

Soft substrate crinoids (Crinoidea: Comatulida) and their macrosymbionts in Halong Bay (North Vietnam)

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Abstract. The soft-bottom fauna of feather stars (Comatulida) and their associated symbionts of Halong Bay (Gulf of Tonkin, northern Vietnam) are described. Five species from four families were found, of which three were recorded from the Gulf of Tonkin for the first time; two species, *Capillaster gracilicirrus* and *Oligometra serripinna*, are new records for the coast of Vietnam. These findings extend the list of crinoids living in the Gulf to 10 species and the list of Vietnam crinoids to 71 species. Four species belonging to three families represent the first records of feather stars on sediment substrates in Vietnamese waters. One species, *O. serripinna*, was found attached to gorgonians. The assemblage consists of both inhabitants of sediments and coral reef species, with morphological and behavioral adaptations allowing them to occupy soft sediments (i.e., clinging to gorgonians, employment of long cirri and arms for elevating body above the bottom). All species examined harbour specialised macrosymbionts. Species composition of symbiotic associates differs substantially from that of feather stars from adjacent areas. Amphipods were most common in Halong Bay but were rarely reported from other areas, whereas shrimps and crabs, the most important feather star associates in other areas, were completely absent in Halong Bay. We suggest that this is related to peculiar environmental conditions in the Halong Bay i.e., intensive sedimentation, low water temperature, and decreased salinity during winter, rather than to its geographical location.

Key words. Comatulida, feather star, Vietnam, soft-bottom community, symbionts

INTRODUCTION

Feather stars, members of the crinoid order Comatulida that loses its stalk following a postlarval stage, are common inhabitants of shallow-waters of the tropics, with the highest diversity of more than 100 species recorded from the East Indian Archipelago (Messing, 1994). Feather stars prefer to colonise hard substrates, e.g., dead and living scleractinians, rocks, boulders, wrecks, gorgonians, and sponges, and are rarely reported on the soft substrates (e.g., Zmarzly, 1984; Messing, 2007). Nevertheless, a number of feather star species inhabit soft substrates and even form relatively rich assemblages, playing an important role in epibenthic communities (Stevens & Connolly, 2003). The most diverse one, including 12 species of comatulids, was discovered in the vicinity of Lizard Island (Messing et al., 2006).

The shallow-water crinoid fauna of Vietnam includes 69 feather star species, most of which are hard substrate inhabitants (Mekhova & Britayev, 2012). For comparison, among 31 species reported for the Bay of Nhatrang (Central Vietnam), the best studied local area, only one, *Phanogenia multibrachiata* (Carpenter, 1888), was recorded

on unconsolidated substrates (Mekhova & Britayev, 2012). Geographically, surveys of crinoids in Vietnam have been concentrated in the central and southern part of the coast, while its northern part, the Tonkin Gulf, has been poorly investigated. Till now, six species, two stalked crinoids and four feather stars have been found there, while data on their habitats, distributional depths and substrates have not been provided (Guryanova, 1972; Ho, 1994). Among feather stars reported in the Gulf, three species, *Comaster schlegelii* (Carpenter, 1881), *Zygometa comata* AH Clark, 1911, and *Cenometra bella* (Hartlaub, 1890) are known as inhabitants of hard substrates, while only one species, *Comatula solaris* Lamarck, 1816, has been reported from soft substrates (Zmarzly, 1985; Messing, 2007; Mekhova & Britayev, 2012).

The aim of the current report is to provide first information on the comatulids inhabiting unconsolidated substrates of Halong Bay, North Vietnam. The Bay lies in the inner part of the Tonkin Gulf. The Red River brings abundant suspended matter, cools the water to 16–18°C, and decreases salinity to 28‰ in winter (Guryanova, 1972; Latypov, 2003). As a consequence, coral reefs are less developed and grow only at depths shallower than 4 m, while most of the Bay is floored by soft sediment, such as silts and silty sand with shell fragments (Latypov, 2003).

Special attention is paid to the location of the animals on the substrate, shape of the filtration fan, coloration, and composition of associated symbiotic fauna.

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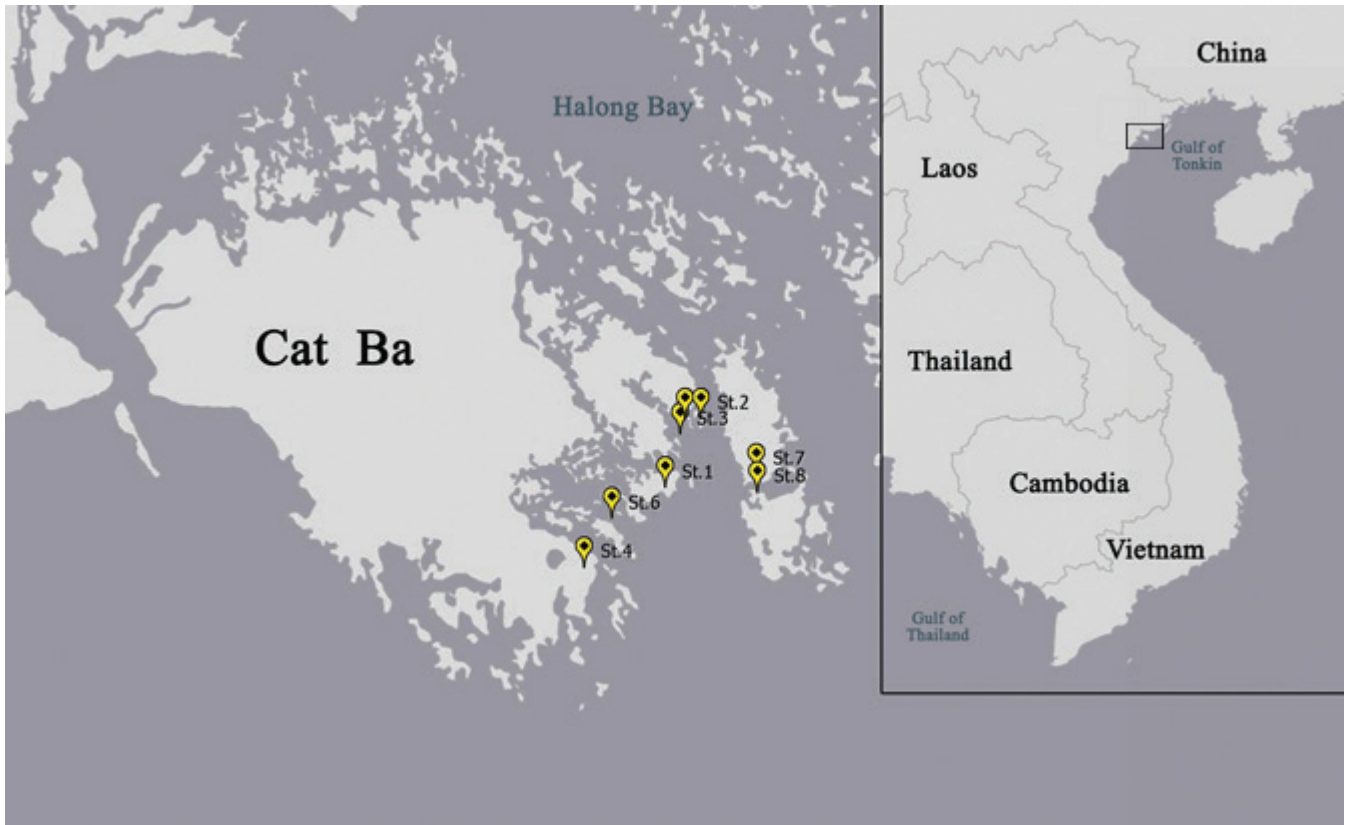


Fig. 1. Location of stations in Halong Bay on the coast of Katba Island, Tonkin Gulf, South China Sea.

MATERIAL AND METHODS

Crinoids were collected on the east coast of Katba Island (Halong Bay, northern Vietnam) in April and May 2012 (Fig. 1, Table 1). Sampling was performed by SCUBA diving at depths of 1–15 m during the day. Water visibility never exceeded 1 m; and currents were very weak or absent. To prevent mixing and loss of symbionts, crinoids were placed individually in plastic zip-lock bags in situ and raised onboard. During the sampling, the existence of aggregations, inhabited substrate, position on the substrate, dial activity, shape of filtration fan, coloration, and depth were registered.

Terminology of arms arrangement follows Meyer & Macurda (1980). According to their distributions and occurrences in the Bay, we divided collected crinoids into four groups (Mekhova & Britayev, 2012): (1) numerous, species found at most sampling sites and forming numerous aggregations; (2) common, species found at several sampling sites and forming numerous aggregations; (3) rare, species found at several sampling sites, but only in low numbers; (4) very rare, species found at few sites and only in low numbers.

In the laboratory, arms and cirri were counted, longest arm length was measured in each specimen, and crinoids were carefully checked for symbionts under a binocular microscope. Additional symbionts were extracted by washing the crinoids in a 20% solution of alcohol in seawater, and sieving the solution through a 100 μ m mesh screen. After that, crinoids and their symbionts were preserved in 70% ethanol.

For identification of symbiotic polynoids and myzostomids we employed papers of Britayev et al. (1999) and Eeckhaut et al. (1998) respectively, ophiuroids was identified by A Martynov.

RESULTS

A total of 37 specimens of crinoids were collected. Five species of feather stars from four families were found. Four of them were recorded for the first time in the Gulf of Tonkin, and one species, *Capillaster gracilicirrus*, is a new record for the Vietnamese coast. Thus, the list of crinoid species for the Gulf of Tonkin contains 10 species, eight species of feather stars and two species of stalked crinoids (Table 2).

Family Comatulidae

Comatula cf. solaris Lamark, 1816

(Fig. 2a)

Comatula solaris Lamark 1816: 533; Clark AH, 1921: 233 pl.1 figs. 960–962; Clark & Rowe, 1971: pp. 6–7, 14, pl. 1 figs. 7, 8; Rowe & Gate, 1995: 148; Messing, 2015.

Material. South China Sea, Halong Bay, Katba Is., St.1, 1–4 m depth, 30 April 2012 – 1 specimen; St. 2, 10–15 m depth, 30 April 2012 – 15 specimens; St. 3, 4–5 m depth, 1 May 2012 – 3 specimens; St.7, 0–3 m depth, 4 May 2012 – 3 specimens; St. 8, 1–10 m depth, 6 May 2012 – 4 specimens.

Table 1. List of sampling stations with geographical coordinates, sampling dates, substrate, and comatulids species collected.

Station No	Coordinates	Data	Depth (m)	Substrate	Crinoids (individuals number)
1	N 20° 46' 02.5'' E 107° 05' 48.0''	30 April 2012	1–4	muddy sand	<i>Amphimetra tessellata</i> (1) <i>Comatula solaris</i> (1)
2	N 20° 47' 23.1'' E 107° 06' 31.9''	30 April 2012	10–15	muddy sand with shell fragments	<i>Amphimetra tessellata</i> (2) <i>Comatula solaris</i> (15) <i>Oligometra serripinna</i> (3) <i>Zygometra comata</i> (1)
3	N 20° 47' 05.4'' E 107° 06' 06.2''	01 May 2012	4–5	dead coral reef, muddy sand with fragments of corals	<i>Comatula solaris</i> (3)
4	N 20° 44' 29.8'' E 107° 04' 05.9''	01 May 2012	4–6	dead corals	No comatulids
5	N 20° 47' 22.7'' E 107° 06' 13.0''	03 May 2012	1–5	octocorals on silty-sand (1–3 m), silt (3–5 m)	No comatulids
6	N 20° 45' 26.7'' E 107° 04' 41.6''	03 May 2012	1–6	scleractinian and octocorals	<i>Oligometra serripinna</i> (1)
7	N 20° 46' 18.6'' E 107° 07' 42.0''	04 May 2012	0–3	octocorals on the muddy sand, muddy sand	<i>Comatula solaris</i> (3)
8	N 20° 45' 57.4'' E 107° 07' 43.3''	06 May 2012	1–10	scleractinian and octocorals, muddy sand	<i>Comatula solaris</i> (4) <i>Capillaster gracilicirrus</i> (1) <i>Oligometra serripinna</i> (5)

Table 2. Species list of crinoids of the Gulf of Tonkin with notes on their dial activity and preferred substrates in the Gulf. D – diurnal species, N – nocturnal species, UN – activity and substrate is unknown in the Gulf. Species reported for the first time from the Gulf and the coast of Vietnam marked by bold and asterisk, respectively.

Crinoid species	Dial activity	Substrate	References
<i>Amphimetra tessellata</i>	D	muddy sand	This report
<i>Capillaster gracilicirrus</i> *	N?	muddy sand	This report
<i>Cenometa bella</i>	D	on gorgonians	Guryanova, 1972
<i>Comaster schlegelii</i>	UN	UN	Guryanova, 1972
<i>Comatula solaris</i>	UN	UN muddy sand	Guryanova, 1972, this report
<i>Metacrinus superbus</i>	UN	UN	Guryanova, 1972
<i>Metacrinus</i> sp.	UN	UN	Guryanova, 1972
<i>Oligometra serripinna</i> *	D	on gorgonians	This report
<i>Zygometra comata</i>	D	muddy sand	Ho, 1994

Coloration. Uniformly brown with a pinkish tinge, red in alcohol.

Measurements. Ten arms 80–120 mm in length: 9–16 cirri 7–12 mm in length.

Taxonomic remarks. Genus *Comatula* consists of seven species with four having cirri (Messing, 2015). Cirri arranged in one row around centrodorsal, numbers usually exceeding 10 (Fig. 2). Number of cirrals usually less than 16. P1 and P2 have long combs with 20–26 confluent teethes. P3 and following pinnules without combs. Second and third basal segments of P2 with small ridge-like extensions on the

aboral sides. Five of 10 arms without ambulacral grooves. These features are in accordance with diagnoses of *C. solaris* provided by Messing (2015). Closely related species, *C. pectinata* and *C. tenuicirra* have less number of cirri on 1–2 interradial corners.

Ecological notes. Common. Found both solitarily and in groups of three to seven individuals, on soft ground in burrows, recesses, or under dead bivalve shells; depth range 1–15 m. Probably nocturnal; during the day arms are usually folded. In some individuals arms were extended but did not form a filtration fan. Reported previously on soft substrate under a small rock (Messing et al., 2006).

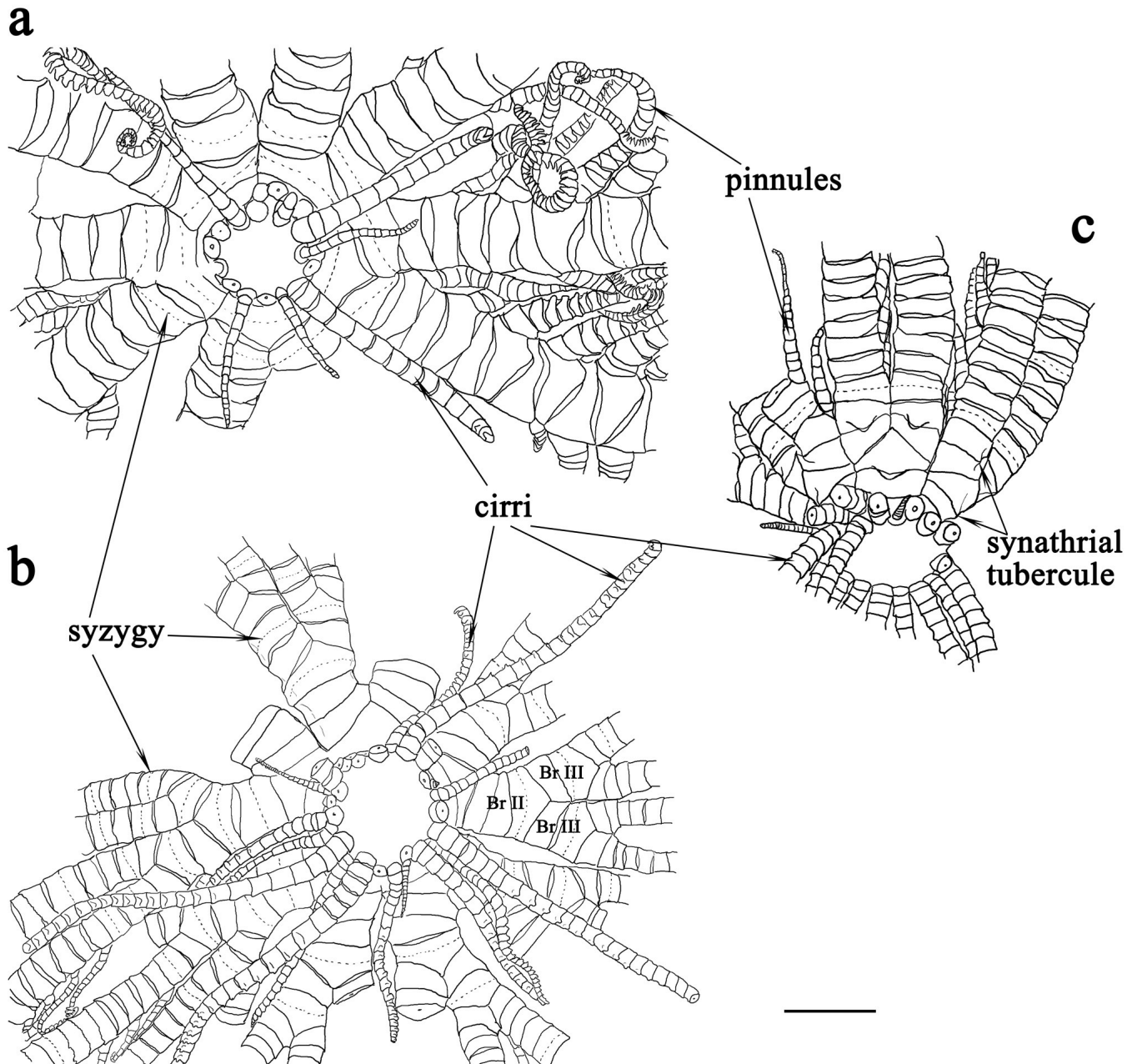


Fig. 2. Proximal ray articulations, branching patterns and arrangement of cirri: a, *Comatula purpurea*; b, *Capillaster gracilicirrus*; c, *Amphimetra tessellata*. IIBr and IIIBr division series. Scale bar = 1 cm.

Symbionts. Polychaetes *Hololepidella* cf. *laingensis* Britayev, Doignon & Eeckhaut, 1999, *Myzostoma* cf. *fissum* Graff, 1884; ophiuroid *Ophiomaza cacaotica* Lyman, 1871; gastropod Eulimidae gen. sp.; Amphipoda gen. sp.

Distribution. Vietnam, China, Singapore (Lane et al., 2000), North Australia, West India (Clark & Rowe, 1971; Messing, 2014).

***Capillaster gracilicirrus* Clark AH, 1912**
(Fig. 2b)

Capillaster gracilicirra Clark AH, 1912: p. 18; Clark AH, 1918: pp. 10 (in key), 11, 276, pl. 11, fig. 3; Messing, 2015.

Material. South China Sea, Halong Bay, Katba Is., St. 8, 5 m depth, 6 May 2012 – 1 specimen.

Coloration. Dark brown pinnules and light brown arms, becoming fully dark brown in alcohol.

Measurement. Thirty eight arms, with length unknown (damaged); 22 cirri 19 mm in length.

Taxonomic remarks. Morphology of this specimen is in accordance with the diagnoses of *C. gracilicirrus* provided by Messing (2015).

Ecological notes. Very rare. Solitary, 5 m depth, on muddy sand close to the base of zoantarian. Probably nocturnal, during the day, fully exposed but with arms folded. Habitat of *C. gracilicirrus* was previously unknown.

Symbionts. Polychaete *Hololepidella* cf. *laingensis*.

Table 3. Symbiotic species associated with comatulids in the Halong Bay and number of their individuals. P – polychaeta, G – gastropoda, C – crustacean, O – ophiuroid.

Symbiont\Host	<i>Amphimetra tessellata</i>	<i>Comatula solaris</i>	<i>Capillaster gracilicirra</i>	<i>Zygometra comata</i>	<i>Oligometra serripinna</i>
<i>Hololepidella</i> cf. <i>laingensis</i> (P)	1	25	2	2	0
<i>Myzostoma</i> cf. <i>fissum</i> (P)	1	1	0	0	1
Eulimidae gen. sp. (G)	0	1	0	0	0
Amphipoda gen. sp. (C)	46	3	0	1	0
<i>Ophiomaza cacaotica</i> (O)	15	39	0	3	0

Distribution. Halong Bay, northern Vietnam; Madura Island, Indonesia (Messing, 2015). First record from the coast of Vietnam.

Family Himerometridae

Amphimetra tessellata (Müller, 1841)

(Fig. 2c)

Alecto tessellata Müller, 1841: 179–189

Amphimetra tessellata discoidea Clark AH, 1909:

Amphimetra discoidea Clark AH, 1911: 435–467

Amphimetra tessellata Clark AH, 1921: 128; Mekhova & Britayev, 2012: 461–462; Messing, 2015.

Material. South China Sea, Halong Bay, Katba Is, St.1, 1–4 m depth, 30 April 2012 – 1 specimen; St. 2, 10–15 m depth, 30 April 2012 – 2 specimens.

Coloration. White, becoming purple in alcohol. It differs from our specimens from Nhatrang Bay having bright-brown coloration (Mekhova & Britayev, 2012).

Measurements. Ten arms 70–140 mm in length, 21–30 cirri 23–31 mm in length.

Taxonomic remarks. Morphology of this specimen is in accordance with the diagnoses of *A. tessellata* provided by Messing (2015). It differs by a small synarthrial tubercle on IBr2 from closely related species, *A. ensifer* (Clark AH, 1909) having a synarthrial tubercle on IBr2 developed as a tall conical process (Messing, 2015). Our specimens slightly smaller than that found in Nhatrang Bay (Mekhova & Britayev, 2012).

Ecological notes. Rare. Found solitary, 4–15 m depth, on muddy sand. Diurnal, during the day fully exposed with the arms arranged in a parabolic filtration fan. Reported earlier clinging to algae, rocks and boulders (Messing et al., 2006; Mekhova & Britayev, 2012).

Symbionts. Polychaetes *Hololepidella* cf. *laingensis*, *Myzostoma* cf. *fissum*; ophiuroid *Ophiomaza cacaotica*; Amphipoda fam. et gen. sp.

Distribution. Japan, China, Vietnam, Philippines, Indonesia, Thailand, Australia, Fiji, India. (Clark & Rowe, 1971; Lane et al., 2000; Mekhova & Britayev, 2012; Messing, 2015). First record from the Tonkin Gulf.

Family Zygometridae

Zygometra cf. *comata* AH Clark, 1911

(Fig. 3a, b)

Zygometra comata Clark, AH, 1911: 537; Clark AH, 1921: 19–20, 70, 83, 88, figs. 27, 28; Clark AM & Rowe 1971: 17, Liao & Clark AM, 1995: 32, fig. 15; Kogo, 1998: 53, fig. 41; Mekhova & Britayev 2012: 466; Messing, 2015.

Material. South China Sea, Halong Bay, Katba Is., St. 2, 10–15 m depth, 30 April 2012 – 1 specimen.

Coloration. Dark brown, becoming red-brown in alcohol.

Measurements. Twenty-nine arms more than 50 mm in length (damaged); 39 cirri 23 mm in length.

Taxonomic remarks. It is also similar to *Zygometra elegans* (Bell, 1882) in size, number of arms and segments in cirri. *Z. comata* and *Z. elegans* can be distinguished by the number of ossicles in Br III: *Z. comata* with only external Br III of 2 ossicles, while *Z. elegans* with both external and internal Br III of 4 ossicles (Messing, 2015). Our specimen has external and internal Br III with 4 ossicles in several radii, and in several others external Br III absent, while internal has two ossicles. Taking into account the morphology of cirri and radii, this specimen was identified as *Z. comata* here.

Ecological notes. Very rare. Solitary, 10 m depth, on muddy sand. Diurnal; during the day fully exposed with arms arranged in a parabolic filtration fan. Found both on soft and hard substrates (Mekhova & Britayev, 2012) while morphological or behavioral differences between specimens from different grounds unknown.

Symbionts. Polychaete *Hololepidella* cf. *laingensis*; ophiuroid *Ophiomaza cacaotica*; Amphipoda gen.sp.

Distribution. Vietnam, from Burma to Indonesia and North Australia (Ho, 1994; Lane et al., 2000; Messing, 2015), Japan (Kogo, 1998).

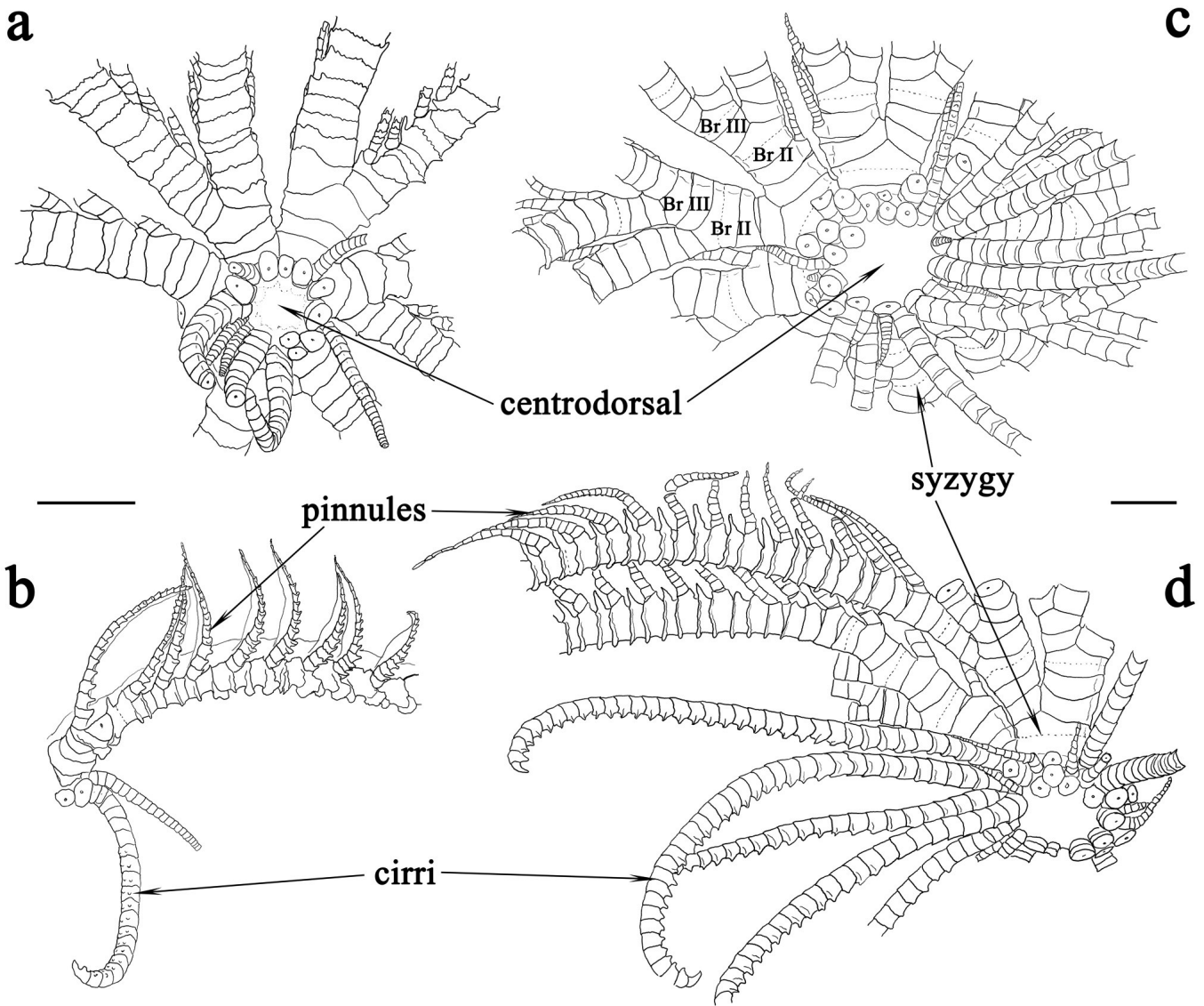


Fig. 3. Proximal ray articulations, branching patterns and arrangement of cirri. Scale bar = 1 cm. a, b, *Oligometra serripinna*; c, d, *Zygometra cf. comata*.

Family Colobometridae

***Oligometra serripinna* (Carpenter, 1881)**

(Fig. 3c, d)

Antedon serripinna Carpenter, 1881: 175, 182.

Oligometra serripinna: Clark AH, 1918: 130–131; Clark AH, 1921: 37–38, pl. 33, figs. 58, 59; Clark HL, 1946: 49–50; Clark AM, 1975: 403–404; Clark & Rowe, 1971: 10, 19; Messing, 2015.

Material. South China Sea, Halong Bay, Katba Is., St. 2, 10–15 m depth, 30 April 2012 – 3 specimens; St. 6, 1–6 m depth, 3 May 2012 – 1 specimen; St. 8, 1–10 m depth, 6 May 2012 – 5 specimens.

Coloration. Dark brown body mottled with white and yellow stripes and spots, becoming pinkish-brown when fixed in alcohol.

Measurements. Ten arms 44–77 mm in length: 11–16 cirri 7–12 mm in length.

Taxonomic remarks. Morphology of our specimens is in accordance with the diagnoses provided by Messing (2015).

Ecological notes. Common, found both solitary and in groups of three to five individuals, depth range 2–7 m, on unidentified gorgonians. One individual was found on a large specimen of *Amphimetra tessellata* attached to the arm. Diurnal, during the day arms are arranged in the radial filtration fan. Previously found on gorgonian corals (Meyer & Macurda, 1980; Marsh & Morrison, 2004)

Symbionts. Polychaete *Myzostoma cf. fissum*.

Distribution. Madagascar, Red Sea, Japan, Philippines, Maldives, India (Clark & Rowe, 1971), Palau (Meyer & Macurda, 1980), Thailand (Putchakarn & Sonchaeng, 2004) and Australia (Clark AM, 1975).

DISCUSSION

Our findings extend the list of crinoids living in the Tonkin Gulf to 10 species (Table 2), and the list of Vietnamese crinoids to 71 species. Among the species collected in the present research, only one, *Zygometa comata*, had been found in the Gulf earlier (Ho, 1994), while four others are reported here for the first time. *Capillaster gracilicirrus* and *Oligometra serripinna*, are the first records from the coast of Vietnam.

Feather stars were found in most of the sampling stations (six of eight), while they were most diverse and abundant at station 2 (four species and 21 specimens, Table 1). Four species belonging to three families occurred on sediment, and one, *O. serripinna*, attached to gorgonians (Table 2). The most common was *C. cf. solaris*, the other species were relatively rare. Among them, *A. tessellata* was reported earlier clinging to algae, rocks and boulders (Messing et al., 2006; Mekhova & Britayev, 2012) suggesting ecological plasticity, *Z. comata* was recorded previously on hard substrate (Mekhova & Britayev, 2012), and a unique previous finding of *C. gracilicirrus* was on fine mud (Clark AH, 1931: 170). Although crinoid assemblage is less diverse than one found at the Lizard Island (Messing et al., 2006), this is nevertheless the first record of soft substrate feather star assemblage discovered at the coast of Vietnam.

Three of the species found, *O. serripinna*, *Z. comata* and *A. tessellata*, were diurnal. They demonstrated behavioral or morphological adaptations allowing them to inhabit soft ground. Crinoids are known as moderately or strongly rheophilic (Meyer, 1979), since they are filter feeders. Elevation above the bottom allows them to avoid both, exposition in the near bottom layer with reduced speed of currents, and to be buried by sediments. *Oligometra serripinna* is elevated above the substrate clinging to gorgonians, while *Z. comata* and *A. tessellata* have strong long cirri which tips immersed in the silt, slightly anchoring them and raising above the substrate.

The possibly nocturnal comatulids, *Comatula cf. solaris* and *Capillaster gracilicirrus* have poorly developed cirri which are not able to elevate them above the bottom. It is known, that several comatulid species e.g., *Comaster* spp., *Clarkcomanthus* spp., and *Phanogenia* spp. have longer anterior arms employed for feeding, and the shorter posterior ones employed for anchoring within the reef infrastructure (Meyer & Macurda, 1980). We suggested that *C. cf. solaris* and *C. gracilicirrus* have similar adaptation for attachment. It was proved indirectly for *C. cf. solaris* by the presence of several shortened posterior arms without ambulacral grooves probably specialised for attachment. Arms of *C. gracilicirrus* have no pronounced morphological differentiation.

Crinoid species collected in Halong Bay were infested by five species of specialised symbionts. The most numerous among them were the ophiuroid *Ophiomaza cacaotica*, an unidentified amphipod, and the polychaete *Hololepidella cf. laingensis* (Table 3). The identified symbiotic species are

not specific for soft substrate and well-known inhabitants of feather stars living on hard substrates in other areas (Fabricius & Dale, 1993; Eekhaut et al., 1998; Britayev et al., 1999; Marsh & Morrison, 2004), while species composition of symbiotic assemblage is specific to the studied area and differs substantially from that of adjacent ones, including Hong Kong, Taiwan and the southern coast of Vietnam (Morton & Mladenov, 1992; Huang et al., 2005; Britayev & Mekhova, 2011). Among specific features of the assemblage are the presence and high abundance of amphipods, the group rarely reported among crinoid associates (Fabricius & Dale, 1993), and the absence of decapods (shrimps and crabs) the very important component of symbiotic assemblages in other areas, including elsewhere along the Vietnamese coast (Fishelson, 1974; Zmarzly, 1984; Huang et al., 2005; Britayev & Mekhova, 2011). We suggest that the peculiar composition of the assemblage is related rather to environmental conditions in the Bay i.e., intensive sedimentation, low water temperature, and decreased salinity during winter, than to the geographical location.

The rather rich and diverse (Table 3) symbiotic assemblage associated with soft substrate feather stars highlight their role in increasing the diversity and abundance of soft substrate epifauna in the bay. Earlier, it has been hypothesized that presence of biotic substrates, like cidaroid sea-urchins, modulates epibentic biodiversity on the soft substrate in the Antarctic by providing attachment sites for ectosymbionts (H  t  rier et al., 2008). Our finding proved indirectly this hypothesis and demonstrates that it can be expanded to shallow-water tropical areas. Although more quantitative studies are needed to understand the input of ectosymbionts of feather stars and other macroinvertebrates in soft substrate epibentic biodiversity and abundance.

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