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# Eight new records of the family Cavoliniidae (Gastropoda: Pteropoda) from the Andaman Islands, India

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**Marine Record**

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## Abstract

This research focuses on pteropods of the family Cavoliniidae, which remains an under-studied taxa in Indian waters. Sediment samples collected by the FORV Sagar Sampada from the Andaman Islands, India, yielded eight species of the family Cavoliniidae, representing the genera *Cavolinia* and *Diacavolinia* of the subfamily Cavoliniinae, and the genus *Diacria* of the subfamily Diacriniinae. Notably, four species – *Diacavolinia aspina*, *D. bandaensis*, *D. deblainvillei* and *Diacria erythra* represent new distributional records for India. Furthermore, *Cavolinia uncinata*, *Diacavolinia angulata*, *D. bicornis* and *D. flexipes* are recorded for the first time in the Andaman Sea. This study is significant in expanding the understanding of pteropod diversity in the Indian Ocean, contributing to a better understanding of their ecosystem and geographical range.

## Introduction

Pteropods, commonly called 'Sea Butterflies', are holoplanktonic marine gastropods. These zooplankton are ubiquitous in the world's oceans, exhibiting vast vertical and geographical distributions (Byrne, 2011; Ikeda, 2014). Although they are generally epipelagic, occurring in the upper 200 m, some are mesopelagic species that undergo diurnal vertical migrations from the epipelagic to the mesopelagic zone (Myers, 1968; Haagensen, 1976; Bè and Gilmer, 1977; Almogi-Labin *et al.*, 1998). These organisms are key contributors to the carbonate pump, owing to their aragonite shells that represent a significant source of calcium carbonate ($CaCO_3$). Approximately 10–42% of the ocean's $CaCO_3$ flux is contributed by pteropod shells, playing a crucial role in carbon cycling (Bednaršek *et al.*, 2012b). They are ecologically essential because they are primary food sources for marine organisms such as fish, seabirds and whales (Fabry *et al.*, 2008). Being highly sensitive to ocean chemistry changes, pteropods are used as bioindicators of climate change and ocean acidification, emphasizing their importance in ecological and climate studies (Bednaršek *et al.*, 2014). Pteropods are highly significant for paleoclimatic studies as they are the only living metazoan planktons with abundant fossil records (Bé and Gilmer, 1977).

Pteropods of the family Cavoliniidae Gray, 1850 (1815) comprise uncoiled, non-tubular, globose Euthecosomes. Their shells are primarily triangular and oval. The presence of lateral spines in the caudal end is typical in this family. Cavoliniids prefer deeper waters and are found mainly in the upper mesopelagic zones (Bednarsek *et al.*, 2012a, 2012b; Wall-Palmer *et al.*, 2014; Howes *et al.*, 2015). These are rarely available in zooplankton samples, but the dead shells collected are relatively more numerous from the benthic sediment samples (Oakes *et al.*, 2019). Like other pteropods, highly diverse species of cavoliniids are present in tropical and subtropical regions than in polar waters (Lazzari *et al.*, 2013; Howard *et al.*, 2014; Burridge *et al.*, 2016; Anglada-Ortiz *et al.*, 2021, 2023). Cavoliniidae comprises 39 species belonging to four genera under three subfamilies (MolluscaBase, 2025). The subfamily Cavoliniinae comprises the genera *Cavolinia*, with nine species reported so far, and *Diacavolinia*, which has twenty species under this family (MolluscaBase, 2025). The subfamily Diacriniinae has two genera; among them, the genus *Diacria* has seven species, and the genus *Teleodiacria* has four species (MolluscaBase, 2025). Meanwhile, the newly introduced subfamily Vaginellinae (Janssen, 2020) has mostly fossil records, and no proper genus has been assigned to it yet.

The pteropod review by Siddique *et al.* (2021) reveals that sixteen species of Cavoliniids are reported from the Indian subcontinent. Among these, the subfamily Cavoliniinae included four species of the genus *Cavolinia* (*C. globulosa*, *C. inflexa*, *C. tridentata* and *C. uncinata*) and eight species of the genus *Diacavolinia* (*D. angulata*, *D. bicornis*, *D. flexipes*, *D. longirostris*, *D. soulyeti*, *D. striata*, *D. triangulata* and *D. vanutrechti*) are available in the Indian waters so far. Whereas, from the subfamily Diacriniinae, only one species of the genus *Diacria* (*D. trispinosa*) and three species of the genus *Telodiacria* (*T. costata*, *T. danae* and *T. quadridentata*) are reported from India (Siddique *et al.*, 2021). The study also suggests that the Cavoliniid species diversity is highest in the Bay of Bengal (10 species), followed by the Andaman Sea (8 species), the Arabian Sea (7 species) and finally the Laccadive Sea (3 species). Taxonomic and

distributional studies of pteropods are scarce in India. Being in the tropical region, India is favourable for the availability of diverse pteropod species (Panchang *et al.*, 2007).

Our study revealed four species of the family Cavoliniidae that had never been recorded in the Indian waters before. Additionally, we found four other species in the Andaman Islands for the first time. In this paper, we discuss the global and Indian distribution of the species. We also describe the key features that identify these species and provide detailed morphological measurements and descriptions of their shells.

### Oceanographic setting

The present study area includes the Andaman Islands, encompassing the Andaman Sea on the east coast and the Bay of Bengal on the west. This distinct oceanographic region of the northern Indian Ocean is characterized by unique hydrographic features. The semi-enclosed Andaman Sea is a tropical basin connected to the Bay of Bengal through channels. The circulation patterns in both regions are primarily influenced by the monsoon system, with the Southwest Monsoon Current (SMC) from June to September and the Northeast Monsoon Current (NMC) from November to February. These currents are crucial for water mass movement in this region (Kumar *et al.*, 2002). Furthermore, the Bay of Bengal is characterized by the East India Coastal Current (EICC) that flows northward in February–May and southward in October–December, influencing the mixing of water mass (Shankar *et al.*, 2002). This region is also under the influence of the Indonesian Throughflow (ITF), which aids in transporting Pacific Ocean waters through the Malacca Strait in the Andaman waters (Gordon *et al.*, 2012). The Equatorial Counter Current (ECC) also facilitates cross-basin mixing between the eastern and western Indian Ocean. The complex interactions of SMC, NMC, EICC, ITF, and ECC create multiple pathways for the mixing of marine organisms.

## Materials and methods

### Sampling

The Centre for Marine Living Resources and Ecology (CMLRE), Kochi, manages the Fishery Oceanography Research Vessel (FORV) Sagar Sampada. This multidisciplinary research vessel carries out research in fisheries, marine biology and oceanography. The seabed sediment samples from the littoral zones of the Andaman Islands were collected during the voyage of FORV Sagar Sampada (Cruise 355). The samples were collected from 16 December 2016, to 4 January 2017. Collection was carried out at different depths of 50, 100 and 200 m using a Smith McIntyre Grab sampler. The sampling stations included off Port Blair (PB), Rangat (RT), and Diglipur (DI) on the eastern coast, i.e. the Andaman Sea and off Little Andaman (LA), Mayabundar (MA), Rangat (RT), South Andaman (SA) and Wandoor (WA) in the western coast from the Bay of Bengal (Figures 1 and 2). The coordinates of the sampling stations from the Andaman Sea (Eastern coast) and the Bay of Bengal (Western coast) are provided in Tables 1 and 2, respectively.

### Sample preservation and analysis

The collected seabed sediment samples were preserved using a 4% neutral buffered formaldehyde solution and dried in a hot oven at 40°C overnight. The pteropods were arranged in a paleontological slide, and a stereo-binocular microscope (LEICA M205C) was

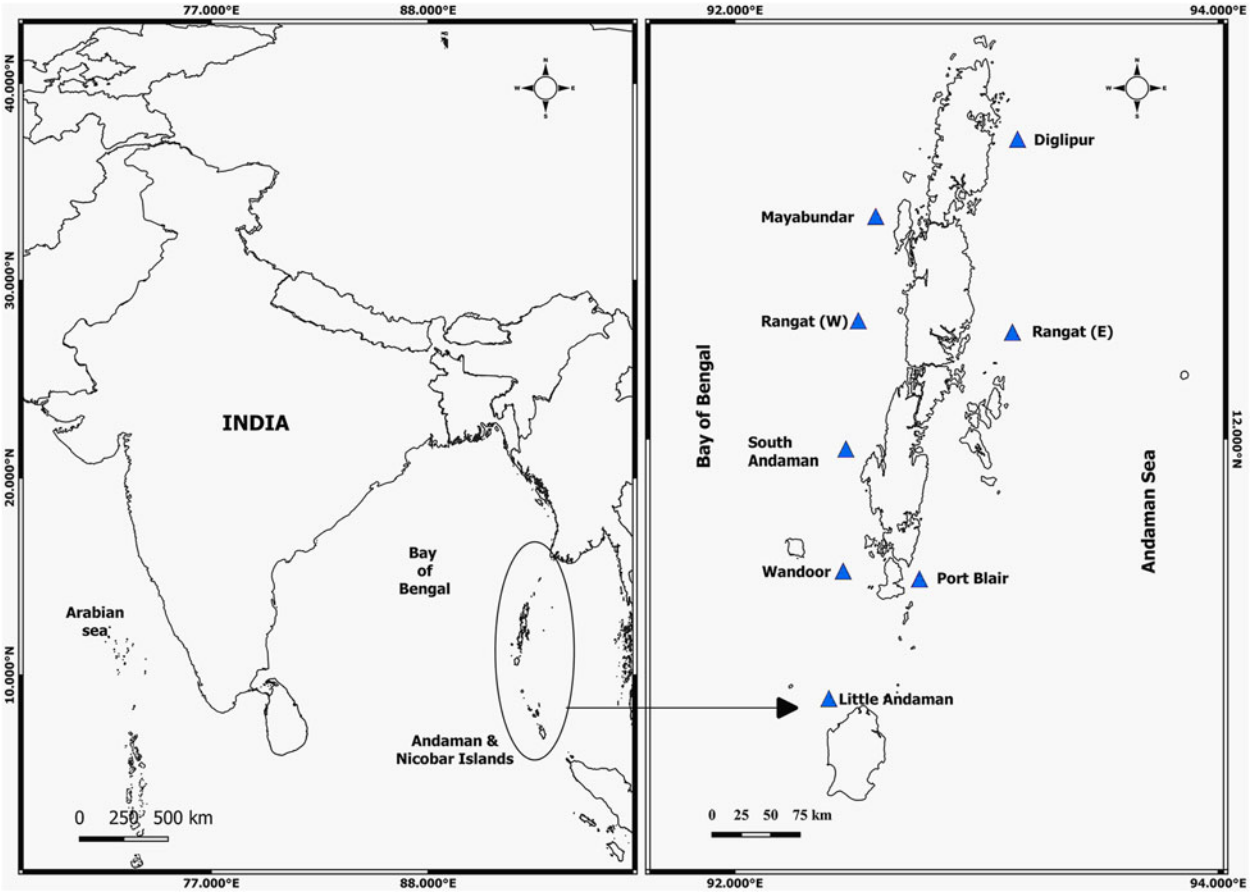


**Figure 1.** Map of the study area.

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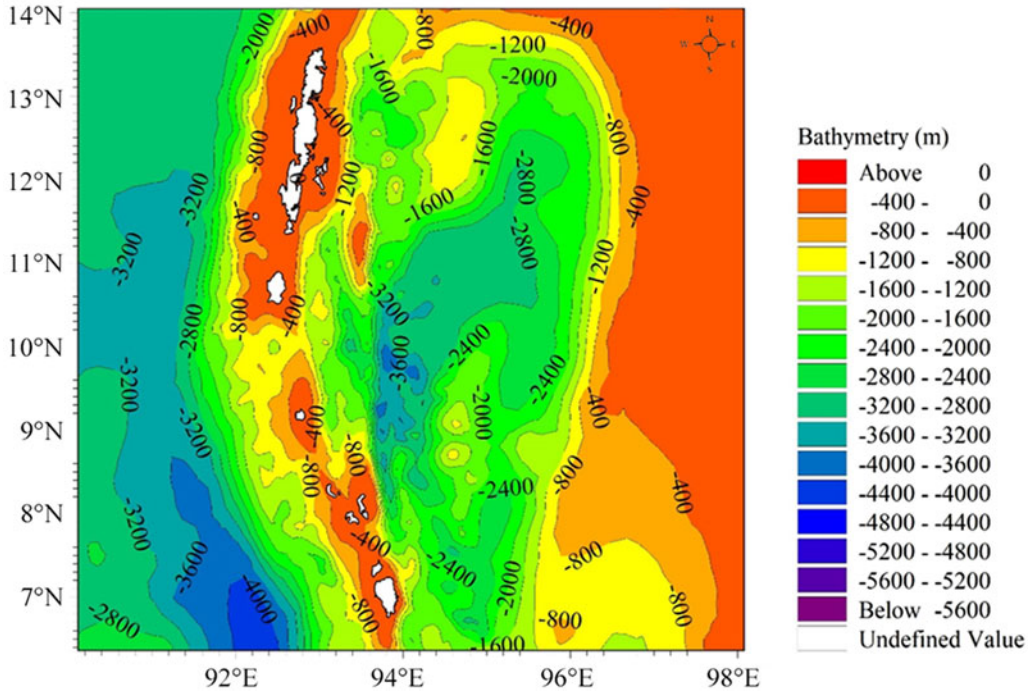


**Figure 2.** Bathymetric map of the Andaman and Nicobar Islands.

used to sort, take morphometric measurements and photograph the Cavoliniid specimens. The keys of van der Spoel *et al.* (1993) were used for preliminary identification, followed by the descriptions provided by d'Orbigny (1836–1846), van der Spoel (1967, 1973), Sakthivel (1976), Janssen (2012, 2020) and Janssen *et al.* (2019). The significant morphological features of Cavoliniid shells used for identification are provided in Figure 3.

## Results

### *Taxonomic description*

Systematic account
Order Pteropoda
Suborder Euthecosomata
Family Cavoliniidae
Subfamily Cavoliniinae
**Genus *Cavolinia*** Abildgaard, 1791
*Cavolinia uncinata* d'Orbigny, 1834

Type species: *Hyalea uncinata* d'Orbigny, 1834

Global distribution: Indo-Pacific region, Mediterranean Sea, Western Atlantic

Indian distribution: Arabian Sea, Bay of Bengal

Specimen details: Registration No.: ZSI/ANRC/M/30775; location: Andaman Sea (DI: 100 m)

**Table 1.** Sampling locations in the Andaman Sea (Eastern coast)

| Location | Depth (m) | Latitude | Longitude |
|---|---|---|---|
| Port Blair (PB) | 100 | 11°25.66′N | 92°43.96′E |
| Port Blair (PB) | 200 | 11°25.71′N | 92°44.34′E |
| Rangat (RT) | 50 | 12°27.35′N | 93°05.08′E |
| Rangat (RT) | 100 | 12°27.25′N | 93°07.90′E |
| Diglipur (DI) | 50 | 13°14.60′N | 93°05.59′E |
| Diglipur (DI) | 100 | 13°13.99′N | 93°06.67′E |

### *Diagnosis*

Dorsal: Dorsal side flat with 5 radial ribs that disappear towards the caudal end. Dorsal lip forms a hood over the aperture, lack ribs. Transverse growth lines present.

Lateral: Lateral spines short and not bent (Figure 4A).

Ventral: Globular in shape. Eight imbricate transverse striae near ventral lip. Ventral lip with median depression. Aperture wide. Caudal spine in the protoconch II area is elongated, strongly bent dorsally. Fine irregular transverse striations present on the caudal spine. Protoconch I is broken off from the caudal spine. Caudal fold straight. Shell colourless, with a mild brown hue near the ventral lip and caudal spine (Figure 4B).

Morphometric measurements: Length: 5.25 mm; width: 3.90 mm; aperture: 0.90 mm; caudal spine: 0.85 mm; caudal fold: 1.25 mm.

**Table 2.** Sampling locations in the Bay of Bengal (Western coast)

| Location | Depth (m) | Latitude | Longitude |
|---|---|---|---|
| Little Andaman (LA) | 100 | 10°93.83′N | 92°13.95′E |
| Little Andaman (LA) | 200 | 10°39.44′N | 92°11.24′E |
| Mayabundar (MA) | 50 | 12°53.40′N | 92°35.15′E |
| Mayabundar (MA) | 100 | 12°54.97′N | 92°27.72′E |
| Mayabundar (MA) | 200 | 12°55.04′N | 92°23.86′E |
| Rangat (RT) | 100 | 12°25.45′N | 92°22.11′E |
| Rangat (RT) | 200 | 12°25.55′N | 92°19.36′E |
| South Andaman (SA) | 50 | 11°58.27′N | 92°31.17′E |
| South Andaman (SA) | 100 | 12°00.04′N | 92°24.61′E |
| South Andaman (SA) | 200 | 12°00.09′N | 92°21.74′E |
| Wandoor (WA) | 50 | 11°22.98′N | 92°26.22′E |
| Wandoor (WA) | 100 | 11°28.11′N | 92°14.35′E |
| Wandoor (WA) | 200 | 11°27.41′N | 92°10.98′E |

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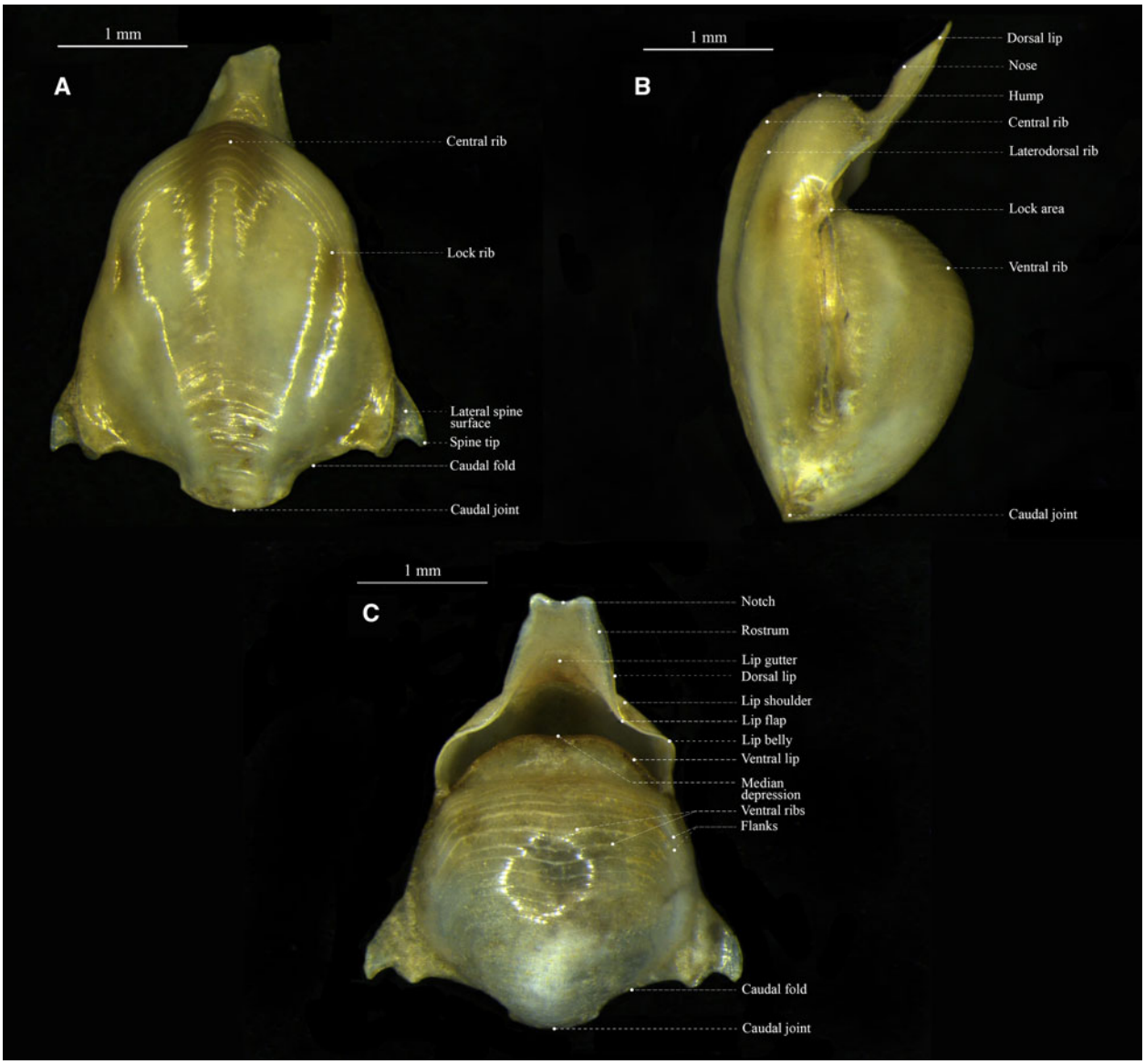


**Figure 3.** Morphology of Cavoliniid shells in various orientations: (A) dorsal; (B) lateral; (C) ventral.

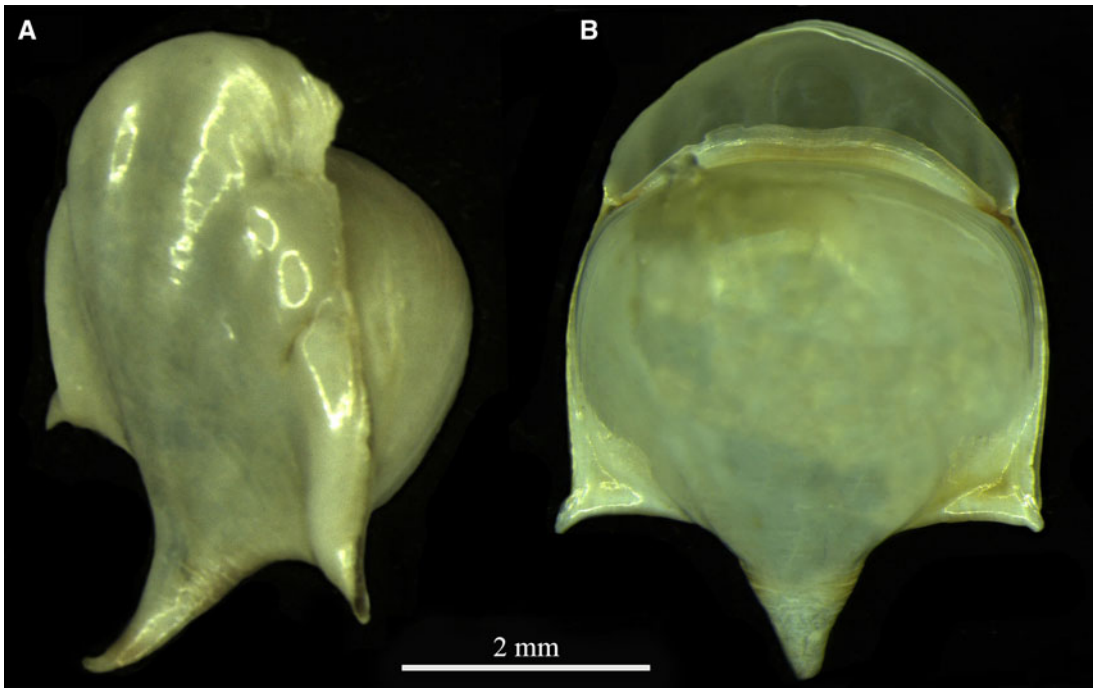


**Figure 4.** *Cavolinia uncinata*: (A) lateral; (B) ventral.

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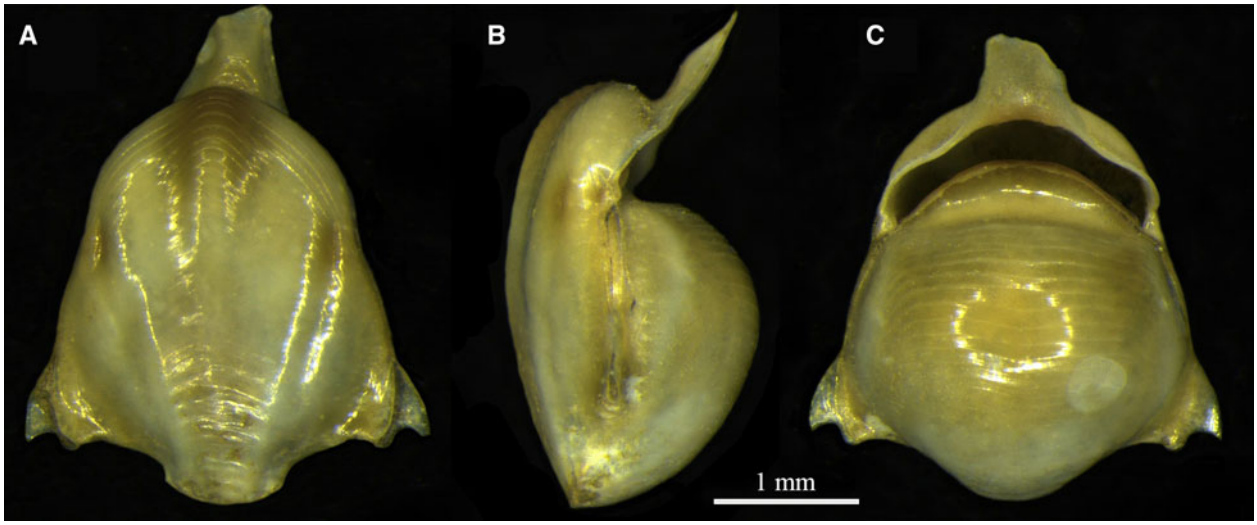


**Figure 5.** *Diacavolinia angulata*: (A) dorsal; (B) lateral; (C) ventral.

Genus *Diacavolinia* van der Spoel, 1987

*Diacavolinia angulata* Souleyet, 1852

Type species: *Cavolinia angulosa* Gray, 1850

Global distribution: Atlantic Ocean, Indian Ocean

Indian distribution: Laccadive Sea

Specimen details: Registration No.: ZSI/ANRC/M/30776; location: Andaman Sea (PB: 200 m)

### *Diagnosis*

Dorsal: Dorsal side slightly convex with prominent central and laterodorsal ribs. Lock ribs small and thick. 11–14 transverse growth lines present. Hump and nose strongly developed. Dorsal lip strongly bent towards the ventral side. Brown colouration present on the hump and the lock ribs (Figure 5A).

Lateral: Flanks absent. Lateral spines hooked and unbent with a sharp tip. Gutter corners small. Brown colouration on the lateral spine surface area (Figure 5B).

Ventral: Ventral side globular. Eighteen thin line-shaped ventral ribs present. Ventral lip is moderate size. Median depression absent. Broad rostrum in the dorsal lip. Notch, gutter and constriction absent. Aperture narrow. Lip bellies and the lip shoulders mildly developed; lip flaps are absent. Protrude protoconch II area and caudal joint. Caudal joint extends far beyond the lateral spines. Caudal fold curved and moon-shaped. Brown hue present on the entire ventral surface (Figure 5C).

Morphometric measurements: Length: 3.45 mm; width: 2.75 mm; aperture: 0.25 mm; caudal joint: 0.80 mm; caudal fold: 0.45 mm.

Remarks: According to the description of *Diacavolinia angulosa* by van der Spoel *et al.* (1993), the species had a clear median depression contrary to the absence of a median depression in the present species.

*Diacavolinia aspina* van der Spoel, Bleeker and Kobayasi, 1993

Type species: *Diacavolinia aspina* van der Spoel, Bleeker and Kobayasi, 1993

Global distribution: Indian Ocean (Mentawai Islands)

Indian distribution: Absent

Specimen details: Registration No.: ZSI/ANRC/M/30777; location: Andaman Sea (PB: 200 m)

### *Diagnosis*

Dorsal: Dorsal side flattened with moderately developed central and laterodorsal ribs, and small lock ribs. Transverse growth lines present. Indication of hump. Nose absent. Dorsal lip slightly bent to the ventral side. Mostly colourless with a brownish hue near the hump of the dorsal lip (Figure 6A).

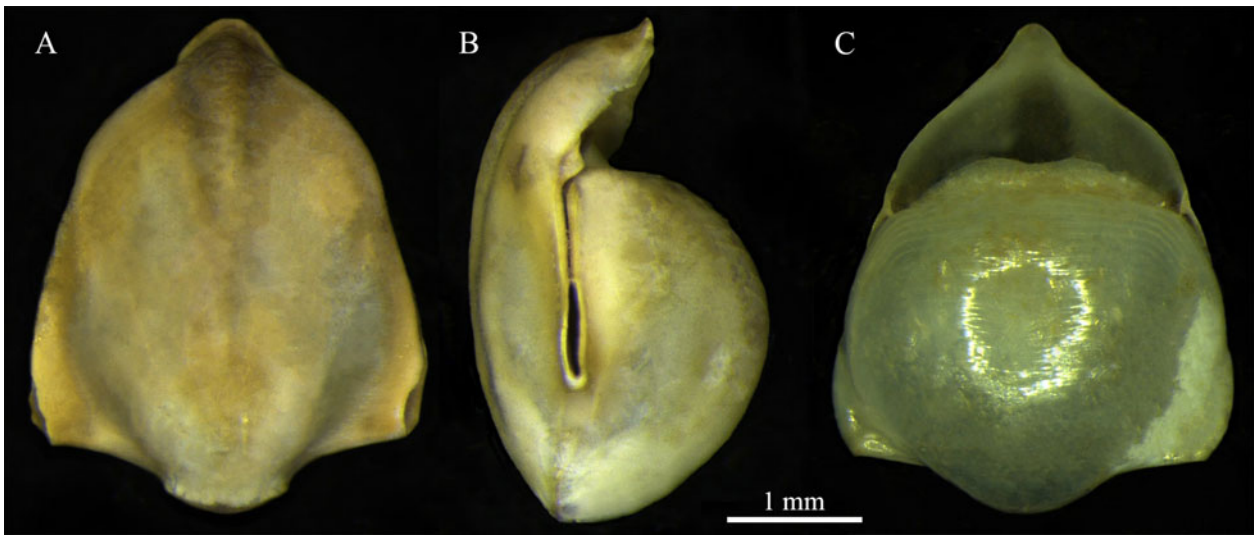


**Figure 6.** *Diacavolinia aspina*: (A) dorsal; (B) lateral; (C) ventral.

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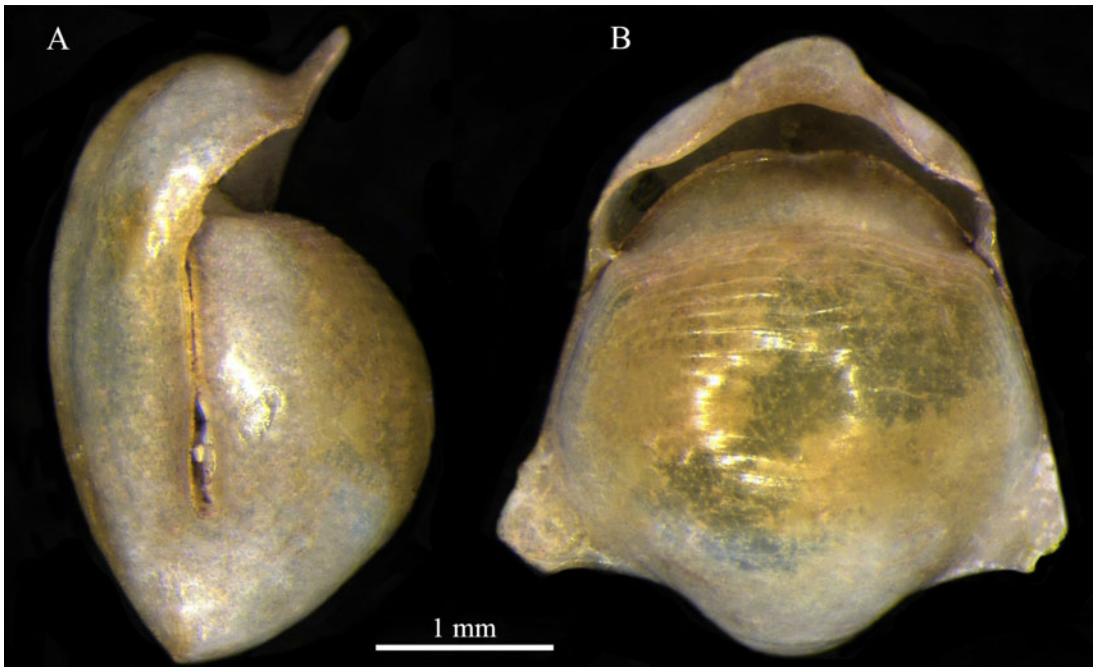


**Figure 7.** *Diacavolinia bandaensis:* (A) lateral (B) ventral.

Lateral: Flanks faint. Lateral spines unbent, reduced and rounded. Small gutter corners present (Figure 6B).

Ventral: Globular ventral side with 12 line-shaped ventral ribs. Ventral lip normal-sized with a moderately visible median depression. Rostrum broad, constriction, notch and gutter absent. Aperture broad. Weak lip bellies and small lip shoulders present, lip flaps absent. Slightly projecting protoconch II and caudal joint. Caudal fold almost straight. Colourless ventral side (Figure 6C).

Morphometric measurements: Length: 3.61 mm; width: 2.89 mm; aperture: 0.93 mm; caudal joint: 0.92 mm; caudal fold: 0.53 mm.

*Diacavolinia bandaensis* van der Spoel, Bleeker and Kobayasi, 1993

Type species: *Diacavolinia bandaensis* van der Spoel, Bleeker and Kobayasi, 1993

Global distribution: Banda Sea, North-western Taiwan Strait

Indian distribution: Absent

Specimen details: Registration No.: ZSI/ANRC/M/30778; location: Andaman Sea (RT: 100 m)

### *Diagnosis*

Dorsal: Flattened with highly developed central rib. Poorly developed laterodorsal ribs and lock ribs. Transverse growth lines faint. Strong hump present. Nose absent. Dorsal lip strongly bent towards the ventral side. Brown colouration on hump, lock ribs and caudal end.

Lateral: Well-developed flanks. Lateral spines reduced, not hooked and do not bend dorsally (Figure 7A).

Ventral: Bulged ventral side with 14 line-shaped ventral ribs. Ventral lip huge and thickened with a distinct median depression. Broad rostrum on thickened dorsal lip. Notch and constriction absent. Small gutter present. Aperture remarkably narrow. Moderate lip bellies and large lip shoulder. Lip flaps absent. Moderately protruding protoconch II area. Caudal joint almost on the same level as lateral spine. Caudal fold moon-shaped. Brown colouration present along ventral lip rim and central globular region (Figure 7B).

Morphometric measurements: Length: 3.47 mm; width: 3.26 mm; aperture: 0.28 mm; caudal joint: 0.38 mm; caudal fold: 0.70 mm.

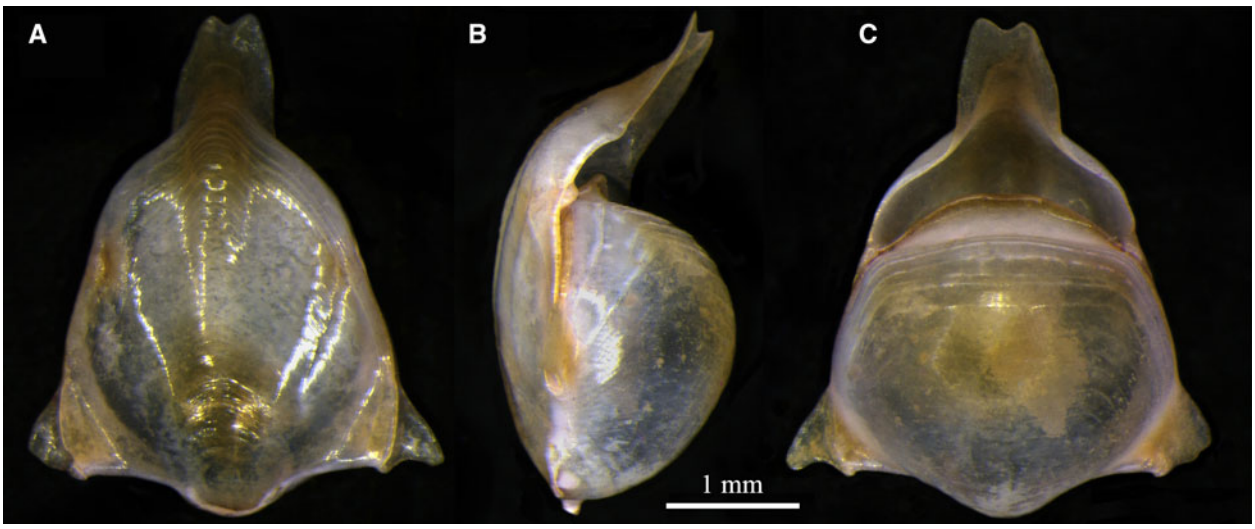


**Figure 8.** *Diacavolinia bicornis:* (A) dorsal; (B) lateral; (C) ventral.

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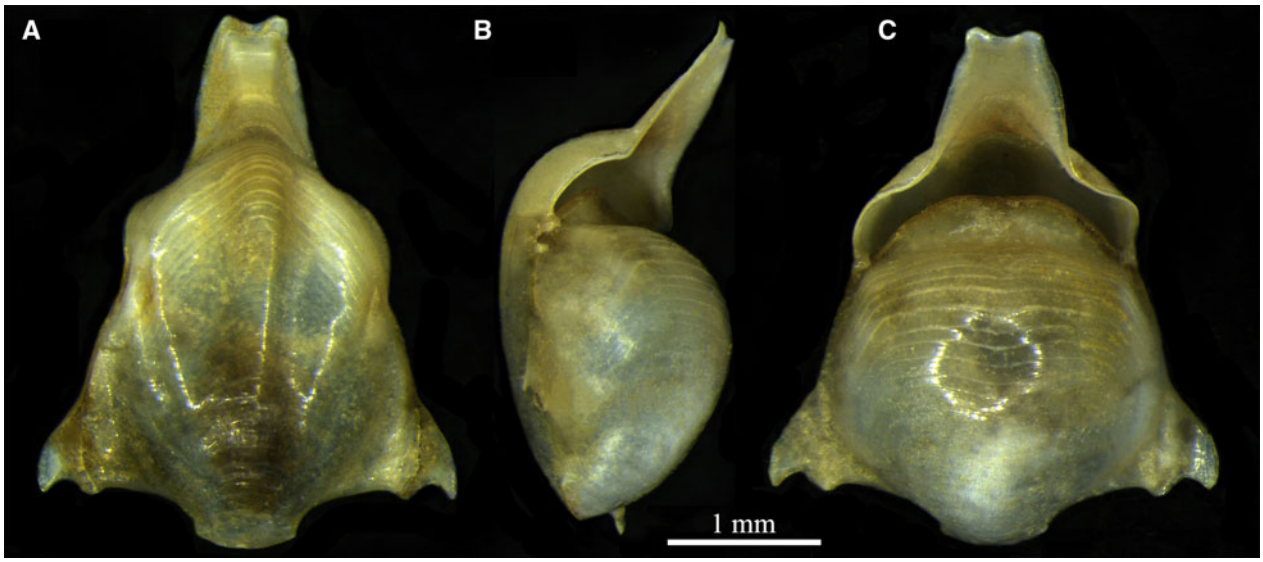


**Figure 9.** *Diacavolinia deblainvillei*: (A) dorsal; (B) lateral; (C) ventral.

*Diacavolinia bicornis* van der Spoel, Bleeker and Kobayasi, 1993

Type species: *Diacavolinia bicornis* van der Spoel, Bleeker and Kobayasi, 1993

Global distribution: Indian Ocean, Western Atlantic Ocean

Indian distribution: Laccadive Sea

Specimen details: Registration No.: ZSI/ANRC/M/30779; location: Andaman Sea (LA: 200 m)

### *Diagnosis*

Dorsal: Convex dorsal side with distinct central and lateral rib, moderate lock ribs. Prominent transverse growth lines. Hump and nose absent. Dorsal lip slightly bent towards the ventral side. Brown colour present on the dorsal lip, lock ribs and caudal end (Figure 8A).

Lateral: Flanks underdeveloped. Lateral spines sharp, unbent and lance-shaped. Gutter corners small. Brownish hue on the lateral spine surface (Figure 8B).

Ventral: Globular with 8 line-shaped ventral ribs. Ventral lip rim thick and medium-sized, with a weak median depression. Dorsal lip with broad rostrum, deep gutter and prominent notch. Constriction absent. Aperture moderate. Slightly developed lip bellies and small lip shoulder. Lip flaps absent. Slightly projected protoconch II with small caudal joint. Caudal fold curved. Prominent brown colouration on rostrum, gutter, and edge of the ventral lip (Figure 8C).

Morphometric measurements: Length: 3.78 mm; width: 3.24 mm; aperture: 0.72 mm; caudal joint: 0.41 mm; caudal fold: 0.41 mm.

Remarks: The aperture in the present species is quite wide with respect to the size of the shell, and the lip bellies are somewhat developed. However, the species described by van der Spoel et al. (1993) had a narrow aperture, whereas the lip bellies were well-developed. The shell size in their study was much bigger (7.84 mm) than the specimens encountered from the Andaman Islands.

*Diacavolinia deblainvillei* van der Spoel, Bleeker and Kobayasi, 1993

Type species: *Diacavolinia deblainvillei* van der Spoel, Bleeker and Kobayasi, 1993

Global distribution: Caribbean Sea, North Atlantic Ocean

Indian distribution: Absent

Specimen details: Registration No.: ZSI/ANRC/M/30780; location: Andaman Sea (PB: 200 m)

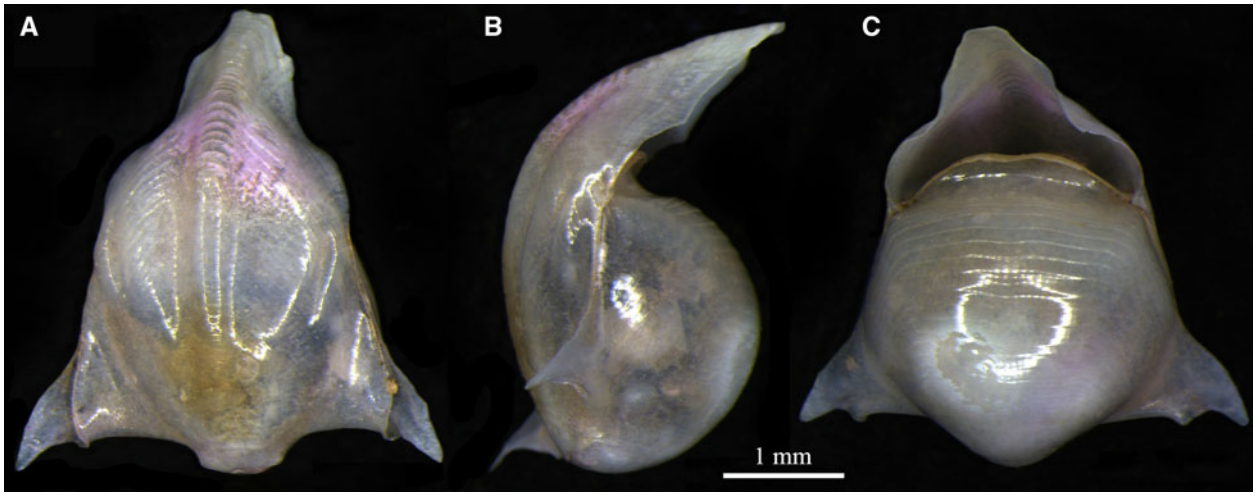


**Figure 10.** *Diacavolinia flexipes*: (A) dorsal; (B) lateral; (C) ventral.

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### *Diagnosis*

Dorsal: Convex with well-developed central, lateral, and lock ribs. Prominent growth lines. Hump and nose absent. Dorsal lip with a slight bent on the ventral side. Brown colouration throughout the dorsal side, more prominent in the caudal end (Figure 9A).

Lateral: Flanks prominent. Short, sharp, hooked lateral spines slightly bent to the dorsal side. Brown hue on the lateral spine surface (Figure 9B).

Ventral: Globular with 17 comb-shaped ventral ribs. Ventral lip normal in size, with a median depression. Dorsal lip with a broad rostrum, remarkable notch and shallow gutter. Constriction absent. Aperture moderately wide. Lip flaps absent, highly pronounced lip bellies, tiny lip shoulders. Protoconch II area and caudal joint not projecting. Caudal fold moon-shaped. Brown colouration on ventral bulged region, ventral lip and gutter (Figure 9C).

Morphometric measurements: Length: 3.05 mm; width: 2.98 mm; aperture: 0.68 mm; caudal joint: 0.71 mm; caudal fold: 0.55 mm.

*Diacavolinia flexipes* van der Spoel, Bleeker and Kobayasi, 1993

Type species: *Diacavolinia flexipes* van der Spoel, Bleeker and Kobayasi, 1993

Global distribution: Atlantic Ocean, North Indian Ocean, Pacific Ocean

Indian distribution: Arabian Sea, Bay of Bengal

Specimen details: Registration No.: ZSI/ANRC/M/30781; location: Andaman Sea (PB: 200 m)

### *Diagnosis*

Dorsal: Highly convex dorsal side with strong central rib. Laterodorsal ribs small, lock ribs faint. Well-developed growth lines. Hump and nose absent. Dorsal lip strongly bent towards the ventral side. Very faint brownish hue at the caudal end (Figure 10A).

Lateral: Flanks absent. Lateral spines hooked, sharp and strongly bent dorsally. Gutter corners prominent, groove present along the spine surface (Figure 10B).

Ventral: Bulged ventral surface with 15 line-shaped ventral ribs. Ventral lip medium, with prominent median depression. Dorsal lip gutter-shaped with a broad rostrum; constriction and notch absent. Aperture very wide. Strong lip bellies; lip shoulders and lip flaps absent. Slightly projecting protoconch II and caudal joint. Caudal fold straight. Slight brown tinge on the ventral lip (Figure 10C).

Morphometric measurements: Length: 3.66 mm; width: 3.57 mm; aperture: 1.20 mm; caudal joint: 0.95 mm; caudal fold: 0.49 mm.

Remarks: The species description by van der Spoel *et al.* (1993) stated the absence of projection of the protoconch II area. They also described the caudal fold as having a moon shape. The present study from the Andaman Islands observed the presence of a mild projection of the protoconch II area and the caudal fold, which was straight, contrary to the moon shape of the Red Sea species.

Subfamily Diacriinae

Genus *Diacria* J. E. Gray, 1840

*Diacria erythra* van der Spoel, 1971

Type species: *Diacria quadridentata erythra* van der Spoel, 1971

Global distribution: Western Indian Ocean

Indian distribution: Absent

Specimen details: Registration No.: ZSI/ANRC/M/30782, location: Andaman Sea (DI: 100 m)

### *Diagnosis*

Dorsal: Flat with 5 strongly developed longitudinal dorsal ribs. Eight dorsal striae near the dorsal lip. Dorsal lip short, thickened and bends to form a hood over the aperture on the ventral side. Prominent reddish hue in the dorsal lip (Figure 11A).

Lateral: Lateral spines, extremely reduced, do not bend dorsally, not hooked.

Ventral: Sub-globose shape, strongly convex. Closely placed 17 imbricate ventral striae. Ventral lip thickened. Aperture broad. Protoconch does not protrude. Caudal joint elliptical. Caudal fold moon-shaped. Caudal spine absent. Reddish-brown hue in entire shell (Figure 11B).

Morphometric measurements: Length: 3.44 mm; width: 3.11 mm; aperture: 1.66 mm; caudal joint: 1.11 mm; caudal fold: 0.44 mm.

Remarks: *Diacria erythra* resembled *Telodiacria quadridentata* (Blainville, 1821), but the latter shows a strong folding of the dorsal lip to overhang in the aperture on the ventral side. The dorsal lip is highly thickened in *T. quadridentata* compared to *D. erythra*. The difference is also noted in the dorsal side as *T. quadridentata* consists of faint longitudinal ribs and 3 dorsal striae on the dorsal side. The aperture is also remarkably narrow in *T. quadridentata*.

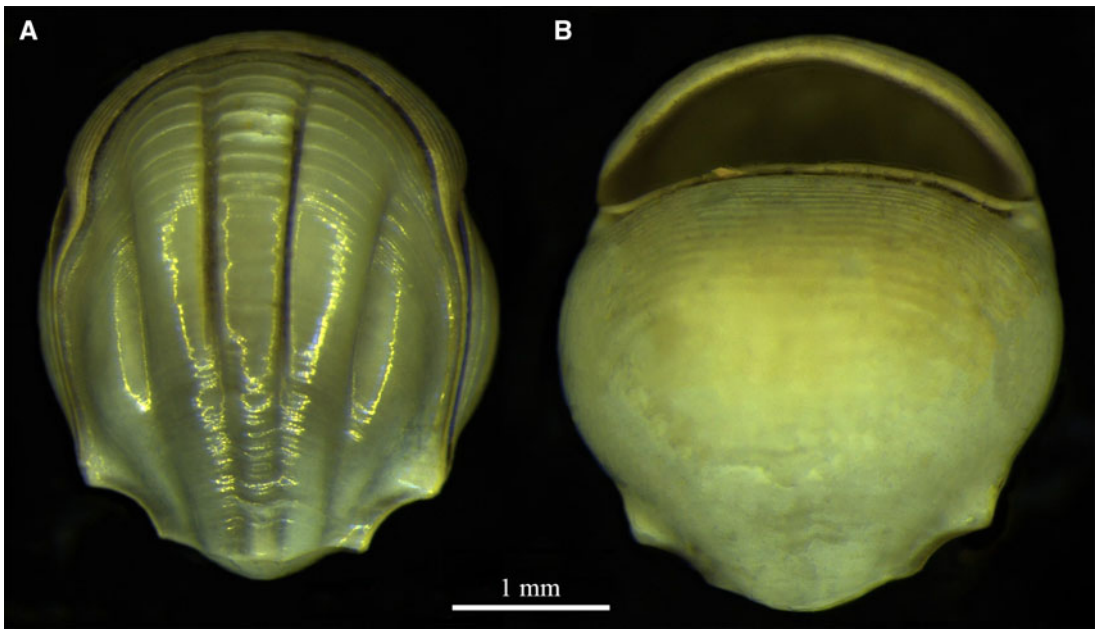


**Figure 11.** *Diacria erythra*: (A) dorsal; (B) ventral.

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**Table 3.** Presence of the studied Cavoliniids in the Andaman Sea (eastern coast)

| | Sampling stations (Andaman Sea) | | | | | |
|---|---|---|---|---|---|---|
| Species | PB 100 m | PB 200 m | RT 50 m | RT 100 m | DI 50 m | DI 100 m |
| *Cavolinia uncinata* | + | + | – | – | – | + |
| *Diacavolinia angulata* | – | + | – | – | – | + |
| *Diacavolinia aspina* | – | + | – | – | + | + |
| *Diacavolinia bandaensis* | + | + | – | + | + | + |
| *Diacavolinia bicornis* | – | + | – | – | – | – |
| *Diacavolinia deblainvillei* | – | + | – | – | – | – |
| *Diacavolinia flexipes* | – | + | – | – | – | – |
| *Diacria erythra* | + | + | – | + | + | + |

Present: +, absent: –.

### *Species distribution*

The systematic identification of the family Cavoliniidae from the sediments of the Andaman Islands revealed seven species of the subfamily Cavoliniinae and one species of the subfamily Diacriniinae. The species identified from the subfamily Cavoliniinae included *C. uncinata*, *Diacavolinia angulata*, *D. aspina*, *D. bandaensis*, *D. bicornis*, *D. deblainvillei* and *D. flexipes*. The species *C. uncinata* was widespread and available in 11 stations (Tables 3 & 4), which included both the Andaman Sea (PB – 100 m, 200 m; DI – 100 m) and the Bay of Bengal (LA – 200 m; MA – 200 m; RT – 100 m, 200 m; SA – 50 m, 100 m; WA – 100 m, 200 m). *Diacavolinia angulata* was found in two stations of the Andaman Sea (PB – 200 m; DI – 100 m) and in one station of the Bay of Bengal (LA – 200 m). *Diacavolinia aspina* was found in eight stations (Tables 3 and 4) from various depths at 50 m (DI), 100 m (DI, SA) and 200 m (PB, MA, RT, SA, WA). *Diacavolinia bandaensis* was found in six stations at 50 m (DI), 100 m (PB, RT, DI) and 200 m (PB, LA). From the Bay of Bengal, this species was available only in LA (Table 4), whereas it was well distributed in the Andaman Sea (Table 3). *Diacavolinia bicornis* was present in three stations, exclusively at a depth of 200 m. These were available in the Andaman Sea from PB – 200 m (Table 3) and the Bay of Bengal from LA – 200 m and MA – 200 m (Table 4). *Diacavolinia deblainvillei* was absent in all the stations of the Bay of Bengal and was exclusively found in one station (PB – 200 m) of the Andaman Sea (Table 3). *Diacavolinia flexipes* were found in PB at 200 m in the Andaman Sea (Table 3), and MA – 200 m, and RT – 200 m in the Bay of Bengal (Table 4). The subfamily Diacriniinae comprised the species *D. erythra*, which was available in 12 stations (Tables 3 and 4) of varying depths, viz., 50 m (DI, WA), 100 m (RT, SA, WA) and 200 m (PB, LA, MA, RT, WA).

*Cavolinia uncinata*, *Diacavolinia angulata*, *D. aspina*, *D. bandaensis*, *D. bicornis*, *D. deblainvillei*, *D. flexipes* and *Diacria erythra* are the eight species newly recorded from the Andaman waters. The first distributional record of *Diacavolinia aspina*, *D. bandaensis*, *D. deblainvillei* and *Diacria erythra* in the Indian EEZ was also marked during the present study.

## Discussion

According to the results of the present study, it is observed that the Cavoliniids prefer deeper epipelagic zones. Species like *Diacavolinia angulata*, *D. bicornis*, *D. deblainvillei* and *D. flexipes* were exclusively found in depths beyond 100 m. *Cavolinia uncinata*, *Diacavolinia aspina*, *D. bandaensis* and *Diacria erythra* were well-distributed throughout the depths but dominated mainly beyond the 100 m. The studies of Wormelle (1962), van der Spoel (1967) and Bé and Gilmer (1977) also stated the similar occurrence of Cavoliniids at a depth of 200 m in tropical and subtropical regions.

The Cavoliniid assemblage in the present study showed similarities and dissimilarities with other regions of the Indian Ocean. The presence of *Cavolinia uncinata* across multiple depths aligns with its widespread distribution, as Siddique *et al.* (2021) reported from the Arabian Sea and Bay of Bengal. However, the presence of *Diacavolinia aspina*, *D. bandaensis*,

**Table 4.** Presence of the studied Cavoliniids in the Bay of Bengal (western coast)

| | Sampling stations (Bay of Bengal) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Species | LA 100 m | LA 200 m | MA 50 m | MA 100 m | MA 200 m | RT 100 m | RT 200 m | SA 50 m | SA 100 m | SA 200 m | WA 50 m | WA 100 m | WA 200 m |
| *Cavolinia uncinata* | – | + | – | – | + | + | + | + | + | – | – | + | + |
| *Diacavolinia angulata* | – | + | – | – | – | – | – | – | – | – | – | – | – |
| *Diacavolinia aspina* | – | – | – | – | + | – | + | – | + | + | – | – | + |
| *Diacavolinia bandaensis* | – | + | – | – | – | – | – | – | – | – | – | – | – |
| *Diacavolinia bicornis* | – | + | – | – | + | – | – | – | – | – | – | – | – |
| *Diacavolinia flexipes* | – | – | – | – | + | – | + | – | – | – | – | – | – |
| *Diacria erythra* | – | + | – | – | + | – | + | – | + | – | + | + | + |

Present: +, absent: –.

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**Table 5.** Distribution of the family Cavoliniidae and the potential impact of ocean currents in the studied regions

| Species | Global distribution | Distribution in Indian waters | Newly reported regions | Ocean current influences |
|---|---|---|---|---|
| *Cavolinia uncinata* | Indian Ocean, Pacific Ocean, Western Atlantic, Mediterranean Sea | Arabian Sea, Bay of Bengal | Andaman Sea | Southwest Current, Equatorial Counter Current |
| *Diacavolinia angulata* | Atlantic Ocean, Indian Ocean | Laccadive Sea | Andaman Sea, Bay of Bengal | Agulhas Return Current, West Wind Drift, West Australian Current, Equatorial Counter Current, Tareev Current* |
| *Diacavolinia aspina* | Indian Ocean (Mentawai Islands) | N/A | Andaman Sea, Bay of Bengal | Indonesian Throughflow (ITF), South Java Current, Equatorial Counter Current |
| *Diacavolinia bandaensis* | Banda Sea, North-western Taiwan Strait | N/A | Andaman Sea, Bay of Bengal | Indonesian Throughflow (ITF), South Java Current, Equatorial Counter Current |
| *Diacavolinia bicornis* | Western Atlantic, Indian Ocean | Laccadive Sea | Andaman Sea, Bay of Bengal | Agulhas Return Current, West Wind Drift, West Australian Current, Equatorial Counter Current, South West Monsoon Current, East India Coastal Current |
| *Diacavolinia deblainvillei* | Caribbean Sea, North Atlantic Ocean | N/A | Andaman Sea | Brazil Current, South Atlantic Current, West Wind Drift, Agulhas Return Current, West Australian Current, South Java Current, Equatorial Counter Current |
| *Diacavolinia flexipes* | Atlantic Ocean, North Indian Ocean, Pacific Ocean | Arabian Sea, Bay of Bengal | Andaman Sea | East Indian Coastal Current, Equatorial Counter Current, Southwest Current |
| *Diacria erythra* | Western Indian Ocean | N/A | Andaman Sea, Bay of Bengal | Agulhas Return Current, South Indian Current, Equatorial Counter Current |

*D. deblainvillei* and *Diacria erythra* in the Andaman region, previously unknown from the Indian waters, suggested unique oceanographic conditions of the region. Several factors are likely involved in facilitating the distribution of these new reports. The location of the Andaman Sea at the confluence of major current systems, such as the Indian Ocean Equatorial Current and the ITF, created potential corridors for these species (Schott and McCreary, 2001).

Earlier, *Diacavolinia aspina* was reported in the Indian Ocean from the Mentawai Islands of Western Sumatra (van der Spoel *et al.*, 1993). The combined effect of the South Java Current and the Equatorial Counter Current can be the plausible reason for transporting *D. aspina* from the Indian Ocean to the Andaman Islands (Table 5). This transportation mechanism is further proved by the studies of regional circulation patterns and their influence on plankton distribution (Kumar and Narvekar, 2015). *Diacavolinia bandaensis* seemed endemic to the Banda Sea till 1993 (van der Spoel *et al.*, 1993) unless the study of pelagic pteropods by Chang and Hsueh (2005), where they reported it from the North-western Taiwan Strait owing to ITF. The occurrence of *D. bandaensis* from the present study in the Indian EEZ may be attributed to ITF, which facilitates connectivity between the Philippine Sea and the Indian Ocean (Gordon *et al.*, 2012). The species *Diacavolinia deblainvillei* had earlier been reported from the Caribbean Sea and parts of the Northern and Western Atlantic Ocean (van der Spoel *et al.*, 1993). Its presence in the Andaman Sea is possibly due to the influence of the Agulhas Return Current (Beal *et al.*, 2011) and the West Wind Drift, which connects the Atlantic Ocean to the Indian Ocean (Table 5). More distributional studies of *Diacavolinia* from the nearby waterbodies are necessary to confirm the reason for their availability in the Andaman Sea. Understandably, the species from the Indo-Pacific region (Banda Sea, Mentawai Islands, Arabian Sea) and the Indian Ocean are available in the Andaman waters because of their immediate vicinity and connection through the Indian Ocean Current, Southwest Monsoon Current, Northeast Monsoon Current and the ITF.

The co-occurrence of these Cavoliniid species with different biogeography (Indo-Pacific, Atlantic and Western Indian Ocean) in the Andaman waters signifies a potential mixing zone for pteropods through surface and subsurface circulation patterns (Kumar and Narvekar, 2015). However, more research on the influence of ocean currents and the Cavoliniid distribution is required to justify the presence of these holoplanktonic species from the Atlantic Ocean in the Andaman waters.

## Conclusion

This study records eight Cavoliniid species new to the Andaman Islands, four new in the Indian waters. Even though the significant features remained the same, slight variations of characters were observed during systematic identification in some species owing to the regional differences. Most species from the Andaman waters showed a smaller shell size, contrary to those encountered in the Atlantic Ocean and the Mediterranean Sea.

An attempt was made to justify the influence of global ocean currents in the distribution of newly reported species in the Andaman waters. Although this paper gives a preliminary insight into the species composition of Cavoliniids in the Andaman waters, there is a scope for further research pertaining to their diversity in this region. Since pteropods are bioindicators of ocean acidification, a thorough understanding of their taxonomy and biogeography will better aid the research on climate change and ocean acidification.

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