



Deep-water Asteroidea (Echinodermata) collected during the TALUD cruises in the Gulf of California, Mexico

Asteroidea (Echinodermata) de aguas profundas recolectados durante cruceros TALUD en el golfo de California, México

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Abstract. During a series of cruises aboard the R/V “El Puma” aimed at collecting the deep-water benthic and pelagic fauna off the Pacific coast of Mexico, in the eastern Pacific, samples of Asteroidea were collected below 500 m depth (587-1 526 m). A total of 335 specimens were collected, belonging to 18 species, 14 identified to species, 3 to genus, and 1 previously undescribed species. New records are provided for *Dipsacaster laetmophilus* Fisher, 1910, *Myxoderma sacculatum* (Fisher, 1905), *Peribolaster biserialis* Fisher, 1905, *Ampheraster chiroplus* Fisher, 1928, *Ampheraster hyperoncus* (H. L. Clark, 1913), *Anteliaster coscinactis* Fisher, 1923, *Nearchaster aciculosus* (Fisher, 1910), *Ceramaster leptoceramus* (Fisher, 1905), *Mediaster transfuga* Ludwig, 1905, and *Lophaster furcilliger* Fisher, 1905. All species were collected below the oxygen minimum zone that extends throughout the central and southern Gulf of California, or within the threshold zone where severe to mild hypoxic conditions prevail. Epibenthic dissolved oxygen concentrations associated with the capture of the specimens show support for strong tolerance to severe hypoxia (<1.0 ml O₂/l) for most species, but only mild hypoxia for *Ctenodiscus crispatus* (Retzius, 1805), and *Nymphaster diomedae* Ludwig, 1905. A checklist of all species of Asteroidea occurring below 500 m depth off the Pacific coast of Mexico is included.

Key words: Asteroidea, continental slope, western Mexico.

Resumen. Durante una serie de campañas oceanográficas realizadas a bordo del B/O “El Puma”, enfocadas a la recolección de la fauna bentónica y pelágica de aguas profundas en la costa del Pacífico de México, en el Pacífico oriental, se recolectaron ejemplares de Asteroidea por debajo de 500 m de profundidad (587-1 526 m). Un total de 335 ejemplares fueron recolectados, pertenecientes a 18 especies; 14 fueron determinadas hasta especie, 3 hasta género y 1 especie no descrita. Se proporcionan nuevos registros para *Dipsacaster laetmophilus* Fisher, 1910, *Myxoderma sacculatum* (Fisher, 1905), *Peribolaster biserialis* Fisher, 1905, *Ampheraster chiroplus* Fisher, 1928, *Ampheraster hyperoncus* (H. L. Clark, 1913), *Anteliaster coscinactis* Fisher, 1923, *Nearchaster aciculosus* (Fisher, 1910), *Ceramaster leptoceramus* (Fisher, 1905), *Mediaster transfuga* Ludwig, 1905, y *Lophaster furcilliger* Fisher, 1905. Todas las especies se recolectaron por debajo de la zona del mínimo de oxígeno que se extiende por las zonas central y sur del golfo de California, o en el umbral de la zona donde prevalecen condiciones de hipoxia de leves a severas. Las concentraciones de oxígeno disuelto epibentónicas asociadas con la captura de los ejemplares indican una fuerte tolerancia a la hipoxia severa (<1,0 ml O₂ / l) para la mayoría de las especies, y a hipoxia leve para *Ctenodiscus crispatus* (Retzius, 1805) y *Nymphaster diomedae* Ludwig, 1905. Se incluye una lista de todas las especies de asteroideos que se encuentran por debajo de 500 m de profundidad frente a la costa del Pacífico de México.

Palabras clave: Asteroidea, talud continental, Pacífico este, México.

Introduction

Deep-sea macroinvertebrates communities are characterized by high diversity values (see Grassle, 1989;

Smith et al., 1998). In areas where the oxygen-minimum zone (OMZ) intercepts the continental slope, anoxic and severely hypoxic benthic fringes are species-poor. This is in contrast to the hypoxic zone extending into even deeper water, which is species-rich. In the OMZ, depth and dissolved oxygen concentration are the most important factors affecting the composition and species size of deep-

water communities (Levin and Gage, 1998; Rogers, 2000; Hendrickx, 2001; Levin et al., 2001; McClain and Rex, 2001; McClain, 2004; Méndez, 2006; Zamorano et al., 2006).

Environmental conditions occurring on the deep-sea benthos (i.e., muddy sediments, abundant detritus as food source, stable values of salinity and temperature) favor settlement and dominance of infauna and epifauna communities which are often highly diverse (Rex et al., 2000; Borowski, 2001; Levin et al., 2001; Reynolds, 2002; Kröncke and Türkay, 2003; Méndez, 2006; Tilot, 2006). As a generality, deep-water crustaceans, echinoderms and fish are better represented in benthic samples obtained from sledges or beam-trawls than in box cores. Due to difficulties that stem from operating in deep water, therefore a general lack of information exists related to their distribution, abundance and community composition.

Deep-water echinoderms have been scantily studied in the East Pacific south of the California Current area. The Asteroidea collected from the deep-water HMS "Challenger" expeditions, off the Galapagos Islands and Panama, were studied by Sladen (1883, 1889) who described 6 deep-water species. The second major deep-water sampling program off the Pacific coast of America took place at the end of the 19th and beginning of the 20th centuries (1892-1911), when the USFC "Albatross" surveyed the west coast of the Americas, from Peru to California, including Mexico, and collected many specimens during trawling operations in deep water. The "Albatross" Asteroidea collections were described by Ludwig (1905, 1907) and H. L. Clark (1913, 1920, 1923). Northeast Pacific asteroids were monographed by Walter K. Fisher in a long series of contributions published from 1905 to 1940 (e.g., Fisher, 1905, 1906a, 1906b, 1910a, 1910b, 1917, 1928a, 1928b).

Maluf (1988) indicated that 109 species of Asteroidea occurred below 500 m depth in the central eastern Pacific. Some of these species, however, occurred on the continental shelf in relatively shallow water and were only occasionally present at depths greater than 500 m (i.e., *Luidia asthenosoma*, 20-620 m; *Odontaster crassus*, 27-595 m; *Henricia aspera*, 18-572 m; *Stylasterias forreri*, 29-532 m). Most of these 109 species were described based on material collected from the eastern Pacific in the early to mid 20th Century and were monographed by Ludwig (1905; 1907: 39 species described), Fisher (1905, 1906a, 1906b, 1910a, 1910b, 1917, 1928 a, b: 44 species described), and H. L. Clark (1913, 1920: 8 species described).

Maluf (1988) showed that 52 of these 109 species had at least 1 record off the western coast of Mexico. Subsequent accounts summarizing the distribution of

species of Asteroidea occurring off the Pacific coast of Mexico include Maluf (1991), Nybakken et al. (1998), Solís-Marín et al. (2005), Maluf and Brusca (2005), Keller et al. (2007), and Honey-Escandón et al. (2008). Alton (1966) reported 54 species of bathyal and abyssal sea stars from northern Oregon. Carey (1972) summarized distributions of sublittoral to abyssal asteroids from the Northeast Pacific Ocean and listed their feeding type and food sources. Mah (2007) reviewed the Zoroasteridae, providing new data for zoroasterid species occurring off western Mexico and nearby areas.

Because very few sampling efforts in deep water of the East Pacific have been undertaken by Mexican institutions, a major exploring project aimed at studying the invertebrate and fish communities associated with the continental slope (the TALUD project) was designed. The aim of this project was to increase or knowledge of the bathyal fauna and to estimate species diversity in Mexican waters.

Materials and methods

Samples of Asteroidea were obtained from depths of 587-1 525 m on the continental slope along the Pacific coast of Mexico using an Agassiz dredge and a benthic sledge (2.5 m width, 0.9 m high) equipped with a modified shrimp net (ca 5.5 cm stretched mesh size) with a ca 2.0 cm (3/4") internal lining net. A total of 13 cruises were organized in the Gulf of California from 1989 to 2008. Specimens of Asteroidea were collected during the following cruises: TALUD III, 17-24 August 1991; TALUD IV, 23-27 August 2000; TALUD V, 13-18 December 2000; TALUD VI, 13-17 March 2001; TALUD VII, 5-9 June 2001; TALUD VIII, 16-23 April; TALUD IX, 10-15 November 2005; and TALUD X, 9-15 February 2007. During these cruises, a total of 117 localities were sampled, from 377 to 2 394 m depth, and Asteroidea were captured in 25 of these. Positional coordinates for each sampling station were plotted using a GPS navigation system. Depth was measured with an EdoWestern, analogic recorder (TALUD III-VIII) or a digital recorder (TALUD IX-X). Epibenthic water temperature and salinity were measured with a Seabird CTD, and dissolved oxygen content was estimated with the Winkler method (all cruises) and with a probe attached to the CTD (TALUD VIII-X). Specimens were fixed on board with a 4% formalin sea water solution for a short period (usually a few days), washed with tap water and preserved in 70% ethanol. Density of abundant species was evaluated using the swept area method considering an average sampling speed of 1.75 knots, the trawling time (30 minutes in most cases), and the width of the gear-mouth (2.5 m).

In the systematic section below, primary synonyms and other significant references are included for each species. References to Mexican material are all included, together with comments and additional data related to the distribution and ecology of each species. The material collected during this survey is deposited in the Regional Collection of Marine Invertebrates (EMU), in Mazatlán, Mexico. Duplicates of several species were also deposited in the Echinoderms Collection M. E. Caso Muñoz, ICML, UNAM, in México D.F., Mexico, and in the Smithsonian Institution collection (USNM), in Washington D.C., USA.

Based primarily on Maluf (1988), a list of all species with at least 1 record within Mexican waters of the Pacific Ocean was established (Table 1). Records following 1988 were recovered from the literature or based on the material collected during the TALUD cruises and are incorporated herein. Classification of Asteroidea adopted herein follows Clark and Downey (1992). To establish synonymies, original literature dealing with descriptions and records of deep-water Asteroidea in the East Pacific was consulted, in addition to important reviews by A. M. Clark (1989, 1993, 1996) and A. M. Clark and Mah (2001). Other sources are indicated in the text where appropriate.

Table 1. Species of deep-water Asteroidea (> 500 m depth) occurring off the coast of Mexico (northernmost limit set at 32°28'16"N; southernmost limit set at 14°32'27"N), including the California Current area (CC), the Gulf of California (GC), the area of southwestern Mexico, south of Banderas Bay (SWM), and the offshore islands (OI). Data used in the table was taken from the following sources: TL, type locality MA, Maluf (1988); MA2, Maluf (1991) (only those data complementary to Maluf, 1988); SO, Solís-Marín et al. (2005); MB, Maluf and Brusca (2005); MC, Mah (2007); HE, Honey-Escandón et al. (2008); PS, present study. Bold face: species collected during the TALUD cruises. (?) Dubious record or identification; Rev., Revillagigedo Islands. For convenience, the sequence of species follows Maluf (1988)

| <i>Species</i> | CC | GC | SWM | OI |
|---|--------|-------------|-----|--------------|
| <i>Luidia asthenosoma</i> Fisher, 1906 | MA | | | |
| <i>Luidia foliolata</i> Grube, 1865 (1) | MA | MA | MA | |
| <i>Dipsacaster laetmophilus</i> Fisher, 1910 | | PS | | |
| <i>Dytaster gilberti</i> Fisher, 1905 | MA MA2 | | | |
| <i>Leptychaster inermis</i> (Ludwig, 1905) | MA | | | |
| <i>Psilaster armatus</i> Ludwig, 1905 | | MA MB | | |
| <i>Psilaster pectinatus</i> (Fisher, 1905) | MA | | | |
| <i>Thrissacanthias penicillatus</i> (Fisher, 1905) | | MA MB PS | | |
| <i>Eremicaster crassus gracilis</i> (Salden, 1883) (2) | MA HE | MA MB | MA | |
| <i>Eremicaster pacificus</i> (Ludwig, 1905) | MA HE | MA MB SO PS | MA | |
| <i>Hyphalaster inermis</i> Sladen, 1883 (3) | MA | | | |
| <i>Ctenodiscus crispatus</i> (Retzius, 1805) | MA HE | MA MB SO PS | | |
| <i>Benthopecten acanthonotus</i> Fisher, 1905 | MA | MA MB | | |
| <i>Benthopecten pectinifer</i> (Ludwig, 1905) | | MA MB SO | | |
| <i>Nearchaster aciculosus</i> (Fisher, 1910) | MA | PS | | MA (Clarion) |
| <i>Pectinaster agassizii</i> (Ludwig, 1905) (4) | MA | MA MB SO PS | | |
| <i>Odontaster crassus</i> Fisher, 1905 | MA | MA MB | | |
| <i>Radiaster</i> sp. nov. | | PS | | |
| <i>Ceramaster leptoceramus</i> (Fisher, 1905) | MA | PS | MA | |
| <i>Ceramaster grenadensis patagonicus</i> Sladen, 1889 | | MA MB | | |
| <i>Cryptopeltaster lepidonotus</i> Fisher, 1905 | | MA MB | | |
| <i>Mediaster tenellus</i> Fisher, 1905 | | | MA | |
| <i>Mediaster transfuga</i> Ludwig, 1905 (5) | | PS | TL | |
| <i>Nymphaster diomedae</i> Ludwig, 1905 | | MA MB PS | | |
| <i>Pseudarchaster pectinifer</i> Ludwig, 1905 | MA | MA MB | | |
| <i>Pseudarchaster pulcher</i> Ludwig, 1905 | | | MA | |
| <i>Pseudarchaster pusillus</i> Fisher, 1905 | MA | MA MB | | |
| <i>Anthenea mexicana</i> A.H. Clark, 1916 (6) | ? | ? | ? | |
| <i>Lophaster furcilliger</i> Fisher, 1905 (7) | MA | PS | | |
| <i>Lophaster validus</i> (Ludwig, 1905) (7) | | MA MB | | |
| <i>Peribolaster biserialis</i> Fisher, 1905. | | PS | | |
| <i>Pythonaster pacificus</i> Downey, 1979 | MA | | | |

Table 1. Continues

| <i>Species</i> | <i>CC</i> | <i>GC</i> | <i>SWM</i> | <i>OI</i> |
|---|-----------|-----------|------------|-------------|
| <i>Hymenaster pellucidus</i> W. Thomson, 1873 | MA | | | |
| <i>Hymenaster quadrispinosus</i> Fisher, 1905 | MA | | | |
| <i>Hymenaster violaceus</i> Ludwig, 1905 | | | MA | |
| <i>Pteraster jordani</i> Fisher, 1905 | MA | | | |
| <i>Poraniopsis inflatus</i> Fisher, 1906 | MA | | | |
| <i>Henricia aspera</i> Fisher, 1906 | MA | MA? MB | | |
| <i>Henricia asthenactis</i> Fisher, 1905 | | MA MB | | |
| <i>Henricia clarki</i> Fisher, 1910 | HE | MA MB SO | | MA HE (Rev) |
| <i>Henricia gracilis</i> (Ludwig, 1905) | | MA MB | | |
| <i>Henricia polyacantha</i> Fisher, 1906 | MA | MA MB | | |
| <i>Henricia seminuda</i> (A.H. Clark, 1906) | | | | MA HE (Rev) |
| <i>Henricia</i> sp. 1 | | PS | | |
| ? <i>Henricia</i> sp. 2 | | PS | | |
| <i>Cnemidiaster nudus</i> (Ludwig, 1905) | MA | MA MB SO | | |
| <i>Myxoderma platyacanthum</i> (H.L. Clark, 1913) | MA MC | MC | | |
| <i>Myxoderma sacculatum</i> (Fisher, 1905) | MA | SO PS | | |
| <i>Myxoderma longispinum</i> (Ludwig, 1905) (8) | | PS | | |
| <i>Myxoderma qawashqari</i> (Moyana & Larrain Prat, 1976) | | MA MB SO | | |
| <i>Sagenaster evermanni</i> (Fisher, 1905) (9) | | MC | | |
| <i>Zoroaster actinocles</i> Fisher, 1919 | MC | | | |
| <i>Zoroaster hirsutus</i> Ludwig, 1905 | MC | SR | MA MC | |
| <i>Zoroaster ophiurus</i> Fisher, 1905 | MA MC | | | |
| <i>Ampheraster chiroplus</i> Fisher, 1928 | | PS | | |
| <i>Ampheraster hyperoncus</i> (H.L. Clark, 1913) | MA | PS | | |
| <i>Ampheraster marianus</i> (Ludwig, 1905) | | MA MB MC | | |
| <i>Anteliaster coscinactis</i> Fisher, 1923 | MA | PS | | |
| <i>Rathbunaster californicus</i> Fisher, 1906 | HE | MA? SO | | |
| <i>Astrolirus panamensis</i> (Ludwig, 1905) | MA | MA MB | | |

- (1) To 476 m depth.
- (2) Cited as *Eremicaster crassus* by Maluf and Brusca (2005) and Honey-Escandon et al. (2008).
- (3) Unconfirmed record. See Maluf (1988:116) for details.
- (4) Cited as *Cheiraster agassizii* by Solís-Marín et al. (2005).
- (5) Included in the synonymy of *M. tenellus* by Maluf (1988).
- (6) Unknown locality off Mexico.
- (7) The status of these species and of *L. furcifer* (Duben and Koren, 1846) needs to be reviewed.
- (8) Cited as *Zoroaster longispinus* (Maluf, 1988; Maluf and Brusca, 2005).
- (9) Cited by Maluf (1988) as *Zoroaster evermanni*.

Results

A total of 335 specimens were collected during the survey, belonging to 18 species in 17 genera in 9 families. This collection is among the largest for the west coast of Mexico since the “Albatross” made her exploratory survey in the region.

Order Paxillosida
 Family Astropectinidae
Dipsacaster laetmophilus Fisher, 1910

Fig. 1A, B
Dipsacaster laetmophilus Fisher, 1910b: 546 (key), 547; Fisher, 1911b: 86 (key), 95, pl. 12, fig. 3, pl. 15, figs. 1, 2, pl. 52, figs. 3, 3a, 3b, pl. 53, fig. 2.

Taxonomic summary

Material examined. TALUD III, St. 14A (24°38'48"N, 108°26'54"W), 19/August/1991, two specimens (R= 58.1-

66.6 mm, $r = 19.0\text{--}22.7$ mm), Agassiz dredge, 1016-1020 m (EMU-8963).

TALUD VIII, St. 16 (25°24'24"N, 110°37'36"W), 18/April/2005, two specimens ($R = 13.9\text{--}25.9$ mm, $r = 6.7\text{--}11.6$ mm), bottom sledge, 1030m (EMU-8964).

TALUD X, St. 10 (27°50'06"N, 112°10'06"W), one specimen ($R = 97.1$ mm, $r = 31.4$ mm), 10/Feb/2007, bottom sledge, 1399-1422 m (EMU-8962) (Fig. 2 A).

Previous records in Mexico. None.

Distribution and ecology. According to Fisher (1911b), this species was known only from the type locality, between Unalaska and Kodiak, USA, in depth of 1 272 m (695 fms.). Carey (1972) reported a closely related species, *D. anoplus*, as omnivorous, feeding on bivalves, gastropods, ophiuroids, crustaceans, polychaetes and some sediment. The material collected during this study (in depths of 1 030-1 422 m) was obtained within the known depth range of this species. Epibenthic temperature and dissolved oxygen concentration: 3.19-5.00°C and 0.20-0.44 ml O₂/l (this study).

Remarks

Four species of *Dipsacaster* occur in the North Pacific and adjacent regions as listed by Fisher (1911b). Of these 4, Maluf (1988) shows *D. eximius* as occurring south from Monterey to Guaymas. Little is known regarding morphological boundaries between *Dipsacaster* species. Variation between species due to size and other factors are poorly understood and diagnostic characters for species were based on adults. Although specimens reported herein conform with descriptions of *D. laetmophilus*, this species is known only from the unique holotype. Further comparisons with a full size and distribution range of specimens in conjunction with additional revision work are needed.

Thrissacanthias penicillatus (Fisher, 1905)

Fig. 1C, D

Persephonaster penicillatus Fisher, 1905: 297.

Thrissacanthias penicillatus.- Fisher, 1910a: 171; 1911b: 79, pl. 17, fig. 4, pl 18, figs. 1-5, pl. 53, figs. 1, 1a, 1b, 1d,

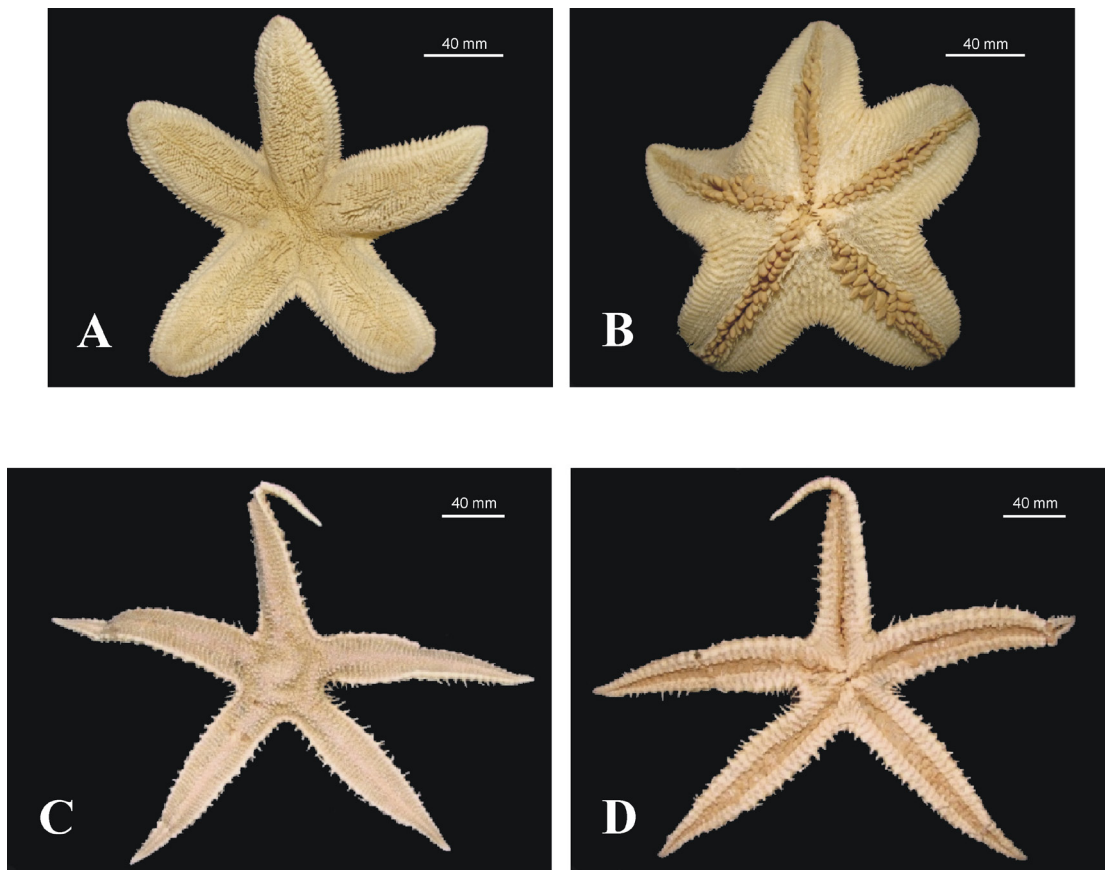


Figure 1. Paxillosoidea. A. *Dipsacaster laetmophilus* Fisher, 1910, aboral view. B. Same, oral view. C. *Thrissacanthias penicillatus* (Fisher, 1905), aboral view. D. Same, oral view.

1e; 1930: 190 (list).- H. L. Clark, 1913: 190; 1923: 149.- Ziesenhenné, 1937: 212.- Alton, 1966: 1696.- Blake, 1973: 45.- Muscat, 1980: 264.- Luke, 1982: 9.- Maluf, 1988: 30 (table), 116 (list).- Maluf and Brusca, 2005: 329 (list).

Taxonomic summary

Material examined. TALUD III, St. 14A (24°38'48"N, 108°26'54"W), 19/August/1991, one specimen (R= 109.9 mm, r= 26.2 mm), Agassiz dredge, 1016-1020 m (EMU-8965).

TALUD III, St. 24A (25°45'12"N, 109°46'48"W), 24/August/1991, one specimen (R= 108.1 mm, r= 17.9 mm), Agassiz dredge, 1027-1060 m (EMU-8966).

TALUD V, St. 19 (24°16'N, 108°24W), 15/December/2000, one specimen (R= 94.7 mm, r= 17.8 mm), bottom sledge, 1180-1200 m (EMU-8967).

TALUD VIII, St. 3 (24°31'42"N, 109°29'36"W), 16/April/2005, one specimen (R= 2.9 mm; r= 1.4 mm), bottom sledge, 1100 m (EMU-8968).

TALUD VIII, St. 16 (25°24'24"N, 110°37'36"W), 18/April/2005, three specimens (R= 11.2-12.8 mm; r= 3.5-3.6 mm), bottom sledge, 1030 m (EMU-8969A, B).

TALUD VIII, St. 20 (25°56'24"N, 110°43'06"W), 19/April/2005, one specimen (R= 6.4 mm, r= 2.5 mm), bottom sledge, 1150 m (EMU-8970) (Fig. 2A).

Previous records in Mexico. Type locality, "Albatross" St.

4380 (32°26'00"N, 117°18'00"W), off Los Coronados Islands, in depths of 970-1168 m (530-638 fms.). Santa Inés Bay, east coast of the Baja California Peninsula (Ziesenhenné, 1937). Off San Pedro Island (27°40'N, 111°22'36"W), 931-952 m depth (Luke, 1982) (Fig. 2A).

Distribution and ecology. From Washington, USA, to Santa Inés Bay, Gulf of California, Mexico. From 55-1 503 m (Maluf, 1988). Present records are from both coasts of the southern Gulf of California, thus confirming the presence of this species in the area. The material collected during this study (in depths of 1 016-1 200 m) was obtained within the known depth range of this species. Carey (1972) identified this species as a predator following the recognition of bivalves, gastropods, echinoids, ophiuroids, crustaceans, and scaphopods from gut contents. Epibenthic temperature and dissolved oxygen concentration: 5.0°C (41.1°F) ("Albatross" St. 4380); 3.00-5.00°C and 0.20-0.40 ml O₂/l (this study).

Remarks

H. L. Clark (1913) provided several records of *T. penicillatus* for California ("Albatross" stations), at depths of 805-1 206 m (440-659 fms.) and epibenthic temperatures of 3.27-4.38 °C (37.9-39.9°F). The record of Ziesenhenné (1937) for Santa Inés Bay corresponds to young specimens taken in depth of 55-64 m (30-35 fms.),

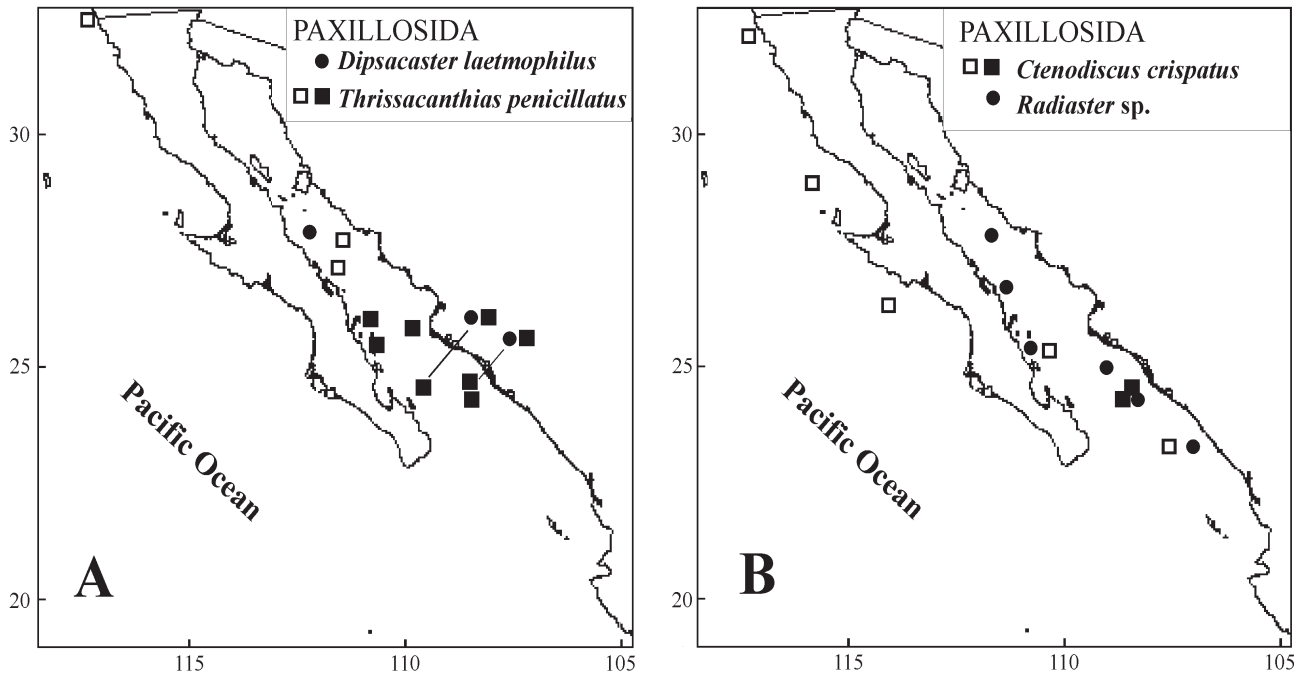


Figure 2. Distribution of examined species of Paxillosida off the Pacific coast of Mexico, including previous records (open symbols) and localities where material was collected during the TALUD survey (solid symbols).

and represents the upper bathymetric limit reported by Maluf (1988) for this species. All other records available for *T. penicillatus* are in much deeper water. The Santa Inés area was sampled extensively in 1982 and 1985, at depths between 23 -101 m (see Hendrickx and Salgado-Barragán, 1991) and this species was never collected in this region. Furthermore, the presence of an OMZ at water deeper than 100-150 m in this area represents a distributional barrier between the continental shelf and the upper slope fauna (see Hendrickx and Serrano, 2010). It seems therefore reasonable to consider this Santa Inés, shallow-water record as erroneous.

Family Ctenodiscidae

Ctenodiscus crispatus (Retzius, 1805)

Fig. 3A, B

Asterias crispatus Retzius, 1805: 17.

Ctenodiscus krauseri Ludwig, 1905: 293 (Bering Sea).

Ctenodiscus procurator Sladen, 1889: 173, 174, pl. XXX, figs. 7-12 (between 45 and 53°S, W South America).- Madsen, 1956: 16.

Ctenodiscus crispatus.- Ludwig, 1905: 104, pl. VI, figs. 32, 33.- Fisher, 1911b: 31, pl. 3, figs. 1-4, pl. 4, figs. 1-6; 1930: 188 (list).- H. L. Clark, 1913: 188; 1920: 78.- Alton, 1966: 1695.- Luke, 1982: 10.- Maluf, 1988: 32 (table), 117 (list).- Maluf and Brusca, 2005: 329.- Solís-Marín et al., 2005: 125.- Honey-Escandón et al., 2008: 60.

Taxonomic summary

Material examined. TALUD IV, St. 21 (24°29'06"N, 108°56'12"W), 25/August/2000, one specimen (R= 37.0 mm, r= 13.9 mm), bottom sledge, 2170-2320 m (EMU-8979).

TALUD V, St. 20 (24°14'42"N, 108°35'18"W), 15/December/2000, one specimen (R= 20.5 mm, r= 9.7 mm), bottom sledge, 1470-1525 m (EMU-8980) (Fig. 2 B).

Previous records in Mexico. "Albatross" St. 3430 (23°16'N, 107°31'W), Gulf of California, 1558 m (Ludwig, 1905). "Albatross" St. 5686, off Ballenas Bay (26°14'N, 114°W), 1680 m (930 fms.) (H. L. Clark, 1913). Off Descanso Bay (32 05'12"N, 117 14'W) and off N of Cedros Island (28 55'18"N, 115 45'54"W), Baja California; Gulf of California (25 18'N, 110 19'30"W); in depths of 1244-1908 m (Luke, 1982). Records by Solís-Marín et al. (2005) and Honey-Escandón et al. (2008) correspond to material collected by the "Albatross" (Solís-Marín, pers. comm.) (Fig. 2 B).

Distribution and ecology. Bering Sea, Alaska, USA, to Punta Mariato (Coiba), Panama; Arctic, Japan, North Atlantic, in depths of 73-2 423 m (Maluf, 1988; Maluf and Brusca, 2005) and 10-1 890 m (A. M. Clark, 1989). *C. crispatus* is

an abundant infaunal species, which non-selectively feeds on organic rich sediment and occurs on muddy bottoms (see Shick et al., 1981; Carey, 1972). Epibenthic temperature and dissolved oxygen concentration: 3.28°C (Ludwig, 1905); 2.94°C (37.3°F) (H. L. Clark, 1913); 2.40-2.80°C and 1.20-1.82 ml O₂/l (this study).

Remarks

Classification of *C. crispatus* follows the classification of Blake (1987) who separated *Ctenodiscus* from the Gonioplectinidae. The material of the "Albatross" examined and reported by Ludwig (1905) is from the Gulf of Panama and the Gulf of California (young specimens). *Ctenodiscus* occurs widely around the world, with 2 other similar species, *C. procurator* and *C. australis* occurring in the South Atlantic and Magellanic regions.

Family Radiasteridae

Radiaster sp.

Fig. 3C, D

Taxonomic summary

Material examined. TALUD IV, St. 25 (24°53'12"N, 108°59'24"W), 26/August/2000, three specimens (R= 22.0-32.1 mm, r= 7.1-11.0 mm), benthic sledge, 835-870 m (EMU-8957).

TALUD V, St. 11 (23°15'N, 106°59'W), 18/December/2000, two specimens (R= 27.9-30.1 mm, r= 9.1-9.3 mm), benthic sledge, 860 m (EMU-8956).

TALUD VI, St. 18 (24°14'54"N, 108°16'12"W), 15/March/2001, five specimens (R= 27.1-32.9 mm, r= 8.5-9.8 mm), benthic sledge, 890-950 m (EMU-8959).

TALUD IX, St. 17 (25°20'54"N, 110°46'24"W), 12/November/2005, 41 specimens (R= 7.8-30.9 mm, r= 3.36-10.74 mm) (EMU-8956A, B), and three specimens (R= 22.3-25.0 mm; r= 7.2-8.1 mm) (USNM-1146557/567), benthic sledge, 826-846 m.

TALUD X, St. 14. (27°44'48"N, 111°36'54"W), 11/February/2007, 53 specimens (R= 5.3-31.2 mm, r= xx mm) (EMU-8961A, B), and three specimens (R= 25.3-29.6 mm, r= 9.1-10.3 mm) (USNM-1146564/558), benthic sledge, 905-943 m.

TALUD X, St. 25 (26°39'06"N, 111°18'18"W), 14/February/2007, six specimens (R= 9.4-18.9 mm, r= 3.5-6.7 mm), benthic sledge, 837-840 m (EMU-8960) (Fig. 2B).

Previous records in Mexico. None for this genus. Not reported for the central eastern Pacific by Maluf (1988) or by subsequent authors.

Distribution and ecology. Widely distributed off the east coast of the Gulf of California, roughly from 23°15'N

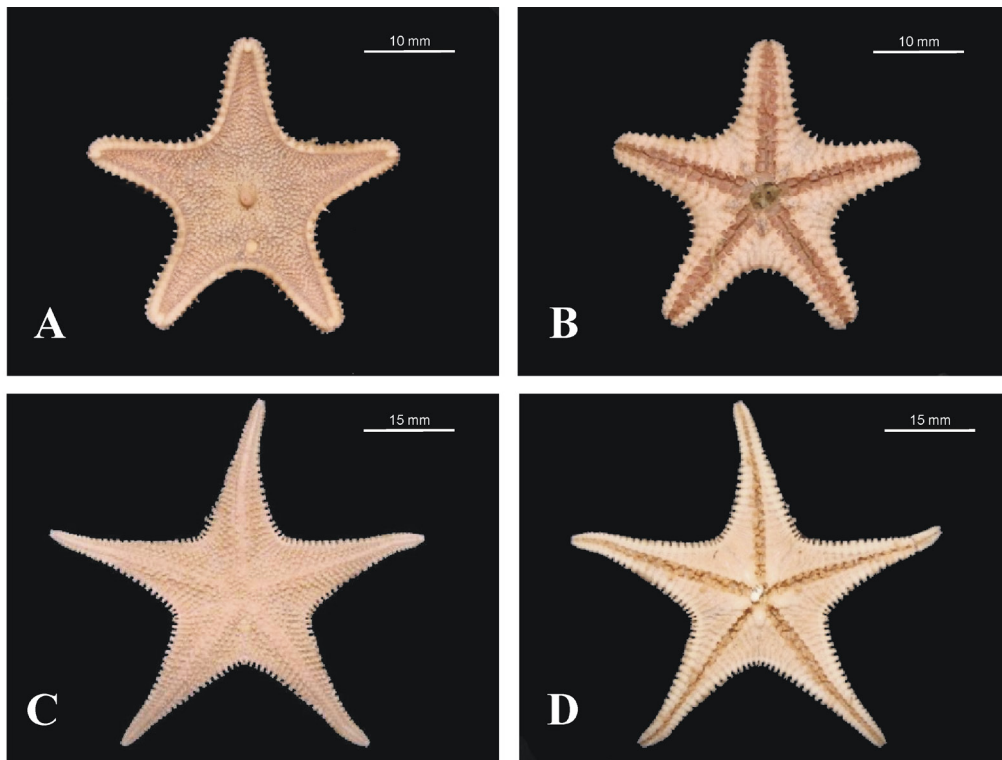


Figure 3. Paxillosida. A. *Ctenodiscus crispatus* (Retzius, 1805), aboral view. B. Same, oral view. C. *Radiaster* sp. nov., aboral view. D. Same, oral view.

(off Mazatlán) to 27°45'N (off Guaymas). The material collected during this study is from depths of 826-950 m. Epibenthic temperature and dissolved oxygen concentration: 4.64-5.40°C and 0.07-0.29 ml O₂/l.

Remarks

The specimens of *Radiaster* reported belong to a new species that will be described in a forthcoming paper when a comprehensive revision of material belonging to other species of this genus is completed.

Order Notomyotida

Family Benthoptectinidae

Nearchaster aciculosus (Fisher, 1910)

Fig. 4A, B

Acantharchaster aciculosus Fisher, 1910b: 549 (key), 550.

Saraster insignis A. H. Clark, 1916: 54.

Nearchaster aciculosus .- Fisher, 1911a: 91 (*A. aciculosus*, type species of the genus), 92, figs. 1, 3, 5; 1911b: 133, pl. 24, fig. 1, pl. 26, figs. 1-3, pl. 55, figs. 1, 1a, 1b, pl. 56, fig. 3, pl. 118, fig. 3; 1930: 191 (list).- H. L. Clark, 1913: 191.- Alton, 1966: 1699.- Muscat, 1980: 264.- Luke,

1982: 12.- Maluf, 1988: 33 (table), 117 (list).

Taxonomic summary

Material examined. TALUD V, St. 19 (24°16'24"N, 108°24'18"W), 15/December/2000, five specimens (R= 41.9-58.5 mm, r= 5.3-7.3 mm), bottom sledge, 1180-1200 m (EMU-8996A, B).

TALUD V, St. 25 (24°51'42"N, 108°57'54"W), 16/December/2000, one specimen (R= 46.6 mm, r= 5.8 mm), bottom sledge, 800-860 m (EMU-8997).

TALUD IX, St. 17 (25°20'54"N, 110°46'24"W), 13/November/2005, 14 specimens (R= 9.7-48.9 mm, r= 1.7-4.9 mm), bottom dredge, 826-846 m (EMU-8998).

TALUD X, St. 10 (27°50'06"N, 112°10'06"W), 10/February/2007, six specimens (R= 82.5-191.0 mm, r= 11.2-22.1 mm), bottom sledge, 1399-1422 m (EMU-8999A, B).

TALUD X, St. 14 (27° 44'48" N, 111° 36'54" W), 11/February/2007, 75 specimens (R= 19.7-57.7 mm, r= 2.9-7.1 mm) (EMU-9000A, B), three specimens (R= 34.9-39.7 mm, r= 4.2-5.1 mm) (ICML-UNAM 2.203.0), and three specimens (R= 28.9-41.6 mm, r= 5.2-6.2 mm) (USNM-

1146560), bottom sledge, 905-943 m.

TALUD X, St. 25 (26°39'04"N, 111°18'20"W), 14/February/2007, six specimens (R= 16.3-47.5 mm, r= 2.8-6.0 mm), bottom sledge, 837-840 m (EMU-9001) (Fig. 5). *Previous records in Mexico.* "Albatross" St. 5688 (27°38'5"N 115°17'40"W), of Cedros Island, Baja California, 960 m (525 fms.) (H. L. Clark, 1913); St. 2992, off Clarion Island, 842 m (460 fms.) (A. H. Clark, 1916; as *Saraster insignis*); St. 4381 (32°26'00"N 117°18'0"W) (ca Coronados I.) (Fisher, 1911b) (Fig. 5).

Distribution and ecology. Type locality between San Diego and San Clemente Island, California, USA, 992 m (542 fms.). Alaska Peninsula, USA to off Clarion Island, Mexico, in 466-1 903 m (Maluf, 1988). The material collected during this study (in depths of 837-1 422 m) was obtained within the known depth range of this species. This increases the distribution range of this species to the southern and central Gulf of California. Epibenthic temperature and dissolved oxygen concentration: 4.38°C (39.9°F) (H. L. Clark, 1913); 3.19-5.75°C and 0.03-0.44 ml O₂/l (this study).

Remarks

Nearchaster forms a wide-ranging species complex that includes the more southern ranging *N. aciculosus* with *N. variabilis* and *N. pedicellaris* ranging north to the Sea of Okhotsk.

Pectinaster agassizii (Ludwig, 1905)

Fig. 4C, D

Cheiraster agassizii Ludwig, 1905: 1, pl. I, figs. 3, 4, pl. II, figs. 5-12, pl. XVI, figs. 81-84.

Cheiraster agassizii evoplus Fisher, 1910b: 551 (off San Diego, California).

Pectinaster agassizii.- Ludwig, 1910 : 449.- H. L. Clark, 1913: 191; 1920: 82; 1923: 149.- Maluf, 1988: 33 (table), 117 (list); 1991: 348 (list).- Maluf and Brusca, 2005: 330 (list).

Pectinaster agassizi.- Luke, 1982: 13.

Pectinaster agassizi evoplus.- Fisher, 1911b: 123, pl. 28, figs. 1, 2, pl. 55, figs. 4, 4a, pl. 57, fig. 1; 1930: 191 (list).- Alton, 1966: 1697.- Luke, 1982: 13.

Cheiraster agassizii.- Solís-Marín et al., 2005: 125.

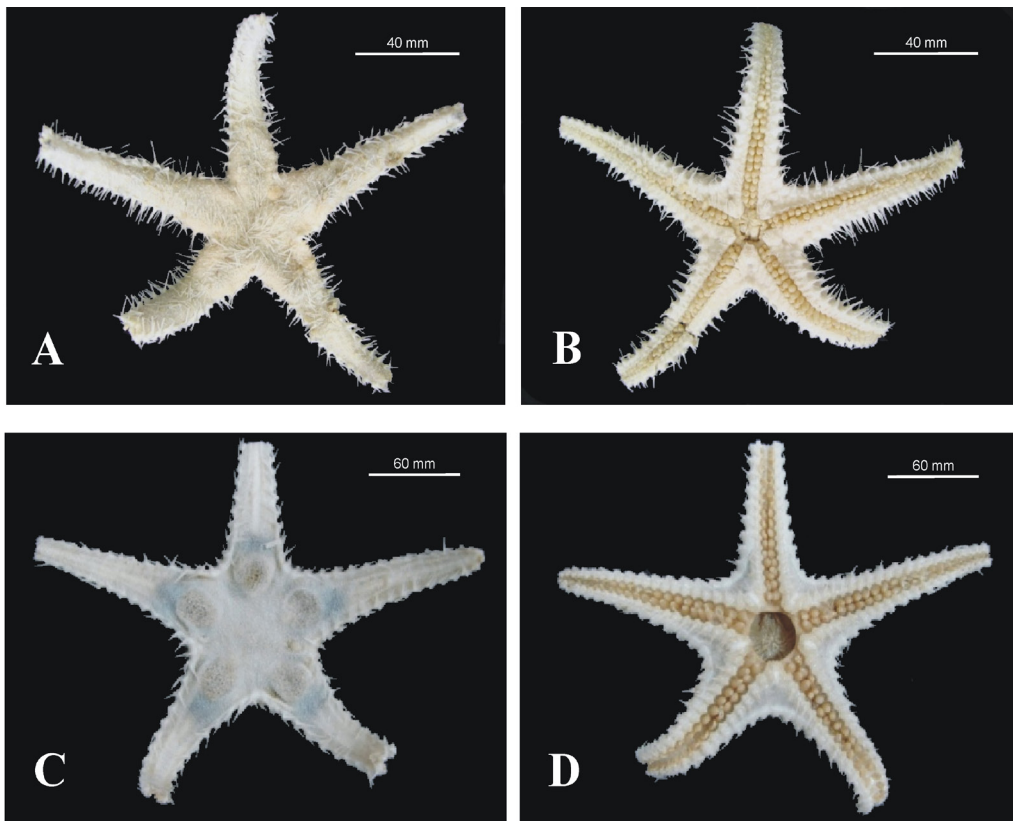


Figure 4. Notomyotida. A. *Nearchaster aciculosus* (Fisher, 1910), aboral view. B. Same, oral view. C. *Pectinaster agassizii* (Ludwig, 1905), aboral view. D. Same, oral view.

Taxonomic summary

Material examined. TALUD IV, St. 19 (24°15'18"N, 108°24'06"W), 25/August/2000, one specimen (R= 60.9 mm, r= 12.0 mm), bottom sledge, 1240-1245 m (EMU-9002).

TALUD IV, St. 34 (25°40'41"N, 109°54'24"W), 27/August/2000, one specimen (R= 84.6 mm, r= 13.7 mm), bottom sledge, 1240-1250 m (EMU-9003).

TALUD X, St.18 (27°09'06"N, 111°46'54"W), 12/February/2007, two specimens (R= 94.5-155.5 mm, r= 16.3-16.5 mm), bottom sledge, 1526 m (EMU-9004A, B) (Fig. 5).

Previous records in Mexico. "Albatross" Sts. 3431 (23°59'N, 108°40'W) and 3435 (26°48'N, 110°45'W), Gulf of California, 1271-2323 m depth (Ludwig, 1905). Off Punta Santo Tomas ("Albatross" Sts.: 5673, 31°26'N, 117°42'W; 5674, 31°28'45"N, 117°09'50"W; and 5692, 31°23'45"N, 118°31'30"W); off Ballenas Bay (Sts. 5686, 26°14'N, 114°W; and 5689, 29°23'N, 116°14'W); and off Rosario Bay (St. 5690, 29°29'N, 116°18'W), Baja California, in depths of 1080-1995 m (590-1090 fms.) (H. L. Clark, 1913).

Off Descanso Bay (32°05'12"N, 117°14'W), N. of Cedros Island (28 55'18"N, 115 45'54"W), and off San Hipolito Bay (26°26'12"N, 114°07'06"W), Baja California, in depths of 1244-2136 m; SW of Cabo San Lucas (22°42'30"N, 110°21'W; 22°45'N, 110°23'W), Baja California Sur, in depths of 1893-2014 m (as *P. agassizi evoplus*) (Luke, 1982). Gulf of California (25°18'N, 110°19'30"W), in depths of 1244-1908 m (Luke, 1982). The record off Baja California Sur, Gulf of California by Solís-Marín et al. (2005) corresponds to material collected by the "Albatross" (Solís-Marín, pers. comm.) (Fig. 5).

Distribution and ecology. Syntypes from Panama, off the Cocos and Galapagos Islands, and in the Gulf of California. Southern California Borderland to Panama (Punta Mariato), and off the Galapagos, Coco, and Malpelo Islands; Indian Ocean. At depths: 790-2 323 m (Maluf, 1988; Maluf and Brusca, 2005). Off northern Oregon (Alton, 1966). The material collected during this study (in depths of 1 240-1 526 m) was obtained within the known depth range of this species. Other species of *Pectinaster* are recorded as feeding primarily on sediment, mollusks and crustaceans (Carey, 1972). Epibenthic temperature and dissolved oxygen concentration: 2.39-3.8°C (Ludwig,

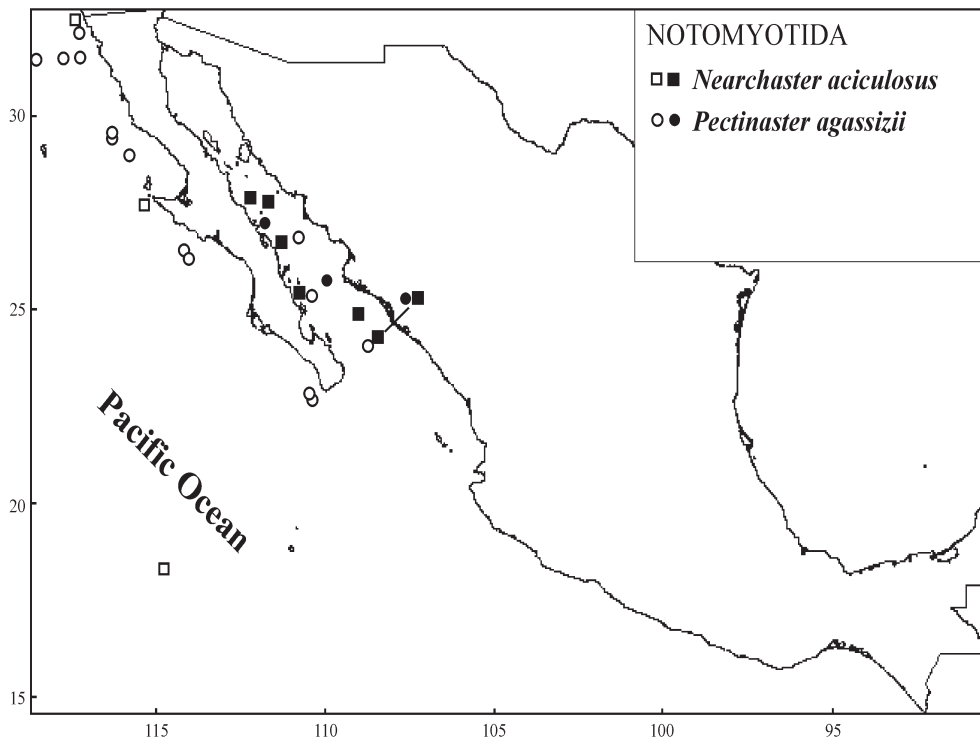


Figure 5. Distribution of examined species of Notomyotida off the Pacific coast of Mexico, including previous records (open symbols) and localities where material was collected during the TALUD survey (solid symbols).

1905); 2.83-4.11°C (37.1-39.4°F) (H. L. Clark, 1913); 3.17-3.69 °C and 0.59-0.79 ml O₂/l (this study).

Remarks

Similar to *Nearchaster*, species in *Pectinaster* are wide-ranging but generally very similar in morphology, suggesting that they are all part of a broadly distributed species complex (Fisher, 1911b). Morphological boundaries between species across a range can often be difficult to distinguish.

Order Valvatida

Family Goniasteridae

Ceramaster leptoceramus (Fisher, 1905)

Fig. 6A, B

Tosia leptoceramata Fisher, 1905: 306

Ceramaster leptoceramus.- Fisher, 1911b: 206 (key), 210, pl. 39, figs. 1-3, pl. 58, figs. 3, 3a, pl. 60, fig. 2; 1930: 192 (list).- H. L. Clark, 1913: 193; 1923: 150.- Blake, 1973: 51.- Muscat, 1980: 264.- Luke, 1982: 14.- Maluf, 1988: 33 (table), 118 (list).

Taxonomic summary

Material examined. TALUD IV, St. 25 (24°51'42"N, 108°57'54"W), 26/August/2000, one specimen (R= 13.6 mm, r= 7.5 mm), bottom sledge, 789 m (EMU-8986).

TALUD V, St. 18 (24°15'12"N, 108°17'06"W), 15/December/2000, one specimen (R= 40.6 mm, r= 26.1 mm), bottom sledge, 940-990 m (EMU-8987).

TALUD VIII, St. 16 (25°24'24"N, 110°37'36"W), 18/April/2005, one specimen (R= 18.5 mm, r= 13.3 mm), bottom sledge, 1030 m (EMU-8988).

TALUD X, St. 4 (28°16'06"N, 112°32'48"W), 9/February/2007, five specimens, (R= 8.0-30.4 mm, r= 5.4-16.9 mm) (EMU-8990A, B), two specimens (R= 11.5-12.1 mm, r= 8.0 mm) (ICML-UNAM 2.183.1), and three specimens (R= 15.3-22.3 mm, r= 9.1-13.0 mm) (USNM-1146563), bottom sledge, 587-633 m (Fig. 7).

Previous records in Mexico. "Albatross" St. 5675 (27°07'08"N 114°33'10"W), SW off San Cristobal Bay, Baja California, 520 m (284 fms.). Off Salina Cruz (14°50'N, 96°15'W), Gulf of Tehuantepec, 1042-1134 m depth (Luke 1982) (Fig. 7).

Distribution and ecology. Type locality, "Albatross" St. 4378 (32°42'0"N 117°14'0"W), off Point Loma, San Diego, California, USA, 688-1 087 m (376-594 fms.). From Conception Point, California, USA, to off Chicama, Chile, in depths of 366-1 811 m (Maluf, 1988). Present records extend the distribution of this species to the SE, SW and central Gulf of California, in depths

of 587-1 030 m. Epibenthic temperature and dissolved oxygen concentration: 7°C (44.6°F) (H. L. Clark, 1923); 5.00-8.22°C and 0.15-0.38 ml O₂/l (this study).

Remarks

This species appears to be 1 of several *Ceramaster* spp. occurring in the North Pacific, including *C. japonicus* (Sladen, 1889), *C. patagonicus* (Sladen, 1889), *C. clarki* Fisher, 1910, and *C. arcticus* (Verrill, 1909) which may form a species complex along the continental shelf of North America. However, Fisher (1911) noted that *C. leptoceramus* showed no intergradation with *C. japonicus*. Further sampling to show the range of *Ceramaster* along the coast is needed.

Mediaster transfuga Ludwig, 1905

Fig. 6C, D

Mediaster transfuga Ludwig, 1905: 120, pl. VIII, figs. 44, 45, pl. XXII, figs. 122-125, pl. XXV, figs. 139-141.

Mediaster tenellus.- Maluf, 1988: 34 (table), 118 (list) (part, the record of *M. transfuga*).

Taxonomic summary

Material examined.- TALUD IV, St.25 (24°53'12"N, 108°59'24"W), 26/August/2000, one specimen (R= 43.5 mm, r= 11.1 mm), bottom sledge, 778-800 m (EMU-8993).

TALUDV, St. 11 (23°15'N, 106°59'W), 18/December/2000, two specimens (R= 47.4-54.2 mm, r= 12.6-17.0 mm), bottom sledge, 860 m (EMU-8994) (Fig. 7).

Previous records in Mexico. Type locality, "Albatross" St. 3417 (16°32'N, 99°48'W), off Guerrero, 902 m depth (Fig. 7).

Distribution and ecology. *M. transfuga* is known from the type locality, at 902 m depth. The material collected during this study was obtained in depths of 778-860 m and extends its distribution range to the SE Gulf of California. Epibenthic temperature and dissolved oxygen concentration: 4.8°C (Ludwig, 1905); 5.03-5.40°C and 0.07-0.29 ml O₂/l (this study).

Remarks

Material described herein conforms to the description of *M. transfuga* as described by Ludwig (1905). *M. transfuga* was thought by Fisher (1911b) to intergrade with the closely related *Mediaster tenellus*, possibly forming different morphological extremes of the same species. Maluf (1988) considered *M. transfuga* a synonym of *M. tenellus* whereas A. M. Clark's checklist (1913)

retained the 2 species as separate. *M. transfuga* specimens examined herein showed a more weakly calcified body wall and slight differences from *M. tenellus* but several, including those listed by Fisher (1911b), are clearly shared. *M. transfuga* may represent a deeper-water form of *M. tenellus*, although a full revision of *Mediaster* spp., especially for those taxa in this region, is needed to fully address the question.

Nymphaster diomedea Ludwig, 1905

Fig. 6E, F

Nymphaster diomedea Ludwig, 1905: 128, pl. X, figs. 48, 49, 52, 53, pl. XI, figs. 54, 55.

Nymphaster diomedea.- Fisher, 1928b: 490.- Maluf, 1988: 34 (table), 118 (list); 1991: 349 (list).- Maluf and Brusca, 2005: 331 (list).

Taxonomic summary

Material examined. TALUD VII, St. 13b (23°30'18"N, 107°44'W), 6/June/2001, 2 specimens (R= 19.9-47.5 mm, r= 6.2-19.3 mm), bottom sledge, 1400-1450 m (EMU-8995A, B) (Fig. 7).

Additional material. TALUD VI, St. 19 (24°16'18"N, 108°24'18"W), 15/March/2001, one specimen (R= 13.2 mm, r= 3.3 mm), bottom sledge, 1160-1200 m. Uncatalogued.

Previous records in Mexico. Off Punta Piaxtla, SE Gulf of California, Mexico (Maluf, 1988). This is the only record provided by Maluf (1988) for the Gulf of California, and it certainly corresponds to material of the Allan Hancock Foundation presently deposited in the Natural History Museum of Los Angeles County. Data from this collection are: off Río Elata (=“Río Elota”, close to Punta Piaxtla), Sinaloa, Mexico, between 23°40'30" N, 107°38'30" W, and 23°37'00" N, 107°51'48" W, 1367-1385 m (747-757 fms.) (Gordon Hendler, pers. comm.) (Fig. 7).

Distribution and ecology. Syntypes from Panama, and off the Cocos and the Galapagos Islands. Known only from the southern Gulf of California to the Gulf of Panama and the Galapagos Ridge, found in depths of 702-1 618 m (Ludwig, 1905; Maluf, 1988; Maluf and Brusca, 2005). The material collected during this study (in depths of 1 160-1 450 m) was obtained within the known depth range of this species and confirms the previous record along the SE coast of the Gulf of California. Epibenthic temperature and dissolved oxygen concentration: 2.89-6.28°C (Ludwig, 1905); 3.00-3.70°C and 0.73-1.04 ml O₂/l (this study).

Remarks

This is one of the few records available for this species.

Fisher (1928b) cited 1 specimen from south of Cocos Island, in 1 144 m (625 fms.) depth. This species may be closely related to the North Atlantic *Nymphaster arenatus* (Perrier, 1881), as separated from the East Pacific by the Panamanian Isthmus.

Order Spinulosida
Family Echinasteridae
Henricia sp. 1

Taxonomic summary

Material examined. TALUD VIII, St. 11 (24° 54.5' N, 110° 25.5' W), 17/April/2005, one specimen (R= 6.2 mm; r= 1.9 mm), bottom sledge, 920 m (EMU-9009).

TALUD X, St. 4 (28°16'06"N, 112°32'48"W), 9/February/2007, seven specimens (R= 9.9-31.8 mm; r= 2.0-6.7 mm), bottom sledge, 587-633 m (EMU-9010A) (Fig. 8).

Remarks

According to Maluf (1988: 42, 43) there are 8 species of *Henricia* known to the central eastern Pacific, all except *H. nana* (Ludwig, 1905) with at least 1 record in Mexican waters. *Henricia* represents a highly diverse, but morphologically difficult group with a widespread distribution. In addition to upcoming molecular revision for this group (Eernisse et al., pers. comm.), there are problematic boundaries for several of the species listed as occurring in this region by Maluf (1988). The shallow-water *H. leviuscula* (Stimpson, 1857), for example, represent up to 4 different cryptic species (Eernisse and Strathmann, pers. comm., 2005). Thus full descriptions of these 2 species should accompany the monograph for *Henricia* in this region.

Henricia sp. 2

Taxonomic summary

Material examined. TALUD X, St. 4 (28°16'06"N, 112°32'48"W), four specimens (R= 41.3-43.6 mm; r= 6.7-7.4 mm), 9/February/2007, benthic sledge, 587-633 m (EMU-9011A) (Fig. 8).

Remarks

See above.

Order Velatida
Family Solasteridae

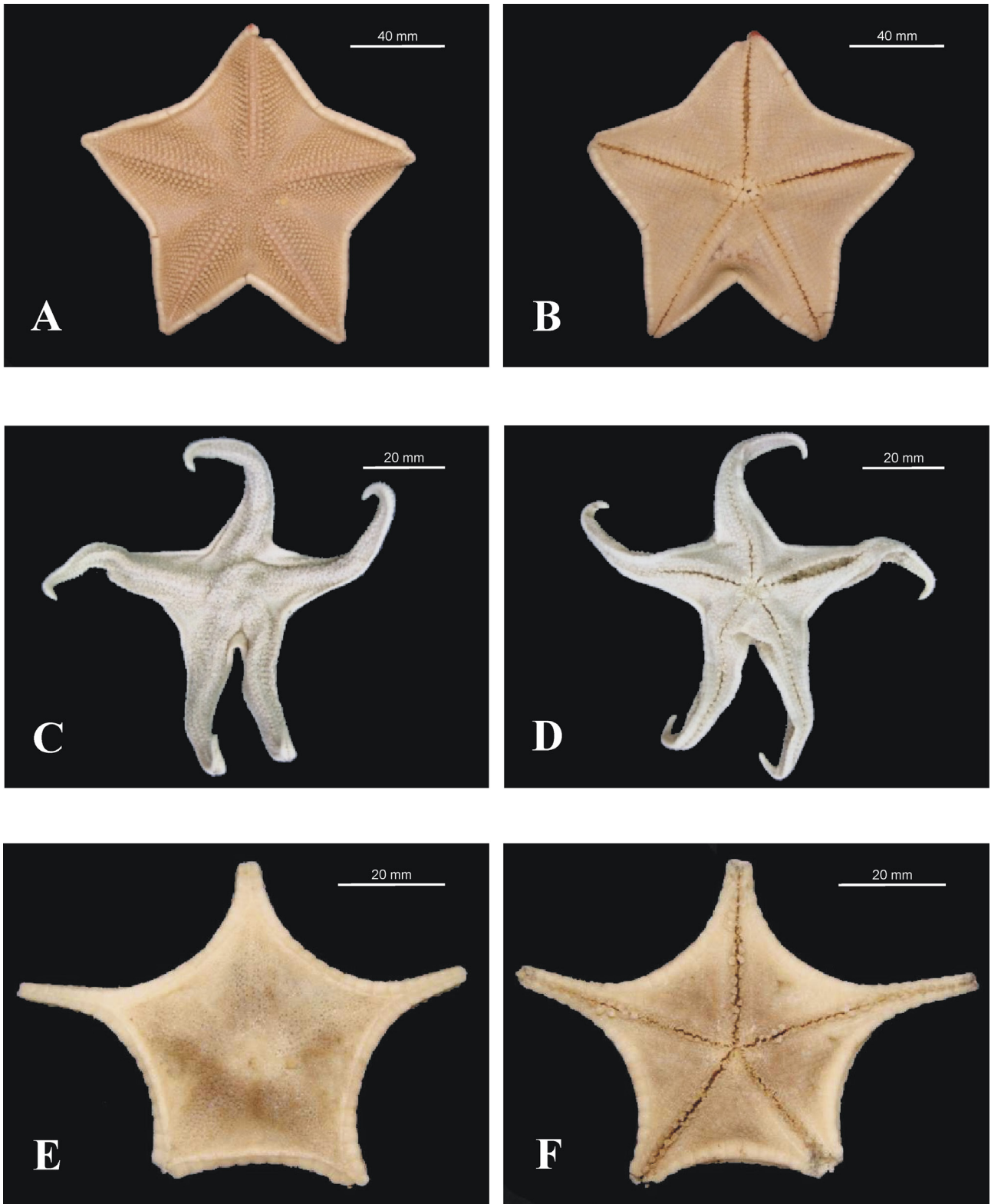


Figure 6. Valvatida. A. *Ceramaster leptoceramus* (Fisher, 1905), aboral view. B. same, oral view. C. *Mediaster transfuga* Ludwig, 1905, aboral view. D. Same, oral view. E. *Nymphaster diomedea* Ludwig, 1905, aboral view. F. same, oral view.

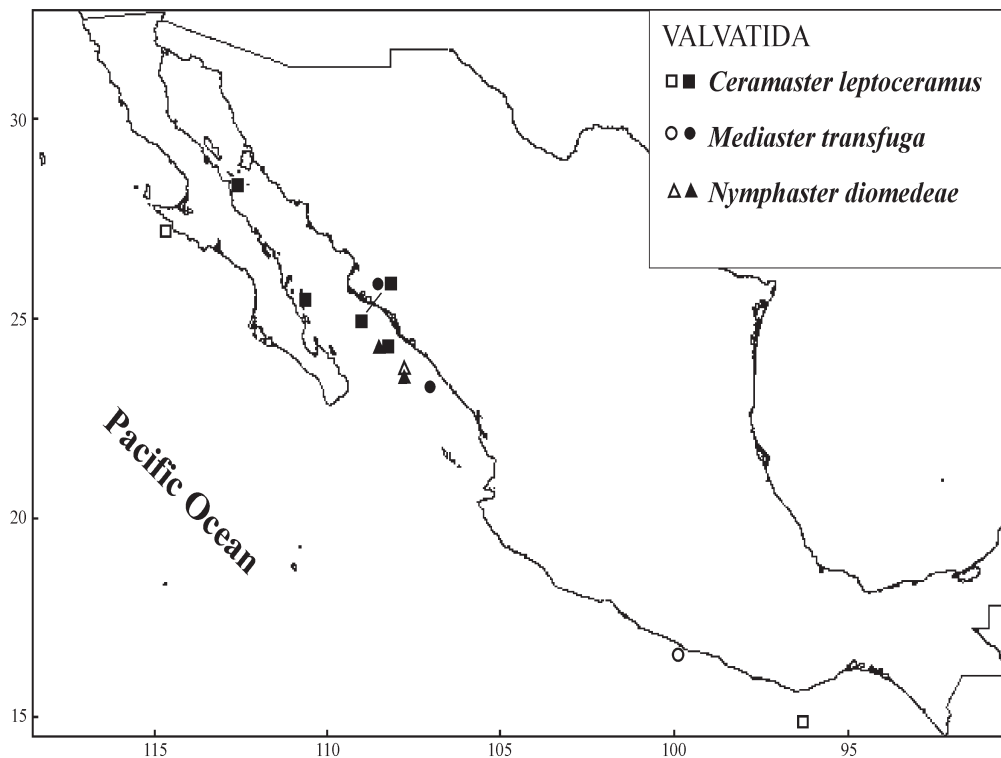


Figure 7. Distribution of examined species of Valvatida off the Pacific coast of Mexico, including previous records (open symbols) and localities where material was collected during the TALUD survey (solid symbols).

Lophaster furcilliger Fisher, 1905

Fig. 9A, B

Lophaster furcilliger Fisher, 1905: 312.

Lophaster furcilliger vexator Fisher, 1910c: 574 (off Punta Arena, Northern California); 1930: 198 (list).

Lophaster furcilliger.- Fisher, 1911b: 334, pl. 79, figs. 1, 2, pl. 114, figs. 1, 1a-g, pl. 116, fig. 5; 1930: 198 (list).- H. L. Clark, 1913: 197; 1923: 151.- Alton, 1966: 1706.- Muscat, 1980: 265.- Maluf, 1988: 39 (table), 122 (list); 1991: 350 (list).

Taxonomic summary

Material examined. TALUD VIII, St. 11 (24°54'24"N, 110°25'30"W), 12 specimens (R= 6.2-27.1 mm, r= 1.9-10.7 mm) (EMU-9005A, B), two specimens (R= 16.6-19.9 mm, r= 5.0-6.0 mm) (ICML-UNAM 2.199.1), and three specimens (R= 14.2-27.5 mm, r= 4.7-6.6 mm) (USNM-1146559), 17/April/2005, bottom sledge 920 m.

TALUD X, St. 4 (28°16'06"N, 112°32'48"W), 9/February/2007, one specimen (R= 31.0 mm, r= 7.4 mm), bottom sledge, 587-633 m (EMU-9006).

TALUD X, St. 5 (28°14'50"N, 112°24'53"W), 19 specimens (R= 12.6-46.2 mm, r= 6.1-13.5 mm), 9/February/2007, bottom sledge 820-837 m (EMU-9007A

and USNM-1146566) (Fig. 8).

Previous records in Mexico. Off the west coast of Baja California (ca 28°20'N, 32°N, and 32°20'N) (Maluf, 1988) (Fig. 8).

Distribution and ecology. Type locality, "Albatross" St. 4425 (33°14'0"N 119°29'0"W), 1 984-2 013 m (1 084-1 100 fms.), between Santa Barbara and San Nicholas Island, California, USA; Alaska, USA, to the Galapagos Islands, in 86-2 012 m (Maluf, 1988). To 2 852 m (Alton, 1966). The material collected during this study (in depths of 587-920 m) was obtained within the known depth range of this species. This increases the distribution range of this species to the SW and central Gulf of California. Epibenthic temperature and dissolved oxygen concentration: 3.3-3.8°C (37.9-38.9°F) (H. L. Clark, 1913); 5.00-8.22 °C and 0.11-0.38 ml O₂/l (this study).

Korethrasteridae Danielssen & Koren, 1884

Peribolaster biserialis Fisher, 1905

Fig. 9C, D

Peribolaster biserialis Fisher, 1905: 313; 1911b: 341, pl. 97, figs. 1, 2, pl. 114, figs. 3, 3a-c, pl. 115, fig. 5.- H. L. Clark, 1913: 197.- Djakonov, 1950: 76.- Baranova, 1957: 16.- Maluf, 1988: 122 (text), p. 40, (table), 122 (list).- Lambert, 2000: 28 (checklist).- A. M. Clark, 1996: 216.

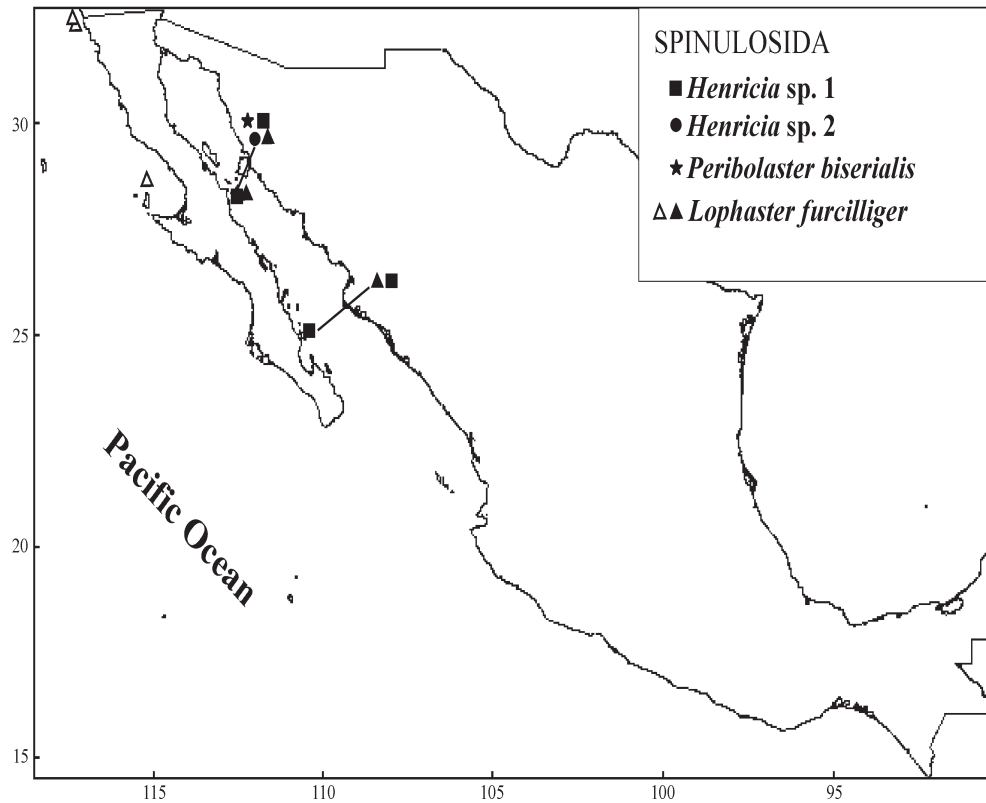


Figure 8. Distribution of examined species of Spinulosida off the Pacific coast of Mexico, including previous records (open symbols) and localities where material was collected during the TALUD survey (solid symbols).

Taxonomic summary

Material examined. TALUD X, St. 4 (28°16'06"N, 112°32'48"W), one specimen (R= 31.5 mm, r= 8.1 mm), 9/February/2007, benthic sledge, 587-633 m (EMU-9008A).

Previous records in Mexico. None.

Distribution and ecology. Type locality, "Albatross" St. 4410 (33°23'N, 118°25'W), California, USA, 325-357 m (178-195 fms.) (Fisher, 1905). Bering Sea to Southern California, in depths of 104-805 m (Maluf, 1988). This present record is the first for Mexico and the Gulf of California (Fig. 8). The unique specimen collected during the TALUD X cruise was found at a depth included in the depth range of the species. Epibenthic temperature and dissolved oxygen concentration: 4.4°C (39.9°F) (H. L. Clark, 1913); 8.22 °C and 0.38 ml O₂/l (this study).

Remarks

Another species of this genus, *P. folicullatus* Sladen, 1889, is reported from off Chile (Fisher, 1911b).

Order Forcipulatida

Family Pedicellasteridae

Ampheraster chiroplus Fisher, 1928

Fig. 10A, B

Ampheraster chiroplus Fisher, 1928 a: 81 (key), 84, pl. 31, figs. 3, 3a-d, pl. 32, fig. 2, pl. 35, fig. 2, pl. 37, fig. 2; 1930: 201 (list).- Alton, 1966: 1710.- Muscat, 1980: 265.- Maluf, 1988: 45 (table), 126 (list).

Taxonomic summary

Material examined. TALUD VIII, St. 11 (24°54'24"N, 110°25'30"W), 17/April/2005, one specimen (R= 50.3 mm, r= 9.6 mm), bottom sledge, 920 m (EMU-8981) (Fig. 11A).

Previous records in Mexico. None.

Distribution and ecology. Known from the type locality, "Albatross" St. 4427 (34°02'0"N, 119°31'0"W), off Santa Cruz Island, California, in depths of 818-933 m (447-510 fms.) (Fisher, 1928a), and from northern Oregon, 732 m (400 fms.) (Alton, 1966). Maluf (1988:

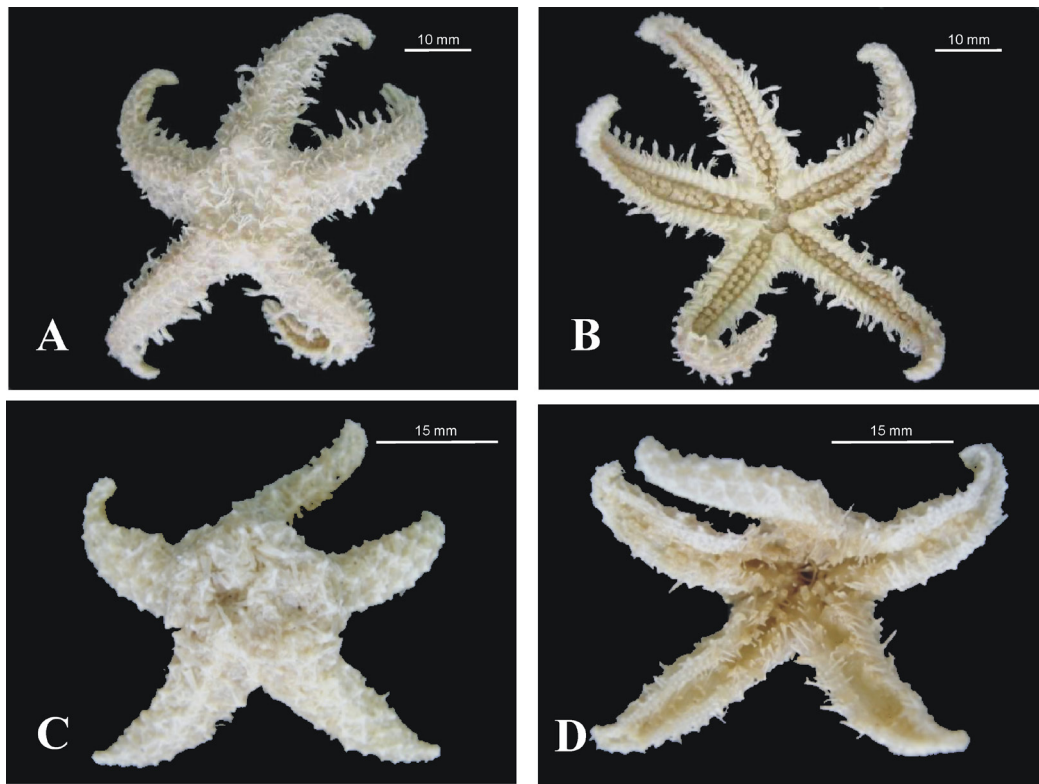


Figure 9. Spinulosida. A. *Lophaster furcilliger* Fisher, 1905, aboral view. B. Same, oral view. C. *Peribolaster biserialis* Fisher, 1905, aboral view. D. Same, oral view.

45) reports only the type locality for this species, but indicated a depth range of 417-933 m, probably due to a conversion error from fathoms to meters. The present record extends the distribution of this species to the SW Gulf of California, at a depth similar to the one registered at the type locality. Epibenthic temperature and dissolved oxygen concentration: 5.0°C and 0.20 ml O₂/l (this study).

Remarks

Ampheraster is a member of the uncommonly encountered Pedicellasteridae, which are characterized by the absence of an aboral carina, weakly calcified skeletons and biserial tubefoot rows (quadraserial tube feet proximally in some species). The 2 species included herein are distinguished by relatively few characteristics and may represent variations in 1 widely ranging species. Although some discrete differences in skeletal morphology support the separation between these more southern species from the northern *A. marianus* (Ludwig, 1905), several characters are shared, suggesting a close relationship.

Ampheraster hyperonchus (H. L. Clark, 1913)

Fig. 10C, D

Pedicellaster hyperonchus H. L. Clark, 1913: 201, pl. XLIV, figs. 3, 4.

Ampheraster hyperonchus.- Fisher, 1928 a: 81 (key).- Maluf, 1988: 46 (table), 126 (list).

Taxonomic summary

Material examined. TALUD IV, St. 25 (24°51'47"N, 108°57'59"W), 26/August/2000, two specimens (R= 40.6-63.5 mm, r= 3.8-5.8 mm), bottom sledge, 778-800 m (EMU-8982A, B).

TALUD IX, St. 17 (25°20'54"N, 110°46'24"W), 13/ November/2005, one specimen (R= 21.2 mm, r= 4.0 mm), bottom sledge, 826-846 m (EMU-8983).

TALUD X, St. 4 (28°16'06"N, 112°32'48" W), 9/ February/2007, 14 specimens (R= 15.7-30.5 mm, r= 2.7-5.2 mm) (EMU-8984A, B), two specimens (R= 18.4-25.0 mm, r= 2.9-3.8 mm) (ICML-UNAM 2.202.0), and three specimens (R= 20.6-23.5 mm, r= 2.8-3.8 mm) (USNM-1146562), bottom sledge, 587-633 m.

TALUD X, St. 5 (28°14'48"N, 112°24'54"W), 9/ February/2007, 2 specimens (R= 11.7-16.7 mm, r= 1.9-2.41 mm) (EMU-8992).

TALUD X, St. 14 (27°44'48"N, 111°36'54"W), 11/ February/2007, 7 specimens (R= 10-6-36.1 mm, r= 1.8-6.2 mm) (EMU-8991A, B).

Previous records in Mexico. Type locality, "Albatross" St. 5675 (27°07'08"N, 114°33'10"W), SW of San Cristobal Bay, west coast of Baja California, Mexico, 519 m (284 fms.) (H. L. Clark, 1913) (Fig. 11A).

Distribution and ecology. Only known from 2 localities in the East Pacific: the type locality in Mexico and northern Peru, in depths of 519 m (Maluf, 1988). Present records extend the distribution of this species to the SE, SW and central Gulf of California, in depths of 587-846 m. Epibenthic temperature and dissolved oxygen concentration: 7°C (44.6°F) (H. L. Clark, 1913); 5.03-8.22 C and 0.03-0.38 ml O₂/l (this study).

Remarks

See above.

Anteliaster coscinactis Fisher, 1923

Fig. 10E, F

Anteliaster coscinactis Fisher, 1923: 252.

Anteliaster coscinactis.- Fisher, 1928 a: 69 (key), 70, pl. 29, figs. 1, 1a-e, pl. 35, fig. 6, pl. 36, fig. 4, pl. 37, fig. 3; 1930: 201 (list).- Alton, 1966: 1711.- Maluf, 1988: 46 (table), 126 (list).

Anteliaster coscinactis megatretus Fisher, 1928 a: 69 (key), 71, pl. 29, figs. 2, 2a, 2b, pl. 35, figs. 5, 5a (off San Pablo Point, Baja California).

Pedicellaster improvisus.- H. L. Clark, 1913: 202 (by error).

Anteliaster coscinactes.- Muscat, 1980: 265.

Taxonomic summary

Material examined. TALUD VIII, St. 11 (24°54'24"N, 110°25'30"W), 17/April/2005, one specimen (R= 33.5 mm, r= 3.9 mm), bottom sledge, 920 m (EMU-8985) (Fig. 11A).

Previous records in Mexico. Type locality of *Anteliaster coscinactis megatretus*, "Albatross" St. 5675, San Pablo Point, San Cristobal Island (27°07'08"N, 114°33'10"W), Baja California, 284 fms. (Fisher, 1923). Same station ("Albatross" St. 5675), as *P. improvisus* (H. L. Clark, 1913) (Fig. 11A).

Distribution and ecology. From Santa Cruz Island (type locality, "Albatross" St. 4427 (34°02'0"N 119°31'0"W), 818-933 m (447-510 fms.), California, USA, to San

Cristobal Island, Baja California, Mexico, in depths of 519-933 m (Maluf, 1988). Also present off northern Oregon (Alton, 1966). This present record extends the distribution of this species to the SW Gulf of California, at a depth similar to its maximum known depth. Epibenthic temperature and dissolved oxygen concentration: 5.0°C and 0.20 ml O₂/l (this study).

Remarks

Species of the genus *Anteliaster* are uncommonly encountered pedicellasterids, that are largely differentiated on the basis of papulae and pedicellariae, both of which are easily removed during turbulent collection methods, such as nets. The collection of more specimens showing better morphological details will further elucidate boundaries between species in *Anteliaster*. *Anteliaster coscinactis megatretus* was recognized as a junior synonym of the nominal subspecies, *A. c. coscinactis*, by Alton (1966: 1711).

Family Zoroasteridae

Myxoderma platyacanthum (H. L. Clark, 1913)

Fig. 12A, B

Zoroaster platyacanthus H. L. Clark, 1913: 199, pl. XLIV, figs. 1, 2; 1920: 95.

Myxoderma platyacanthum.- Fisher, 1919: 392 (key); 1928 a: 45 (key), 52, pl. 15, fig. 3, pl. 16, figs. 2, 2a, pl. 23, fig. 2, pl. 24, fig. 1, pl. 25, figs. 1, 2; 1930: 201 (list).- H. L. Clark: 1920: 99 (key); 1923: 152.- Muscat, 1980: 266.- Maluf, 1988: 44 (table), 124 (list).- Solís-Marín et al. 2005: 126.- Mah, 2007: 192.

Myxoderma platyacanthum rhomaleum Fisher, 1919: 392 (key), 393 (text); 1928 a: 45 (key), 45 (text), 54, pl. 14, figs. 3, 3a, pl. 15, fig. 2, pl. 16, fig. 1, pl. 23, fig. 1, pl. 24, fig. 2, pl. 25, fig. 3; 1930: 201 (list).- Alton, 1966: 1709.

Taxonomic summary

Material examined. TALUD IV, St. 25 (24°53'12"N, 108°59'24"W), 26/August/2000, one specimen (R= 53.1 mm, r= 7.4 mm), bottom sledge, 835-870 m (EMU-8971). TALUD VI, St. 18 (24°14'55"N, 108°16'17"W), three specimens (R= 56.4-59.1 mm, r= 6.1-7.8 mm), 15/ March/2001, bottom sledge, 890-950 m (EMU-8972A, B). TALUD VIII, St. 16 (25°24'24"N, 110°37'36"W), 18/ April/2005, one specimen (R= 22.7 mm, r= 4.9 mm), bottom sledge, 1030 m (EMU-8973).

TALUD IX, St. 17 (25°20'54"N, 110°46'24"W), 13/ November/2005, two specimens (R= 20.0-21.0 mm, r= 4.3-4.5 mm), bottom sledge, 836 m (EMU-8974).

TALUD X, St. 5 (28°14'48"N, 112°24'54"W), 9/

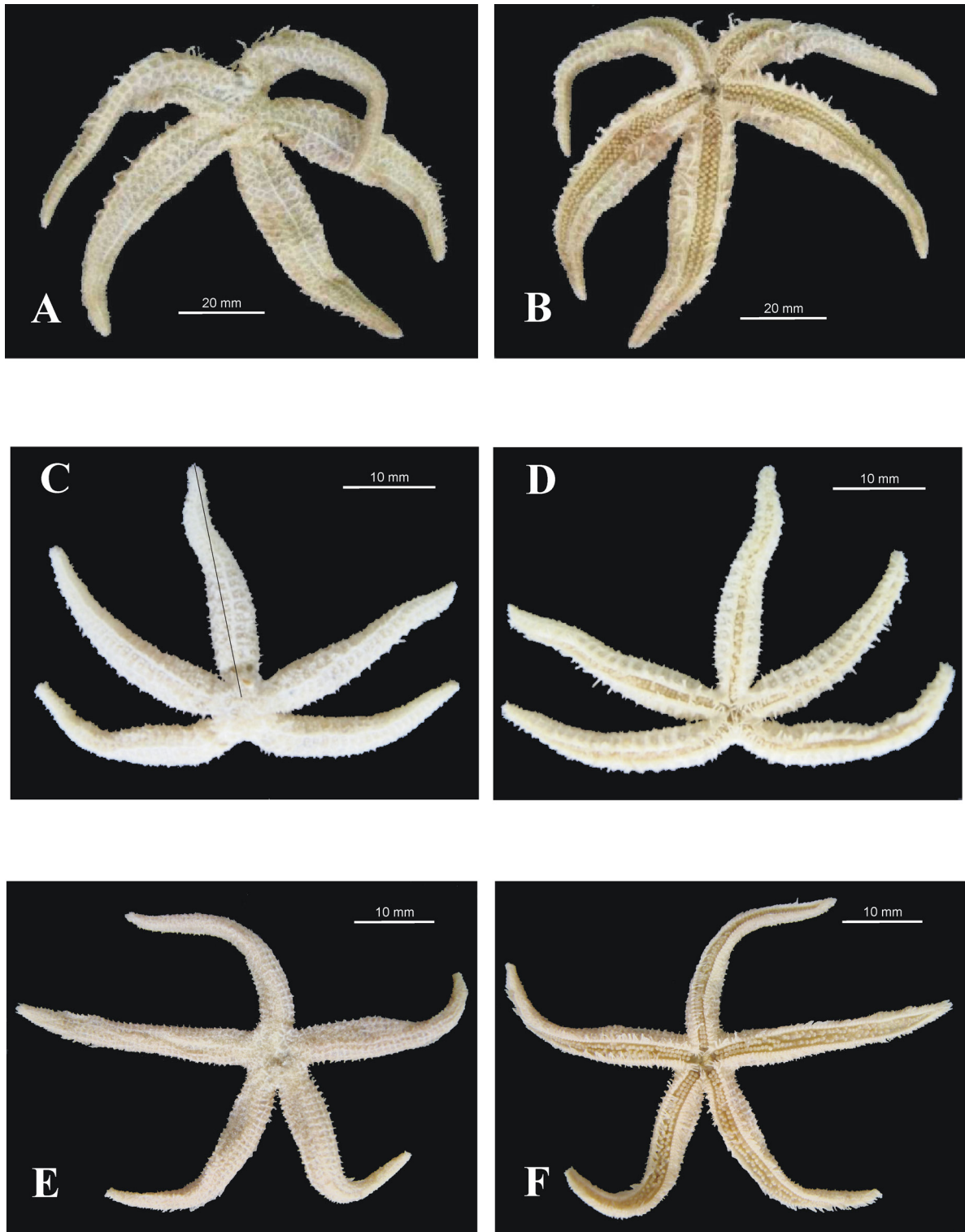


Figure 10. Forcipulatida. A. *Ampheraster chiroplus* Fisher, 1928, aboral view. B. Same, oral view. C. *Ampheraster hyperonchus* (H. L. Clark, 1913), aboral view. D. Same, oral view. E. *Anteliaster coscinactis* Fisher, 1923, aboral view. F. Same, oral view.

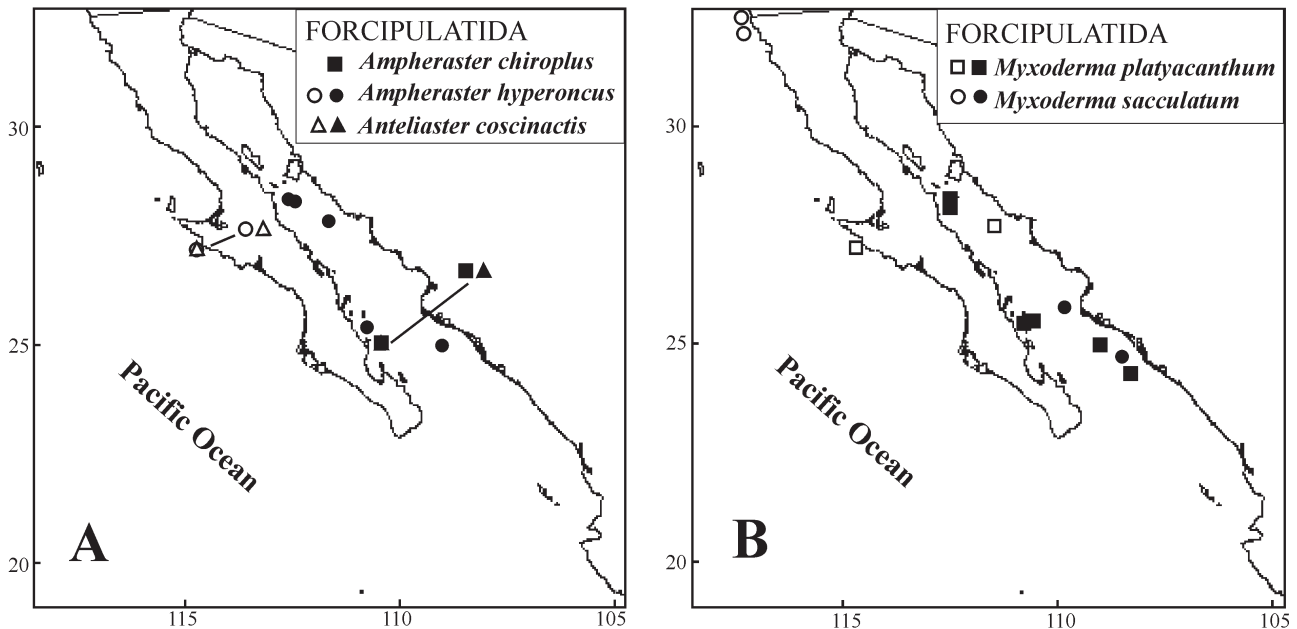


Figure 11. Distribution of examined species of Forcipulatida off the Pacific coast of Mexico, including previous records (open symbols) and localities where material was collected during the TALUD survey (solid symbols).

February/2007, four specimens (R= 33.2-42.4 mm, r= 8.5-11.3 mm) (EMU-8975), two specimens (R= 28.2-32.7 mm, r= 5.2-5.7 mm) (ICML-UNAM 2.129.4), and three specimens (R= 20.0-35.0 mm, r= 3.3-5.4 mm) (USNM-1146561), bottom sledge, 820-837 m.

TALUD X, St. 8 (28°05'54"N, 112°26'48"W), 10/ February/2007, one specimen (R= 60.2 mm, r= 9.7 mm), bottom sledge, 975-1007 m (EMU-8976).

Previous records in Mexico. Type locality, "Albatross" St. 5675, San Pablo Point (27°07'08"N, 114°33'10"W), SW of San Cristobal Bay, 515 m (284 fms.) (H. L. Clark, 1923). Sonora (no precise locality; Solís-Marín, pers. comm.), Gulf of California (Solís-Marín et al., 2005). South of San Pedro Island (27°40'N, 111°29'36"W to 27°32'06"N, 111°20'06"W), 931-952 m, Mexico (Mah, 2007) (Fig. 11B).

Distribution and ecology. Piedras Blancas Point, USA, to San Cristobal Bay, Baja California, Mexico, in depths of 256-768 m (Maluf, 1988). Off Sonora, central Gulf of California, Mexico (Solís-Marín et al., 2005). Present records confirm the presence of *M. platyacanthum* in the Gulf of California to off the State of Sonora, to ca 28°14'N, Mexico, in depths of 820-1 030 m, slightly deeper than the deepest record known to date.

Gut contents from *M. platyacanthum* include ophiuroid ossicles and bivalves (Mah, 2007).

Epibenthic temperature and dissolved oxygen concentration: 7°C (44.6°F) (H. L. Clark, 1923); 4.25-6.65°C and 0.03-0.29 ml O₂/l (this study). The type

locality of *Myxoderma platyacanthum rhomaleum* is off Oregon ("Albatross" St. 2890, 43°46'N, 124°57'W). Fisher (1928 a) reports material from Oregon to Southern California, in depths of 507-542 m (277-296 fms.), with bottom temperatures of 5.4-5.7°C (41.8-42.2°F).

Remarks

Myxoderma forms part of a species complex extending down the west coast of North America to Chile (Mah, 2007). As summarized by Mah (2007) *Myxoderma* frequently occurs on soft bottoms in great abundance when collected.

Myxoderma sacculatum (Fisher, 1905)

Fig. 12C, D

Zoroaster (Myxoderma) sacculatus Fisher, 1905: 316 ("Albatross" St. 4517, off Point Pinos, Monterey Bay, California).

Zoroaster evermanni.- H. L. Clark, 1913: 198.

Myxoderma sacculatum ectenes Fisher, 1919: 392 (key), 392 (text); 1928 a: 45 (key), 49, pl. 14, figs. 4, 4a, 4b, pl. 21, fig. 1, pl. 22, fig. 1, pl. 25, figs. 5-12 ("Albatross" St. 5694, SW of Santa Cruz Island, California); 1930: 200 (list).

Myxoderma sacculatum.- Fisher, 1919: 392 (key); 1928 a: 45 (key), 45 (text), 54, pl. 14, fig. 5, pl. 15, fig. 1, 1a-c, pl. 20, fig. 2, pl. 21, figs. 2, 3, pl. 22, figs. 2, 3, pl. 25, fig. 4; 1930: 200 (list).- H. L. Clark, 1920: 99 (key); 1923: 152.- Alton, 1966: 1709.- Muscat, 1980: 266.- Maluf,

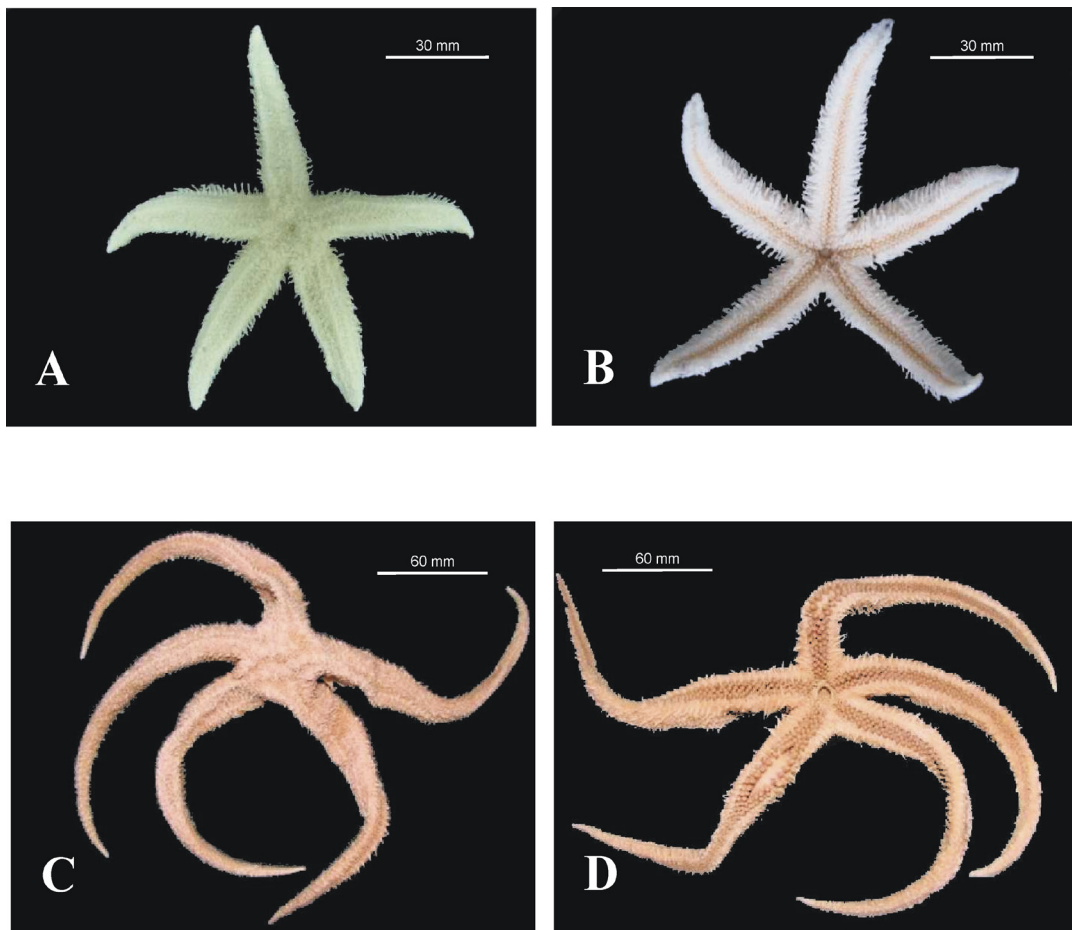


Figure 12. Forcipulatida. A. *Myxoderma platyacanthum* (H. L. Clark, 1913), aboral view. B. Same, oral view. C. *Myxoderma sacculatum* (Fisher, 1905), aboral view. D. Same, oral view.

1988: 44 (table), 125 (list).- Mah, 2007: 193.
Myxoderma cf. *sacculatum* cf. *ectenes*.- Luke, 1982: 21.

Taxonomic summary

Material examined. TALUD III, St. 14A (24°38'48"N, 108°26'54"W), 19/August/1991, one specimen (R= 118.9 mm, r= 14.7 mm), Agassiz dredge, 1016-1020 m (EMU-8977).

TALUD III, St. 24A (25°45'12"N, 109°46'48"W), 24/August/1991, one specimen (R= 156.8 mm, r= 32.5 mm), bottom sledge, 1027-1060 m (EMU-8978).

Previous records in Mexico. "Albatross" St. 4380 (32°26'00"N, 117°18'00"W), off Los Coronados Islands, Baja California, 970-1131 m (530-618 fms.) (Fisher, 1928a; as *M. s. ectenes*). Probably the record of *M. cf. sacculatum* cf. *ectenes*, off Descanso Bay (32°05'12"N, 117°14'W), Baja California, in depths of 1244-1332 m (Luke, 1982) (Fig. 11B).

Distribution and ecology. The type locality is off Point Pinos ("Albatross" St. 4517, 36°38'0"N, 121°55'0"W; 916 fms., ca 1 670 m), Monterey, California (Fisher, 1905). Known from Bering Sea, Alaska, USA, to "Tijuana", west coast of Baja California, in depths of 519-1 936 m (Maluf, 1988). Present record extends the distribution of *M. sacculatum* to the Gulf of California, off southern Sinaloa (Fig. 11 B). The material collected during this study (in depths of 1 016-1 060 m) was obtained within the known depth range of this species. Epibenthic temperature and dissolved oxygen concentration: 3.27-4.38°C (37.9-39.9°F) (H. L. Clark, 1913); 0.40 ml O₂/l (this study).

Remarks

Based on Fisher 1928(a) *Z. evermanni* H. L. Clark (1913) from "Albatross" Sts. 5694 to 99 were in error and all correspond to *M. sacculatum*, in depths of 842-1 190 m (460-650 fms.) (H. L. Clark, 1913).

Depth distribution of species

Considering all samples of Asteroidea obtained during the TALUD cruises (Table 2), occurrence of species according to depth varies considerably (Table 3). During the survey, gears were operated in a depth range of 377-2 394 m. Sampling effort was not always successful, however, and a significant number of samples (90 out of a total of 116, or 78%) contained no Asteroidea. Six species were obtained in the depth range of 377-750 m, corresponding to a unique sample (in 587-633 m depth). The 7 additional trawls in that range failed to collect any asteroids. Comparatively,

11 species were captured in the 751-1 000 m depth range (11 samples of Asteroidea obtained in 27 trawls), 8 in the 1 001-1 250 m range (9 samples in 27 trawls), and 4 in the 1 251-1 500 m range (3 samples in 18 trawls). Only 1 species was found in deeper water, although the sampling gears sampled 36 times in depths between 1 500 -2 394 m. No species covers the entire depth range as defined in Table 3. *Ceramaster leptoceramus* was collected in the 3 shallowest depth intervals and *Nerachaster aciculosus* in the 3 deepest intervals (Table 3).

Table 2. Sampling stations of the TALUD cruises where specimens of Asteroidea were collected and list of species per station. Position, depth, and epibenthic water temperature and dissolved oxygen concentration are indicated for each station. Precision of data may vary according to the method used during the survey

| <i>Cruise</i> | <i>Station</i> | <i>Species</i> | <i>Depth (m)</i> | <i>T°C</i> | <i>O₂ ml/l</i> |
|---------------|----------------|--|------------------|------------|---------------------------|
| TALUD III | St. 14A | <i>Dipsacaster laetmophilus</i> <i>Thrissacanthias penicillatus</i> <i>Myxoderma sacculatum</i> | 1 016-1 020 | ND | 0.4 |
| TALUD III | St. 24A | <i>Thrissacanthias penicillatus</i> <i>Nerachaster aciculosus</i> <i>Myxoderma sacculatum</i> | 1 027-1 060 | ND | ND |
| TALUD IV | St. 19 | <i>Pectinaster agassizii</i> | 1 240-1 245 | 3.7 | 0.73 |
| TALUD IV | St. 21 | <i>Ctenodiscus crispatus</i> | 1 200 | 2.4 | 1.82 |
| TALUD IV | St. 25 | <i>Radiaster</i> sp. <i>Ceramaster leptoceramus</i> <i>Mediaster transfuga</i> <i>Myxoderma platyacanthum</i> | 835-870 | 5.0 | 0.29 |
| TALUD IV | St. 34 | <i>Pectinaster agassizii</i> | 1 240-1 250 | 3.5 | 0.79 |
| TALUD V | St. 11 | <i>Radiaster</i> sp. <i>Mediaster transfuga</i> | 860 | 5.4 | 0.07 |
| TALUD V | St. 18 | <i>Ceramaster leptoceramus</i> | 940-990 | 5.0 | 0.15 |
| TALUD V | St. 19 | <i>Thrissacanthias penicillatus</i> <i>Nerachaster aciculosus</i> | 1 180-1 200 | 4.0 | 0.38 |
| TALUD V | St. 20 | <i>Ctenodiscus crispatus</i> | 1 470-1 525 | 2.8 | 1.20 |
| TALUD V | St. 25 | <i>Nerachaster aciculosus</i> | 800-860 | 5.2 | 0.13 |
| TALUD VI | St. 18 | <i>Radiaster</i> sp. <i>Myxoderma platyacanthum</i> | 890-950 | 5.3 | 0.29 |
| TALUD VII | St. 13B | <i>Nymphaster diomedeeae</i> | 1 400-1 450 | 3.0 | 1.04 |
| TALUD VIII | St. 3 | <i>Thrissacanthias penicillatus</i> | 1 100 | 3.0 | 0.39 |
| TALUD VIII | St. 11 | <i>Henricia</i> sp. 1 <i>Lophaster furcilliger</i> <i>Ampheraster chiroplus</i> <i>Anteliaster coscinactis</i> | 920 | 5.0 | 0.2 |
| TALUD VIII | St. 16 | <i>Dipsacaster laetmophilus</i> <i>Thrissacanthias penicillatus</i> <i>Ceramaster leptoceramus</i> <i>Myxoderma platyacanthum</i> | 1 030 | 5.0 | 0.2 |
| TALUD VIII | St. 20 | <i>Thrissacanthias penicillatus</i> | 1 150 | 4.0 | 0.30 |

Table 2. Continues

| <i>Cruise</i> | <i>Station</i> | <i>Species</i> | <i>Depth (m)</i> | <i>T°C</i> | <i>O₂ ml/l</i> |
|---------------|----------------|--|------------------|------------|---------------------------|
| TALUD IX | St. 17 | <i>Radiaster</i> sp. <i>Nearchaster aciculosus</i> <i>Ampheraster hyperonchus</i> <i>Myxoderma platyacanthum</i> | 826-836 | 5.75 | <0.05 |
| TALUD X | St. 4 | <i>Ceramaster leptoceramus</i> <i>Henricia</i> sp. 1 <i>Henricia</i> sp. 2 <i>Lophaster furcilliger</i> <i>Peribolaster biserialis</i> <i>Ampheraster hyperonchus</i> | 587-633 | 8.2 | 0.38 |
| TALUD X | St. 5 | <i>Lophaster furcilliger</i> <i>Ampheraster hyperonchus</i> <i>Myxoderma platyacanthum</i> | 820-837 | 6.6 | 0.11 |
| TALUD X | St. 8 | <i>Myxoderma platyacanthum</i> | 975-1007 | 4.2 | 0.26 |
| TALUD X | St. 10 | <i>Dipsacaster laetmophilus</i> <i>Nearchaster aciculosus</i> | 1 399-1 422 | 3.2 | 0.44 |
| TALUD X | St. 14 | <i>Radiaster</i> sp. <i>Nearchaster aciculosus</i> <i>Ampheraster hyperonchus</i> | 905-943 | 4.6 | 0.2 |
| TALUD X | St.18 | <i>Pectinaster agassizii</i> | 1 526 | 3.2 | 0.59 |
| TALUD X | St.25 | <i>Radiaster</i> sp. <i>Nearchaster aciculosus</i> | 837-840 | 5.0 | 0.18 |

Table 3. Occurrence of deep-water species of Asteroidea collected during the TALUD survey per bathymetric intervals (377 to 2 250 m) in the Gulf of California. Data taken from table 2. Average depths were used for trawls with a minimum and a maximum operating depths (e.g., 1 498 m was used for the 1 470-1 525 depth interval). Extreme depth values (bold) correspond to the lowest and deepest trawls during the entire survey. Number of trawls of the survey, of samples with Asteroidea, and of collected species are indicated for comparison purposes

| | |
|--|--|
| 377-750 m 8 trawls, 1 sample, 6 species <i>Ceramaster leptoceramus</i> <i>Henricia</i> sp. 1 <i>Henricia</i> sp. 2 <i>Lophaster furcilliger</i> <i>Peribolaster biserialis</i> <i>Ampheraster hyperonchus</i> | 1 001-1 250 m 27 trawls, 9 samples, 8 species <i>Dipsacaster laetmophilus</i> <i>Thrissacanthias penicillatus</i> <i>Ctenodiscus crispatus</i> <i>Nearchaster aciculosus</i> <i>Pectinaster agassizii</i> <i>Ceramaster leptoceramus</i> <i>Myxoderma platyacanthum</i> <i>Myxoderma sacculatum</i> |
| 751-1 000 m 27 trawls, 12 samples, 12 species <i>Radiaster</i> sp. <i>Nearchaster aciculosus</i> <i>Ampheraster chiroplus</i> <i>Ampheraster hyperonchus</i> <i>Henricia</i> sp. 1 <i>Lophaster furcilliger</i> <i>Pectinaster agassizii</i> <i>Ceramaster leptoceramus</i> <i>Mediaster transfuga</i> <i>Anteliaster coscinactis</i> <i>Myxoderma platyacanthum</i> | 1 251-1 500 m 18 trawls, 3 samples, 4 species <i>Dipsacaster laetmophilus</i> <i>Ctenodiscus crispatus</i> <i>Nearchaster aciculosus</i> <i>Nymphaster diomedea</i> |
| | 1 501-2 250 m 36 trawls, 1 sample, 1 species |

Discussion

In total, 18 species of Asteroidea were collected in the Gulf of California during the TALUD survey, 15 identified to species-level. The material was obtained in 25 samples. Eleven of these contained only 1 species of Asteroidea, 5 samples contained 2 species, 4 samples 3 or 4, and 1 sample 6 species (Table 2). Taxonomic affinities of the sampled asteroids show a strong continuity with the deep-water shelf faunas present along the continental shelf of the west coast of North America, as summarized in Fisher (1911b, 1928a, b) and in Maluf (1988).

Recent reviews of Pacific coast Asteroidea in Mexican waters include contributions of Maluf (1988), Maluf and Brusca (2005), Solís-Marín et al. (2005), and Honey-Escandón et al. (2008). Solís-Marín et al. (1997) reviewed shallow-water echinoderms of the Bay of La Paz, but their list does not include deep-water species. Eleven of the 52 species listed by Maluf (1988) were collected during this survey. The other collected species include an undescribed *Radiaster*, in addition to *Dipsacaster letmophilus*, which had previously been known only from Alaska; *Peribolaster biserialis*, previously known only from Alaska to California; *Ampheraster chiroplus* previously known only from Southern California; and *Mediaster transfuga*, which had been included in the synonymy of *M. tenellus* Fisher, 1905 by Maluf (1988). Apart from the identified or new species, additional material includes 2 unidentified species of *Henricia*. Of the 44 species listed by Maluf (1991) for the Galapagos, 24 have been found below or near 500 m depth, but only 4 species, i.e., *Luidia foliolata* (deepest record at 476 m), *Pectinaser agassizii*, *Nymphaster diomedae*, and *Lophaster furcilliger*, occur in Mexican waters. Pawson and Ahearn (2001) reported 10 asteroid species from bathyal depths in the Galapagos, including some range extensions for 2 species occurring in Mexican waters (i.e., *Ceramaster grenadensis patagonicus* and *Cryptopeltaster lepidonotus*). Maluf and Brusca (2005) included 63 species of Asteroidea in their checklist of the Gulf of California. Of these, 25 correspond to the deep-water species (see Table 1). In the contributions of Solís et al. (2005) and Honey-Escandón et al. (2008), 10 species with at least 1 record in Mexico are enlisted, 9 present within the Gulf of California and 5 elsewhere (i.e., California Current or SW Mexico).

Not including the unidentified material, a total of 54 records of deep-water Asteroidea were obtained for the Gulf of California during this survey. Comparatively, only 9 records were previously known for this area for the same set of species (compare solid and open symbols on the distribution maps). Ten new distributions records were obtained during this survey for *Dipsacaster laetmophilus*

and *Perolobaster biserialis* (first record for Mexico), *Myxoderma sacculatum*, *Anteliaster coscinactis*, *Mediaster transfuga*, and *Ampheraster chiroplus* (to the southern Gulf of California), *Ceramaster leptoceramus* (first records within the Gulf of California), *Ampheraster hyperonchus* and *Nearchaster aciculosus* (to the southern and central Gulf of California), and *Lophaster furcilliger* (first record within the Gulf of California). With 6 records between ca 24°16'N and ca 25°56'N, the presence of *Thrissacanthias penicillatus* is confirmed throughout the southern Gulf of California. *Myxoderma platyacanthum*, reported off Sonora by Solís-Marín et al. (2005), is confirmed as a Gulf of California species, well represented in the TALUD samples (6 lots), between ca 24°15'N and ca 28°14'N.

Based on the present study and recent contributions, the number of deep-water (>500 m) species known to occur off the Pacific coast of Mexico is updated to a grand total of 60 species. Without considering the Mexican record of *Anthenea mexicana* (no locality available), 34 species have at least 1 record in the California Current area, 41 in the Gulf of California, and only 8 off Southwestern Mexico. Three species have been captured close to offshore islands (Table 1). These figures clearly indicate the lack of sampling activities off SW Mexico.

When compared to the environmental data associated with previous captures of the 15 species identified during this survey, data obtained during the TALUD cruises conform to known records for these species. For example, bathymetric range was within the known depth range of most species. We extended the depth range of *Dipsacaster letmophilus*, from 1 272 m to 1 422 m. The depth range of *Myxoderma platyacanthum* and of *Ampheraster hyperonchus* was extended, from 768 to 1 030 m for the former and from 519 m to 846 m for the latter, while the depth range for *Mediaster transfuga* is now set as 789-902 m. Previous data available for bottom temperature (mostly recorded at the "Albatross" sampling stations) are close to those recorded during this study (Table 4). Epibenthic dissolved oxygen concentrations associated with the capture of the specimens show a strong tolerance to severe hypoxia (<1.0 ml O₂/l) for most species. *Ctenodiscus crispatus* and *Nymphaster diomedae* (Table 3) showed less tolerance and occur in more mildly hypoxic settings. Shick (1976) reported that *C. crispatus* (at 5°C) can withstand exposure to hypoxia more than any echinoderm known in the literature, but our data indicate that several other species of Asteroidea feature a stronger tolerance to hypoxia than *C. crispatus*.

The depth interval at which the Asteroidea were collected during this survey (587-1 525 m) is much reduced compared to the global depth interval of the entire survey (377 to 2 394 m depth). Only 2 specimens of sea-stars were

Table 4. Number of specimens collected and number of stations where Asteroidea were found during the TALUD cruises. Environmental data measured at bottom level (T°C, temperature; O₂, dissolved oxygen concentration) are indicated for previous records and for samples obtained during the TALUD cruises. ND, no data

| Species | Number of specimens | Number of stations | T°C (TALUD) | T°C (Previous) | O ₂ (TALUD) |
|-------------------------------------|---------------------|--------------------|-------------|----------------|------------------------|
| <i>Dipsacaster laetmophilus</i> | 5 | 3 | 3.19-5.00 | ND | 0.20-0.44 |
| <i>Thrissacanthias penicillatus</i> | 8 | 6 | 3.00-5.00 | 5.0 | 0.20-0.40 |
| <i>Ctenodiscus crispatus</i> | 2 | 2 | 2.40-2.80 | 2.94-3.28 | 1.20-1.82 |
| <i>Radiaster</i> sp. nov. | 116 | 6 | 4.64-5.40 | ND | 0.07-0.29 |
| <i>Nearchaster aciculatus</i> | 107 | 6 | 3.19-5.75 | 4.38 | 0.03-0.44 |
| <i>Pectinaster agassizii</i> | 4 | 3 | 3.17-3.69 | 2.39-4.11 | 0.59-0.79 |
| <i>Ceramaster leptoceramus</i> | 8 | 4 | 5.00-8.22 | 7.0 | 0.15-0.38 |
| <i>Mediaster transfuga</i> | 3 | 2 | 5.03-5.40 | 4.8 | 0.07-0.29 |
| <i>Nymphaster diomedae</i> | 3 | 2 | 3.0-3.7 | 2.89-6.28 | 0.73-1.04 |
| <i>Henricia</i> sp. 1 | 8 | 2 | 5.0-8.22 | ND | 0.2-0.38 |
| <i>Henricia</i> sp. 2 | 4 | 1 | 8.22 | ND | 0.38 |
| <i>Lophaster furcilliger</i> | 32 | 3 | 5.00-8.22 | ND | 0.11-0.38 |
| <i>Peribolaster biserialis</i> | 2 | 1 | 8.22 | ND | 0-38 |
| <i>Ampheraster chiroplus</i> | 1 | 1 | 5.0 | ND | 0,2 |
| <i>Ampheraster hyperoncus</i> | 17 | 3 | 5.03-8.22 | 7.0 | 0.03-0.38 |
| <i>Anteliaster coscinactis</i> | 1 | 1 | 5.0 | 7.0 | 0,2 |
| <i>Myxoderma platyacanthum</i> | 12 | 6 | 4.25-6.65 | 7.0 | 0.03-0.29 |
| <i>Myxoderma sacculatum</i> | 2 | 2 | ND | 3.27-4.38 | 0,4 |
| Total of specimens | 335 | | | | |

found below 1 525 m, but deep-water invertebrates often feature a patchy distribution. The lack of material below that depth, however, cannot be attributed to low frequency of sampling because as many as 36 trawls were at a depth greater than 1 500 m during the survey.

Comparative data related to communities of deep water Asteroidea are lacking for the area between Mexico and northern Peru. In the northwestern part of the American continent, however, there have been several deep water surveys of the megafauna on the continental slope and abyssal plains using both conventional trawls and camera sled. One of the most abundant and diverse collection of deep-water Asteroidea was reported by Alton (1966), off northern Oregon. He reported as many as 54 species, 46 below 460 m (250 fms.). Of these, only 9 species were collected during the TALUD survey. In a more recent survey, off central California, Nybakken et al. (1998) report 14 species of Asteroidea captured below 2 300 m, none of which were collected during the TALUD survey. Tilot (2006) reported 7 species observed during deep-water dives in the fracture area of Clarion and Clipperton with only 1 species, *Pectinaster agassizii*, collected during the TALUD cruises. Keller et al. (2007) reported 53 species (some unidentified) of Asteroidea off the coast of California to Washington, 51 with at least 1 specimen below 300 m depth. Of these, 7 were found during the TALUD survey.

Asteroid specimens were found in only 25 of the 116 samples taken during this survey. This is certainly significant, and indicates that species distribution is far from being homogeneous. Species richness was low, and only 9 samples contained 3 or more species (maximum of 6; St. 4, TALUD X). Due to lack of additional sampling effort, however, it is difficult to explain the distribution patterns of these species. Factors such as patterns of deep-water currents and species dispersion, food supply and bottom structure can have an additional effect on depth, temperature and dissolved oxygen concentration.

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