, 2004), but we cannot exclude that they might be living in underwater caves there.

Several genera of termobaenacens have been reported mainly in Italy, and in some cases, on the Bahamas Islands. Termobaenaceans considered of the monotypic genus *Tulumella* have been reported previously at two localities in México, in nearby systems of Tulum, Yucatán (Illife, 1992 and 1993), and on Cozumel Island, specifically in the Cueva Quebrada System. But individual species have not been determined there. In this study we report a second cenote where these crustaceans live, and determined that they are members of the genus *Tulumella*, but presumably of an undescribed species.

Other interesting crustaceans that we found in a cenote on Cozumel Island are those of the genus *Barbouria*. To date, this genus has only a unique species *Barbouria cubensis*, and it has been reported on other islands (Hobbs et al., 1977). We have also identified organisms of the genus *Bahalana* in sinkholes that are apparently unconnected.

Conclusions

With this study we increase the known number of identified cenotes on Cozumel Island, and for the first time give their exact geographic positions. It is important to say that several cenotes are under cover in the tropical forest, and this inaccessibility has limited surveys there. Because of the human population increase and its increasing water demand, these environments are potentially in danger of severe damage. Also, we report for the first time the physical water parameters of three cenotes on the island, and conclude that the main component of these waters is saline at shallow depths.

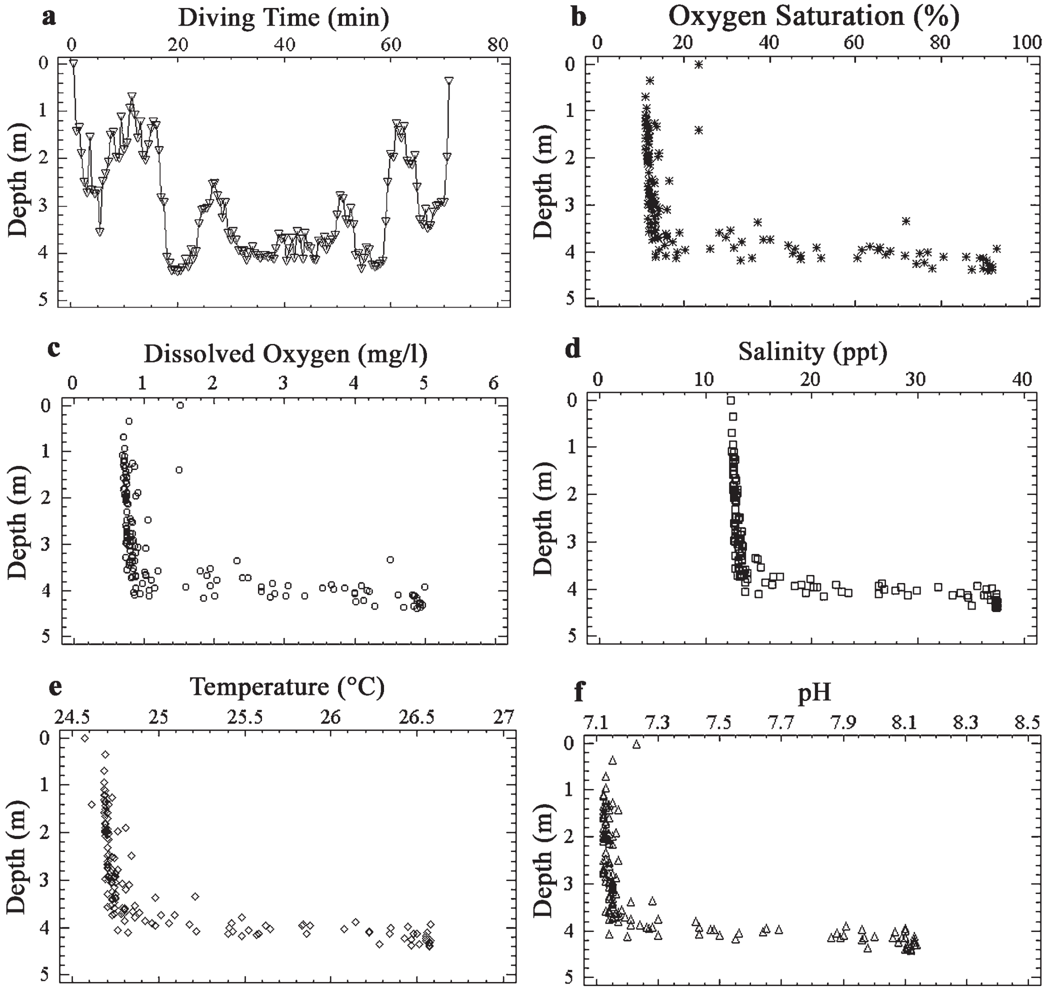

Figure 3. Profiles at an entrance to the horizontal Quebrada System (Chankanaab) for instrument diving time, dissolved oxygen, percentage of oxygen, temperature, salinity, and pH.

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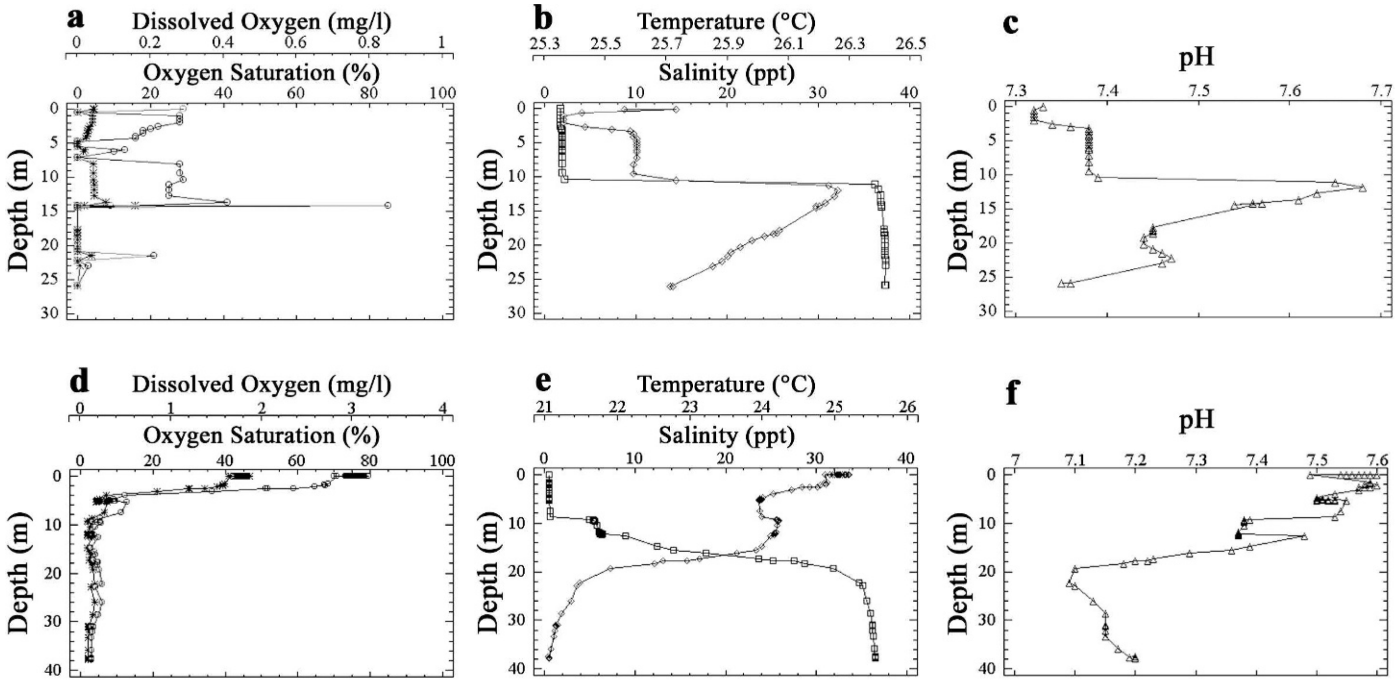

Figure 4. Vertical profiles at Cenote Tres Potrillos (a, b, and c) and Cenote Xkan-ha (d, e, and f) for dissolved oxygen (o) percentage of oxygen (*) temperature (◆), salinity (□), and pH (Δ).

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