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Medusae and polyps (Scyphozoa: Coronatae) collected from the South Java Deep-Sea (SJADES) Biodiversity Expedition 2018

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Abstract. Medusozoans in the order Coronatae were trawled from depths between 957 and 1,539 metres off the southwest coast of Java during a collaborative expedition in 2018 targeting deep-sea fauna in general. A brief taxonomic account of specimens of coronate medusae from the species *Atolla wyvillei* and *Periphylla periphylla* (families Atollidae and Periphyllidae respectively) is provided. Preliminary cnidae examination conducted on *Periphylla* specimens revealed seven nematocyst types present in tentacles and gastric filaments. Scyphistomae, solitary benthic scyphopolyps, of the genus *Nausithoe* (family Nausithoidae) collected from a box corer sample from the same expedition were also observed.

Key words. Coronatae, deep-sea, Indonesia, jellyfish, *Atolla*, *Nausithoe*, *Periphylla periphylla*

INTRODUCTION

Studies on medusozoan species in Indonesia have primarily focused on the edible scyphomedusae (e.g., Asrial et al., 2015a, b; Yusuf et al., 2018). Indeed, a new edible species was discovered from Central Java recently (Nishikawa et al., 2015). Jellyfishes from the order Rhizostomeae in the aforementioned studies occur in the shallow seas of the Indian Ocean around Indonesia and form an important component of sustainable fisheries (Asrial et al., 2015b). Other studies examined scyphozoan distribution around the Indonesian archipelago (including Banda, Celebes, Ceram, and Java Seas), based on museum collections (Kramp & Blanner, 1972; Mujiono et al., 2013; see Table 1 for a list of known scyphozoan medusae recorded around the archipelago). Associations of crustaceans and fish juveniles with scyphomedusae observed in Indonesia (Ohtsuka et al., 2010) have also shed some light on the role of jellyfish in the marine ecosystem. Complex symbiotic interactions can be expected from a variety of organisms with host medusae (Purcell & Arai, 2001) beyond simple predator–prey relationships. However, less is known of the present state of deep-sea medusozoans around the Indonesian archipelago.

Studying the deep trenches and beds, regardless of the target organism, requires substantial monetary and logistical support in addition to the need of taxonomic experts for effective and accurate identification. Additionally, the less robust gelatinous creatures require delicate handling during collection for quality observations and specimen examination. Due to relatively challenging and unique conditions of the deep ocean, the extent of deep-sea cnidarians' occurrence, ecological role, life cycle adaptations, and behaviour still remain poorly known.

Both the pelagic and benthic forms of medusozoans from the order Coronatae were found during the South Java Deep-Sea (SJADES) expedition conducted in 2018. Pelagic medusae were collected using beam trawls and benthic polyps were found during the sorting of sediment from the topmost layer of a box corer sample.

Current knowledge on deep-sea medusozoan fauna around the Indonesian archipelago is based mainly on historical material such as those from the Dana (1928–1930) and Galathea 1951–1952 expeditions (see e.g., Kramp & Blanner, 1972; Marshall, 1960; H.M.K., 1932). This account provides a brief update on the presence of scyphozoan presence in the deep sea and serves to highlight what is still largely unknown about seemingly "cosmopolitan" cnidarian species.

MATERIAL AND METHODS

Collection. Both the pelagic and benthic forms of medusozoans from the order Coronatae were found during the South Java Deep-Sea (SJADES) expedition conducted from 24 March 2018 to 4 April 2018. Four fairly intact adult medusozoan specimens were collected using a 4-metre-wide beam trawl. Tows' bottom on and off depths are noted in the "Material Examined" sections, but as hauls were conducted with open nets, note that medusae could have been caught at any depth along the water column during the haul up. Three solitary coronate polyps (scyphistomae) were obtained from

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Table 1. List of scyphozoans recorded from Indonesia. Where relevant, original locality information in Bahasa Indonesia is listed in parentheses, with localities within regions listed separated by semi-colon. *Jakarta Bay Blooms refer to personal observations made in 2018, 2019, and 2020 by Sianturi. Specimens observed in the Jakarta Bay Blooms were collected and deposited in the Research Centre for Oceanography collections (Jakarta).

Order	Family	Species	Locality	References
Coronatae	Atollidae	*Atolla parva*	Indian Ocean (off Sumatra); Pacific Ocean (off West Papua)	Kramp & Blanner, 1972
		Atolla vanhoeffeni	Celebes Sea; Ceram Sea; Banda Sea; Indian Ocean (numerous stations); Pacific Ocean (many stations off West Papua)	Kramp & Blanner, 1972
		Atolla wyvillei	Celebes Sea; Banda Sea; Indian Ocean (numerous stations); Pacific Ocean (off West Papua)	Kramp & Blanner, 1972
	Nausithoidae	*Nausithoe simplex* (as *Stephanoscyphus simplex*)	Banda Trench; Sunda Trench	Calabuig, 2016
Rhizostomeae	Cassiopeidae	*Cassiopea andromeda*	Bali (Pejarakan, Kec. Gerokgak, Kab. Buleleng; Gilimanuk)	Mujiono et al., 2013
		Cassiopea ornata	Misool Islands, Papua (Keramat Lake)	Purba et al., 2017
	Catostylidae	*Acromitus flagellatus*	Banten, East Java (Pantai Kohod, Kec. Pakuhaji, Tangerang; Pantai Lontar Kec. Tirtayasa, Serang); Surabaya, East Java (Pantai Kenjeran, Surabaya-Jawa Timur); Jakarta (Tanjong Pasir; Muara Ange); Port of Cirebon, West Java (Pelabuhan Cirebon-Jawa Barat)	Mujiono et al., 2013
		Catostylus ouwensi	Papua	Mujiono et al., 2013
		Catostylus sp.	Jakarta (Teluk Jakarta)	*Jakarta Bay Blooms
		Catostylus townsendi	Port of Cirebon, West Java (Pelabuhan Cirebon-Jawa Barat); Jakarta (Tanjong Pasir); Sebatic Island, Kalimantan (Pantai Batu Lumampauw, Pulau Sebatic)	Mujiono et al., 2013
		Crambione mastigophora	Muncar, East Java	Kitamura & Omori, 2010; Asrial et al., 2015a
		Crambionella sp.	Central Java (Cilacap; Karangbolong near Cilacap; Menganti Gombong, Kebumen-Jawa Tengah)	Kitamura & Omori, 2010; Mujiono et al., 2013
	Lobonemidae	*Lobonemoides robustus*	Kalimantan (Kotabaru; Kuala Tanbangan)	Kitamura & Omori, 2010
	Mastigiidae	*Phyllorhiza punctata*	Jakarta (Teluk Jakarta); Port of Cirebon, West Java (Pelabuhan Cirebon-Jawa Barat); Belitung Islands (Riau archipelago); Banten, East Java (Pangkalan Grengseng, Kec. Pulo Ampel, Kab, Serang)	Mujiono et al., 2013; *Jakarta Bay Blooms
		Mastigias papua	Surabaya, East Java (Pantai Kenjeran Surabaya-Jawa Timur); Jakarta (Muara Angke; Pulau Dua Kepulauan Seribu; Tanjong Pasir; Teluk Jakarta); Misool Islands, Papua (Lenmakana, Karawapop and Keramat lakes)	Mujiono et al., 2013; Purba et al., 2017
	Rhizostomatidae	*Rhopilema hispidum*	Kalimantan (Kotabaru; Kuala Tanbangan)	Kitamura & Omori, 2010

Order	Family	Species	Locality	References
	Versurigidae	*Versuriga anadyomene*	Jakarta (Pulau Pari Kepuluan Seribu)	Mujiono et al., 2013
Semaeostomeae	Pelagiidae	*Chrysaora* sp.	Jakarta (Teluk Jakarta)	*Jakarta Bay Blooms
		Pelagia noctiluca	Papua (Batanta Utara, Raja Ampat); East Java (Sendang Biru Malang- Jawa Timur)	Mujiono et al., 2013
		Sanderia malayensis	East Java (Sendang Biru Malang- Jawa Timur)	Mujiono et al., 2013
	Ulmaridae	*Aurelia* sp.	Misool Islands, Papua (Lenmakana and Keramat lakes)	Purba et al., 2017

the top 15 cm sediment layer of a single box corer sample (Station code CR09, depth 377 m). Box corer's dimensions (in cm): 60 length × 50 width × 50 height. Two scyphistomae were found attached to pumice and one attached to a shell fragment. The periderm of polyps featured appears pink as they were dyed with Rose Bengal stain during the processing of sediment from the box corer sample.

Morphology. Identification and description of morphological structure and characters of adult coronate medusae follow Mayer (1910), Kramp (1961), Russell (1970), and Calder (2009). Measurements of medusae were made on preserved specimens. Measurements and characterisation of scyphistomae follow Jarms (1991) and Jarms et al. (2002).

Cnidome examination. Nematocysts were observed using a DIC (differential interference microscopy)-equipped Olympus BX50 light microscope under 1000× magnification and photographs taken with an attached Olympus DP22 digital camera. Nematocyst identification and comparison follow Mariscal (1974), Jarms et al. (2002), and Östman (2000).

RESULTS

Class Scyphozoa Göette, 1887

Subclass Coronamedusae Calder, 2009

Order Coronatae Vanhöffen, 1892

Scyphomedusae with umbrella margin cleft into lappets; with single mouth opening provided with simple lips; with sense organs (rhopalia) and solid marginal tentacles arising from clefts between lappets; with circular coronal furrow in the exumbrella, and peripheral to this zone of gelatinous thickenings (pedalia) divided by radiating clefts alternating in position with the tentacles and rhopalia.

Family Atollidae Hickson, 1906

Atolla Haeckel, 1880

Atolla wyvillei Haeckel, 1880

Material examined. One specimen, in 4% formaldehyde; ZRC.CNI.1405; station CP18 - Sunda Strait (between Sumatra and Java); Beam trawl; Depth 1060–1073 m; Bottom on: 6°10.758′S, 105°05.589′E; Bottom off: 6°11.587′S, 105°05.735′E; One specimen, in 4% formaldehyde; ZRC. CNI.1406; station CP14 - Sunda Strait (between Sumatra and Java); Beam trawl; Depth 1528–1539 m; Bottom on: 6°08.044′S, 104°50.086′E; Bottom off: 6°08.518′S, 104°49.879′E.

Description. Coronatae with more than 8 rhopalia, alternating with equal number of tentacles; marginal lappets twice the number of tentacles. Atollidae with 8 adradial gonads; umbrella flat, with deep coronal groove. Flattened umbrella with deep coronal groove close to umbrella margin. Lappets smooth and elongated with round margins. Thick mesoglea.

Systematic remarks. Both specimens are significantly damaged (see Fig. 1A), but due to the characteristic shape of the exumbrella and separate levels of tentacles and rhopalar pedalia, it is possible to refer to the specimens as genus *Atolla*. Of the 10 species of *Atolla* described to date, four are known to occur in the Indian Ocean around the Indonesian Archipelago, namely *Atolla parva*, *A. valdiviae*, *A. vanhoeffeni*, and *A. wyvillei* (from Kramp & Blanner, 1972, and Jarms & Morandini, 2019). All but *Atolla valdiviae* (doubtful species) are considered cosmopolitan in deep-water distribution. Sampling by the Dana cruise (1921–1922) in the coastal areas of the Indian Ocean discovered that *Atolla wyvillei* "was found almost everywhere" (Kramp & Blanner, 1972). The two *Atolla* specimens collected in this study from the Sunda Strait were approximately 35 and 61 mm, corresponding to most (if not all) species' size range that are known to occur around the archipelago (see Table 2). None of the specimens from this expedition had any exceptionally long tentacle described by Russell (1959) or Repelin (1966) on *Atolla parva* or *A. wyvillei* (Fewkes, 1886). It could be that such characteristic tentacles were damaged during the collection process. However, it is possible to further diagnose

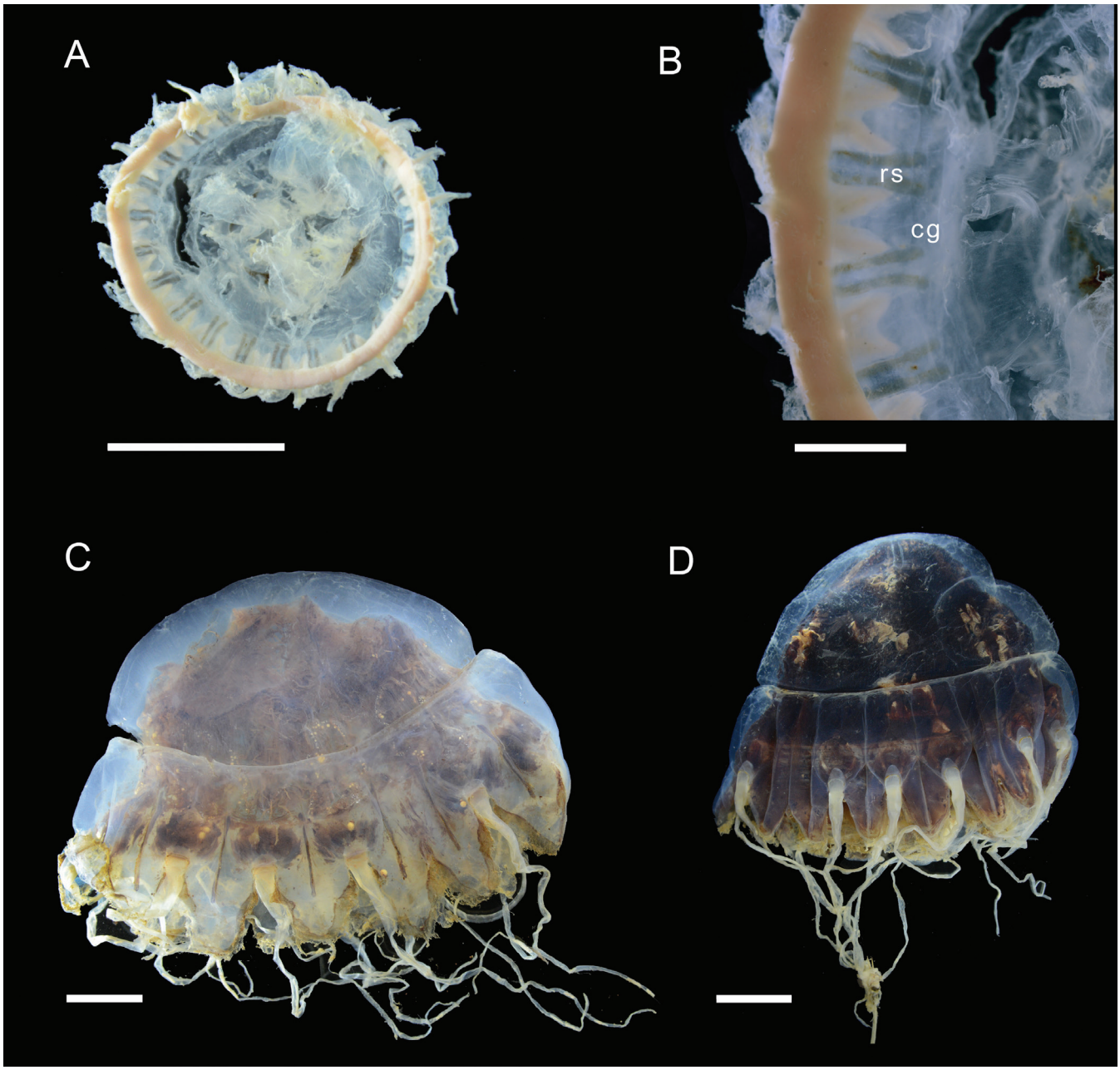

Fig. 1. Formalin-fixed specimens of coronate medusae from the Sunda Strait, Indonesia. A, oral view of *Atolla wyvillei* (ZRC.CNI.1405); B, close-up view of *A. wyvillei* showing position of radial septum (*rs*) and coronal groove (*cg*); C, lateral view of female *Periphylla periphylla* (ZRC.CNI.1407); D, lateral view of *P. periphylla* (ZRC.CNI.1408). Scale bars: A, C, D = 2 cm; B = 1 cm.

their identity by the shape of radial septa (Fig. 1B): the paired diverging radial septa visible from the oral view of collected specimens are characteristic of *A. wyvillei* (see Jarms & Morandini, 2019).

Family Periphyllidae Haeckel, 1880

***Periphylla* F. Müller, 1861**

***Periphylla periphylla* (Péron & Lesueur, 1810)**

Material examined. One female specimen, in 4% formaldehyde – ZRC.CNI.1407; station CP13 - Sunda Strait (between Sumatra and Java); Beam trawl; Depth 1259–1268 m; Bottom on: 6°00.521′S, 104°49.410′E; Bottom off: 6°00.828′S,104°49.428′E; One specimen, in 4% formaldehyde – ZRC.CNI.1408; station CP53 - Indian Ocean (Pelabuhanratu Bay); Beam trawl; Depth 1521–1714 m; Bottom on: 7°09.610′S, 106°18.632′E; Bottom off: 7°10.184′S, 106°17.714′E.

Diagnosis. Pointed or dome-shaped umbrella with deep coronal groove; 12 tentacles, three between each rhopalia, four rhopalia in interradial position, eight gonads (U-shaped).

Description. Rounded to conical apex, with clear coronal groove between umbrella margin and apex. Apical canal was present in one specimen (ZRC.CNI.1408) but absent in the other (ZRC.CNI.1407). General shapes of specimens are comparable to the variation described by Stiasny (1934) in

Table 2. Comparison of features of *Atolla* species known to occur in the Indonesian archipelago, based on Jarms & Morandini (2019). Measurements of specimens collected from SJADES 2018 in preserved state.

Feature \ Species	***A. parva*** **Russell, 1958**	***A. vanhoeffeni*** **Russell, 1957**	***A. wyvillei*** **Haeckel, 1880**	***A. wyvillei*** **Haeckel, 1880 [this study]**
Size	Small 30–63 mm	Small Up to 50 mm	Medium sized Larger than 40 mm up to 150 mm	35 mm (height 10 mm) [ZRC.CNI.1405] 61 mm (height 15 mm) [ZRC.CNI.1406]
No. of tentacles	20, 24, 26	20 (rarely 18 or 19)	22 (rarely 17, 19, 20, 21, 29, 32 or 36)	23 [ZRC.CNI.1405] 28 [ZRC.CNI.1406]
No. of lappets	40, 48, 52	40 (rarely 36 or 38)	2 × no. of tentacles	46 [ZRC.CNI.1405] 56 [ZRC.CNI.1406]
Shape of lappets	Elongated with round edges	Smooth, slightly elongated with round edges	Smooth, elongated with rounded edges	Damaged, rounded edges [Both ZRC.CNI.1405 & 1406]
Shape of radial septa	Paired, straight	Paired, thick, straight, covered by thin inner portion of coronal muscle	Paired, divergent adaxially, extending beyond margin of coronal muscle	Paired, diverging away from margin (adaxially) [Both ZRC.CNI.1405 & 1406]
Colour	Reddish-brown, stomach intensely dark red pigmented, gonads, musculature and periphery of gastric system cream-orange	Eight blackened spots (pair at each end of base of stomach), generally translucent with some pigmentation at the tentacle's bases, minute spots above ring muscle, gonads yellow-brown	Dark reddish-brown, stomach deep red to black; gonads and musculature cream-orange	Extremely damaged, with traces of rusty pigment within mesoglea. Other characters indiscernible Lacking dark pigment spot characteristic of *A. vanhoeffeni* [Both ZRC.CNI.1405 & 1406]
Other remarks (life cycle, behaviour)	One tentacle hypertrophic Life cycle unknown No data of feeding habits and associations	Sometimes found above 800 m; reports on diel vertical migration No data of feeding habits and associations	One tentacle hypertrophic Eggs up to 1 mm in diameter; believed to develop directly Below 500 m depth	Possibly from 1,060 to 1,539 m

Periphylla hyacinthina. Interradial rhopalia without ocellus. Sixteen elongated marginal lappets. U-shaped gonads. Manubrium quadrilateral, not extending beyond umbrella margin. Stomach attached to subumbrella by four interradial gastric septa. Live colour red-maroon, but become dark brown in preserved state. Developing yolky eggs observed through mesoglea of female specimen (ZRC.CNI.1407; coronal diameter 114 mm), with the largest observable egg being 2 mm in diameter. Sex of smaller specimen (ZRC.CNI.1408; coronal diameter 82 mm) could not be determined.

Systematic remarks. Cosmopolitan species in mesopelagic (200–1,200 m) depths. Size, proportion, and colour are variable among different populations and individuals. A comprehensive study on the development of red pigment of *Periphylla periphylla* occurring in abundance in Lurefjorden, Norway showed that colouration develops gradually, starting from the tentacles, and medusa is fully pigmented by 4 cm diameter (Jarms et al., 2002). However, no pigment was observed in the tentacles of a freshly caught specimen (see Fig. 3). For full list of synonyms refer to Russell (1970), Larson (1986), and Jarms & Morandini (2019).

Cnidome. Cnidae were sampled from the tentacles and gastric filaments from both specimens. Nematocysts were not examined from the exumbrella, especially close to the coronal furrow between the bases of tentacles to ring muscle where developmental phases of nematocysts, if any, could be found (Jarms et al., 2002). Seven cnidae types were found in the specimens, while only six types were previously reported

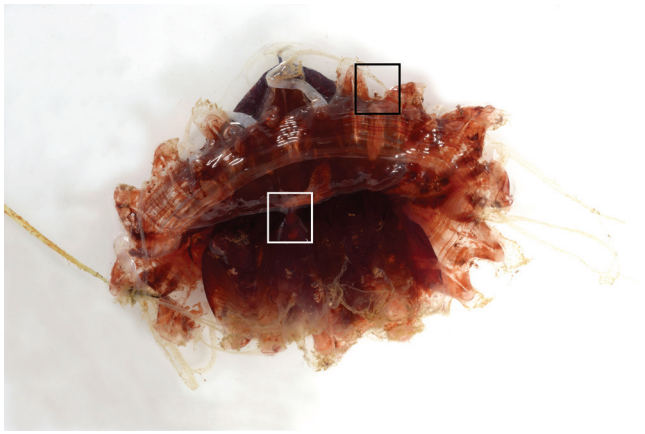

Fig. 2. Freshly collected specimen of *Periphylla periphylla* (ZRC. CNI.1408); from station CP53 - Indian Ocean (Pelabuhanratu Bay), max. depth 1,714 m. Tentacles whitish and translucent, non-pigmented prior to preservation. White box indicates one side of stomach attachment (perradial position); black box indicates position of a rhopalium (interradial position).

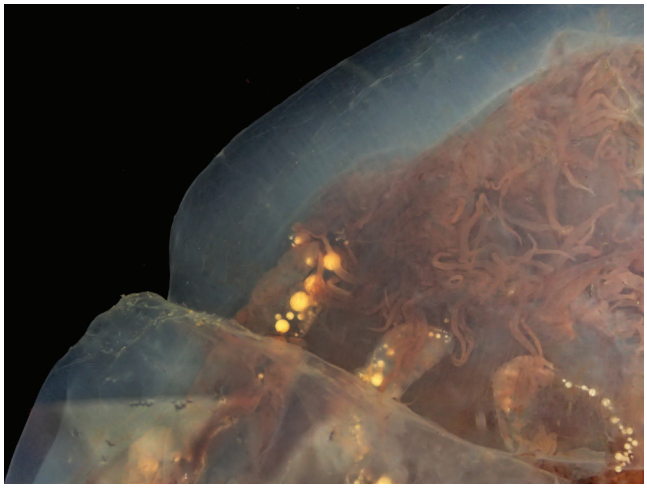

Fig. 3. Large yolky eggs developing within mesoglea of female *Periphylla periphylla* (ZRC.CNI.1407); from station CP13 - Sunda Strait (between Sumatra and Java); max. depth 1,268 m. Largest egg size 2 mm.

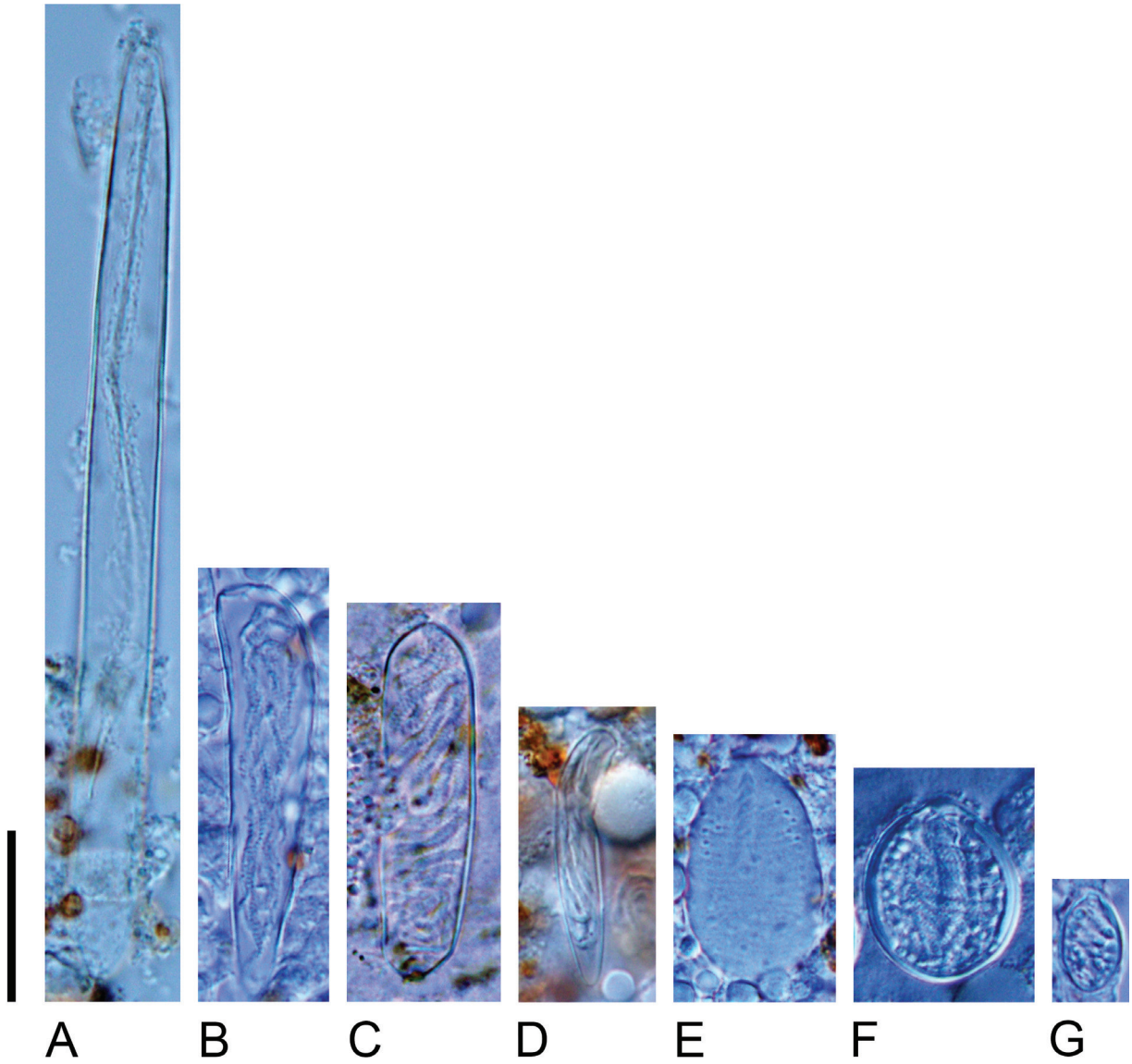

Fig. 4. Undischarged cnidae sampled from tentacles and gastric filaments of two preserved *Periphylla periphylla* specimens collected from SJADES 2018 expedition [ZRC.CNI.1407 & ZRC.CNI.1408]. A, giant ellipsoid heterotrichous microbasic eurytele; B, large elongate isorhiza; C, ellipsoid heterotrichous microbasic eurytele; D, slim elongate isorhiza; E, microbasic p-mastigophore; F, round heterotrichous microbasic eurytele; G, small holotrichous isorhiza. Scale bar = 20 µm.

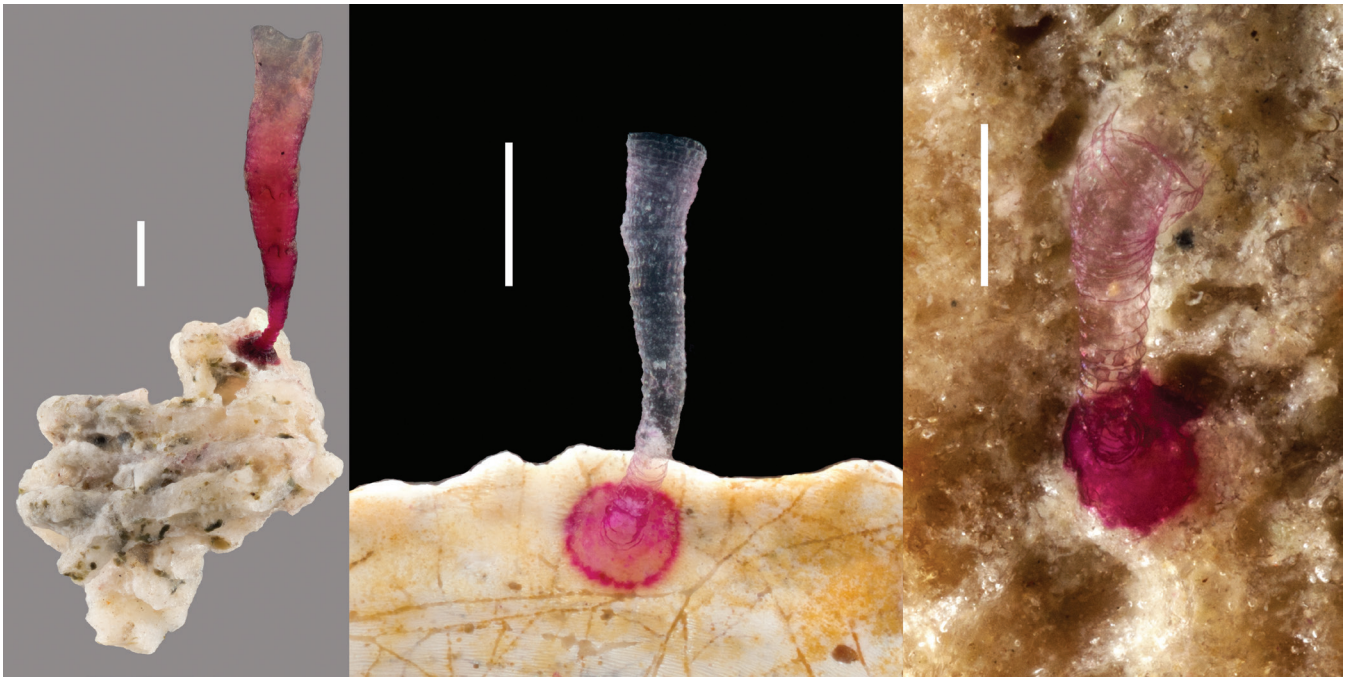

Fig. 5. Three *Nausithoe* scyphopolyps found from a box core sample station CR09 - Sunda Strait (between Tabuan Island and Sumatra), depth: 377 m. Length of scyphistomae tube (left to right): 2.4 mm, 1.4 mm, and 0.98 mm. Periderm tubes are stained pink with Rose Bengal. Scale bar = 0.5 mm.

in *P. periphylla* of the Norwegian fjord (Jarms et al., 2002). Unfortunately, no discharged capsules were found.

Three types of microbasic heterotrichous microbasic eurytele were found: giant ellipsoid (Fig. 4A), ellipsoid (Fig. 4C), and round (Fig. 4F). Additionally, three types of holotrichous isorhizae were found: large elongate (Fig. 4B), slim elongate (Fig. 4D), and small holotrichous (Fig. 4G). The last type of nematocyst is microbasic p-mastigophore (Fig. 4E). In our case, four types found were already reported in Jarms et al. (2002) (Fig. 4A, C, F, G), while three other nematocyst types found are unique to this paper (Fig. 4B, D, E). Of 355 nematocysts observed, the most encountered were the round heterotrichous microbasic eurytele (60.0%) and small holotrichous isorhiza (32.9%). In comparison, the rest of the nematocyst types composed less than 5% of cnidae examined. The discrepancy in the nematocyst types found by Jarms et al. (2002) and those observed in this study could be that the observations on the cnidome were based on differing development stages. Jarms et al. (2002) reported cnidae from developing individuals with coronal diameter of 1.19–3.40 mm, while our specimens could be considered adults (coronal diameters 82 and 114 mm).

Our preliminary observations on the cnidome profile suggest two cnidae types are unique to the female individual of *P. periphylla* (ZRC.CNI.1407): ellipsoid heterotrichous microbasic eurytele (Fig. 4C) and microbasic p-mastigophore (Fig. 4E). The characteristic V-shaped notch at the base of undischarged shaft distinguishes the p-mastigophore from a eurytele (see Östman, 2000). And two nematocysts were unique to the other individual (ZRC.CNI.1408): giant ellipsoid heterotrichous microbasic eurytele (Fig. 4A) and large elongate isorhiza (Fig. 4B). A better characterisation of the cnidome of the species should be made with more specimens, ideally at various developmental stages of the medusae, and also from different populations.

Family Nausithoidae Haeckel, 1880

***Nausithoe* Kölliker, 1853**

Material examined. Three polyp specimens, in 70% ethanol – ZRC.CNI.1461; station CR09 - Sunda Strait (between Tabuan Island and Sumatra); Box corer; Depth 377 m; Bottom on/off: 5°44.960′S, 104°52.731′E.

Description. Polyp solitary, with periderm and small basal disc for attachment. Ringed tube surface.

Systematic remarks. Historically, benthic polyps and pelagic medusae of members in order Coronatae have separate classifications due to collection efforts yielding individuals of only one or the other life form. Of the solitary polyps, the specimens could be classified into either of two monotypic scyphozoan families: Atorellidae and Nausithoidae (Morandini & Jarms, 2005). Compared to *Atorella*, polyps of *Nausithoe* have less conspicuous transversal rings, conferring a smoother outlook even at sizes less than 5 mm above the base (Molinari & Morandini, 2019). For meaningful comparisons of characters to other scyphistomae studies (e.g., Jarms, 1990, 1991; Jarms et al., 2002; Morandini & Jarms, 2012), however, polyps should be developed to at least 5 mm (Molinari & Morandini, 2019). None of the specimens in this study reached this size; observations of characters such as cusp projections, relative rugosity, and calculations of form quotients could not be made. There was also insufficient material to assess variation in taxonomic

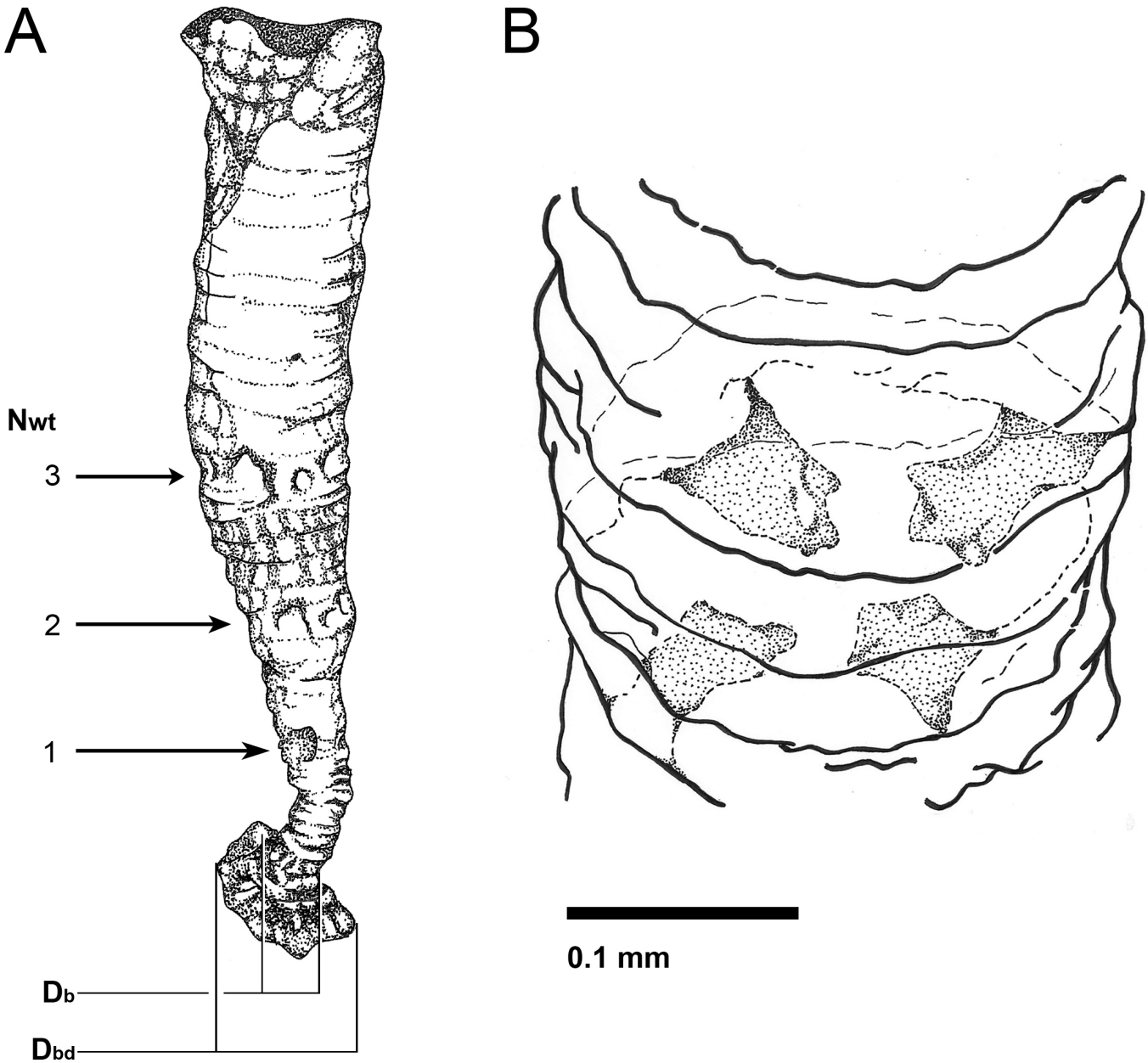

Fig. 6. *Nausithoe* sp. polyp (ZRC.CNI.1461) collected from SJADES 2018, station CR09 - Sunda Strait (between Tabuan Island and Sumatra), depth: 377 m. A, periderm detail with 3 whorls of cusps (indicated by arrows); total tube length 2.4 mm from basal disc, Db = 0.15 mm, Dbd = 0.36 mm; B, internal cusps of whorl viewed through the periderm, located 0.39 mm above basal disc. Nwt = number of whorls of cusps, Db = diameter of tube at the basal disc, Dbd = diameter of basal disc [following Jarms, 1991 and Morandini & Jarms, 2012].

characters. For accurate diagnosis of scyphistomae's identity, life cycle studies are also imperative (Werner, 1971, 1983; Jarms, 1990; Meroz & Ilan, 1995; Molinari et al., 2020).

Published in an expedition catalogue hosted on the Global Biodiversity Information Facility (GBIF) as *Stephenoscyphus simplex*, the coronate scyphistomae was reportedly collected from the Sunda Trench and Banda Trench around the Indonesian archipelago during the Galathea II stint (Calabuig, 2016). It is unclear how well the Galathea II expedition materials agree with the species redescription by Morandini & Jarms (2012) of *Nausithoe simplex* from the North Atlantic, but that is beyond the scope of this report. Based on general shapes of whorls of cusps (external periderm) and internal cusps (see Fig. 6), nonetheless, the material from the Sunda Strait differed from the *N. simplex* reported in Morandini & Jarms (2012).

Considering the sampling location, we could consider other species found close to the region: *Nausithoe clausi* (known from the western Pacific Ocean, Caroline Islands) and *N. picta* (known from the South Pacific Ocean, French Polynesia) (Jarms & Morandini, 2019). However, only their medusae stages are known and their scyphopolyps have not been documented. Furthermore, no medusae from the families Atorellidae or Nausithoidae, which are known to have the polyp stage with periderm, were collected in this expedition for comparison. Cnidome profiling could not be conducted for scyphopolyps as tissue was wanting.

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