

A new species of *Caymanostella* seastar from deep-sea wood falls off the South Java coast, Indonesia

David J.W. Lane^{1*}, Indra B. Vimono² & Iffah Iesa¹

Abstract. During a joint Indonesia-Singapore South Java Deep-Sea Biodiversity Expedition (SJADES 2018), surveying the benthic biodiversity of the slopes of the Sunda Trough in the Indian Ocean and the Sunda Strait, a large number of *Caymanostella* seastars (114) were recovered on wood fall material in beam trawl hauls at depths ranging from 312–1,068m. Based on morphological criteria these specimens are herein described as a new taxon, *Caymanostella javaensis*, new species, only the second member of the genus reported from the Indian Ocean. *C. javaensis* differs from its nearest congener *C. madagascariensis* in several respects anatomically but shares with it a peripheral fringe of clawed ambital spinelets that may be adaptive in anchoring to substrata. Molecular evaluation and comparison of the present material awaits the availability of molecular sequences for neighboring species. Abundant and predictable input of wood fall material to a deep-sea environment close to forested land represents a biodiversity hotspot of organic material that may be replicated throughout Indonesia, thus the potential for discovery of new records and taxa of caymanostellids and other fauna on sunken wood in the many deep-sea locations of the Indonesian Archipelago is considered to be high.

Key words. Caymanostellidae, Sunda Trough, Indian Ocean, SJADES 2018

INTRODUCTION

The genus *Caymanostella* (Belyaev, 1974) belongs to a small family of mostly fingernail-sized asteroids, the Caymanostellidae whose phylogenetic relationships and taxonomic position within the Asteroidea remain uncertain. Morphology-based phylogenies have variously placed this family within the order Velatida (Blake, 1987) or Valvatida (Rowe, 1989; Mah & Blake, 2012). Although still formally listed under the order Velatida in the World Asteroidea Database (Mah, 2026), recent molecular analyses support its placement within the polyphyletic order Valvatida (Martin-Cao-Romero et al., 2021; Dilman et al., 2022; Shen et al., 2024). As potentially obligate associates of sunken woody substrates in the deep ocean, caymanostellids are rarely encountered and usually only in small numbers during deep-sea expeditions. A joint Indonesia-Singapore research cruise exploring the biodiversity of the deep sea in the Indian Ocean off South and West Java (SJADES 2018—23 March to 5 April 2018) recovered a rich collection of Asteroidea, most of which have been documented and reported (Lane &

Vimono, 2020; Vimono & Lane, 2021). The collection also includes numerous caymanostellids that form the basis of the following taxonomic description and population analysis.

MATERIAL AND METHODS

A series of beam trawls from the research vessel *Baruna Jaya VIII* at numerous stations on the slopes of the Sunda Trough, a forearc component of the Sunda (Java) Trench system, and in the Sunda Strait (Fig. 1) recovered much woody debris, some of which harboured caymanostellid sea stars. A total of 114 specimens were collected at 14 stations over a depth range of 312–1,068 m, all of them similar in appearance and associated with waterlogged sunken timber, bamboo, or coconut shell fragments. Sometimes, several individuals were clustered together.

Following close-up photography of representative living examples on-board *Baruna Jaya VIII*, using a Nikon DSLR camera and 60 mm macro lens, all caymanostellids were preserved in 70% ethanol. Subsequently, in the laboratory of the Lee Kong Chian Natural History Museum, focus-stacked images, recorded for selected specimens using a Canon EOS 6D with an MP-E65 macro-lens, were then processed using Zerene Stacker software. One of these specimens was briefly pre-treated with diluted domestic bleach to expose the skeletal plates prior to photography. Additionally, some ethanol-preserved specimens were prepared for SEM, either by a bleach-wash, air-drying protocol or by CO₂ critical point drying, followed by gold sputter coating for imaging in a JEOL JSM-6010 scanning electron microscope at 10 kV.

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¹Lee Kong Chian Natural History Museum, Faculty of Science, National University of Singapore, 2 Conservatory Drive, Singapore 117377; Email: david_jwlane@hotmail.com (*corresponding author)

²Research Center for Biota Systems, National Research and Innovation Agency (BRIN), Jl. Raya Jakarta-Bogor Km.46, Cibinong, Kab. Bogor, 16911, Indonesia



Fig. 1. SJADES 2018 cruise stations (CP12–CP59) off the south coast of western Java and in the Sunda Strait at which *Caymanostella* specimens were collected. Google Earth map.

Most of the type material is held in the Zoological Reference Collection (ZRC) of the Lee Kong Chian Natural History Museum (LKCNCNHM), National University of Singapore. The remaining material is divided between LKCNCNHM and the Reference Collection of the Research Centre for Oceanography (RCO) of the Indonesian Institute of Sciences (LIPI), Jakarta, with the latter collection now being transferred to the National Research and Innovation Agency (BRIN), Bogor, West Java, Indonesia.

A preliminary dendrogram of species relationships within the genus *Caymanostella* was derived using multivariate Bray-Curtis similarity analysis (software: Primer Ver. 7) of binary presence absence data for a series of attributes in the 11 currently recognised taxa (Table 1).

TAXONOMY

Family Caymanostellidae Belyaev, 1974

Genus *Caymanostella* Belyaev, 1974

Caymanostella javaensis, new species

Diagnosis. Body rounded sub-pentagonal to near-circular. Periphery of seastar formed by inferomarginal plates, the superomarginal plate series being entirely abactinal. Abactinal plates not conventionally imbricated, unlike congeners; plate abutments take the form of step-like scarf joints with a thin distal shelf extension underlying the thick proximal edge of the next distal plate, resulting in a tessellate appearance. Distinct carinal plate series and a single dorsolateral row intercalating with the carinal series

on either side. Inferomarginal plates longer than their superomarginal counterparts. Gonopores pierce proximal-most superomarginal plates. Abactinal armament of closely-spaced, spherical to slightly oval granules. Stereom microstructure of granules smooth basally, thorny apically. Clavate, longitudinally ribbed ambital spinelets with claw-like array of terminal points. Madreporite slit-like. Irregular rows of rugose actinal spines on bar-like adambulacral plates and on proximal areas of inferomarginals. Gonads, with ova in some specimens, visible in membrane-covered actinal chambers.

Material examined. Holotype. ZRC.ECH.1307, One specimen in ethanol, R:r = 4.5:4.1 mm (R/r ratio = 1.1; disc diameter = 8.5 mm), on wood, Stn. CP50, Indian Ocean, Pelabuhanratu Bay, S07°03.542', E106°26.504' (mid-point of beam trawl), 2 April 2018, depth = 383–425 m. Substrate: mostly mud.

Paratypes. ZRC.ECH.1611, One specimen bleach-treated for light microscopy, R:r = 4.8:4.4 mm (R/r ratio = 1.09; disc diameter = 9.4 mm), Stn. CP 51, Indian Ocean, Pelabuhanratu Bay, S07°05.111', E106°25.220' (mid-point of beam trawl), 2 April 2018, depth = 569–657 m. Substrate: coarse sand, mud and plastic trash.

ZRC.ECH.2458, One specimen critical point dried for SEM, R:r = 4.2:4.0 mm (R/r ratio = 1.05; disc diameter = 8.2 mm), same location data as Holotype.

ZRC.ECH.1309, One specimen critical point dried for SEM, R:r = 3.1:2.8 mm (R/r ratio = 1.11; disc diameter = 5.8 mm), Stn. CP 47, Indian Ocean, south of Pameungpeuk, S07°48.115', E107°45.502' (mid-point of beam trawl), 1 April 2018, depth = 530–476 m. Substrate: coarse sand.

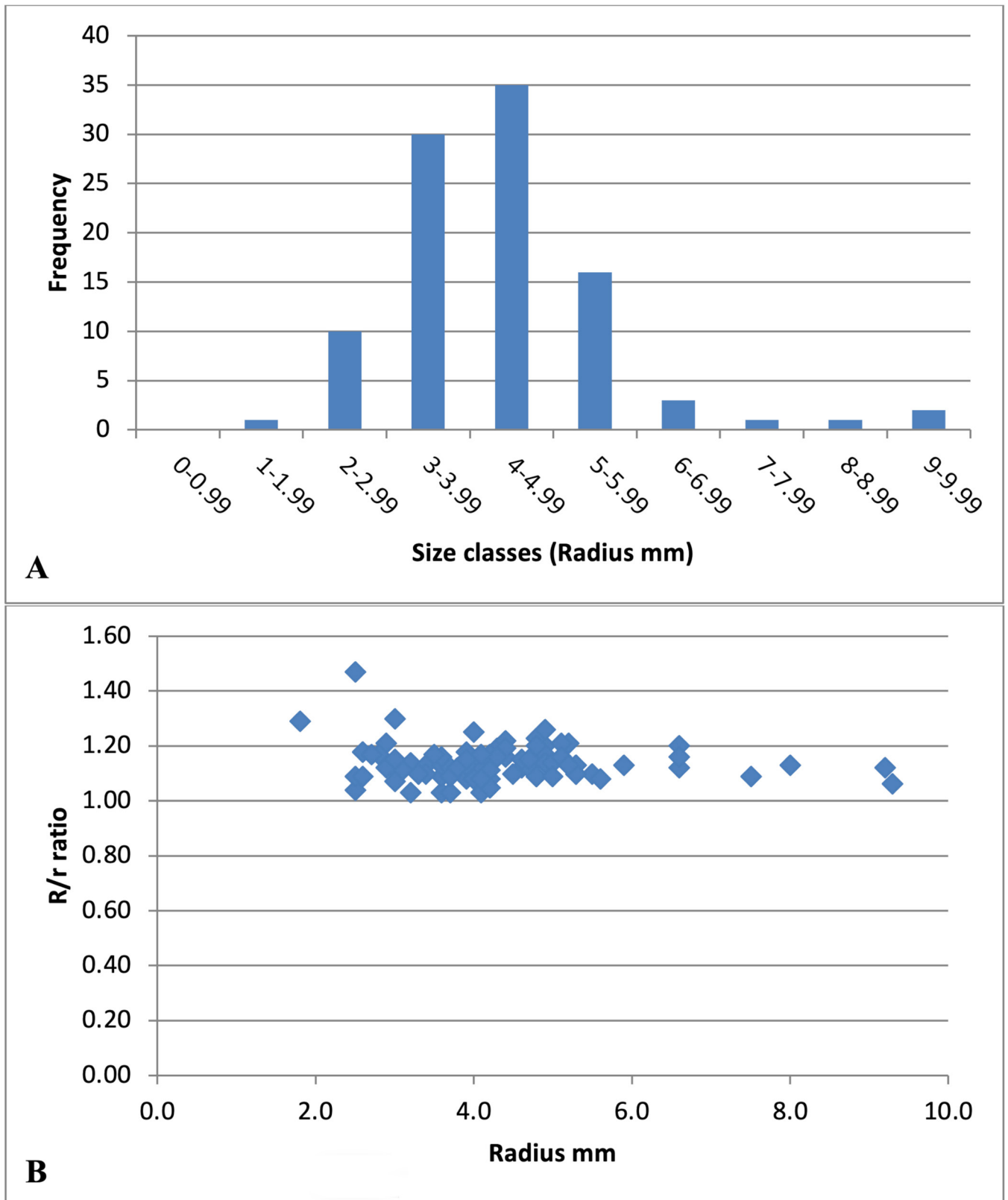


Fig. 2. Size distribution (A) and R/r ratio plot (B) for a *Caymanostella javaensis*, new species, population sample (n = 99) off South Java. The population has a unimodal size distribution (A) with a median diameter of about 1 cm and with a few individuals approaching 2 cm in diameter. The majority conform to a subpentagonal to circular R/r ratio of 1.25– 1.0 but a few small ones, presumably juveniles, with a higher R/r ratio are slightly more stellate (B).

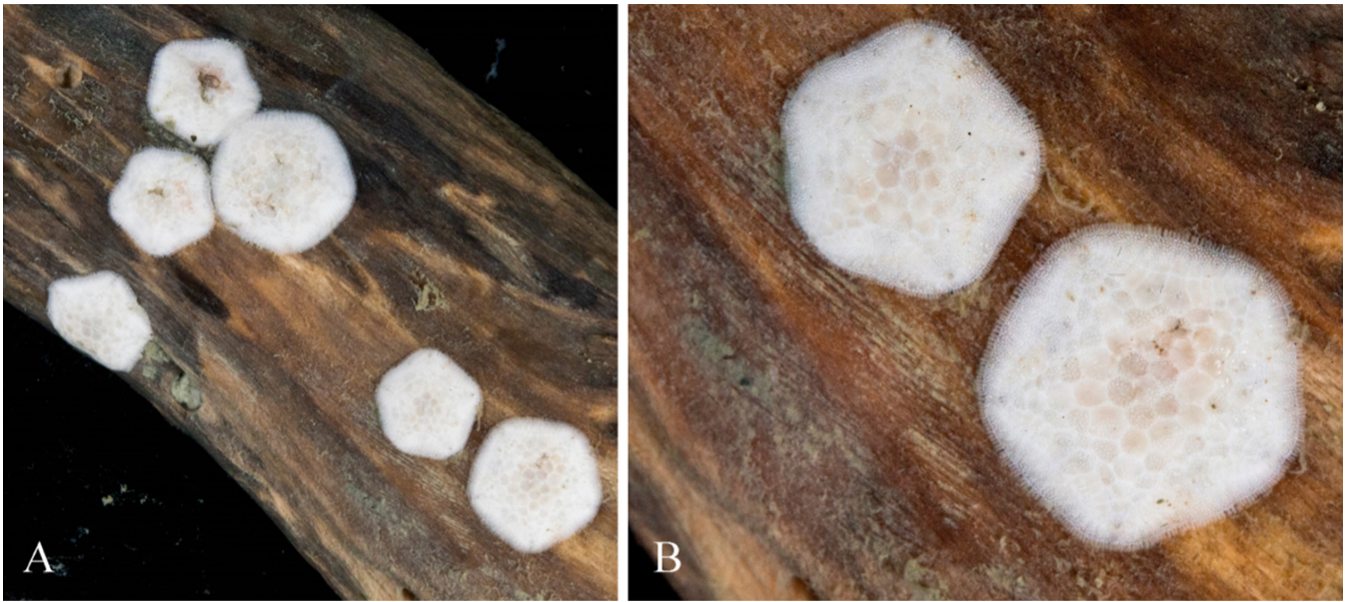


Fig. 3. Live *Caymanostella javaensis*, new species. A, cluster of 6 individuals on a piece of sunken wood from CP12 in the Sunda Strait; B, close-up of two of the individuals in Fig. 3A. Scale bars were not included in the original images but the largest individual in 3A is 10.1 mm in diameter

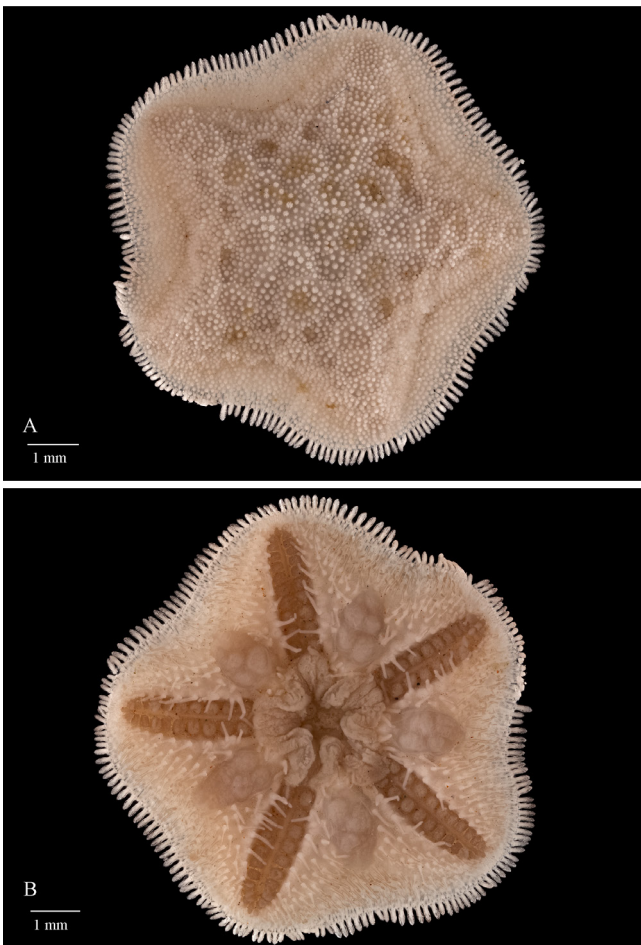


Fig. 4. Focus-stacked images of holotype of *Caymanostella javaensis*, new species, ZRC.ECH.1307, R = 4.5 mm, ethanol-preserved. A, abactinal view; B, actinal view. Plates are discernable through the abactinal tissue and granulation. At the superomarginal plate margin the profile is more stellate. Gonadal tissue, possibly ova, in interradial chambers indicates maturity.

ZRC.ECH.1308, Two specimens bleached and air-dried for SEM, R:r = 5.3:4.8 mm (R/r ratio = 1.10; disc diameter = 10.1 mm) & R:r = 9.2:8.2 mm (R/r ratio = 1.12; disc diameter = 17.4 mm), Stn. CP44, Indian Ocean south of Cilicap, S08°09.934', E108°37.292' (mid-point of beam trawl), 31 March 2018, depth = 1013–970 m. Substrate: mud with pieces of wood.

RCO.ECH.3149, Three specimens, R:r = 5.5:5.0 mm (R/r ratio = 1.10; disc diameter = 10.6 mm), R:r = 4.2:3.6 mm (R/r ratio = 1.17; disc diameter = 8 mm), R:r = 4.4:3.8 mm (R/r ratio = 1.16; disc diameter = 8.4 mm), Stn. CP39, Indian Ocean south of Cilicap, S08°15.972', E109°10.553' (mid-point of beam trawl), 30 March 2018, depth = 528–637 m. Substrate: mud.

Other material. Additional collected specimens are listed by station number in the Appendix.

Description. Body outline rounded pentagonal to roughly circular (Figs. 3A, B; 4; 5); R:r ratios 1.03–1.47, the majority being within the ratio range of 1.0 to 1.25 at all sizes, except for a few small individuals that are more stellate (Fig. 2B); abactinally convex, actinally flattened. Polygonal abactinal plates appear to abut in a tessellate manner without imbrication or overlap in the conventional sense but the abutments forming step-like scarf joints with a thin distal shelf extension underlying the thick proximal edge of the next distal plate (Fig. 8A). Disc abactinals (Fig. 6A) comprise the following: a centrodorsal plate (c) adjacent to the anal aperture which is ringed by 7 small angular platelets; an inner ring of 5 hex-heptagonal or fan-shaped / shield-shaped plates; an outer ring of 10 hex-heptagonal plates comprising alternating primary interradials and radials. The radial or carinal series continues along the arm as 5 further plates, an initial hexagonal shield-shape/fan-shape gradually changing to a more rectangular shape and diminishing markedly in size distally prior to the terminal plate. Terminal plate

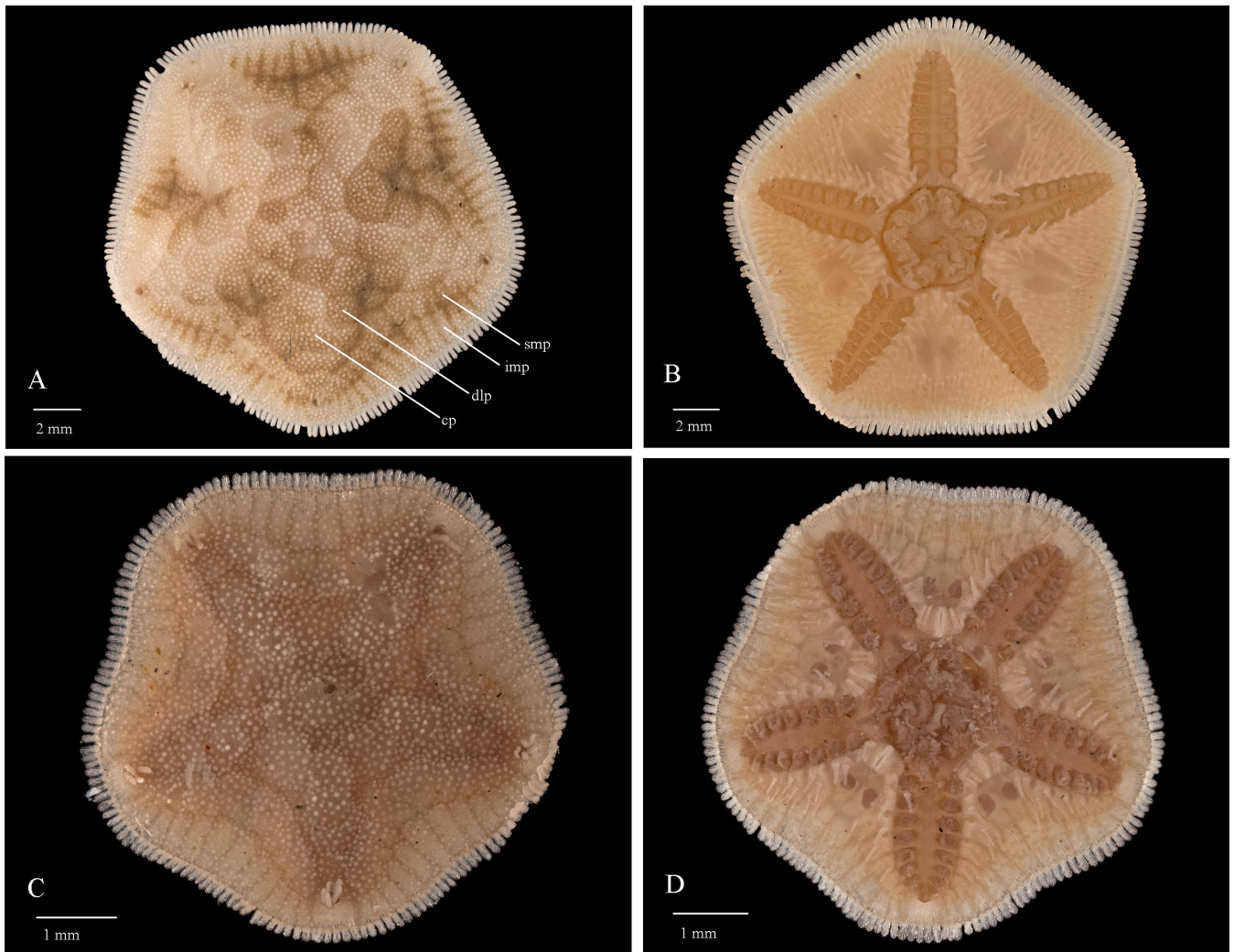


Fig. 5. Focus-stacked images of paratypes of *Caymanostella javaensis*, new species, one of the largest and one of the smallest specimens, ethanol-preserved. A, B, abactinal and actinal views of ZRC.ECH.1308, R = 9.2 mm; C, D, abactinal and actinal views of ZRC.ECH.1309, R = 3.1 mm. Counts for characters such as inferomarginal plates, superomarginal plates, adambulacral plates, tube feet and number of ambital spinelets for these and the holotype, detailed in the text, are more or less isometrically size-dependent. Superomarginal (smp), inferomarginal (imp) and other abactinal plates, including the carinal series (cp), are visible through granulated abactinal tissue. Dorsolateral plates (dlp) are evident only in the large individual, forming a prominent row on either side of the carinals (A). Dorsolateral plates are indistinct in the small seastar (C); they are either underdeveloped or possibly even absent. Comparison of the individuals in Fig. 4 and Fig. 5 indicates that while overall R/r ratio does not change significantly with growth, ontological changes in dorsolateral plate development alter the internal profile from a more stellate to less stellate form at the superomarginal plate margins, particularly the internal margin, with arm bases being much narrower in the juvenile.

hexagonal/shield-shaped, longer than wide, with a relatively large pore approximately $\frac{1}{3}$ to $\frac{1}{2}$ of the plate width and located closer to the proximal than distal edge (Fig. 6A, B); a single row of 2–3 dorsolateral plates either side of and alternating with plates of the carinal series (Fig. 6A) but dorsolaterals are not evident, possibly underdeveloped, in juveniles (Fig. 5C) resulting in a much narrower and more stellate profile to the abactinal plate component of the arm compared with larger individuals (compare Figs., 4A; 5A); a small wedge-shaped plate (*), distal to the large primary interradial (p), is bordered on either side by the first dorsolateral plate and separates the inner parts of the proximal-most superomarginal plates in each interradius (Fig. 6A); these proximal-most, trapezoid superomarginals, on either side of the interradius, much larger than the others and pierced by a gonopore opening more or less centrally (Fig. 6A); superomarginal plates entirely abactinal. Inferomarginal

plates aligned with superomarginals and form the border of the seastar, the marginal series numbering 6–8 on either side of each arm in adults of a range of sizes (Figs. 4A; 5A; 6A); inferomarginals generally rectangular and up to one third longer than their superomarginal counterparts, their length increasing towards the interradius, making the seastar less stellate compared with the superomarginal outline (Figs. 4A; 5A, C). Marginal plates, like the abactinals, have a porous stereom microstructure (Figs. 6B; 8A–D). Longitudinal skeletal elements within the translucent peripheral region of denuded (bleach-treated) inferomarginal and terminal plates correspond with the crenulated outer edge of these plates (Fig. 6B).

Live seastars and ethanol-preserved specimens that have not been bleach-treated, bear an ambital fringe of 2 to 3, sometimes 4, clavate spinelets articulating on each

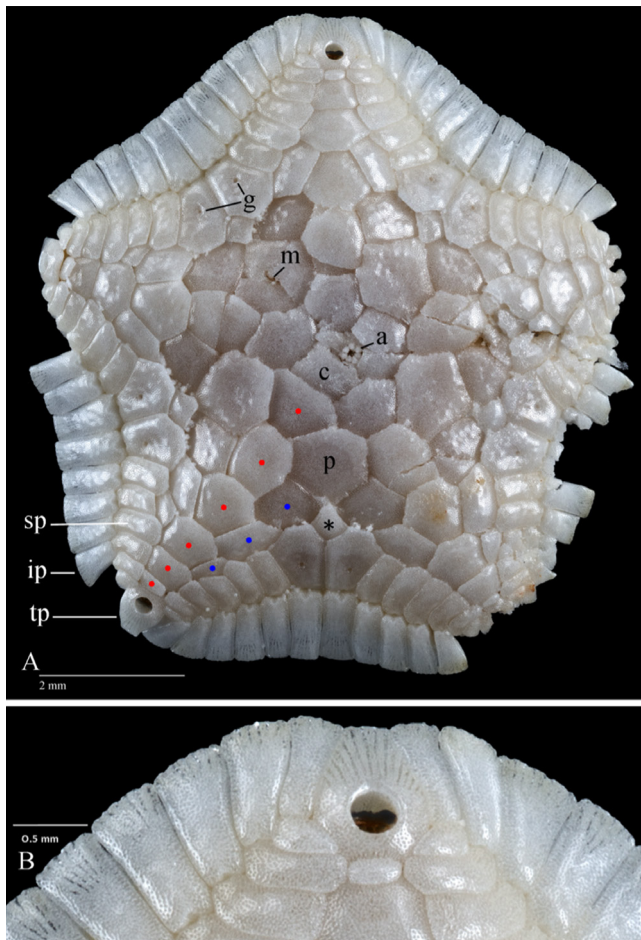


Fig. 6. Focus-stacked optical image of paratype (ZRC.ECH.1611, R = 4.8 mm) of *Caymanostella javaensis*, new species, pre-treated with bleach to remove surface tissue and air-dried. Abactinal aspect. A, some marginal plates and all granules and ambital spinelets lost during bleaching. B, closer view of arm tip; internal longitudinal skeletal elements in distal parts of inferomarginal and terminal plates associated with the crenulated peripheral margin of these plates. a: anus; c: centrodorsal disc plate (fractured); g: gonopores; ip: inferomarginal plate; m: madreporite; p: primary interradial plate; sp: superomarginal plate; tp: terminal plate. * = small, diamond-shaped distal interradial plate. Red and blue dots indicate, respectively, carinal and dorsolateral plates.

inferomarginal plate (Figs. 4; 5) and 2 to 4 for each terminal plate; spinelet number, arm tip to arm tip, ranges from 33–34 at R = 3.1 mm and 44–45 at R = 9.2 mm for paratypes ZRC.ECH.1309 and ZRC.ECH.1308 respectively (Fig. 5A; C). Ambital spinelets clavate, flattened on the actinal side (Fig. 9B) and arched abactinally are formed of slightly diverging, cross-linked longitudinal ribs whose downwardly curved, pointed extremities form a claw-like array around the outer edge of the spinelet (Fig. 9C, D). Similar ribbed spinelets, but more cylindrical and without clawed extremities, ring each terminal plate pore (Fig. 9D). Entire upper surface of seastar has an evenly spaced granular armament covered with a thin membrane (Figs. 4A; 5A, C); granules spherical to slightly oval, 75–100 μm in diameter with a spacing of 10–12 per mm; their stereom microstructure is smooth at the base and echinate at the apex (Fig. 8D); distal-lateral disc plates lacking; madreporite slit-like, in one of the primary interradial plates (Fig. 6A); no abactinal papulae.



Fig. 7. Focus-stacked optical image of paratype (ZRC.ECH.1611, R = 4.8 mm) of *Caymanostella javaensis*, new species, pre-treated with bleach to remove surface tissue and air-dried. Actinal aspect; many actinal spines on adambulacral and inferomarginal plates lost during the bleach procedure but two rows of staggered spines can be seen on the larger adambulacral plates. o = oral plate; 1–7 = adambulacral plate series.

Ambulacra elongated in adults (Figs. 4B, 5B) to sub-petaloid in small, presumably juvenile, individuals (Fig. 5D), with 8 to 11 paired podia; oval interradial area lacks actinal plates and forms a membrane-covered chamber containing gonads (Fig. 4B), with eggs in some specimens. Oral plates approximately square, each with a pair of spines at the oral edge; the first of 7 to 9 adambulacral plates is short; second adambulacral rectangular and elongated, extending obliquely to the inferomarginals, as do numbers from 3 onwards, their lengths decreasing distally along the ray (Fig. 7); each of the elongated adambulacral plates bears a single furrow spine plus, for the larger plates, a double staggered row of rugose actinal spines along each plate, the spines being directed peripherally; actinal spination continues on proximal part of the inferomarginals as two to three rows of similar but smaller spines (Figs. 7; 9A). Colour in life: pale without pigmentation; tissues are semi-translucent, the pale whitish appearance (Figs. 3A, B) resulting from the skeletal plates and abactinal granules.

Etymology. Named after the Indonesian island of Java and its trench system off the south coast where the majority of the specimens were collected.

Taxonomic remarks. Morphological comparison of the present Indian Ocean specimens, collected off Java, with descriptions for the 10 *Caymanostella* species thus far described supports the designation of a new species, *Caymanostella javaensis*. Body shape alone, sub-pentagonal to near circular in *C. javaensis*, like several others in the genus, immediately separates it from the stellate form in *C. laguardi* (Martin-Cao-Romero et al., 2021) and *C. scrippscoognaticausa* (Shen et al., 2024). These two geographically distant species (from the Gulf of Mexico and the East Pacific respectively) also differ markedly in

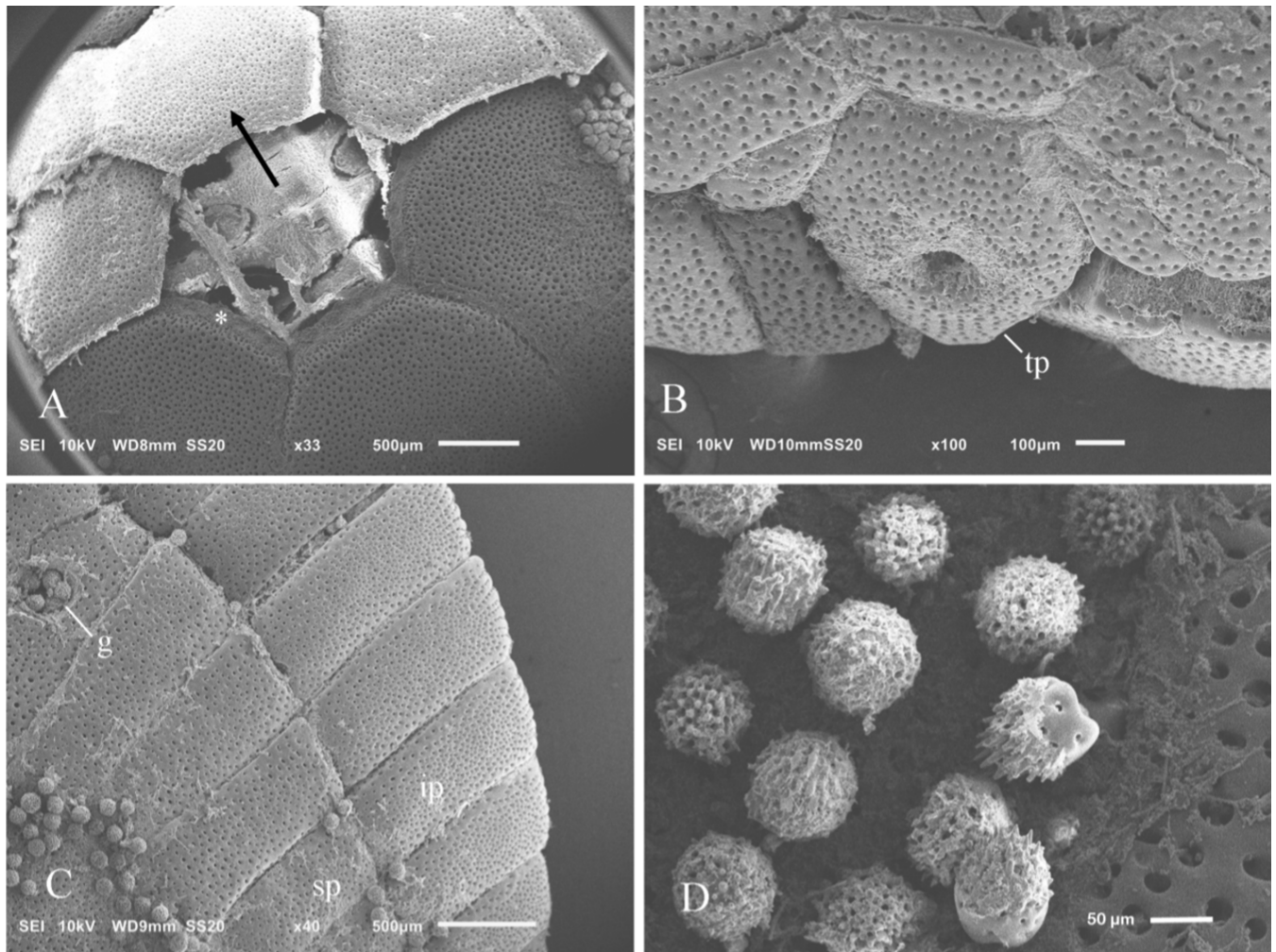


Fig. 8. SEM images of air-dried *Caymanostella javaensis*, new species, specimen (paratype ZRC.ECH.1308, R = 5.3 mm) pre-treated with bleach to remove surface tissues. Porous stereom microstructure of all skeletal elements is evident. A, radial portion of disc/ray. Missing carinal abactinal plate reveals plate abutments as step-like or scarf joints with a thin distal shelf extension (*) underlying the next plate distally (arrow overlaying exposed ambulacral plate series points distally). Clustering of remnant abactinal granules is an artifact of the preparation technique; B, terminal plate (tp) with pore connecting to ambulacral groove; C, abactinal view of superomarginal (sp) and peripheral inferomarginal plates (ip), the latter with a crenulated outer margin. Ambital spinelets and most abactinal granules lost during bleach treatment but some remnant granules have become lodged in a gonopore (g); D, spherical or slightly elongated abactinal granules are smooth basally and echinate apically.

terms of their spiniform abactinal armament, which contrasts with the granuliform armament on abactinal plates in *C. javaensis*. *C. laguardi* also differs in lacking the distinct marginal spinelets that fringe the edge of the seastar in all other *Caymanostella* species, including *C. javaensis*. Another East Pacific species described by Shen et al. (2024), *C. davidalani*, likewise differs from the present species in terms of spiniform abactinal armament and a slightly stellate body shape for the former, but there is a further major distinction, namely the form of the gonopore opening. The gonopore pierces the proximal-most superomarginal plate in *C. javaensis*, as it does in several other *Caymanostella* species, but in contrast the gonopore opens in a notch at the edge of the proximal-most superomarginal plate in the East Pacific species *C. davidalani*, *C. scrippscoognaticausa*, and in both *C. spinimarginata* from the Caribbean Sea (Belyaev, 1974) and in *C. cf. spinimarginata* from the Kuril-Kamchatka Trench (Dilman et al., 2022).

Three other *Caymanostella* species, all recently described from the East Pacific, namely *C. loresae* (Shen et al., 2024) and *C. persephone* and *C. hades* (Christodoulou et al., 2025) show similarities to *C. javaensis*, new species, in terms of sub-pentagonal body shape, granuliform abactinal armament, single row of dorso-lateral plates, gonopores piercing proximal-most superomarginal plates and the presence of fringing spines on the inferomarginals but there are significant microstructural differences in armament and other anatomical differences that set them apart from *C. javaensis*. For example, adambulacral plate counts are reported at 10–11 pairs for each ray in *C. loresae* and 15 in *C. persephone* and *C. hades*, more than or almost double the 7–9 pairs in *C. javaensis*. Similarly, the marginal plate series along each ray in adult sea-stars numbers 6–8 in *C. javaensis* in contrast to higher numbers found *C. persephone* (13) and *C. hades* (15). Furthermore, at the microstructural level the rounded abactinal granules of *C. javaensis*, with a smooth base and thorny apex (Fig. 8D) differ from the

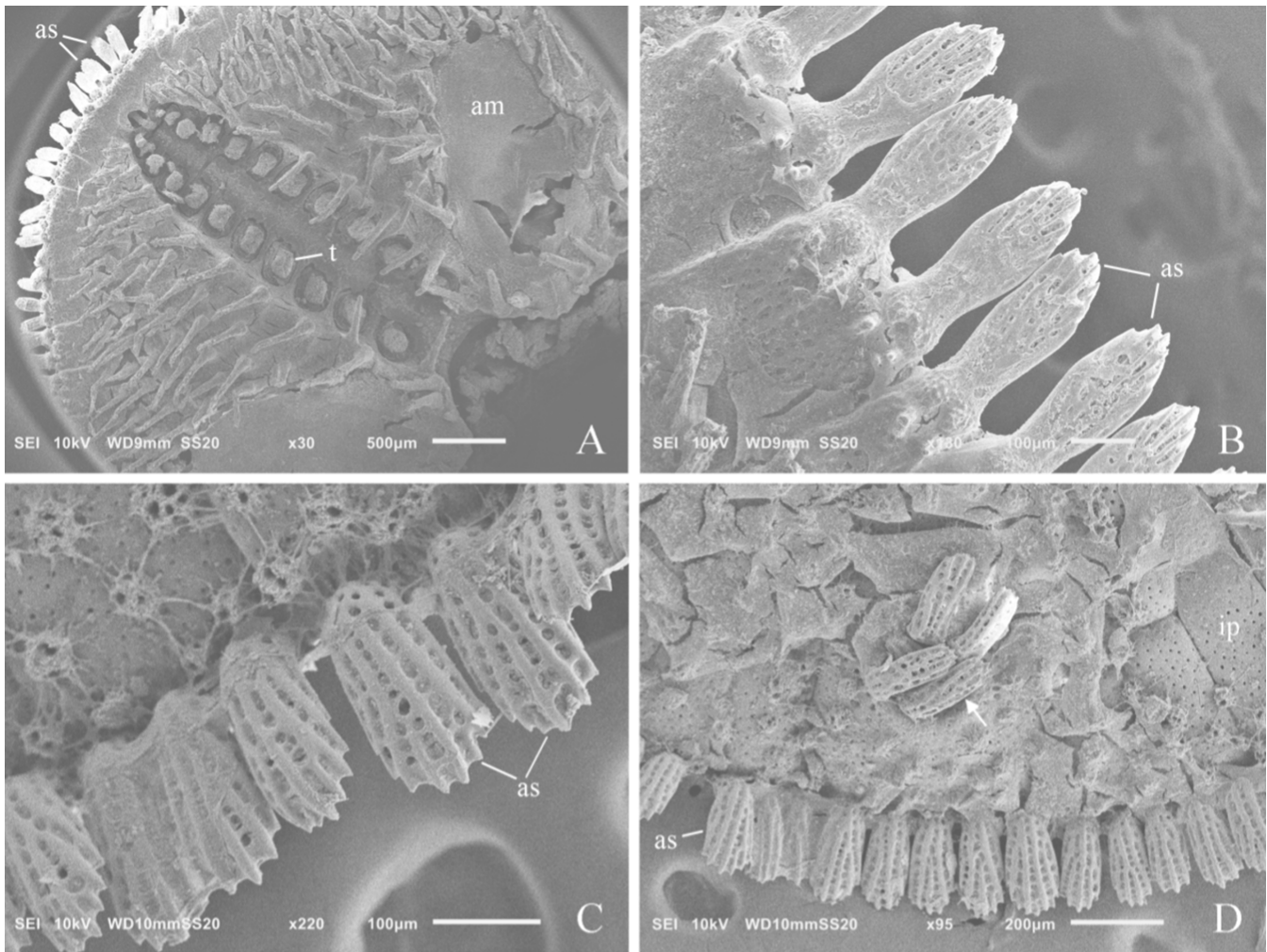


Fig. 9. SEM images of critical point dried *Caymanostella javaensis*, new species, specimens. A, B: paratype ZRC.ECH.2458, R = 4.2 mm, actinal view; C, D: paratype ZRC.ECH.1309, R = 3.1 mm, abactinal view. A, furrow spines paired for the proximal-most adambulacral plate and single thereafter. Actinal spine armament in a double, alternating row on each adambulacral plate; B, ambital spinelets longitudinally ribbed and flattened on actinal side; C, ambital spinelets with convex abactinal surface and formed of slightly diverging, cross-linked longitudinal ribs whose curved, pointed extremities form a downwardly directed, claw-like array around the outer edge of the spinelet; D, ambital spinelets and similar, but more cylindrical spinelets (arrow) bordering the terminal plate perforation. am = actinal membrane, as = ambital spinelets, ip = partially denuded inferomarginal plate, t = tube foot.

conical, multi-pronged granules in *C. persephone* (Figs. 3A–E, Christodoulou et al., 2025). *C. javaensis* granules are similar to those of *C. hades* (Figs. 3F–H, Christodoulou et al., 2025) and *C. loresae* (Figs. 16E, F, Shen et al., 2024) but the microstructure of fringing inferomarginal spinelets in these latter two species and *C. persephone* is quite different from the club-shaped, ribbed and clawed structures of *C. javaensis* (Figs. 9B–D). Inferomarginal fringing spinelets are cylindrical and lack ribs in *C. loresae* (Figs. 16G, H, Shen et al., 2024), cylindrical, ribbed, relatively smooth and blunt-ended in *C. hades* and wing-shaped with finely spinose margins in *C. persephone* (Figs. 3K, L and 3I, J respectively, Christodoulou et al., 2025). The terminal plate of *C. javaensis* differs from these three and all other *Caymanostella* species in being hexa- heptagonal rather than rectangular or square-shaped, and also in position of the terminal plate pore which is closer to proximal edge in *C. javaensis* compared to its congeners.

C. javaensis, new species, differs from the West Pacific species *C. phorcynis* and *C. admiranda* in several respects, notably the small distal-lateral disc plates adjacent to the primary interradial plate in *C. phorcynis* (Fig. 5C, E, Rowe, 1989) and reported also for *C. admiranda* (Belyaev & Litvinova, 1977; Rowe, 1989) are absent in *C. javaensis*. Additional differences include similarity of plate length for adjacent superomarginals and inferomarginals in both *C. phorcynis* and *C. admiranda* whereas inferomarginals are longer than their superomarginal counterparts in *C. javaensis*. For *C. phorcynis*, other differences include: larger number of marginal plates (8–15) and fewer anal platelets (4–5) compared with *C. javaensis* (6–8 and 7 respectively); number of adambulacral plates (minimum of 9 in *C. phorcynis* (Figs. 5B, D, Rowe, 1989; Fig. 6B, Christodoulou et al., 2025) versus 7–9 in *C. javaensis*); number of dorso-lateral plate rows and plates (one, sometimes two rows and 3–6 plates in the primary row for *C. phorcynis* compared with only a single row of 2–3 plates in *C. javaensis*). There are also differences in terminal plate pore location (approximately

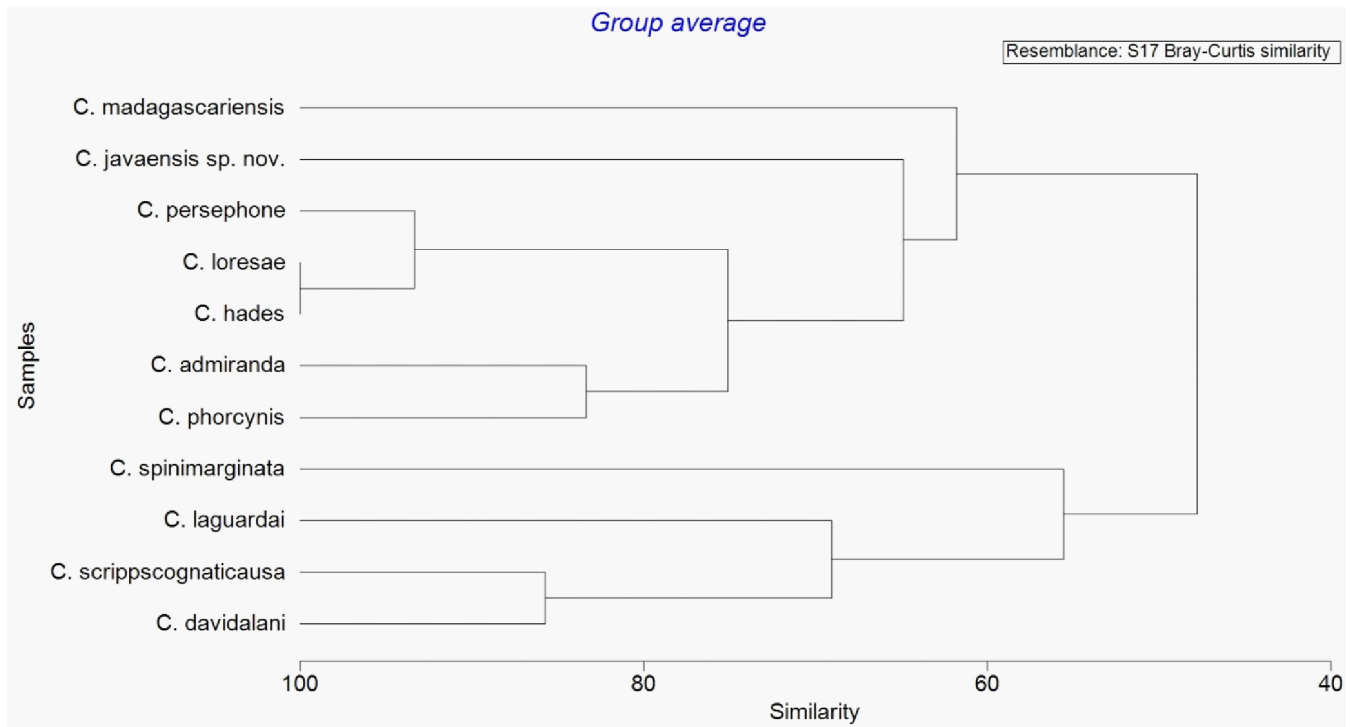


Fig. 10. Bray-Curtis similarity analysis of species relationships within the genus *Caymanostella* Belyaev, 1974.

central in *C. phorcynis* versus closer to the proximal edge in *C. javaensis*). Additionally, there are differences in abactinal granule microstructure. Although not clearly illustrated in Rowe's 1989 paper, granules are described as longer than broad and dome-shaped in *C. phorcynis* versus round to oval with a smooth base and thorny apex in *C. javaensis* (Fig. 8D). For *C. admiranda*, additional differences from *C. javaensis* include abactinal rounded granules being of two sizes for the former but uniform in the latter, and the presence of two additional small square, interrational plates in the inner ring of radial disc plates, making 7 plates in *C. admiranda* (Rowe, 1989) compared with 5 for *C. javaensis*.

Caymanostella madagascariensis, the remaining species to be compared and the only other species of wood-star known from the Indian Ocean, is similar to *C. javaensis*, new species, in several respects, namely: sub-pentagonal body shape, number of adambulacral plates (7 versus 7–9) per ray and number of platelets (7) around the anus. Most notably, the ribbed, clawed inferomarginal fringing spinelets illustrated in the original description of *C. madagascariensis* (Fig. 2A, Belyaev & Litvinova, 1991) and more clearly imaged following a re-examination of the holotype (Fig. 6F, Dilman et al., 2022) are quite similar to the clawed, ribbed, fringing spinelets of *C. javaensis* (Figs. 9B–D). But the small (57–60 µm), smooth, almost spherical abactinal granules of *C. madagascariensis*, lacking any ornamentation (Fig. 2B, Belyaev & Litvinova, 1991; Figs. 6D, E, Dilman et al., 2022), are quite different from the larger (75–100 µm) round to oval, apically thorny granules in *C. javaensis* (Fig. 8D). Additional morphological differences suggest the separation of these two forms at species level. Firstly, irregular polygonal shaped abactinal plates in *C. madagascariensis* (Dilman et al., 2022) contrast with regular fan-shaped/shield-shaped plates, particularly

some of those in the carinal series, in *C. javaensis* (Fig. 6A). Secondly, inferomarginal plates are similar in length to superomarginals in *C. madagascariensis* but longer than superomarginals in *C. javaensis*. Thirdly, absence of a gonopore within the proximal-most superomarginal plate in *C. madagascariensis*, attributed to specimen immaturity (Dilman et al., 2022), is probably a real difference from *C. javaensis* since the holotype of *C. madagascariensis*, although small, is reported to possess gonads (Belyaev & Litvinova, 1991).

Abactinal plate imbrication, an important character, is reported to occur to varying extents in all *Caymanostella* species thus far described, but is not seen in *C. javaensis*, new species. Abactinal plates in SJADES material are without conventional imbrication or overlap, the abutments instead forming step-like or scarf joints (a carpentry term) with a thin distal shelf of the inner plate (Fig. 8A) underlying the thick proximal edge of the next distal plate. This may represent a major anatomical difference separating *C. javaensis* from its congeners, but the precise abutment arrangement of abactinal plates, sometimes described incompletely in the literature as 'irregularly imbricated' or 'tightly imbricated', warrants further investigation in the genus.

Imbrication as a character may need redefining, but it is included here in a preliminary multivariate Bray-Curtis similarity analysis (software: Primer Ver. 7) based on binary presence-absence data for a series of attributes (Table 1). The resulting dendrogram of species relationships within the genus *Caymanostella* (Fig. 10) demonstrates clustering of *C. hades* and *C. loresae* (100% similar for the attributes chosen) and close relationships between *C. admiranda* and *C. phorcynis* and between *C. scrippscognaticausa* and *C.*

Table 1. Binary character matrix for *Caymanostella* Belyaev, 1974 taxa.

		<i>C. spinimarginata</i> Belyaev, 1974	<i>C. admiranda</i> Belyaev & Litvinova, 1977	<i>C. phorcynis</i> Rowe, 1989	<i>C. madagascariensis</i> Belyaev & Litvinova, 1991	<i>C. laguardi</i> Martin-Cao-Romero, Solis-Martin & Bribiesca-Contreras, 2021	<i>C. scrippsocognaticausa</i> Shen, Koch, Seid, Tilic & Rouse, 2024	<i>C. davidalani</i> Shen, Koch, Seid, Tilic & Rouse, 2024	<i>C. loresae</i> Shen, Koch, Seid, Tilic & Rouse, 2024	<i>C. persephone</i> Christodoulou, Mah & Arbizu, 2025	<i>C. hades</i> Christodoulou, Mah & Arbizu, 2025	<i>C. javaensis</i> , new species
Attributes		c1	c2	c3	c4	c5	c6	c7	c8	c9	c10	c11
1	Adult shape more stellate than sub-pentagonal	0	0	0	0	1	1	0	0	0	0	0
2	Abactinal plates show imbrication	1	1	1	1	1	1	1	1	1	1	0
3	Infero- longer than superomarginal plates	0	0	0	0	0	1	1	1	1	1	1
4	Abactinal armament granular	0	1	1	1	0	0	0	1	1	1	1
5	Abactinal armament entirely smooth, not thorny	0	0	0	1	0	0	0	0	0	0	0
6	Abactinal armament cone-shaped	0	0	0	0	0	0	0	0	1	0	0
7	Abactinal armament spiniform	1	0	0	0	1	1	1	0	0	0	0
8	Distinct peripheral fringe of ambital spinelets	1	1	1	1	0	1	1	1	1	1	1
9	Ambital spinelets claw-shaped	0	0	0	1	0	0	0	0	0	0	1
10	Gonopore pierces proximal-most-superomarginal plate	0	1	1	0	0	0	0	1	1	1	1
11	Distinct carinal plate series	0	1	1	1	1	1	1	1	1	1	1
12	More than 1 dorso-lateral plate row	1	0	1	0	0	1	0	0	0	0	0
13	Terminal plate pore closer to proximal edge of terminal plate	0	0	0	0	0	0	0	0	0	0	1
14	No. of adambulacral plate pairs per ray never <10 in adult	0	0	0	0	1	1	1	1	1	1	0
15	Depth range extends to <600 m	0	1	0	0	1	0	0	0	0	0	1

davidalani respectively. *C. javaensis*, new species, is most closely related to *C. madagascariensis* (60% similarity). The present morphology-based dendrogram concurs with recent genetic data (Shen et al., 2024; Christodoulou et al., 2025) for Pacific/Atlantic taxa in showing a distinct clade within the genus for *C. davidalani*, *C. scrippsocognaticausa* and *C. laguardi* and further demonstrates that the sympatric species *C. persephone* and *C. hades* are distinct (Christodoulou et al., 2025). Shen et al. (2024) point out that the taxonomic relationship of *C. spinimarginata* remains uncertain due to molecular data being from sites other than the Caribbean Sea type locality. Molecular analysis of the SJADES caymanostellid material is anticipated to be a further research

objective but a more complete molecular phylogeny of the genus and family is currently hindered by factors such as scarcity, for some taxa, of material from type locations, poor preservation, or difficulty of museum specimen access, including for *Caymanostella madagascariensis*, *Caymanostella phorcynis*, and *Caymanostella admiranda*, which are anatomically and/or geographically closest to *Caymanostella javaensis* and for which published molecular sequences are not yet available.

Population analysis and ecology. *Caymanostella javaensis*, new species, is only the second species of the genus described from the Indian Ocean and brings the global number of

described *Caymanostella* species to 11. Discovery of a significant population of *Caymanostella* seastars on the slopes of the Sunda Trough during this expedition, close to an island with tropical forested catchments, a potential major source of sunken wood, is of considerable interest. Total caymanostellid specimen count was high (114) with sometimes more than 20 individuals per trawl haul. All of them were associated with waterlogged wood fall debris over a depth range of 312–1,068 m on the upper slopes of the Java trough, the minimum depth being shallower than previously reported for the genus (418 m, Shen et al., 2024). However, there is a record of an unidentified *Caymanostella* with a potential minimum depth of 240 m (range 240–572 m) from the Solomon Islands (Christodoulou et al., 2025). Sometimes several individuals were clustered together on the same wood fragment (Fig. 3A). The majority of the seastars collected are within a sub-pentagonal to near circular R:r ratio of 1.0 to 1.25 but a few of the smallest, presumably juvenile individuals, have a slightly more stellate outline, with a marginally higher R:r ratio (Fig. 2B). The population sampled off South Java has an essentially unimodal size distribution (Fig. 2A) with a mean radius of 4.3 mm and with a very few individuals in the largest size class (radius 9–9.9 mm). Virtually nothing is known of the biology, growth rates, or life history of these wood stars but the slightly bimodal size distribution may represent successive recruitment cohorts.

A unique anatomical feature of *Caymanostella javaensis*, new species, shared with the other Indian Ocean species, *Caymanostella madagascariensis*, is the presence of claw-like extremities of the ambital spinelets around the periphery of the seastar. These may be an adaptation to assist anchoring to woody substrata, a role also proposed for the numerous rugose actinal spines on adambulacral and inferomarginal plates in caymanostellids (Dilman et al., 2022).

Deep-sea wood falls are recognised as important inputs of terrestrially derived organic matter that can develop into localised biodiversity hotspots (Wolff, 1979; Bienhold et al., 2013). Unlike open ocean deeps distant from land, this type of habitat is likely to be relatively common and the supply of waterlogged debris predictable in deep-water slopes, basins, and trenches that are close to forest lands and mangroves in the Indonesian Archipelago. Indeed, of the 43 SJADES beam trawl stations, 21 of them (48%) recorded woody debris in the net. Consequently, the potential for discovery of new records and taxa of caymanostellids and other fauna on wood falls in the many deep-sea locations in Indonesia is considered to be high.

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APPENDIX

Other material.

Stn. CP12, 8 wet specimens (ZRC.ECH.2456) R:r = 6.0:5.8 mm (R/r ratio = 1.03; disc diameter = 10.1 mm), R:r = 5.2:4.9 mm (R/r ratio = 1.06; disc diameter = 10.0 mm), R:r = 5.4:4.8 mm (R/r ratio = 1.13, disc diameter = 9.0 mm), R:r = 4.9:4.0 mm (R/r ratio = 1.23; disc diameter = 9.0 mm), R:r = 4.4:4.0 mm (R/r ratio = 1.10; disc diameter = 8.2 mm), R:r = 4.4:4.0 mm (R/r ratio = 1.10; disc diameter = 8.2 mm), R:r = 4.6:4.2 mm (R/r ratio = 1.10; disc diameter = 8.5 mm), R:r = 4.5:3.8 mm (R/r ratio = 1.18; disc diameter = 8.1 mm), Sunda Strait (southeast of Tabuan Island), S05°52.490', E104°56.604' (mid-point of beam trawl), 25 March 2018, depth = 615–698m. Substrate: muddy.

Stn. CP23, 1 wet specimen (RCO.ECH.3146) R:r = 3.0:2.7 mm (R/r ratio = 1.11; disc diameter = 5.8 mm), Sunda Strait, South of Panaitan Island, S06°46.331', E105°08.799' (mid-point of beam trawl), 27 March 2018, depth = 559–571 m. Substrate: gravel with some mud.

Stn. CP24, 1 wet specimen (RCO.ECH.3147) R:r = 6.6:5.9 mm (R/r ratio = 1.12; disc diameter = 12.1 mm), Sunda Strait (South of Panaitan Island), S06°47.629' S, E105°06.262' (mid-point of beam trawl), 27 March 2018, 1,044–1,068 m, Substrate: gravel with pieces of wood.

Stn. CP27, 2 wet specimens (ZRC.ECH.1610) R:r = 4.6:4.1 mm (R/r ratio = 1.12; disc diameter = 8.5 mm) & R:r = 3.6:3.3 mm (R/r ratio = 1.09; disc diameter = 6.7 mm); 4 wet specimens (RCO.ECH.3150) R:r = 4.9:4.1 mm (R/r ratio = 1.20; disc diameter = 9.1 mm), R:r = 5.3:4.7 mm (R/r ratio = 1.13; disc diameter = 10 mm), R:r = 2.6:2.2 mm (R/r ratio = 1.18; disc diameter = 5.2 mm), R:r = 1.8:1.4 mm (R/r ratio = 1.29; disc diameter = 3.6 mm), Indian Ocean, east of Tinjil Island, S06°58.781', E105°53.554' (mid-point of beam trawl), 28 March 2018, depth = 481–557 m. Substrate: gravel.

Stn. CP28, 2 wet specimens (RCO.ECH.3156) R:r = 3.9:3.5 mm (R/r ratio = 1.11; disc diameter = 7.3 mm) & R:r = 2.9:2.4 mm (R/r ratio = 1.21; disc diameter = 5.5 mm), east of Tinjil Island, S06°59.986', E105°54.924' (mid-point of beam trawl), 28 March 2018, depth = 957–1,022 m. Substrate: coarse sand and some mud.

Stn. CP33, 5 wet specimens (RCO.ECH.3153) R:r = 4.1:3.6 mm (R/r ratio = 1.14; disc diameter = 7.9 mm), R:r = 4.3:3.6 mm (R/r ratio = 1.19; disc diameter = 7.9 mm), R:r = 4.1:3.5 mm (R/r ratio = 1.17; disc diameter = 7.7 mm), R:r = 3.6:3.5 mm (R/r ratio = 1.03; disc diameter = 7.1 mm), R:r = 3.9:3.5 mm (R/r ratio = 1.11; disc diameter = 7.1 mm), Indian Ocean (South of Tg. Boyongkareuceng), S07°43.084', E107°36.897' (mid-point of beam trawl), 29 March 2018, depth = 525–312 m. Substrate: coarse sand and some mud.

Stn. CP44, 7 wet specimens (RCO.ECH.3152) R:r = 9.3:8.8 mm (R/r ratio = 1.06; disc diameter = 18.2 mm), R:r = 8.0:7.1 mm (R/r ratio = 1.13; disc diameter = 15.5 mm), R:r = 6.6:5.5 mm (R/r ratio = 1.20; disc diameter = 12.3 mm), R:r = 5.3:4.7 mm (R/r ratio = 1.13; disc diameter = 10.2 mm), R:r = 4.9:4.2 mm (R/r ratio = 1.17; disc diameter = 8.8 mm), R:r = 3.2:2.8 mm (R/r ratio = 1.14; disc diameter = 6.5 mm), R:r = 5.2:4.3 mm (R/r ratio = 1.21; disc diameter = 9.7 mm), Indian Ocean south of Cilicap, S08°09.934', E108°37.292' (mid-point of beam trawl), 31 March 2018, depth = 1013–970 m. Substrate: mud with pieces of wood.

Stn. CP47, 3 wet specimens, (ZRC.ECH.2459) R:r = 4.6:4.1 mm (R/r ratio 1.12; disc diameter = 8.8 mm), R:r = 4.2:4.0 mm (R/r ratio = 1.05; disc diameter = 8.1 mm), R:r = 2.5:2.4 mm (R/r ratio = 1.04; disc diameter = 4.7 mm); 1 wet specimen (RCO.ECH.3155) R:r = 3.7:3.6 mm (R/r ratio = 1.03; disc diameter = 7.5 mm), Indian Ocean, south of Pameungpeuk, S07°48.115', E107°45.502' (mid-point of beam trawl), 1 April 2018, depth = 530–476 m. Substrate: coarse sand.

Stn. CP48, 7 wet specimens (ZRC.ECH.2457) R:r = 5.44:4.72 mm (R/r ratio = 1.15; disc diameter = 10.4 mm), R:r = 2.82:2.77 mm (R/r ratio = 1.02; disc diameter = 5.55 mm), R:r = 3.09:2.82 mm (R/r ratio = 1.10; disc diameter = 5.91 mm), R:r = 3.76:3.67 mm (R/r ratio = 1.03; disc diameter = 6.45 mm), R:r = 3.56:3.06 mm (R/r ratio = 1.16; disc diameter = 7.11 mm), R:r = 4.27:3.5 mm (R/r ratio = 1.22; disc diameter = 8.0 mm), R:r = 3.11:2.78 mm (R/r ratio = 1.12; disc diameter = 5.83 mm); 30 wet specimens (RCO.ECH.3145) R:r = 2.5:2.3 mm (R/r ratio = 1.09; disc diameter = 5.1mm), R:r = 2.5:1.7 mm (R/r ratio = 1.47; disc diameter = 4.3 mm), R:r = 3.4:3.0 mm (R/r ratio = 1.13; disc diameter = 6.4 mm), R:r = 2.6:2.2 mm (R/r ratio = 1.18; disc diameter = 5 mm), R:r = 4.4:3.6 mm (R/r ratio = 1.22; disc diameter = 8.1 mm), R:r = 3.9:3.5 mm (R/r ratio = 1.11; disc diameter = 7.2 mm), R:r = 4.1:4.0 mm (R/r ratio = 1.03; disc diameter = 8.6 mm), R:r = 4.2:3.9 mm (R/r ratio = 1.08; disc diameter = 8.1 mm), R:r = 4.9:4.3 mm (R/r ratio = 1.14; disc diameter = 9.3 mm), R:r = 4.8:4.4 mm (R/r ratio = 1.09; disc diameter = 9.7 mm), R:r = 3.9:3.6 mm (R/r ratio = 1.08; disc diameter = 7.8 mm), R:r = 3.6:3.2 mm (R/r ratio = 1.13; disc diameter = 7 mm), R:r = 3.3:3.0 mm (R/r ratio = 1.10; disc diameter = 6.4 mm), R:r = 3.6:3.3 mm (R/r ratio = 1.09; disc diameter = 7 mm), R:r = 4.4:3.7 mm (R/r ratio = 1.19; disc diameter = 8.6 mm), R:r = 3.1:2.8 mm (R/r ratio = 1.11; disc diameter = 5.9 mm), R:r = 5.1:4.2 mm (R/r ratio = 1.21; disc diameter = 9.9 mm), R:r = 3.9:3.3 mm (R/r ratio = 1.18; disc diameter = 7.6 mm), R:r = 4.7:4.2 mm (R/r ratio = 1.12; disc diameter = 9.6 mm), R:r = 4.2:3.6

mm (R/r ratio = 1.17; disc diameter = 8.1 mm), R:r = 5.0:4.4 mm (R/r ratio = 1.14; disc diameter = 9.6 mm); R:r = 4.1:3.7 mm (R/r ratio = 1.11; disc diameter = 8.2 mm), R:r = 4.2:3.8 mm (R/r ratio = 1.11; disc diameter = 8 mm), R:r = 3.9:3.7 mm (R/r ratio = 1.05; disc diameter = 7.9 mm), R:r = 5.2:4.6 mm (R/r ratio = 1.13; disc diameter = 10 mm), R:r = 4.1:3.8 mm (R/r ratio = 1.08; disc diameter = 8 mm); R:r = 4.6:4.0 mm (R/r ratio = 1.15; disc diameter = 8.7 mm); R:r = 4.8:3.9 mm (R/r ratio = 1.23, disc diameter = 9.6 mm), R:r = 3.6:3.2 mm (R/r ratio = 1.13; disc diameter = 7.1 mm), R:r = 3.7:3.3 mm (R/r ratio = 1.12; disc diameter = 7.3 mm), Indian Ocean (South of Tg. Gede, Java), S07°51.419', E107°46.310' (mid-point of beam trawl), 1 April 2018, depth = 689–637 m. Substrate: some mud and fishing line.

Stn. CP50, 4 wet specimens (RCO.ECH.3144) R:r = 7.5:6.9 mm (R/r ratio = 1.09; disc diameter = 14.6 mm), R:r = 4.7:4.1 mm (R/r ratio = 1.15; disc diameter = 8.8 mm), R:r = 3.4:3.1 mm (R/r ratio = 1.10; disc diameter = 6.7 mm), R:r = 2.8:2.4 mm (R/r ratio = 1.17; disc diameter = 5.7 mm), Indian Ocean, Pelabuhanratu Bay, S07°03.542', E106°26.504' (mid-point of beam trawl), 2 April 2018, depth = 383–425 m. Substrate: mud.

Stn. CP51, 3 wet specimens (ZRC.ECH.2460) R:r = 5.6:5.2 mm (R/r ratio = 1.08; disc diameter = 10.6 mm), R:r = 4.0:3.7 mm (R/r ratio = 1.08; disc diameter = 7.8 mm), R:r = 2.9:2.6 mm (R/r ratio = 1.12; disc diameter = 5.3 mm); 20 wet specimens (RCO.ECH.3151) R:r = 5.2:4.6 mm (R/r ratio = 1.13; disc diameter = 9.7 mm), R:r = 3.7:3.4 mm (R/r ratio = 1.09; disc diameter = 6.9 mm), R:r = 3.0:2.6 mm (R/r ratio = 1.15; disc diameter = 5.6 mm), R:r = 2.6:2.4 mm (R/r ratio = 1.08; disc diameter = 4.6 mm), R:r = 3.8:3.4 mm (R/r ratio = 1.12; disc diameter = 7.4 mm), R:r = 4.8:4.0 mm (R/r ratio = 1.20; disc diameter = 8.6 mm), R:r = 3.6:3.1 mm (R/r ratio = 1.16; disc diameter = 6.8 mm), R:r = 5.1:4.4 mm (R/r ratio = 1.16; disc diameter = 9.4 mm), R:r = 4.9:3.9 mm (R/r ratio = 1.26; disc diameter = 8.9 mm), R:r = 5.2:4.6 mm (R/r ratio = 1.13; disc diameter = 10 mm), R:r = 5.9:5.2 mm (R/r ratio = 1.13; disc diameter = 11 mm), R:r = 3.9:3.4 mm (R/r ratio = 1.15; disc diameter = 7.5 mm), R:r = 4:3.7 mm (R/r ratio = 1.08; disc diameter = 7.8 mm), R:r = 3.5:3.0 mm (R/r ratio = 1.17; disc diameter = 6.6 mm), R:r = 3.0:2.3 mm (R/r ratio = 1.30; disc diameter = 5.4 mm), R:r = 5.3:4.8 mm (R/r ratio = 1.10; disc diameter = 10.2 mm), R:r = 3.2:3.1 mm (R/r ratio = 1.03; disc diameter = 6.5 mm), R:r = 3.0:2.8 mm (R/r ratio = 1.07; disc diameter = 6.2 mm); R:r = 4.3:3.7 mm (R/r ratio = 1.16; disc diameter = 8.3 mm), R:r = 4.0:3.2 mm (R/r ratio = 1.25; disc diameter = 7.4 mm), Indian Ocean, Pelabuhanratu Bay, S07°05.111', E106°25.220' (mid-point of beam trawl), 2 April 2018, depth = 569–657 m. Substrate: coarse sand, mud, and plastic trash.

Stn. CP58, 6 wet specimens (RCO.ECH.3148) R:r = 6.6:5.7 mm (R/r ratio = 1.16; disc diameter = 11.8 mm), R:r = 5.2:4.6 mm (R/r ratio = 1.13; disc diameter = 10 mm), R:r = 5.0:4.6 mm (R/r ratio = 1.09; disc diameter = 9.8 mm), R:r = 4.1:3.5 mm (R/r ratio = 1.17; disc diameter = 8 mm), R:r = 4.1:3.8 mm (R/r ratio = 1.08; disc diameter = 7.8 mm), R:r = 2.7:2.3 mm (R/r ratio = 1.17; disc diameter = 5.2 mm), Indian Ocean, Pelabuhanratu Bay, S07°01.845', E106°23.408' (mid-point of beam trawl), 3 April 2018, depth = 564–505 m. Substrate: Mostly mud with very few fauna.

Stn. CP59, 1 wet specimen (RCO.ECH.3154) R:r = 3.3:3.0 mm (R/r ratio = 1.10; disc diameter = 6.5 mm), Indian Ocean, Pelabuhanratu Bay, S07°02.460' E106°23.126' (mid-point of beam trawl), 3 April 2018, depth = 579–659 m. Substrate: mostly mud with very sparse fauna.