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A new species of starfish (Echinodermata: Asteroidea) from an anchialine cave in the Mexican Caribbean

Una especie nueva de estrella de mar (Echinodermata: Asteroidea) de una caverna anquialina en el Caribe mexicano

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Abstract. *Copidaster cavernicola* n. sp. is described from an anchialine cave system in Cozumel, Mexico. *Copidaster cavernicola* differs from its congeners in having 1-8 papulae in each papular area, and numerous excavate pedicellariae on all surfaces, except between furrow spines and subambulacral spines. *C. cavernicola* is possibly endemic to the anchialine system which it inhabits.

Key words. Echinodermata, Asteroidea, *Copidaster*, anchialine cave, Mexico.

Resumen. Se describe una especie nueva de la estrella de mar del género *Copidaster* encontrada en un sistema de cuevas anquihalinas del Caribe, en Cozumel, México. *Copidaster cavernicola* n. sp. es la primera especie cavernícola de equinodermo que es descrita, y se caracteriza por tener de 1 a 8 pápulas por cada zona papular, numerosos pedicelarios excavados presentes en toda la superficie del cuerpo excepto en el surco ubicado entre las espinas ambulacrales y subambulacrales. Se sugiere que *C. cavernicola* es una especie endémica propia del sistema anquihalino en el que habita.

Palabras clave. Echinodermata, Asteroidea, *Copidaster*, cueva anquihalina, México.

Introduction

Echinoderms are among the rarest invertebrates in the anchialine cave environment. Confirmed records of echinoderms from Mexican Caribbean anchialine caves (Mejía-Ortíz et al., 2007) include 1 species of asteroid (*Asterinides folium*), 1 species of ophiuroid (*Ophionereis* sp.) and 1 species of echinoid (*Eucidaris* sp.).

Cozumel Island is a typical karst environment where highly permeable limestone promotes the formation of complex submerged cave systems and sinkholes, known locally as cenotes (Reddell, 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 fractures and faulting of the region (Illife, 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 (Illife, 1993).

To date, no echinoderm has been ever known to be restricted to inhabit an anchialine cave environment. This is the first troglobitic echinoderm ever described from this unique environment.

Only 2 species of the genus *Copidaster* have been recognized so far: *C. schismochilus* (H. L. Clark, 1922) known only from the Challeger Bank, Bermuda (based on a single specimen) (Clark and Downey, 1992), and *C. lymani* A. H. Clark, 1948 reported from Belize, Panama, and the Florida Keys (Hendler et al,. 1995).

Materials and methods

The study area is the sinkhole (cenote) El Aerolito

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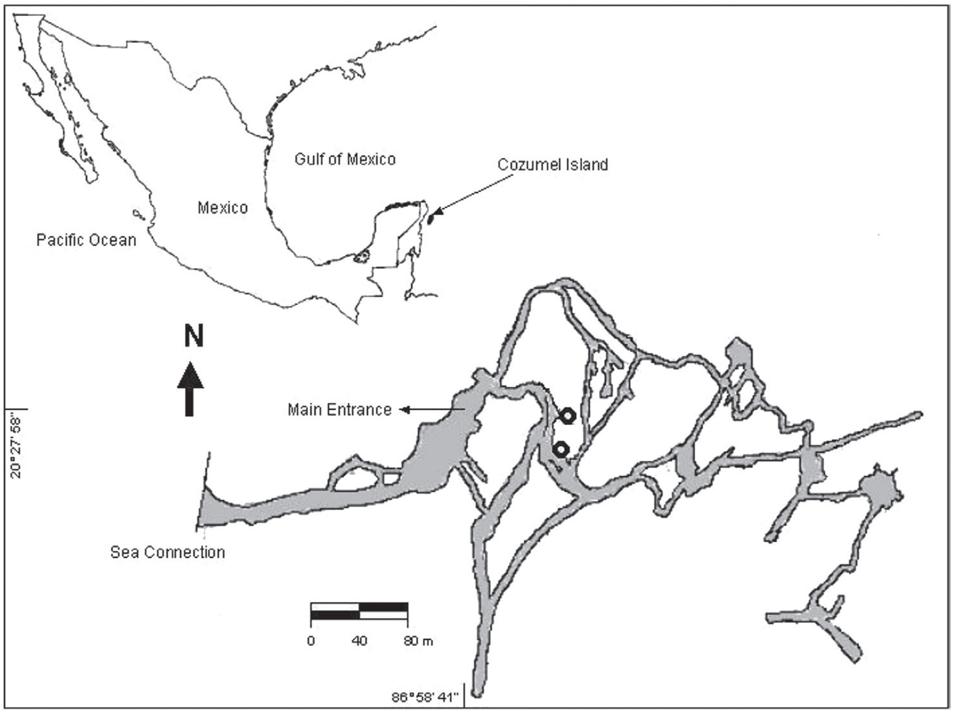

Figure 1. Map of Cenote Aerolito and the distribution of *Copidaster cavernicola* n. sp. in the anchialine cave (modified from Mejía-Ortíz et al., 2007).

de Paraiso, located on Cozumel Island, Quintana Roo, Mexico, at 20° 27' 58" N and 86° 58' 41" W. This system has a length of approximately 6 100 m and a connection with the Caribbean Sea at 240 m from the main entrance (Mejía-Ortíz et al., 2007) (Fig. 1). Its conduits are mainly formed by rock dissolution. Formations, such as stalactites, stalagmites and columns are located in the deeper area. The dominant sediment in the cave is clay and mud (Mejía-Ortíz et al., 2007).

Abiotic data (temperature, conductivity, salinity [measured in Practical Salinity Units, psu], and depth) using the Hydrolab Data Sonde 5 and SCUBA techniques were measured. The animals were collected by hand during the surveys, and fixed and preserved in 70% ethanol. The material is deposited at the Coleccion Nacional de Equinodermos, "Ma. Elena Caso Muñoz", Instituto de Ciencias del Mar y Limnolgia (ICML), Universidad Nacional Autonoma de Mexico (UNAM).

Descriptions

Systematics

Order Valvatida Perrier, 1884

Family Ophidiasteridae Verrill, 1870

Genus *Copidiaster* A. H. Clark, 1948

Copidaster A. H. Clark, 1948: 55-56, Miller, 1984: 194, Clark and Downey, 1992: 270.
Leiaster (pt): Downey, 1973: 62.

Diagnosis (emended from Clark and Downey, 1992): 5 slender cylindrical rays with a rigid skeleton, covered with a smooth skin that wholly conceals underlying plates, but may include scales, granules or small, conical spinelets; abactinal plates in regular longitudinal and transverse series; 7 longitudinal series throughout most of the ray; papular areas large, in 8 series; 1 small madreporite; adambulacral plates of similar size proximally but alternate large and small distally; on proximal half of rays alternate actinals, adjacent to the adambulacrals are connected to the inferomarginals by 2 plates, arranged in tandem; whole animal completely covered with imbricating scales, granules or small conical spinelets. Small clasp-knife pedicellariae abundant on abactinal and actinal surfaces.
Type species: *Copidaster lymani* A. H. Clark, 1948 by original designation.

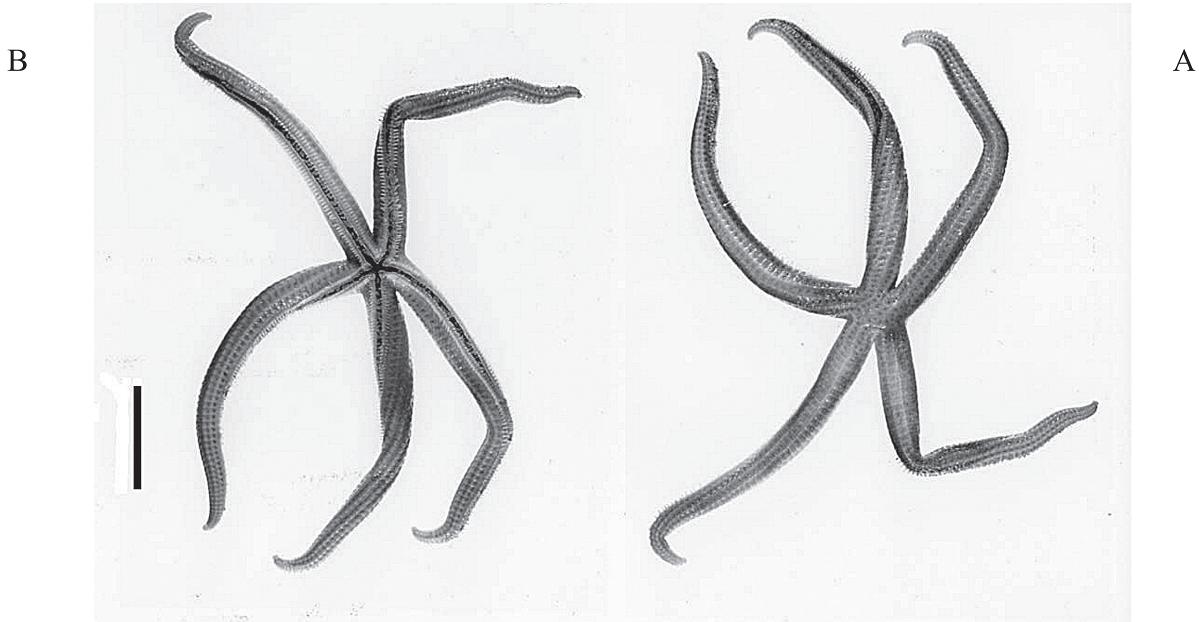

Figure 2. *Copidaster cavernicola* n. sp. Holotype, ICML-UNAM 2.176.0. A. abactinal view; B. actinal view. Scale bar 3.8 cm.

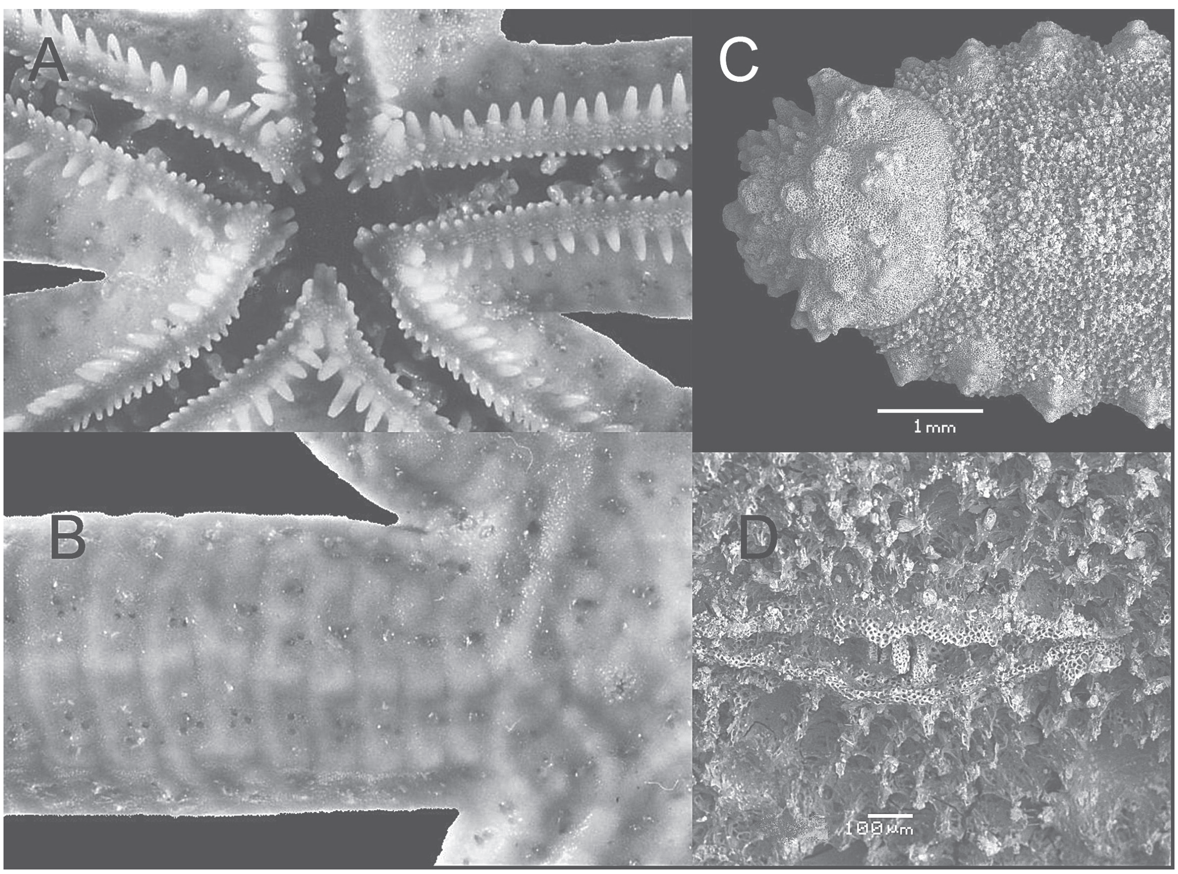

Figure 3. *Copidastar cavernicola* n. sp. Holotype, ICML-UNAM 2.176.0, A, B. mouth and basal part of a ray, C. distal tip of ray showing the terminal plate, D. SEM picture showing an alveolus of an excavate pedicellariae.

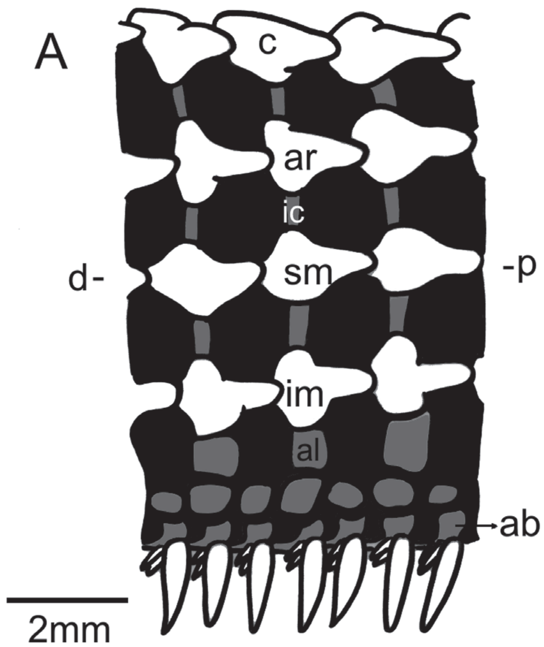

Figure 4. *Copidastar cavernicola* n. sp. A. Planar view of skeletal plates near mid-portion of ray. Abbreviations: d, distal; p, proximal; c, carinal; ic, internal connecting ossicle; ar, adradial; sm, superomarginal; im, inferomarginal; al, actinolateral; ab, adambulacral.

Copidaster cavernicola **new species** (Figs. 2-4)

Copidaster sp., Mejía-Ortíz et al., 2007: 32, fig. 2c,d.

Taxonomic summary

Material examined: 3 specimens.
Type material: Holotype.- ICML-UNAM 2.176.0, (R= 108 mm, r= 8 mm, Rr= 13:13.5), Cenote Aerolito de Paraiso, Cozumel, Quintana Roo., Mexico (20° 27' 58" N and 86° 58' 41" W), February 5, 2005, 45 m from the cave principal entrance, 18 m depth, Coll. German Yañez; Paratype: ICML-UNAM 2.176.1, 1 specimen, (R= 118 mm, r= 8 mm, Rr= 14:14.7), Cenote Aerolito de Paraiso, Cozumel, Quintana Roo., Mexico (20° 27' 58" N and 86° 58' 41" W), March 2006, 240 m from the cave principal entrance, bottom temperature 25.5-26.1°C, 13 m depth, Coll. German Yañez. Paratype: ICML-UNAM 2.176.2, 1 specimen, (R= 115 mm, r= 10 mm, Rr= 11:11.5), Cenote Aerolito de Paraiso, Cozumel, Quintana Roo., Mexico (20° 27' 58" N and 86° 58' 41" W), July 2009, ~200 m from the cave principal entrance, 18 m depth, Coll. German Yañez.
Type locality: Sinkhole (cenote) El Aerolito de Paraiso (20° 27' 58" N and 86° 58' 41" W), Cozumel Island, Quintana Roo, Mexico.
Etymology: The name of the species describes its habitat.
Diagnosis: Disc small; 5 long, narrow cylindrical rays, each tapering to acute point, rays more or less equal in length. Entire skeleton concealed by thin skin, with numerous embedded, equal size conical spinelets actinally and abactinally. Papular areas with 1-8 papulae. Excavate pedicellariae numerous on all surfaces. No pedicellariae present between furrow spines and subambulacrals.
Description: Disc flat, small; rays 5, long, narrow, cylindrical tapering to acute point, often equal in length R= 118 mm, r= 8 mm, R/r= 14.75/1 (fig. 2. A,B). Terminal plate conspicuous, swollen, circular, carrying numerous pointed tubercles (> 50) (Fig. 3. C). Actinal surface of terminal plate with evident, wide groove. Three (occasionally 4 or more) spines present on each side of groove. Single, inconspicuous, small, circular to oval madreporite with smooth, fine gyri. Anus near center of disk, surrounded by 20 or more enlarged spines (Fig. 3. B). Entire skeleton concealed by thin skin, embedded with numerous, small subequal conical spinelets (Fig. 3. C) actinally and abactinally.

In cross-section, the ray has a series of plates consisting of a carinal, adradial, superomarginal, inferomarginal, actinolateral (3 rows proximally), adambulacral ossicles. Primary abactinals quadrilobate; distal plates overlap proximal plates. Beneath and between adjacent longitudinal rows of primary abactinals lie a series of internal ossicles. Adambulacral ossicles broad and small; of similar size proximally but alternate large and small distally; each adambulacral connected directly with an adjacent actinolateral plate. Proximal adambulacral plates carry 1 large, flattened subambulacral spine. On distal end of ray, subambulacral spines are shorter. Marginal face of each adambulacral plate bears 2 equal, subcylindrical furrow spines (Fig. 4). Each half jaw bears a single, flattened, bluntly rounded preoral spine, 4 similar though shorter, marginal spines and 1 large, flattened suboral spine (Fig. 3. A).

Eight longitudinal rows of papular areas with 1-8 papulae per area. Largest papular areas found on inflated abactinal portion of rays.

Excavate pedicellariae numerous on all surfaces, especially disk, basal part of rays, and actinal-interradial area. No pedicellariae between furrow spines and subambulacrals. Pedicellaria consists of thick 2 sickle-shape valves lying in narrow, elongate alveolus, 0.7 a 1 mm in length (Fig. 3. D). Distal tips of valves tapering to acute terminal tooth, crossing when valves close.

Live specimens have an abactinal surface with a tan ground color and pale orange mottling or irregular banding. Actinal surface pale brown; subambulacral spines and furrow spines white. Tube feet transparent with white suckers.

Distribution and habitat. The species inhabits a region of the cave where no light penetrates at 45 and 240 m from the principal cave entrance, 13-18 m depth respectively. Salinity values were constant at 35 psu in the areas where *C. cavernicola* was present.

Remarks

Copidaster cavernicola is very close to its Atlantic congener *Copidaster lymani* A. H. Clark, 1948, but, differs in the shape of the inclusions on the skin, presence and distribution of pedicellariae and number of papulae per area. In *C. cavernicola* the entire skeleton is concealed by thin skin, with numerous embedded, equal size conical spinelets actinally and abactinally whereas *C. lymani* and *C. schismochilus* possess scales or granules embedded by thin skin. In *C. lymani* the area between furrow spines and subambulacrals has a continuous row of pedicellariae, while in *C. cavernicola* these areas are naked. Papular areas in *C. cavernicola* posses from 1 to 8 papulae per area, meanwhile *C. lymani* and *C. schismochilus* have up to only 13 and from 20 to 50 papulae in each area respectively.

Cave animals show various adaptations to survival in their unusual environments, which involve their physiology, behavior, life history, and morphology (Mejía-Ortíz and Hartnoll, 2006). Morphological adaptations include enlargement of the sensory and ambulatory appendages, reduction or lack of pigment in the integument, and reduction or loss of eyes. *C. cavernicola* is restricted to the anchialine cave environment in marine waters (35 psu). It does not exhibit a unpigmented body as commonly found in other troglobitic species, but it is certainly not as strongly pigmented as its marine congener *C. lymani*. Perhaps one of the adaptations of *C. cavernicola* in response to the lack of light in the anchialine cave is the modification of its terminal plates which carry numerous pointed tubercles (> 50) (In *C. lymani* the terminal plate is smooth with 10-12 protuberances). Such numerous tubercles suggest an either tactile or chemosensory function as demonstrated by some troglobitic crustaceans (Mejía-Ortíz and Hartnoll, 2006) where the light receptive function is sometimes enhanced by the presence of a tactile organ.

It is possible that *C. cavernicola* is endemic to the anchialine system in which it lives.

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