Microstellaria juliae – a remarkable new subfamily, new genus and new species in the Pyramidellidae (Gastropoda)

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Key words: *Microstellaria*, Pyramidellidae, Indo-West Pacific, Indonesia, Spratly Islands, Coral Triangle

A new genus and species within the Pyramidellidae are described from offshore corals reefs at various localities in Indonesia and from the Royal Charlotte atoll in the South China Sea: *Microstellaria juliae* gen. et spec. nov. Thus far only dead specimens have been found. The remarkable discoidal, planispiral shells with regularly placed projecting spines appear to be miniature versions of *Stellaria* Möller, 1832 (family Xenophoridae) or juvenile *Astraea* Röding, 1798 (Turbinidae). The heterostrophic protoconch at an almost 90° angle to the teleoconch demonstrates its placement within the Pyramidelloidea, however, the shells have some unique features. The internal septa in the early part of the teleoconch have not been recorded before from the Pyramidelloidea. They are interpreted as preventive measure in case the protoconch is damaged. The planispiral shape is exceptional within the Pyramidellidae, albeit not unique. The projecting spines along the periphery and on the aperture are unique within the superfamily. Therefore the genus is placed within a new subfamily Microstellariinae subfam. nov., currently within the Pyramidellidae, but it could constitute a separate family within the Pyramidelloidea.

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INTRODUCTION

In sediment samples collected during a Naturalis Expedition to Kalimantan, Indonesia in 2003 whilst scuba diving at depths ranging from 10-25 m, the second author collected peculiar, minute planispiral gastropods. In samples collected by Sancia van der Meij in 2007, 2008 and 2009 during Naturalis Expeditions to Raja Ampat, Menado and Ternate (all Indonesia) this peculiar species was found again in sediment samples. The first author collected this species in 2018 in sediment samples from the Spratly Islands in the South China Sea off Brunei.

At first sight these discoidal, planispiral coiled gastropods show similarities to the genus *Astrosansonia* Le Renard & Bouchet, 2003, a genus belonging to the family Pickworthiidae. However, its protoconch is hyperstrophic (a 90° angle to the teleoconch) indicating that it should be classified in the family Pyramidellidae. Planispiral pyramidellids are rare, as far as we know only the Western Atlantic genus *Cyclostremella* K.J. Bush, 1897 (Robertson, 1973), the Indo-West Pacific genus *Moerchia* A. Adams, 1860 (Rubio & Rolán, 2014) and the Australian genus *Pseudoskenella* Ponder, 1974 (Australia) have planispiral shells.

MATERIAL AND METHODS

Collecting efforts. — In the first decade of this century, Naturalis Biodiversity Center (Leiden, The Netherlands) organised several marine expeditions to Indonesia. This area is part of the Coral Triangle, a marine area with a very high biodiversity (Fig. 1). During these expeditions, sediment samples were collected between 10-40 m by scuba diving activities. These samples were dried, sieved and sorted by the second author. In five samples collected during the Berau Expedition (Kalimantan), three samples during the Raja Ampat Expedition (Papua), one sample during the Menado Expedition (Sulawesi) and one during the Ternate Expedition this peculiar discoidal gastropod was found. None of the specimens of this new gastropod was alive when collected.

In 2018, with help from László Kocsis (Universiti Brunei Darussalam, UBD) and Bernard Landau, as part of cooperation between UBD and Naturalis, the first author collected

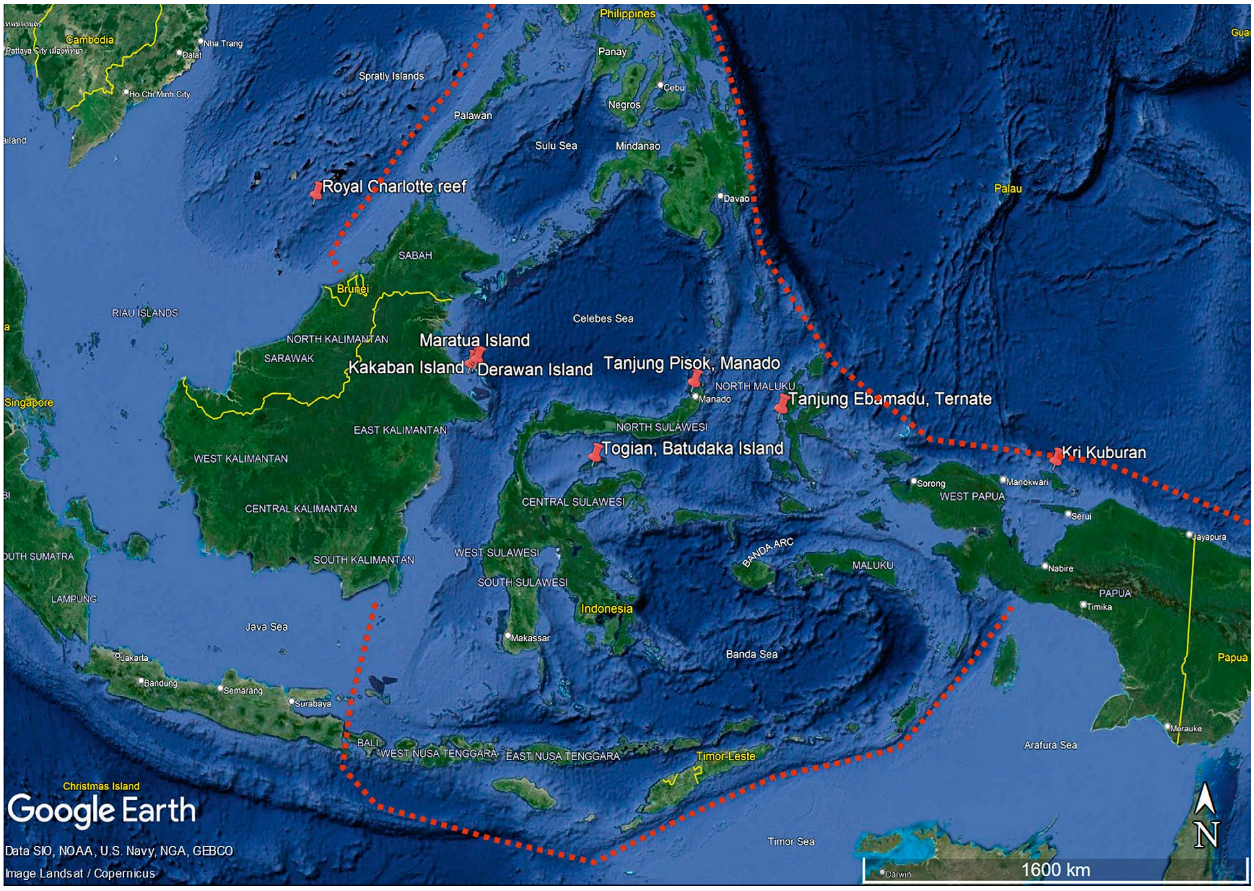

Fig. 1. Distribution map. The dotted line demarcates the Coral Triangle (as defined by Hoeksema, 2007; generally agreed as documented in Coral Triangle Initiative on coral reefs, fisheries and food security, 2011; with the NW border modified as discussed in Raven & Recourt, 2018). Note that the atolls of the Spratly Islands are outside the Coral Triangle. Base map from Google Earth.

sediment samples during a visit to the Royal Charlotte atoll in the Spratly Islands, South China Sea, 265 km offshore from Brunei. A second set was collected in the same area by László Kocsis. All samples were collected through scuba diving, then sieved, dried and sorted. No living specimens have been found.

All material is stored in the malacology collection of Naturalis unless otherwise stated.

Imaging. — Light photographs were made with a stereomicroscope using stacking software. SEM images were made without coating in a JEOL JSM-6480 LV and a JEOL JSM-IT510 using low vacuum, 10 KV voltage and 30 Pa pressure. CT scans were made using a NeoScan N80 micro-CT scanner; output was processed using Avizo software. Based on the CT scan output a 3D model was built which could be sliced, made transparent and processed to show shell thickness. The 3D model can be downloaded from www.Basteria.nl (website under construction).

Abbreviations. — HR = Han Raven, The Hague, The Netherlands; L = shell length; Naturalis = Naturalis Biodiversity Center, Leiden, The Netherlands; RM = Robert Moolenbeek, Ankeveen, The Netherlands; RMNH = Rijksmuseum van Natuurlijke Historie, Leiden, now part of Naturalis; SM = Sancia van der Meij (Naturalis); sp. = specimen(s); Stn = Station; UBD = Universiti Brunei Darussalam, Bandar, Brunei Darussalam; W = shell width.

SYSTEMATICS

Class Gastropoda Cuvier, 1795
Superfamily Pyramidelloidea Gray, 1840
Family Pyramidellidae Gray, 1840

Subfamily Microstellariinae subfam. nov.

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Type genus. — *Microstellaria* gen. nov.

Diagnosis. — Shell small, discoidal, with planispiral coiled whorls. Peripheral keel with regularly placed projecting spines. Protoconch heterostrophic (at an almost

90° angle to the teleoconch). Aperture circular, peristome thickened, outer lip with a strong varix. Umbilicus broad and open. Upper teleoconch whorl with internal septa.

Remarks. Key differentiating characteristics for this subfamily are the planispiral coiled whorls, the sculpture of regularly placed projecting spines and the internal septa. The first is rare, the latter two are unique characteristics within the Pyramidellidae.

Besides *Microstellaria* gen. nov. there are a few other genera of pyramidellids that have shells deviating from the typical elongated shape. The planispiral *Cyclostremella* K.J. Bush, 1897 (North East Pacific) has spiral sculpture on the teleoconch; the planispiral *Moerchia* A. Adams, 1860 (Indo-West Pacific) has a teleoconch with marked sculpture of radial ribs and rows of nodules; *Microthyca* A. Adams, 1863 (Indo-West Pacific), has a globular, smooth shell with rows of nodules; and *Pseudoskenella* (Australia) has a planispiral shell with a smooth surface. The suprageneric organisation within the Pyramidelloidea has not yet been satisfactorily resolved. Schander et al. (1998) gave an overview in which they raised several of the subfamilies in the Pyramidellidae to family level, ending up with 7 families. Bouchet & Rocroi (2005: 258) follow their classification but lower all categories one rank, thus only recognising the Pyramidellidae Gray, 1840, Amathinidae Ponder, 1987, Murchisonellidae Casey, 1904 and the extinct Heteroneritidae Gründel, 1998. Of the four genera mentioned above Schander et al. (1998) include *Cyclostremella* and *Pseudoskenella* within the Cyclostremellinae D. R. Moore, 1966 (as part of the Odostomiidae Pelseneer, 1928), but do not mention *Moerchia* or *Microthyca*. Bouchet & Rocroi (2005) do not address the generic level, but include the tribe Cyclostremellini within the subfamily Odostomiinae Pelseneer, 1928 of the Pyramidellidae. MolluscaBase (2024a-d) lists *Cyclostremella* as the only genus within the subfamily Cyclostremellinae of the Pyramidellidae; *Moerchia* and *Pseudoskenella* Ponder, 1974 have not been assigned to a specific subfamily of the Pyramidellidae, whereas *Microthyca* is unassigned to any family within the Pyramidelloidea, as incertae sedis. All these four genera have a protoconch type C (fully inverted) and none appears to be closely related to *Microstellaria* gen. nov.. Future anatomical studies and molecular analyses might clarify the relationships between these genera and their position within the Pyramidelloidea.

Genera included. — Currently only the genus *Microstellaria* gen. nov. is included within this subfamily.

Genus *Microstellaria* gen. nov.

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Type species. — *Microstellaria juliae* (gender feminine)

Derivatio nominis. — The name refers to the genus *Stellaria* Möller, 1832 (family Xenophoridae) which has similar shape and spines as the new taxon which, superficially, could be a miniature version. Indirectly the name also refers to the star-shaped contour of the base.

Diagnosis — Shell small, discoidal and planispiral coiled whorls. Peripheral keel with regularly placed projecting spines. Protoconch heterostrophic (at an almost 90° angle to the teleoconch). Aperture circular, peristome thickened, outer lip with a strong varix. Umbilicus broad and open. Initial teleoconch whorl with internal septa.

Remarks. — Superficially the new genus looks like *Astrosansonia* Le Renard & Bouchet, 2003 in the family Pickworthiidae (micromollusc, planispiral with rather flat whorls, keel with spines, wide umbilicus, protruding protoconch), but there are numerous differences. The protoconch is heterostrophic, the whorls are more globose and rather smooth (instead of having a marked sculpture on upper and lower side), the projecting spines are more numerous, narrower and preserved on earlier whorls, and are set on the basal keel of the whorl (instead of the upper keel), there is a row of much shorter protrusions just above the row of spines (instead of a row of nodes on the upper keel) and the outer lip has three spines (instead of one blunt protrusion).

The heterostrophic protoconch is of type A (classification of van Aartsen, 1987): the protoconch is at an almost 90° angle to the teleoconch, and in this case partially submerged. Some species with type A protoconchs have the protoconch completely exposed (e.g. *Odostomia conspicua* Alder, 1850), others have it partly submerged (e.g. *Megastomia conoidea* (Brocchi, 1814)).

The new genus is monospecific.

Microstellaria juliae spec. nov.

Figs 2-7

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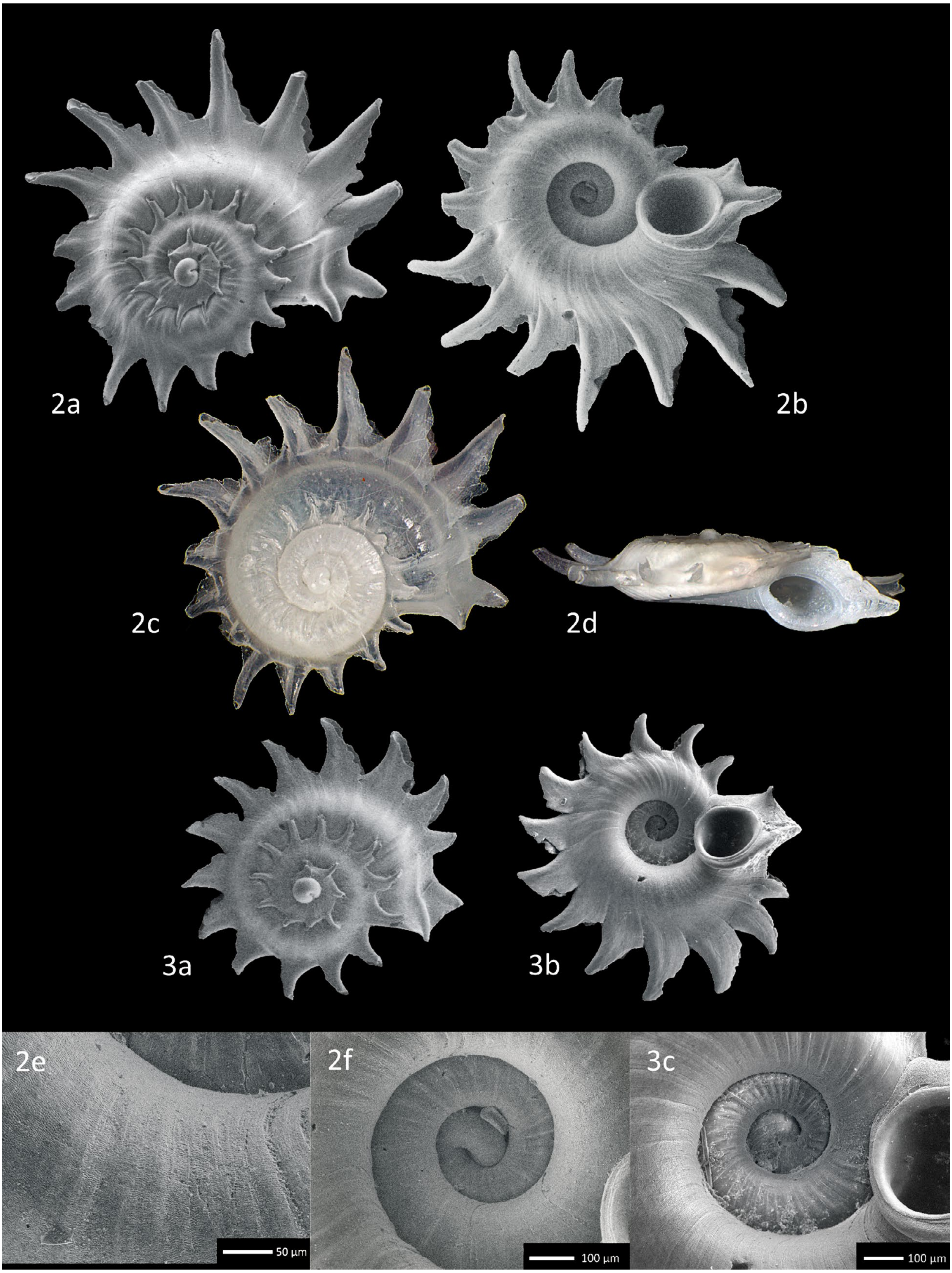
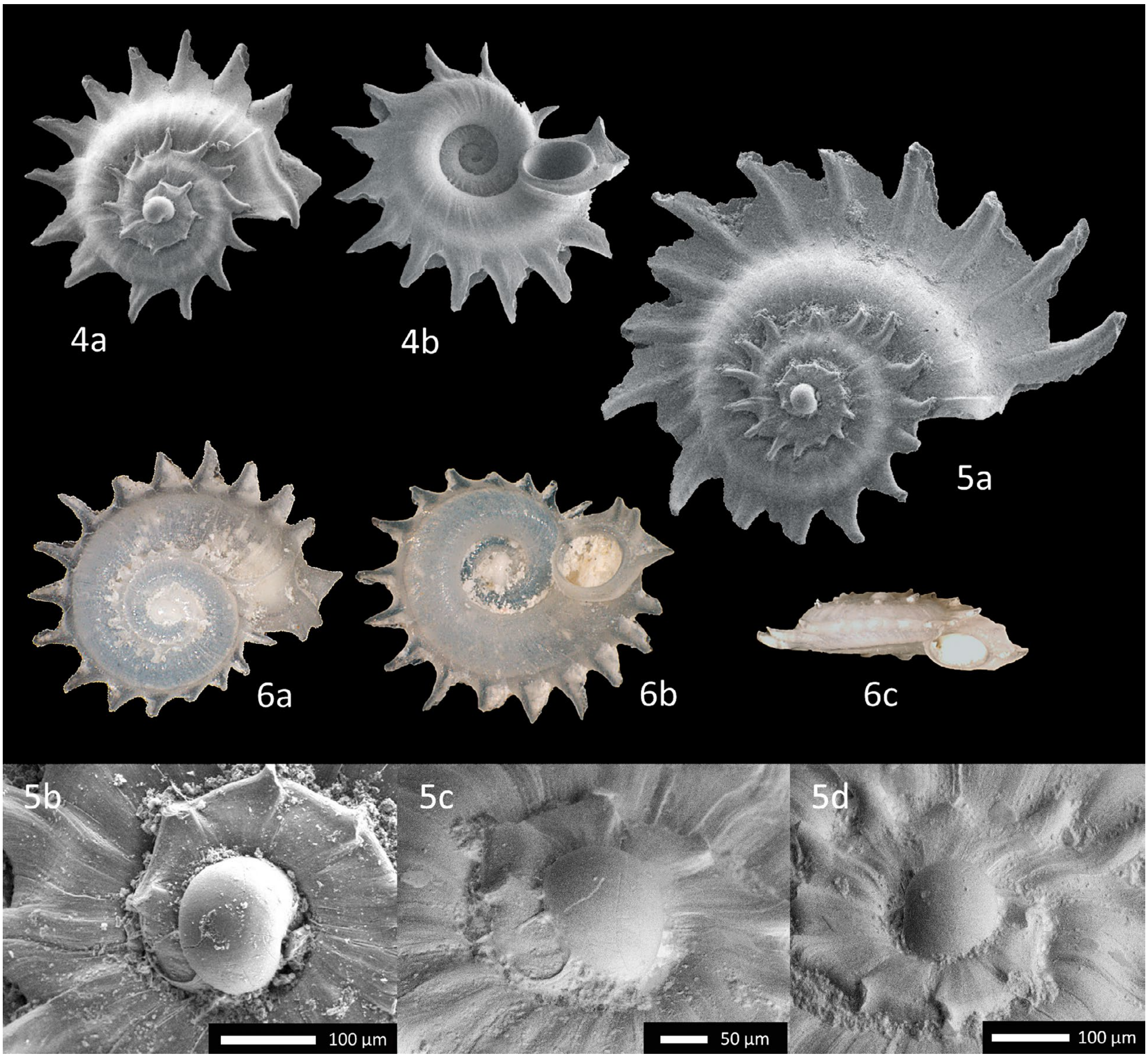
Type locality. — Indonesia, Kalimantan: S of Derawan Island, Lighthouse-1 reef, Netherlands Berau expedition Stn ber 03/3010, 10-25 m depth, 18.x.2003, RM leg.

Type material. — Holotype RMNH.MOL.350829; paratypes (from the type locality) RMNH.MOL.350830, 1 sp. + RMNH.MOL. 350831; 3 sp.

Other material studied. — **Indonesia, Kalimantan**: Berau Islands: Kakaban Island, W side, Netherlands Berau expedition Stn ber 03/35, 10-25 m, 21.x.2003, leg. RM (RMNH.MOL.350834; 2 sp.); Kakaban Island, NE side, entrance tidal lake Kehe Daing, Netherlands Berau expedition Stn ber 03/49, 28.x.2003, leg. RM (RMNH.MOL.350835; 1 sp.); Maratua Island, W side, Netherlands Berau expedition Stn ber 03/38, 10-25 m, 22.x.2003, leg. RM (RMNH.MOL.350836;



Figs 2-3. *Microstellaria* juliae spec. nov., Indonesia, Kalimantan: station ber 03/30, Lighthouse-1 reef, S. of Derawan Island, Kalimantan, Indonesia, leg. RM. **2.** Holotype, W 2.25 mm (RMNH.MOL.350829). **3.** Paratype, W 1.7 mm (RMNH.MOL.350830). **2a-b, 2e-f, 3a-c.** Scanning Electron Microscope images. **2c-d.** Light microscopy images. **2a, 2c, 3a.** Dorsal views. **2b, 3b.** Ventral views. **2d.** Apertural view. **2e.** Detail of ventral side showing fine striations. **2f, 3c.** Details of umbilicus showing sculpture and protoconch.



Figs 4-6. *Microstellaria juliae* spec. nov. **4.** Maya's Mimpi, Irian Jaya, Indonesia, leg. SM, W 1.4 mm (RMNH.MOL.350833). **5.** Juvenile, Ternate, Tanjung Ebamadu, Ternate, North Maluku, leg. SM, W 25 mm (RMNH.MOL.350838). **6.** Royal Charlotte atoll, Spratly Islands, Stn S18.11b, reef slope at S side, 10 m depth, leg. HR, W 1.6 mm (R T09781). **4-5.** Scanning Electron Microscope images. **6.** Light microscopy images. **4a, 5a, 5b, 6a.** Dorsal view. **5c-d.** Dorsal views at angle of ~45°. **4b, 6b.** Ventral view. **6c.** Apertural view. **5b-d.** Details of dorsal side showing the protoconch and the sharp transition from protoconch to teleoconch.

1 sp.).; **Sulawesi**: Menado, Tanjung Pisok, Stn me108/22, 31 m, xii.2008, leg. SM (RMNH.MOL.350837; 1 sp.); **North Maluku**: Ternate, Tanjung Ebamadu, Stn ter09/08, 30 m depth, x. 2009, leg. SM (RMNH.MOL.350838; 2 sp.); **Irian Jaya**: SW Kri Kuburan, Raja Ampat expedition Stn RAJ07/15-15A, 16-26 m, 23.ii.2007, leg. SM (RMNH.MOL.350839; 3 sp.).; Maya's Mimpi, 20 m, x.2007, leg. SM (RMNH.MOL.350840; 3 sp.; RMNH.MOL.350833, 1 sp.). **Spratly Islands**: Royal Charlotte reef (265 km NW from Muara), reef slope at S side, Stn S18.11, 24-26 m depth, leg. HR (HR T09429, 3 sp.); Royal Charlotte reef (265 km NW from Muara), reef slope at S side, Stn S18.11b, 10 m depth, leg. HR (RMNH.MOL.350832, 1 sp.; HR T09781, 1 sp.); Royal Charlotte reef (265 km NW from Muara), reef slope at SE side, Stn S18.14, 20 m depth, leg. HR (HR T10592, 1 sp.).

Derivatio nominis. — The species is named after Julia Maria Morales Calleja, wife of the first author, who always supported him in his malacological research.

Description (holotype). — Very small (L 0.6 mm, W 2.25 mm), with heterotrophic protoconch type A (at 90° angle, diameter ~170 µm), partially submerged within the teleoconch whorls, visible both in apical and ventral views.

Planispiral coiled teleoconch consisting of 2.8 almost smooth whorls with globose dorsal side with growth lines and weakly convex ventral side with regular growth lines and numerous very fine, zigzagging, closely spaced radial grooves. Along the basal keel are regularly placed projecting spines (14 on the last whorl, excluding the one on the aperture) that slightly curve upward whilst most have a hollow underside. The spines are hollow, formed by a thin sheet that is closed posteriorly but open anteriorly where the upper and lower filaments approach each other but do not close completely. The spines along the basal keel of the earlier teleoconch whorls are not absorbed in later whorls, with their points slightly sticking out. Broad, open umbilicus. Aperture round, prosocline, peristome with thick reflected rim that has two spines with radial groove inside. The longer outer spine points sideways/upward and the one just above the carina points forward and slightly down, enforced by a kinked spiral rib that fades upon reaching the anterior spine.

Remarks. — Some characteristics are variable. Size varies (L 0.5-0.6 mm, W 1.3-2.5 mm), there are 2.2-2.8 teleoconch whorls, the number of spines on the last whorl is 13-17, the ventral side of first teleoconch whorl may have radial ribs with fine riblets in between, that both fade to growth lines in the later whorls (Fig. 3C) and the peristome may have two or three spines. Most notable is the variation in development of the spines: which can be straight, pointing towards or away from the aperture; they are short in the specimens from the South China Sea (~150 vs. 700 µm, accounting for the major size difference as without spines the smallest specimen is 1 mm wide, the largest 1.25 mm); they can become long and wide, with the a central convex spike and two flat sides that widen towards the aperture, partially enveloping the following spine (best developed in the specimens from Sulawesi). On the aperture a third, secondary spine may be present on the columellar side of the spine with the kinked spiral rib (e.g. Figs 6a-b) and the spiral rib itself may be absent. The protoconch is tilted, type A (van Aartsen, 1987). On the apical side it is typically represented by a very globose whorl of which about half emerges above the first teleoconch whorl. In most specimens the transition from protoconch to teleoconch is hidden within the shell, but in the specimen of Figs 5b-d it is clearly visible, as a sharp transition, with the protoconch having a concave edge, apparently a deep sinus. In some specimens the transition is partially visible within the umbilicus (e.g. Figs 2f, 3c). The protoconch is clearly paucispiral, but it is impossible to count the protoconch whorls based on the shells. Based on the 3D model there are ~1.5 whorls.

The 3D digital model based on the micro CT scan was made transparent (Figs 7h-j) showing the protoconch lying on its side, and a series of (at least 4) internal septa formed in successive stages to close off the early whorls. The final septum is very thick, occupying about ¼ whorl, with a V-shaped termination (best seen in ventral view, Fig. 7i).

Distribution. — This new species is known from Indonesia (Kalimantan, Sulawesi, Moluccas and Irian Jaya), all localities within the Coral Triangle and from the Royal Charlotte atoll in the South China Sea (Fig. 1). All localities are coral reefs around small islands or atolls, i.e. with very little or no siliciclastic sedimentation. A large specimen (W 2.5 mm) with long spines from 24-26 m depth, Logian, Batudaka Island, Sulawesi, Indonesia is illustrated by Kurtz (2024), identified as *Astrosansonia*? spec. 1.

DISCUSSION

The shell is superficially similar to that of *Stellaria* Möller, 1832 being flat with long spines around the periphery. *Stellaria solaris* (Linnaeus, 1764) feeds on algae and foraminifers and reportedly the spines provide an enclosed space within which the animal can feed (Beechey, 2023). *Microstellaria*, however, is ~100x smaller length (~1,000,000x smaller volume), the protoconch is heterostrophic, the spines are broader at the base and slightly curved, and it does not adhere objects to its upper surface. Also, *Microstellaria* is not dissimilar to very juvenile *Astraea* Röding, 1798 (Turbinidae) or *Pseudoliotia* Tate, 1898 (Tornidae), but first of all has the heterostrophic protoconch, has a much wider umbilicus and lacks the strong growth lines, which indicate a very different build-up of the spines.

Dinapoli et al. (2011) attributed the enormous diversity of the Pyramidellidae (with > 6000 named species and 350 genera and subgenera; Schander et al., 2003) to their piercing styles associated with an acrembolic proboscis, which opened up a wide variety of food sources (Bivalvia, Gastropoda, Polychaeta). Even within this diverse group *Microstellaria* gen. nov. stands out with its planispiral shape and long spines. Nützel (2021) discussed characteristics of the shells of parasitic gastropods, stating that the majority of these are small and high-spired with a generally low shell morphological disparity. As energy-intensive innovation within the Pyramidellidae, the spines must have a practical purpose. The flat shape could be an indication that the animal lives in a restricted space (as seen in *Crepidula fornicata* (Linnaeus, 1758) living inside shells occupied by hermit crabs compared to the typical globose shape of those living on the outside; Raven, 2019), e.g. on a host living in a burrow, in which case the spines allow a more steady positioning on its host, avoiding the specimens to be rubbed off during movement within such a restricted space. On the other hand, it cannot be excluded that the animals live at the sediment surface, in which case the spines widen the shell to increase stability, whilst using as little extra material as possible (as in e.g. the Xenophoridae). The carina

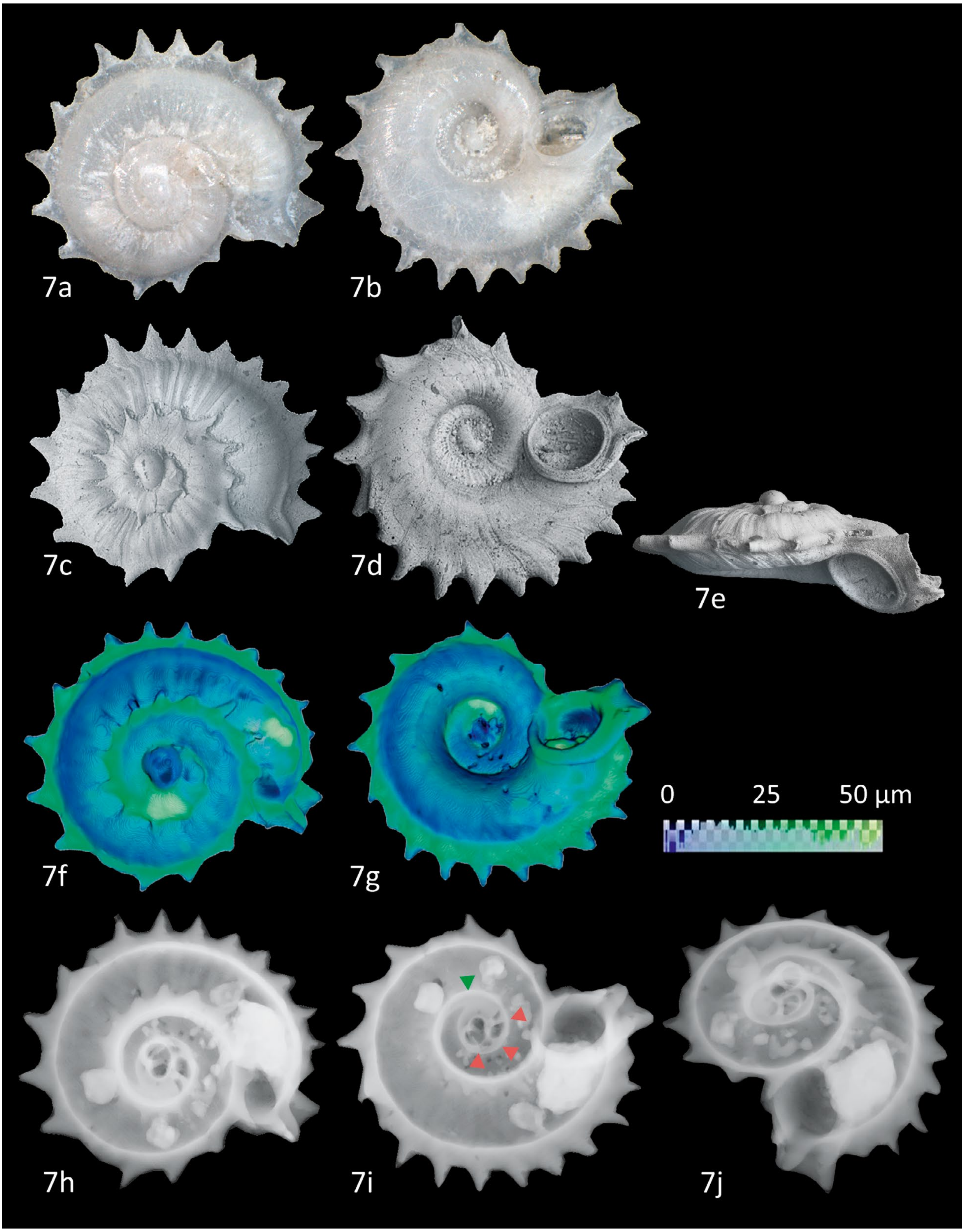


Fig. 7. *Microstellaria juliae* spec. nov., Royal Charlotte atoll, Spratly Islands, Stn S18.11b, reef slope at S side, 10 m depth, leg. HR, L 0.5 mm, W 1.3 mm (RMNH.MOL.350832). **a-b.** Light microscopy image. **c-e.** Scanning Electron Microscope images. **f-g.** 3D model from micro CT scan processed to show shell thickness; scale indicates shell thickness. **h-j.** 3D model from micro CT scan made transparent to show the protoconch and internal septa. The red and green arrowheads indicate the septa, the one indicated by the green arrowhead is very thick. **a, c, f, h**. Dorsal views. **b, d, g, i.** Ventral views. **e.** Apertural view. **j.** View inclined from above.

with spines forms the thickest part of the shell (Figs 7f-g) possibly protecting against predators, or just to avoid the spines breaking off.

Abandonment of early whorls is a phenomenon seen in various gastropods, including terrestrial snails with elongated shells (e.g. *Rumina* Risso, 1826; *Truncatella* Risso, 1826) and marine snails (e.g. *Colina* H. Adams & A. Adams, 1854; Caecidae; various species of *Mitrella* Risso, 1826; Cavoliniidae), which decollate to dispose of the early whorls. Anderson & Allmon (2018) state septa are observed in many Palaeozoic gastropod groups, but also in extant marine gastropods, including Turritellidae, Vermetidae, Cerithiidae, Campanilidae, Ranellidae and Muricidae. During their study they found septa in almost all groups studied. Thus far, however, septa have not been recorded from Pyramidellidae. In Turritellidae they found number and spacing of septa to be highly variable among species. Whilst in decollating species septa clearly have a function (sealing off the shell), Anderson & Allmon (2018) conclude that in non-decollating species they generally are spandrels of shell thickening (i.e. a phenotypic byproduct of the evolution of another characteristic, not a trait developed through adaptive selection). However, Ishikawa et al. (2018) found increased vulnerability to predation in low-spired gastropods, except for two planispiral species (both Architectonicidae) with numerous septa, closing off the shell except for the last half whorl. They concluded that the septa provide a defensive role against predators enhancing mean lifetime by ~20%. In *Microstellaria* the septa are restricted to the uppermost whorls (Figs 7h-j). Even without an advantage regarding predation, septa may serve a purpose: closing off the early whorls. Especially in species that have shells with many whorls (such as Cerithioidea, Architectonicidae, etc.), which if unwound will form a very long tube gradually increasing in size, the animal may only actively use the last part of the shell. Closing of the abandoned upper whorls may then not only be a precautionary measure (for potential breakage or predation) but also assist movement and avoid accumulation of dirt. The 3D model of *Microstellaria juliae* gen. et spec. nov. processed to show shell thickness (Fig. 7f-g) clearly shows that the thinnest and thus most vulnerable part regarding breakage is the protoconch, whilst around the thick final septum the teleoconch is markedly thicker. The formation of septa is interpreted as preventive measure in case the protoconch is damaged, whilst the final septum is the basis for the columellar muscle. As the construction of the septa (especially the thick final septum) must be energy and material intensive it definitively is not a spandrel.

No fossils of this genus or closely related taxa are known, but the number of unique characteristics suggests it must have a substantial evolutionary history.

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