Phytoplankton of cenotes and anchialine caves along a distance gradient from the northeastern coast of Quintana Roo, Yucatan Peninsula

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Abstract

This work details the taxonomic composition of suspended algae (phytoplankton and tycoplankton) communities in five cenotes (sinkholes) and two anchialine caves in northeastern Quintana Roo, Mexico. The sample set of cenotes are Casa, Nohoch Nah Chich, Maya Blue, Cristal, and Carwash, as well as the two associated caves leading from the cenotes of Maya Blue and Cristal. The site distribution represents a distance gradient with respect to the coastline with which we observe the effects of tidal movement and the mixing of waters (e.g. saline water and freshwater) on the composition of the suspended algal communities. Two sample sets were taken, one at the end of the dry season (March–April 1995) and the second at the end of the rainy season (September–October 1995) with the goal of comparing the contrasting climatic conditions of the region. A total of 79 species were identified, of which, diatoms were the most important with respect to species richness with a total of 75% of species. The floristic composition is very similar between the freshwater cenotes. The distance of a cenote site with respect to the coastline was a determining factor in the species composition. Casa Cenote is the most distinct of the sample set for the presence of marine species due to its proximity to the coastline. The tides are a large determining factor of the floristic composition of Casa Cenote with 24% all species identified in this study found exclusively in this system. The anchialine system species are transported from the cenotes and the adjacent cave systems. The largest percentage or species (95%) are freshwater, and only 5% of the total number of identified species are of marine origin. It is recognized that the most distant cenotes from the coast, Carwash and Cristal, as well as Maya Blue and Nohoch Nah Chich, are the most similar, despite being part of different cave systems. In these inland systems the marine species decreased drastically (2.4% in Nohoch Nah Chich and no marine species in the remaining cenotes). Marine species are found at the halocline of the caves.

Introduction

The Yucatan Peninsula is a typical karst environment where highly permeable limestone promotes the formation of complex submerged cave systems and sinkholes, known locally as cenotes (Redell, 1981). The orientation of many of these cave systems gives rise to extensive interconnected passage systems which are parallel to each other and run perpendicular to the coastline due to the fracture and fault orientation of the region (Iliffe, 1993).

In the littoral karst, tidal loading pushes the underlying marine water inland; this displaces from below the shallow fresh water which flows towards the coast under the force of gravity. As a result, anchialine systems form where dense saline water underlies low-density light fresh water. These layers are separated by a marked halocline (Stock et al., 1986). The salinity of the shallow fresh water decreases with distance from the coast, so that fresh water is found at a distance inland (Iliffe, 1993).
The submerged passages of the Yucatan Peninsula cave systems are inhabited by endemic biota, which have been well documented (Illiffe, 1993).

A transition zone exists between open sunlit cenotes and the total darkness of caves. Possibly the most important interaction between the open cenote and the closed cave is the transfer of loose and particulate photosynthetic organic matter (including organisms) from both terrestrial and aquatic sources from the illuminated cenotes to the complete darkness of the cave. Apparently of lesser magnitude are the chemosynthetic processes, which produce organic matter directly within the caves, which in turn may be transported to the downstream cenote in the system.

Phytoplankton are the dominant organisms amongst the primary producers within aquatic ecosystems. However, the phycoflora communities of karstic systems are poorly studied despite the fundamental importance of this knowledge with respect to the biogeochemistry of the submerged systems and the microbial ecology, which in turn may shed light on the ecology of the troglobite macrofauna and nutrient cycling (Martin et al., 1995).

The aim of the present study was to determine the suspended algae (planktonic and benthic algae) community composition in five cenotes and two anchialine caves in northeast Quintana Roo, Mexico. For comparative purposes, five cenotes distributed between the three karstic systems of Nohoch Nah Chich, Naranjal (which includes cenotes Maya Blue and Cristal), and Aktun Ha (which includes Car Wash cenote) were selected to form a perpendicular transect with increasing distance to the coast. This spatial distribution of sampling points allows for evaluation of tidal influence on the suspended algae composition of these systems.

Study site

The study region is located in the northeast part of the state of Quintana Roo and is bordered by 20° 11’ and 20° 17’ latitude north and 87° 23’ and 87° 29’ longitude west (Fig. 1). The sampling sites are located as follows: Casa Cenote (Cenote Manati, Cenote Tankah, in the Nohoch Nah Chich System) (20° 15.97’ N, 87° 23.41’ W), Nohoch Nah Chich System Main Entrance (20° 17.93’ N, 87° 24.20’ W), Maya Blue in the Naranjal System (20° 11.61’ N, 87° 29.74’ W), Cristal also in the Naranjal System (20° 12.50’ N, 87° 28.98’ W), and, Carwash in the Aktun Ha System (20° 16.48’ N, 87° 29.20’ W).

Casa Cenote is located on the coast and is characterized by active exchange with marine water. However, Casa Cenote, like all anchialine caves, is vertically stratified with respect to salinity (Table 1). The upper stratum, the epilimnion, is fresh to brackish water and slightly acidic. The lower stratum, the hypolimnion, is marine water and slightly basic. The intermediate layer, the halocline, is the transition zone between the two layers. The other cenotes are fresh water and slightly acidic (Table 1). Physical and chemical variables displayed minor differences among fresh water masses as well as between salt water ones. Further information on physical, chemical and microbiological characteristics are given in Alcocer et al. (1998, 1999).

The study area is characterized by limestone of Miocene and Pliocene age (Back & Hanshaw, 1970) with a maximum altitude of less than 200 m above sea level (Lesser & Weidie, 1988). The environmental temperature is generally stable over the year, fluctuating from 23 °C in January to a maximum of 28 °C in May. Seasonal variation on Yucatan Peninsula is defined not by temperature variation but by precipitation. The rainy season is from May to October with a precipitation between 500 and 1500 mm per year, and average 1000 mm (Back & Hanshaw, 1970), and a ‘dry’ season from November to April, when 35% of the annual precipitation falls. Infiltration is nearly matched by evaporation, while overland runoff is negligible (Lesser & Weidie, 1988).

Materials and methods

Two sample sets were taken to compare the contrasting seasons of the region. One set was taken at the end of the dry season (March–April of 1995) and another at the end of the rainy season (September–October of 1995). The number of samples from each of the cenotes and anchialine cave water columns varied from one to three depending on environmental heterogeneity which was established through vertical temperature, salinity and dissolved oxygen profiles using a multiparameter water quality monitoring probe (Hydrolab DS3/SVR3). Where stratification was observed (thermocline, halocline, and/or oxycline) three levels of samples were taken: surface, bottom, and cline depth. This sampling strategy occurred at Casa Cenote and in the caves. The remaining cenotes were sampled at mid-water column since homogeneous water columns were observed. A Niskin water-sampling bottle with 6-l capacity was used in the cenotes. From