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

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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 (587-1526 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 furcillator 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 diomedeae 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.

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), Solis-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, México. Duplicates of several species were also deposited in the Echinoderms Collection M. E. Caso Muñoz, ICML, UNAM, in México D.F., México, 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).

<table>
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<tr>
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<th>GC</th>
<th>SWM</th>
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<td>MA</td>
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<td>MA</td>
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<tr>
<td>Astrotilus panamensis (Ludwig, 1905)</td>
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(1) To 476 m depth.  
(2) Cited as Eremicaster crassus by Maluf and Brusca (2005) and Honey-Escandon et al. (2008).  
(4) Cited as Cheiraster ogassizii by Solis-Marin 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).  

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= 19.0-22.7 mm), Agassiz dredge, 1016-1020 m (EMU-8963).
TALUD VIII, St. 16 (25º24’24”N, 110º37’36”W), 18/April/2005, two specimens (R= 13.9-25.9 mm, r= 6.7-11.6 mm), bottom sledge, 1030m (EMU-8964).
TALUD X, St. 10 (27º50’06”N, 112º10’06”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


*Thrissacanthias penicillatus*. - Fisher, 1910a: 171; 1911b: 79, pl. 17, fig. 4, p1 18, figs. 1-5, pl. 53, figs. 1, 1a, 1b, 1d,

Figure 1. Paxillosida. A. *Dipsacaster laetmophilus* Fisher, 1910, aboral view. B. Same, oral view. C. *Thrissacanthias penicillatus* (Fisher, 1905), aboral view. D. Same, oral view.
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°31’12”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 (Ziesenhenne, 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 55-1503 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 1016-1200 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 805-1206 m (440-659 fms.) and epibenthic temperatures of 3.27-4.38 °C (37.9-39.9°F). The record of Ziesenhenne (1937) for Santa Inés Bay corresponds to young specimens taken in depth of 55-64 m (30-35 fms.),
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.


**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 (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. 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. “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. 2B).

**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 *Goniopectinidae*. 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°56′12″W), 25/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
(off Mazatlán) to 27º45’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 ºC 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 Benthopectinidae

*Nearchaster aciculosus* (Fisher, 1910)

Fig. 4A, B

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


**Taxonomic summary**

*Material examined.* TALUD V, St. 19 (24º16’24”N, 108º24’18”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 (24º51’42”N, 108º57’54”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 (25º20’54”N, 110º46’24”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 (27º50’06”N, 112º10’06”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 (27º44’48” N, 111º36’54” 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).


Cheiraster agassizii.- Solis-Marín et al., 2005: 125.
**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 1244-1908 m (L. Luke, 1982). Gulf of California (25°18’N, 110°19’30”W), in depths of 1244-1908 m (Luke, 1982). The record of this species 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, 1905).

*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: 790-2323 m (Maluf, 1988; Maluf and Brusca, 2005). Off northern Oregon (Alton, 1966). The material collected during this study (in depths of 1240-1526 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, 1905).
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 Gonasteridae
Ceramaster leptoceramus (Fisher, 1905)
Fig. 6A, B
Tosia leptocerama Fisher, 1905: 306

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. Type locality, “Albatross” St. 3417 (16°32’N, 99°48’W), off Guerrero, 902 m depth (Fig. 7).

Distribution and ecology. Ceramaster 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 diomedeae* Ludwig, 1905

Fig. 6E, F

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


**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 Panamian Isthmus.

Order Spinulosida

Family Echinasteridae

Henricia sp. 1

**Taxonomic summary**

*Material examined.* TALUD VIII, St. 11 (24°54.5’N, 110°25.5’W), 6/June/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 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).

**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

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).

...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.


**Taxonomic summary**

*Material examined.* TALUD IV, St. 25 (24º51’47"N, 108º57’59"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 (25º20’54"N, 110º46’24"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 (28º16’06"N, 112º32’48" 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 519-846 m. 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

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


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

**Taxonomic summary**

Material examined. TALUD VIII, St. 11 (24°54′24″N, 110°25′30″W), 17/August/2000, 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, Baja California, Mexico, 284 fms. (Fisher, 1923). Same station (“Albatross” St. 5675), as *P. improvisus* (H. L. Clark, 1923) (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

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

*Myxoderma platyacanthus*.- 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 platyacanthus rhomaleum* Fisher, 1919: 392 (key), 393 (text); 1928 a: 45 (key), 45 (text), 54, 14, figs. 3, 3a, pl. 15, fig. 2, pl. 16, fig. 1, pl. 23, fig. 2, 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, 110°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 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), 45 (text), 54, 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.


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.

<table>
<thead>
<tr>
<th>Cruise</th>
<th>Station</th>
<th>Species</th>
<th>Depth (m)</th>
<th>T°C</th>
<th>O₂ ml/l</th>
</tr>
</thead>
<tbody>
<tr>
<td>TALUD III St. 14A</td>
<td>Dipsacaster laetmophilus</td>
<td>1 016-1 020</td>
<td>ND</td>
<td>0.4</td>
<td></td>
</tr>
<tr>
<td>TALUD III St. 24A</td>
<td>Thrissacanthias penicillatus</td>
<td>1 027-1 060</td>
<td>ND</td>
<td>ND</td>
<td></td>
</tr>
<tr>
<td>TALUD IV St. 19</td>
<td>Pectinaster agassizii</td>
<td>1 240-1 245</td>
<td>3.7</td>
<td>0.73</td>
<td></td>
</tr>
<tr>
<td>TALUD IV St. 21</td>
<td>Ctenodiscus crispatus</td>
<td>1 200</td>
<td>2.4</td>
<td>1.82</td>
<td></td>
</tr>
<tr>
<td>TALUD IV St. 25</td>
<td>Radiaster sp.</td>
<td>835-870</td>
<td>5.0</td>
<td>0.29</td>
<td></td>
</tr>
<tr>
<td>TALUD IV St. 34</td>
<td>Ceramaster leptoceramus</td>
<td>1 240-1 250</td>
<td>3.5</td>
<td>0.79</td>
<td></td>
</tr>
<tr>
<td>TALUD V St. 11</td>
<td>Ceramaster leptoceramus</td>
<td>860</td>
<td>5.4</td>
<td>0.07</td>
<td></td>
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<tr>
<td>TALUD V St. 18</td>
<td>Ceramaster leptoceramus</td>
<td>940-990</td>
<td>5.0</td>
<td>0.15</td>
<td></td>
</tr>
<tr>
<td>TALUD V St. 19</td>
<td>Thrissacanthias penicillatus</td>
<td>1 180-1 200</td>
<td>4.0</td>
<td>0.38</td>
<td></td>
</tr>
<tr>
<td>TALUD V St. 20</td>
<td>Ceranaster aciculosus</td>
<td>1 470-1 525</td>
<td>2.8</td>
<td>1.20</td>
<td></td>
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<tr>
<td>TALUD V St. 25</td>
<td>Nearcaster aciculosus</td>
<td>800-860</td>
<td>5.2</td>
<td>0.13</td>
<td></td>
</tr>
<tr>
<td>TALUD VI St. 18</td>
<td>Radiaster sp.</td>
<td>890-950</td>
<td>5.3</td>
<td>0.29</td>
<td></td>
</tr>
<tr>
<td>TALUD VII St. 13B</td>
<td>Nymphaster diomedeae</td>
<td>1 400-1 450</td>
<td>3.0</td>
<td>1.04</td>
<td></td>
</tr>
<tr>
<td>TALUD VIII St. 3</td>
<td>Thrissacanthias penicillatus</td>
<td>1 100</td>
<td>3.0</td>
<td>0.39</td>
<td></td>
</tr>
<tr>
<td>TALUD VIII St. 11</td>
<td>Henricia sp. 1</td>
<td>920</td>
<td>5.0</td>
<td>0.2</td>
<td></td>
</tr>
<tr>
<td>TALUD VIII St. 16</td>
<td>Dipacaster laetmophilus</td>
<td>1 030</td>
<td>5.0</td>
<td>0.2</td>
<td></td>
</tr>
<tr>
<td>TALUD VIII St. 20</td>
<td>Thrissacanthias penicillatus</td>
<td>1 150</td>
<td>4.0</td>
<td>0.30</td>
<td></td>
</tr>
</tbody>
</table>
### Table 2. Continues

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

### 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). Exterme 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.

<table>
<thead>
<tr>
<th>Interval</th>
<th>Trawls</th>
<th>Samples</th>
<th>Species</th>
</tr>
</thead>
<tbody>
<tr>
<td>377-750 m</td>
<td>8</td>
<td>1</td>
<td>Ceramaster leptoceramus, Henricia sp. 1, Henricia sp. 2, Lophaster furcilliger, Peribolaster biserialis, Ampheraster hyperonchus</td>
</tr>
<tr>
<td>751-1 000 m</td>
<td>27</td>
<td>12</td>
<td>Radiaster sp., Nearchaster aciculosus, Ampheraster chiropus, Ampheraster hyperonchus, Henricia sp. 1, Lophaster furcilliger, Pectinaster agassizii, Ceramaster leptoceramus, Mediaster transfuga, Anteliaster coscinactis, Myxoderma platyacanthum</td>
</tr>
<tr>
<td>1 001-1 250 m</td>
<td>27</td>
<td>9</td>
<td>Dipsacaster laetepholus, Thrissacanthias penicillatus, Ctenodiscus crispatus, Nearchaster aciculosus, Pectinaster agassizii, Ceramaster leptoceramus, Myxoderma platyacanthum, Myxoderma sacculatum</td>
</tr>
<tr>
<td>1 251-1 500 m</td>
<td>18</td>
<td>3</td>
<td>Dipsacaster laetepholus, Ctenodiscus crispatus, Nearchaster aciculosus, Nymphaster diomedeae</td>
</tr>
<tr>
<td>1 501-2 250 m</td>
<td>36</td>
<td>1</td>
<td>Anteliaster coscinactis, Myxoderma platyacanthum</td>
</tr>
</tbody>
</table>
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), Solis-Marín et al. (2005), and Honey-Escandón et al. (2008). Solis-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 _Radiastra_, in addition to _Dipsacaster letmophilus_, which had previously been known only from Alaska; _Peribolaster biserialis_, previously known only from Alaska to California; _Ampheraster chiropius_ 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), _Pectinaster agassizii_, _Nymphaster diomedeae_, 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 lcpidentosus_). 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 Solis 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 _Perlobaster biserialis_ (first record for Mexico), _Myxoderma sacculatum_, _Antelaster coscinactis_, _Mediaster transfuga_, and _Ampheraster chiropius_ (to the southern Gulf of California), _Ceramaster leptoceramus_ (first records within the Gulf of California), _Ampheraster hyperoncus_ and _Nearchester 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 platylacanthum_, reported off Sonora by Solis-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 platylacanthum_ and of _Ampheraster hyperoncus_ 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 diomedeae_ (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.

<table>
<thead>
<tr>
<th>Species</th>
<th>Number of specimens</th>
<th>Number of stations</th>
<th>T°C (TALUD)</th>
<th>T°C (Previous)</th>
<th>O₂ (TALUD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dipsacaster laetmophilus</td>
<td>5</td>
<td>3</td>
<td>3.19-5.00</td>
<td>ND</td>
<td>0.20-0.44</td>
</tr>
<tr>
<td>Thrissacanthias penicillatus</td>
<td>8</td>
<td>6</td>
<td>3.00-5.00</td>
<td>5.0</td>
<td>0.20-0.40</td>
</tr>
<tr>
<td>Ctenodiscus crispatus</td>
<td>2</td>
<td>2</td>
<td>2.40-2.80</td>
<td>2.94-3.28</td>
<td>1.20-1.82</td>
</tr>
<tr>
<td>Radiaster sp. nov.</td>
<td>116</td>
<td>6</td>
<td>4.64-5.40</td>
<td>ND</td>
<td>0.07-0.29</td>
</tr>
<tr>
<td>Nearchaster aciculosus</td>
<td>107</td>
<td>6</td>
<td>3.19-5.75</td>
<td>4.38</td>
<td>0.03-0.44</td>
</tr>
<tr>
<td>Pectinaster agassizii</td>
<td>4</td>
<td>3</td>
<td>3.17-3.69</td>
<td>2.39-4.11</td>
<td>0.59-0.79</td>
</tr>
<tr>
<td>Ceramaster leptoceramus</td>
<td>8</td>
<td>4</td>
<td>5.00-8.22</td>
<td>7.0</td>
<td>0.15-0.38</td>
</tr>
<tr>
<td>Mediaster transfuga</td>
<td>3</td>
<td>2</td>
<td>5.03-5.40</td>
<td>4.8</td>
<td>0.07-0.29</td>
</tr>
<tr>
<td>Nymphaster diomedeae</td>
<td>3</td>
<td>2</td>
<td>3.0-3.7</td>
<td>2.89-6.28</td>
<td>0.73-1.04</td>
</tr>
<tr>
<td>Henricia sp. 1</td>
<td>8</td>
<td>2</td>
<td>5.0-8.22</td>
<td>ND</td>
<td>0.2-0.38</td>
</tr>
<tr>
<td>Henricia sp. 2</td>
<td>4</td>
<td>1</td>
<td>8.22</td>
<td>ND</td>
<td>0.38</td>
</tr>
<tr>
<td>Lophaster farcilliger</td>
<td>32</td>
<td>3</td>
<td>5.00-8.22</td>
<td>ND</td>
<td>0.11-0.38</td>
</tr>
<tr>
<td>Peribolaster biseriatus</td>
<td>2</td>
<td>1</td>
<td>8.22</td>
<td>ND</td>
<td>0-38</td>
</tr>
<tr>
<td>Amphipaster chiropus</td>
<td>1</td>
<td>1</td>
<td>5.0</td>
<td>ND</td>
<td>0.2</td>
</tr>
<tr>
<td>Amphipaster hyperoncus</td>
<td>17</td>
<td>3</td>
<td>5.03-8.22</td>
<td>7.0</td>
<td>0.03-0.38</td>
</tr>
<tr>
<td>Antielaster coscinactis</td>
<td>1</td>
<td>1</td>
<td>5.0</td>
<td>7.0</td>
<td>0.2</td>
</tr>
<tr>
<td>Myxoderma platycanthurum</td>
<td>12</td>
<td>6</td>
<td>4.25-6.65</td>
<td>7.0</td>
<td>0.03-0.29</td>
</tr>
<tr>
<td>Myxoderma sacculatum</td>
<td>2</td>
<td>2</td>
<td>ND</td>
<td>3.27-4.38</td>
<td>0.4</td>
</tr>
</tbody>
</table>

Total of specimens 335

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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