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First records of the class Crinoidea (Echinodermata) in the Colombian Pacific Ocean

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Abstract. The class Crinoidea is recorded for the first time in the Colombian Pacific Ocean based on 407 specimens collected on soft bottoms in eight stations at depths ranging from 350 to 934 m. Sampling was carried out using trawls with an epibenthic net (9 × 1 m opening, 2.5 knots for 10 min) during the Tumaco Offshore project (2012–2013). The specimens represent three comatulid crinoids, two of which were identified as *Florometra tanneri* (Hartlaub, 1895) and *Psathyrometra fragilis* (A.H. Clark, 1907); and one to the family level (Antedonidae). Taxonomic descriptions with images of the specimens, distribution, and comments of the two species collected in the Colombian Pacific are presented and discussed.

Key words. *Florometra tanneri*, local distribution, *Psathyrometra fragilis*, Tropical Eastern Pacific

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INTRODUCTION

The class Crinoidea includes the sea lilies (stalked and sessile forms) and feather stars, which lose their stalk early in development and cling to the bottom using the cirri. Some feather stars are able to swim by undulating their arms. Crinoids are the most basal group among the extant representatives of the phylum Echinodermata. Crinoids have the most complete and longest fossil record, dating back 500 million years. They were the dominant forms at that time in both deep and shallow waters; with the majority of fossils being sea lilies (Littlewood et al. 1997; Janies 2001). However, the increasing predation pressure changed the ecological structure of the sea floor ~200 million years ago, causing the migration of sessile invertebrates, such as isocrinid crinoids, from shallow to deep water (Whittle et al. 2018). Currently, Crinoidea is the least specious class of echinoderms. Only around 100 species of sea lilies remain, all in deep waters. The feather stars are the most diverse group of living crinoids, with around 540 species, found in all depths and all oceans (Birkeland 1989; Pearse and Messing 2007; Pawson 2007).

Crinoids are especially abundant in the Western Pacific and Indian Oceans, as well as in the Caribbean Sea. The large-scale distribution of crinoids in the Pacific Ocean shows a sharp decline in species richness from west to east, with lowest richness in the Tropical Eastern Pacific (TEP) (Birkeland 1989; Pérez-Ruzafa et al. 2013), probably as a result of both larval dispersal and nutrient availability (Birkeland 1989). Shorter larval life spans have been described for all living crinoids, which develop via a short-lived non-feeding larva, contrary to other echinoderm classes, some of which possess non-feeding larvae, as well as feeding larvae with longer pelagic larval duration (Birkeland 1989; McEdward and Miner 2001; Raff and Byrne 2006). Perez-Ruzafa et al. (2013) analyzed the patterns of biodiversity and biogeography of Latin American echinoderms, finding the class Crinoidea to be the least diverse, noting their absence in the region of Easter Island and scarcity in the Eastern South America, Galápagos, Panamanian, and Mexican provinces.

Birkeland (1989) revised the distribution of crinoids, recording 91 species in the East Indies, but no records in the Eastern Pacific. Based on a detailed bibliographic revision of the Central Eastern Pacific echinoderms, Maluf (1988) reported 12 species of crinoids from the region. Solís-Marín et al. (2013) listed 21 species in the Eastern Pacific, including records from Mexico to Chile, but did not include any species for the Colombian Pacific Ocean. Some information not considered by Solís-Marín et al. (2013) includes crinoids from northern or southern East Pacific localities, and from bathyal and abyssal depths (Roux 2002; Roux 2004; Messing 2008; Mironov 2008; Roux and Lambert 2011; Roux and Messing 2017; Senckenberg 2020), however, new information about crinoids from the TEP has not been subsequently published. The aim of

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this paper is to present the first record of the class Crinoidea in the Colombian Pacific Ocean based on collected specimens, providing new insights about this relatively depauperate group in the TEP.

STUDY AREA

The Colombian Pacific Ocean covers approximately 339,100 km^2 and extends along 1,300 km of coastline, encompassing multiple ecosystems and environments. It is part of the Panamanian biogeographic province, which is one of the three provinces of the TEP (Hastings 2000). This work took place in the southern region of the Colombian Pacific Ocean, between 01.6087, −079.3883 and 02.5557, −079.0476, a portion of marine territory of approximately 7,308 km^2, near the continental coast that extends offshore from the Sanquianga National Natural Park (Nariño), to the Colombian-Ecuadorian border, with depths ranging from 200 to 1,300 m (INVEMAR-ANH 2013). This area is characterized by large amounts of organic matter carried from continental tributaries such as the Patía, Mira, and Esmeraldas rivers, and for having a greater variety of landforms and substrates. These oceanic landforms include a submarine canyon, one of the most notorious features of the Tumaco area, as well as valleys, scarps, underwater plateaus, mountains, and hills (INVEMAR-ANH 2013; Santos-Barrera 2015).

METHODS

Crinoids were collected in the Colombian waters of the Tropical Eastern Pacific (TEP), during the Tumaco Offshore project (2012–2013), developed by the Institute of Marine and Coastal Research (INVEMAR) and

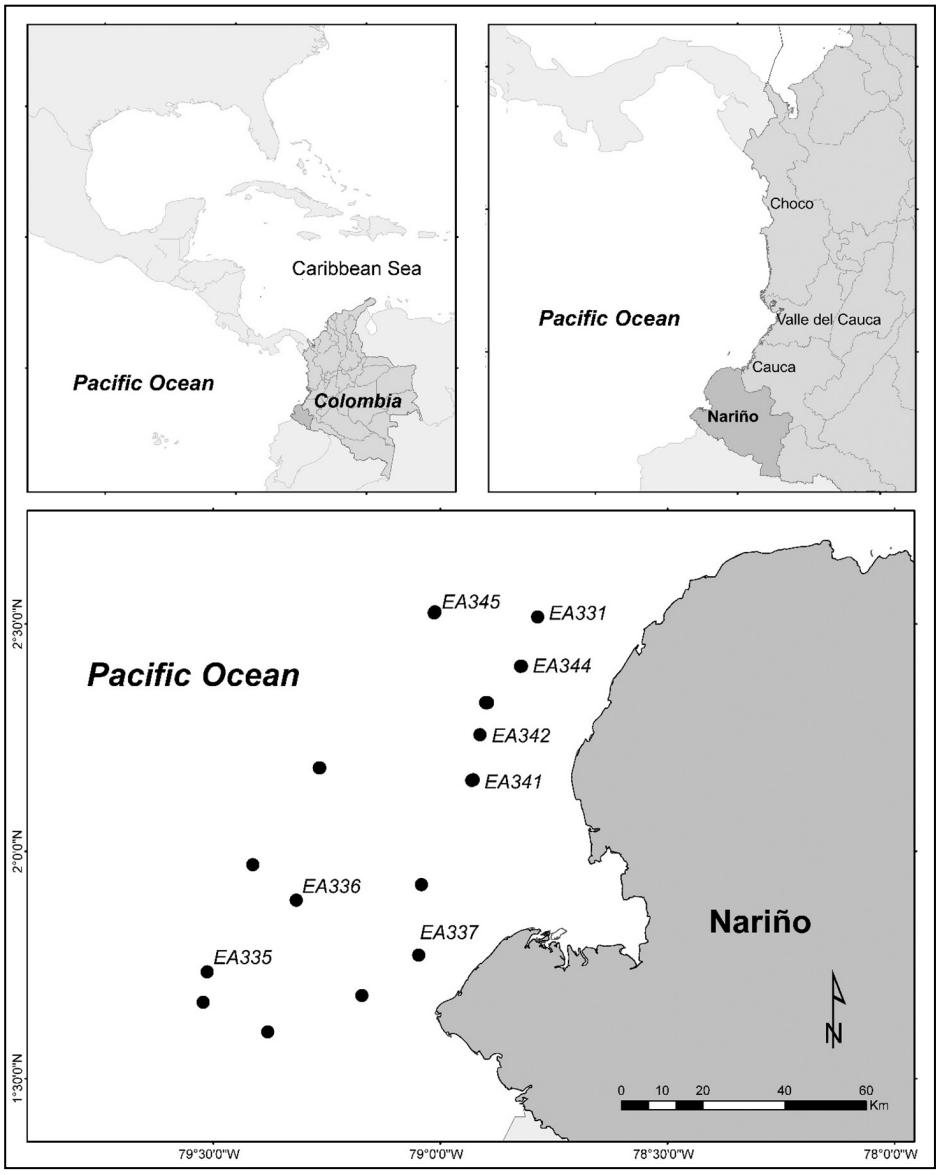

Figure 1. Sampling stations of the Tumaco Offshore Project in the southern Colombian Pacific Ocean. Stations where crinoid specimens were collected are indicated with the prefix EA and number.

the National Agency of Hydrocarbons (ANH) of Colombia. Sampling was carried out on soft bottoms at 15 localities in the Southern Colombian Pacific (offshore of Nariño Department), using trawls with an epibenthic net (9 × 1 m opening, 10 mm mesh size, 2.5 knots for 10 min) (Figure 1). The specimens were collected in 8 of the 15 stations sampled, in depths ranging from 350 to 934 m. Specimens were relaxed, preserved in 96% ethanol and stored in the Echinoderms collection of the Marine Natural History Museum of Colombia (MHNMC) – Makuriwa of INVEMAR (INV EQU). The feather stars were identified based on the external morphological characteristics following the taxonomic information presented by Clark and Clark (1967), Messing and White (2001), Messing (2019), and consultations with other crinoid taxonomists.

RESULTS

Trawling samples collected 407 crinoid specimens representing three morphotypes in the Southern Colombian Pacific Ocean (Figure 1). They belong to the families Antedonidae (2 morphotypes) and Zenometridae (1). Two morphotypes were identified to species: *Florometra tanneri* (Hartlaub, 1895) and *Psathyrometra fragilis* (A.H. Clark, 1907). The third morphotype was identified to family level (Antedonidae). Only two incomplete specimens of this morphotype were collected without cirri and with broken arms, mostly by the first syzygy at br9+10 (Figure 2F, G). They were found in two stations (EA336, EA345) between a depth of 612 to 668 m (INV EQU4014, INV EQU4015).

The two species identified, and therefore the two families, are reported for the first time in the Colombian Pacific Ocean, although they were previously recorded from the TEP (Messing and White 2001; Solís-Marín et al. 2013). The main morphological characteristics of the species collected are detailed below, as well as their distribution and some taxonomic comments.

Class Crinoidea
Order Comatulida
Family Antedonidae

***Florometra tanneri* (Hartlaub, 1895)**
Figure 2A–E

Material examined. COLOMBIA • TEP, Southern Colombian Pacific Ocean, Nariño, Station EA 331, offshore; 02.5078, −078.7993; depth 350 m; 20.XII.2012; trawl net; Tumaco Offshore Expedition leg.; 391 specimens; INV EQU4007.

Identification. (After Clark and Clark 1967). Third syzygy between brachials 16 + 17 (sometimes between brachials 15 + 16); no carinate process on the basal segments of the oral pinnules which therefore appear very slender; the middle and distal pinnules are also more slender with more elongate segments than those of any of the other species in the genus; centrodorsal flattened hemispherical with a more or less deep depression at the dorsal pole; the cirrus sockets completely cover the sides and are arranged in 4 or 5 alternating rows; cirrus segments are for the most part elongated, but distal are shorter and bear a small terminal spine on the dorsal side.

Distribution. The species has been reported from the Tres Marías Islands (Mexico) southward to the Bay of Panama (Clark and Clark 1967; Maluf 1988; Solís-Marín et al. 2013). This is the first record for the Colombian Pacific Ocean and is an extension of the geographic distribution in the TEP. The depth range has been reported between 523-1,429 m by Clark and Clark (1967), however 104 to 207 by Solís Marín et al. (2013); the present record is at 350 m depth.

Comments on identification. Currently, the genus *Florometra* A.H. Clark, 1913 includes nine accepted species (Messing et al. 2023a). Solís-Marín et al. (2013) reported four distributed in the Eastern Pacific: *Florometra magellanica* (Bell, 1882), *Florometra mawsoni* A.H. Clark, 1937, *Florometra serratissima* (A.H. Clark, 1907), and *Florometra tanneri* (Hartlaub, 1895). Although Solís-Marín et al. (2013) also reported *Florometra parvula* (Hartlaub, 1895) in Cocos Island (Costa Rica), it appears to be a mistake, referring instead to the species *Fariometra parvula* (Hartlaub, 1895) (WoRMS 2023, Messing et al 2023a). *Florometra tanneri* is distinguished from *F. mawsoni* because this species has the third syzygy between brachial 14 + 15, and it is distributed in the South East Pacific, in Chile; from *F. magellanica* and *F. serratissima* it is distinguished by the basal segments of the pinnules enlarged and carinate (Clark and Clark 1967). The specimens collected in Colombia resemble those belonging to *F. magellanica* reported by Prieto-Rios et al. (2011). However, the specimens studied here were identified as *F. tanneri* based on geographical distribution, comparison of pinnules, and the general morphology based on the images of *F. magellanica* and *F. serratissima* available in Messing et al. (2023b) and Hendler (1996), respectively. Clark and Clark (1967) mentioned that *F. tanneri* co-occurs with *Fariometra parvula*, which is very easily mistaken for its young. In *Fariometra parvula*, however, the centrodorsal is sharply conical, and the third syzygy is between brachials 14 + 15 (Clark and Clark 1967).

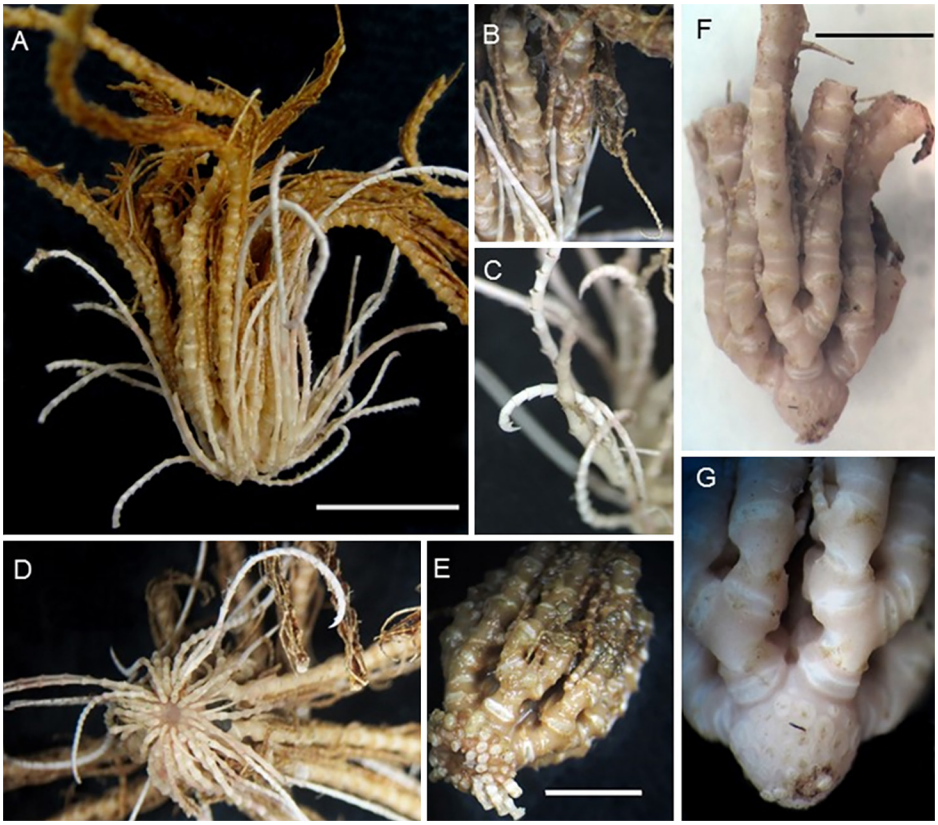

Figure 2. *Florometra tanneri*. **A.** Lateral view of one complete specimen. **B.** Detail of oral pinnules. **C.** Detail of cirri, showing the shorter distal segments bearing a small terminal spine on the dorsal side. **D.** Detail of the flattened and hemispherical centrodorsal with a more or less deep depression at the dorsal pole covered by complete cirri. **E.** Specimen with broken cirri. Antedonidae sp. **F.** Lateral view of one incomplete specimen. **G.** Detail of centrodorsal, showing the cirrus sockets (Photos by Christian Diaz, Scale bars: A: 10 mm; E: 4 mm; F: 3 mm).

Family Zenometridae

***Psathyrometra fragilis* (A.H. Clark, 1907)**
Figures 3, 4, Table 1

Material examined. COLOMBIA • TEP, Southern Colombian Pacific Ocean, Nariño, Station EA 335, offshore; 01.7499, −079.5017; depth 866 m; 11.XII.2012; 105 trawl net; Tumaco Offshore Expedition leg.; 2 specimens; INV EQU4008. • TEP, Southern Colombian Pacific Ocean, Nariño, Station EA 337, offshore; 01.7811, −079.0351; depth 530 m; 11.XII.2012; trawl net; Tumaco Offshore Expedition leg.; 7 specimens; INV EQU4009 • TEP, Southern Colombian Pacific Ocean, Nariño, Station EA 341, offshore; 02.1484, −078.9409; depth 934 m; 11.XII.2012; trawl net; Tumaco Offshore Expedition leg.; 1 specimen; INV EQU4010 • TEP, Southern Colombian Pacific Ocean, Nariño, Station EA 342, offshore; 02.5558, −079.0477; depth 775; 11.XII.2012; trawl net; Tumaco Offshore Expedition leg.; 1 specimen; INV EQU4011 • TEP, Southern Colombian Pacific Ocean, Nariño, Station EA 344, offshore; 02.3905, −078.8288; depth 656 m; 11.XII.2012; trawl net; Tumaco Offshore Expedition leg.; 2 specimens; INV EQU4012 • TEP, Southern Colombian Pacific Ocean, Nariño, Station EA 345, offshore; 02.5557, −079.0476; depth 668 m; 21.XII.2012; trawl net; Tumaco Offshore Expedition leg.; 1 specimen; INV EQU4013.

Identification (After Messing and White 2001). Centrodorsal truncated conical, taller than wide, 2.7–5.7 (6.1) mm across the base, 2.9–7.7 mm tall; H/D usually 0.78–1.53 (rarely less than 0.90); aboral pole ranging from convex to flat or excavated; sometimes bordered with weak eroded spines or papillae. Cirrus sockets crowded or well separated, in three or four columns per radial area with three to six sockets per column, occasionally reduced to two columns near the apex, separated interradially by narrow flat strip with short basal interradial ridge ranging from low but distinct to almost non-existent. Four columns, when present, restricted to broader basal portion of centrodorsal. Distal end of oral margin of middle and mid-distal cirrals often extended distally as triangular spine (visible in oral view); penultimate cirral squarish with weak opposing spine; axil and br2 with concave proximolateral margins, smooth aborally or with very fine spinules; proximal brachials with moderately or well-developed alternating articular tubercles; distal midaboral margins of middle and distal brachials smooth. Colour of most specimens collected is pink, however there were two dark purple specimens (Figure 3A–E).

Distribution. Pacific Rim from southern Japan northward to the Aleutian Islands and southward to Monterey Bay, California (Clark and Clark 1967), and Gulf of Panama (Messing and White 2001). Bathymetric distribution among 439 (possibly 197) to 2,903 m (Clark and Clark 1967). Depth interval in the Colombian Pacific Ocean was 530 to 934 m. This species was not included in the species list presented by Solís-Marín et al. (2013).

Figure 3. *Psathyrometra fragilis*. **A-C.** One specimen INV EQU4012 showing details of the cirrus tips and centrodorsal. **D, E.** One specimen INV EQU4009 showing details of centrodorsal. **F, G.** One specimen INV EQU4009. **H, I.** One specimen INV EQU4008 (Photos by Christian Diaz, Scale bars: A: 5 mm; D: 3 mm; F: 3 mm; H: 5 mm).

Table 1. Variability of centrodorsal height (mm), diameter (mm) and H/D ratio in the crinoid *Psathyrometra fragilis* collected in the southern Colombian Pacific Ocean. Bold values in the far-right column indicate specimens with H/D < 0.90.

Catalog No.	No. ind.	Height (H)	Diameter (D)	H/D
INV EQU4008	1	5.07	4.26	1.19
	2	2.66	2.75	0.97
INV EQU4009	1	4.46	5.08	**0.88**
	2	4.21	3.95	1.07
	3	4.17	3.62	1.15
	4	3.45	3.51	0.98
	5	4.61	4.78	0.96
	6	3.57	3.32	1.08
	7	3.26	3.61	0.90
	8	Broken		
INV EQU4010	1	2.95	2.95	1.00
INV EQU4011	1	4.85	4.71	1.03
INV EQU4012	1	6.14	5.58	1.10
	2	5.4	4.63	1.17
INV EQU4013	1	3.45	3.8	0.91
	2	3.61	3.13	1.15
	3	4.25	4.83	**0.88**
	4	4.05	4.08	0.99
	5	4.05	4.61	**0.88**

Figure 4. *Psathyrometra fragilis* centrodorsals and ray bases morphological variation. **A.** INV EQU4008. **B.** INV EQU4010. **C.** INV EQU4011. **D, E.** INV EQU4009. **F, G.** INV EQU4012. **H.** INV EQU4013. Measurements of these specimens are given in Table 1. (Photos by Giomar Borrero, Scale bar: 5 mm).

Comments on identification. Currently, the genus *Psathyrometra* includes three species: *P. fragilis* (A.H. Clark, 1907), *P. congesta* A.H. Clark, 1908 (known only from the type locality in Kauai Island, Hawaii at 966 m depth), and *P. bigradata* (Hartlaub, 1895), recorded in the Galapagos Islands and possibly in the Gulf of Panama between 484 and 740 m depth (Messing and White 2001). The main characters for distinguishing *P. fragilis* from *P. bigradata* and *P. congesta* are the shape of the centrodorsal and the ratio between the height and the diameter (H/D). The centrodorsal of *P. bigradata* is convex conical, wider than tall (3.4–5.0 mm across, 2.9–4.0 mm tall; H/D = 0.80–0.84), while in *P. congesta* it is truncated conical with convex sides, also wider than tall (4.9 mm, height 3.9 mm; H/D = 0.79) (Messing and White 2001). Although these values are included in the variation range described for *P. fragilis*, in the identification section they are less than 0.90. The measurements of the 18 specimens collected are 2.75–5.58 mm across, 2.66–6.14 mm tall; H/D = 0.88–1.19, always values higher than those of the other species; only three specimens are less than H/D = 0.90 (Table 1; Figure 4). Although the characteristics of the centrodorsal was diagnostic for the species, it was noted on the base of the remaining intact peripheral cirrus (Figure 3B) that the penultimate cirral was longer than wide, tapered, with opposing spine absent, which is characteristic of *P. bigradata*, since *P. fragilis* has the penultimate cirral squarish with weak opposing spine (Messing and White 2001: figure 10, p. 171).

DISCUSSION

Recent biodiversity characterization in shallow and deep ecosystems of the Northern and Southern Colombian Pacific Ocean has revealed new species and new information for echinoderms and other marine invertebrates, such as mollusks and cnidarians, suggesting that the Colombian Pacific Ocean is a region still relatively unexplored (Suárez-Mozo et al. 2018; Borrero-Pérez and Vanegas-González 2019; Vanegas-González and Borrero-Pérez 2020; Mejía-Quintero et al. 2021). The species here reported from Colombia are not new records for the TEP, however, because this is a rare, not common echinoderm group in this area, and little material of these genera and species have been collected since Clark and Clark (1967) and Messing and White (2001), the information presented here increases the knowledge of the crinoids not only in Colombia, but also in the East Pacific.

The record of *Thaumatometra* sp. from Malpelo Island (3,240 m depth) presented by Maluf (1988) has been unnoticed in previous Colombian echinoderms lists, perhaps because the specimens were not identified to the level of species (Cohen-Rengifo et al. 2009; Benavides-Serrato et al. 2013; Solís-Marín et al. 2013). This *Thaumatometra* sp. from Malpelo could be referring to *Fariometra parvula* (Hartlaub, 1895), distributed in the TEP, which is synonymous with *Thaumatometra parvula* (Hartlaub, 1895). No other species of this genus is distributed in the East Pacific, with the exception of *Thaumatometra brevicirra* (A.H. Clark, 1908) from Alaska and California (Orrell 2020).

Different local distribution patterns for each identified crinoid species were found, collecting few individuals (from 1 to 7) of *Psathyrometra fragilis* in six of the 15 stations, being a frequent but not abundant species in the study area. Conversely, a total of 391 specimens of *Florometra tanneri* were collected from a single station, suggesting that the species forms high density populations in the study area. This species was collected in the shallower station (EA331; 350 m depth), where a large amount of wood and plant fragments were found, which could provide substrate for these organisms. There are several references reporting *Florometra* species living in high density populations, such as *Florometra serratissima* (A.H. Clark, 1907) which is recorded as a common and abundant species in temperate, shallow water from central California to Oregon in densities of at least 30 ind./m^2 (Clark and Clark 1967; Hendler 1996; Pearse and Messing 2007). In addition, the two unidentified specimens of Antedonidae was collected from two of the 15 stations sampled.

Because of its oceanographic and geomorphological characteristics, the southern region of the Colombian Pacific Ocean has high levels of spatial heterogeneity and availability of habitats, and is recognized for its high biodiversity (INVEMAR-ANH 2013; Santos-Barrera 2015). In this area, filter feeding organisms similar to crinoids, were collected. They included octocorals associated with a high-density population of brittle stars from the order Euryalida (Mejía-Quintero et al. 2021). During a previous project developed in 2003 in the Colombian northern area, between 04.7669, −077.4389 and 06.9678, −077.7189, from 70 to 500 m depth using the same sampling gear, crinoids were not collected (Macrofauna III project, unpublished data). However, recent observation using a Remotely Operated Vehicle (ROV) from the northern Colombian Pacific Ocean at depths greater than 1,800 m showed the presence of crinoids on rocky and muddy bottoms (Cedeño-Posso et al. 2022 unpublished data). These results demonstrate that exploration of the Colombian Pacific must continue, especially for this group of uncommon echinoderms.

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ADDITIONAL INFORMATION

Conflict of interest

The author declares that no competing interests exist.

Ethical statement

No ethical statement is reported.

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Data availability

All data that support the findings of this study are available in the main text and deposited at GBIF, the Global Biodiversity Information Facility, available at https://doi.org/10.15472/vlngiu.

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