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Diversity of hydromedusae (Cnidaria: Medusozoa: Hydrozoa) at Sentosa, including three new records for Singapore waters

Ling Min Kang[1*], Iffah **Iesa**[2], Danwei **Huang**[1,2,3] & Nicholas Wei Liang **Yap**[3,4]

[1]Department of Biological Sciences, National University of Singapore, 16 Science Drive 4, Singapore 117558; Email: minkangling@u.nus.edu ([*]corresponding author)
[2]Lee Kong Chian Natural History Museum, National University of Singapore, 2 Conservatory Drive, Singapore 117377
[3]Tropical Marine Science Institute, National University of Singapore, S2S Building, 18 Kent Ridge Road, Singapore 119227
[4]St John's Island National Marine Laboratory. c/o Tropical Marine Science Institute, National University of Singapore, S2S Building, 18 Kent Ridge Road, Singapore 119227

Abstract. Despite their potential impact on biodiversity and tourism, the cnidarian jellyfish fauna in Singapore's waters remain poorly researched. In this study, we report the planktonic hydromedusa diversity (Cnidaria: Medusozoa: Hydrozoa) at two beaches, Siloso and Palawan, in Sentosa Island, Singapore. Hydromedusae were collected via vertical point hauls and seine net samplings carried out at three sites over a month-long period, preserved and subsequently examined in the lab. A total of 318 specimens (311 from seining, seven from hauls) from eight families (Abylidae, Aequoreidae, Agalmatidae, Diphyidae, Eirenidae, Geryoniidae, Rhopalonematidae and Solmundaeginidae) were obtained. Three species new to Singapore waters, *Enneagonum hyalinum, Nanomia bijuga* and *Solmundella bitentaculata*, were recorded. Future field sampling over a longer timeframe at more regular intervals is needed to better characterise hydrozoan diversity in Singapore.

Key words. lagoons, jellyfish, Singapore Strait, Southeast Asia, shallow-water

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INTRODUCTION

Jellyfishes from the phylum Cnidaria (e.g., Cubozoa Werner, 1973; Hydrozoa Owen, 1843; Scyphozoa Göette, 1887; Staurozoa Marques & Collins, 2004) have a rich evolutionary history, with fossil records dating to the Cambrian Period (Cartwright et al., 2007) and molecular evidence suggesting that they may even have originated prior to that period (Park et al., 2012). Jellyfishes play crucial roles in contributing to and facilitating the biodiversity of marine ecosystems, serving as predator and prey of other aquatic animals in complex food webs (Purcell, 1997; Richardson et al., 2009), functioning as potential carbon sinks (Condona et al., 2011), helping to cycle nutrients and even serving as habitats for other pelagic marine organisms (Doyle et al., 2014). Additionally, some jellyfishes provide direct biodiversity services to humans, are eaten as delicacies (Kitamura & Omori, 2012; Doyle et al., 2014), and may even serve as potential sources of medical treatments (Lee et al., 2017).

In recent years, there appears to be an increase of jellyfish blooms worldwide (Purcell, 2005; Richardson et al., 2009; Brotz et al., 2012). While several accounts attribute this increase in jellyfish biomass to rising global temperatures, increases in overfishing and habitat degradation (Purcell, 2005, 2012; Purcell et al., 2007), these accounts tend to be made based on information regarding jellyfishes living in temperate waters (Purcell et al., 2007: 158). Moreover, as we currently have a poor understanding of how environmental factors contribute to jellyfish population sizes (Purcell, 2005; Pitt el al., 2019), more research must be carried out to verify these claims. Indeed, given that jellyfish populations may potentially fluctuate in 10- and 20- year cycles in accordance with solar and climate cycles (Purcell, 2012), the surge in jellyfish populations may be the norm rather than the exception, and existing claims that anthropogenic stressors contribute to jellyfish blooms may be exaggerated (Pitt et al., 2019).

Apart from disrupting the delicate balance in marine ecosystems (Gershwin, 2016), blooms also increase the likelihood of encounters between people and jellyfish (Purcell et al., 2007) and bring about a host of problems, potentially hampering economic activities such as fish farming and tourism (Purcell et al., 2007; Richardson et al., 2009; Graham et al., 2014). In Singapore, for example, interactions between the public and jellyfish have made news in recent years. In 2020 alone, multiple box jellyfish sightings were reported in July and October 2020, with mention of several beachgoers stung in July, forcing the management to restrict visitors' access to the waters (Ang, 2020; Shabana, 2020). With Sentosa having a high footfall of nearly 20 million visitors per year (Sentosa Development Corporation, 2019), the three lagoons in Sentosa (Fig. 1), as popular tourist attractions, see a large number of visitors daily. Being shallow bodies of coastal waters, these lagoons are well suited for jellyfish growth (Hale, 1999), making encounters between beachgoers and wild jellyfish inevitable. Given that jellyfish stings may be harmful and potentially deadly, such encounters not only generate considerable concern for tourists, but may also result in loss of tourism revenue (Graham et al., 2014).

However, even as jellyfishes play important roles with respect to Singapore's biodiversity and tourism, records of medusozoan zooplankton in Singapore, particularly Sentosa, remain scarce. While existing literature suggest there are some 30 species of jellyfishes in Singapore, most of these sightings remain unconfirmed (Yap & Ong, 2012). A search with the terms "zooplankton" and "Singapore" on Google Scholar yielded results primarily from around the 1950s to the 1970s. The only source published after 2000 by Schmoker et al. (2014) noted that these sources are unlikely to provide accurate indicators of the zooplankton diversity presently found in Singapore due to their age. Similarly, a search of "jellyfish" and "Singapore" on Google Scholar yielded only two relevant results published between 2010 and 2020 (inclusive), while no relevant literature on medusozoan zooplankton in Sentosa were found, highlighting the scarcity of research in this area.

Investigations into the zooplankton and jellyfish diversity in Sentosa's lagoons are crucial to better understand jellyfish diversity in Singapore and for enabling better predictions of when jellyfish sightings are more likely to occur. Appropriate actions can then be taken to minimise adverse human-wildlife interactions, which would yield public safety and economic benefits. This study examines the hydromedusa diversity at Sentosa Island, Singapore, based on data collected from three seining samples and two preliminary haul samples.

MATERIAL & METHODS

Study sites. Sampling was performed at Sentosa Island, south of the Singapore mainland (Fig. 1), over a month-long period (11 January 2021 to 1 February 2021). All sampling sites are located along the Singapore Strait.

Vertical point hauls. Two preliminary hauls were conducted at site S1 on Siloso beach on 11 January 2021 and processed to determine the feasibility of the study. Subsequently, sampling by vertical point hauls at both Siloso beach and Palawan beach at three sites (S1, S2 and P1; see Fig. 1) were conducted weekly for three consecutive weeks (18 January 2021, 25 January 2021, and 1 February 2021).

For the vertical point hauls, the entire height of the water column in each lagoon (from the bottom of the lagoon to the surface) was sampled using a 25 µm plankton net. Vertical haul samples were obtained in duplicates. After each sample was obtained, the plankton net was rinsed three times through the exterior using seawater from the sampling site. Washings and samples were combined and fixed in 10% buffered formalin. GPS coordinates of haul sites were fixed across sampling occurrences with a Garmin GPSmap 62 GPS to ensure that sampling was carried out at the same points each week. A total of 20 vertical point haul samples (inclusive of two preliminary hauls examined in the current study) were obtained throughout the entire study.

Seine net sampling. Seining was conducted at Siloso beach and Palawan beach across three sites (Fig. 1): S1T1, S2T1 and PT1, on 11 January 2021, 18 January 2021, and 1 February 2021 respectively (refer to Fig. 1 for seining locations). A two–person seine net (2 m, mesh size of 1–2 cm) was used to sample larger jellyfishes at the lagoons. Each transect was approximately 50 m; the net was hauled parallel to the shoreline and retrieved at intervals of approximately 10 m. Coordinates of the start points and end points of each seining transect were recorded with a Garmin GPSmap 62 GPS. Upon sampling, specimens were transferred into bottles of seawater and subsequently fixed in 10% formalin. A total of three transects were sampled, two at Siloso beach and one at Palawan beach.

Fixation and preservation of samples. Haul samples examined in the current study were initially fixed on site with formalin diluted in seawater at a 1:9 ratio, following Bouillon et al. (2004). Fixed samples were subsequently separated using a 63 µm sieve and transferred into 70% ethanol for sorting and preservation. Only hydromedusae were examined in the current study.

Of the samples collected from seine net sampling examined in the current study, subsampling was conducted for species that were more abundant; these subsamples were preserved in 100% ethanol to retain their DNA for future molecular work, allowing for the use of both morphological comparison and genetic analysis for identification of these specimens (Bouillon et al., 2004, 2006; Vivien et al., 2016). The seine net samples preserved in 100% ethanol are subsampled from lots accessioned as ZRC.CNI.2831, ZRC.CNI.2835 and ZRC.CNI.2843. However, as ethanol could cause distortion or loss of morphological diagnostic characteristics (Laakmann & Holst, 2014), the rest of the specimens were preserved in 10% formalin to retain their morphological characters for taxonomic identification.

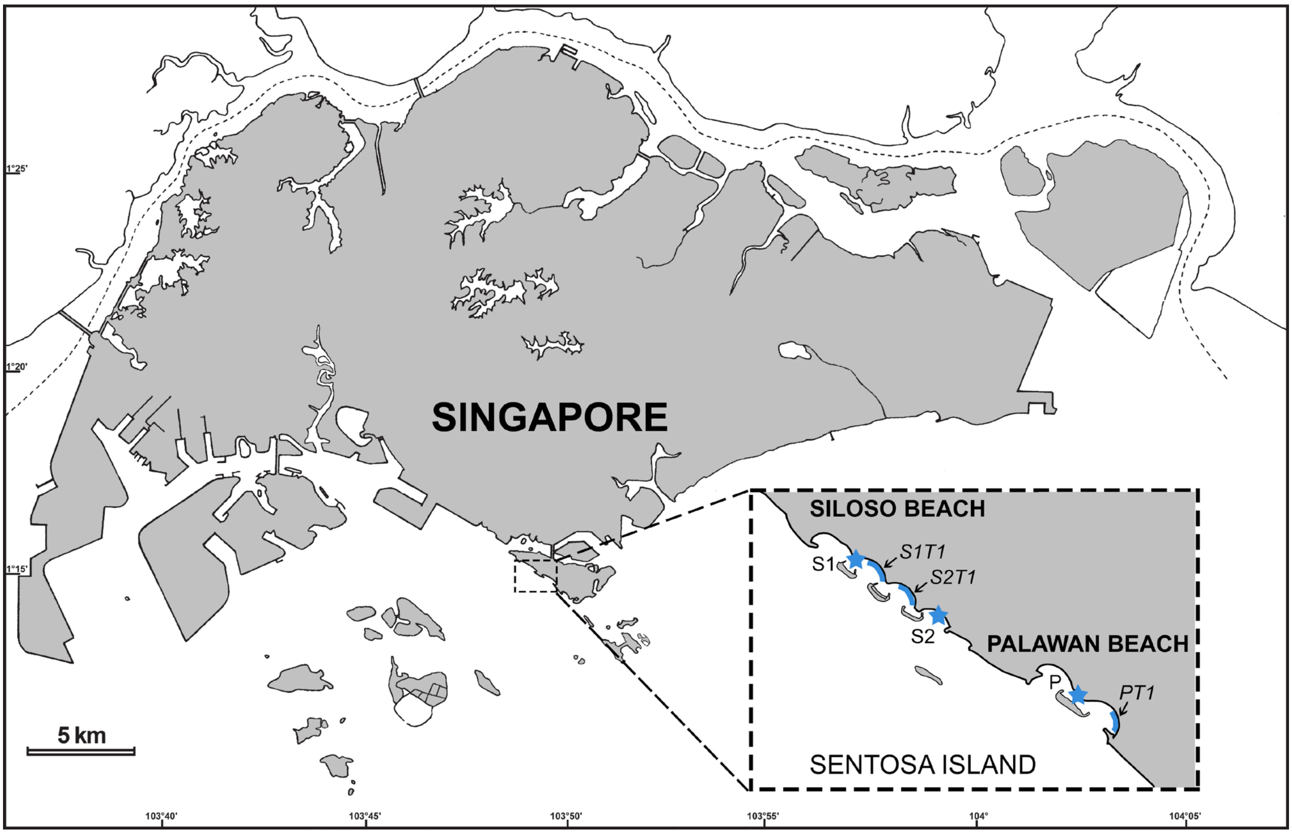

Fig. 1. Sentosa Island, situated at the southern part of Singapore. Inset: Close-up of western Sentosa Island. Locations of point vertical hauls (indicated by blue stars) and seine net transects (indicated by blue lines) on Siloso and Palawan beaches. Abbreviations on map: S1 — Vertical point haul site 1 on Siloso beach at 01°15′17″N, 103°48′42″E; S1T1 — Seine net transect 1 on Siloso beach (coordinates unavailable); S2 — Vertical point haul site 2 on Siloso beach at 01°15′8″N, 103°48′55″E; S2T1 — Seine net transect 2 on Siloso beach from 01°15′11″N, 103°48′52″E (start point) to 01°15′13″N, 103°48′50″E (end point); P — Vertical point haul site on Palawan beach at 01°14′54″N, 103°49′18″E; PT1 — Seine net transect on Palawan beach from 01°14′50″N, 103°49′26″E (start point) to 01°14′46″N, 103°49′26″E (end point). All sampling points are located along the Singapore Strait.

Sorting, documentation and analysis of samples. Specimens from point hauls and seines were viewed under an Olympus SZX16 Microscope, counted and sorted into different taxonomic categories. For point haul samples, only samples obtained at S1 on 11 January 2021 (two samples) for the preliminary hauls were sorted in the interest of time while all seine net samples were sorted. Subsequently, images of samples were taken using a Nikon D600 Camera with Micro NIKKOR 60 mm lens. Preliminary morphological identification of both haul and seining samples to the class level was carried by referencing existing literature regarding jellyfishes previously reported in local waters and taxonomic descriptions in Wickstead (1958), Shirota (1966), Bouillon et al., (2004, 2006), Suthers et al. (2009), Yap & Ong (2012) and Schmoker (2014). Thereafter, hydromedusa specimens from both hauls and seining were further identified to family, genus, or species level by comparing the specimens to descriptions in Wickstead (1958), Bouillon et al. (2004, 2006) and Yap & Ong (2012) (see Table 1 for a list of specimens identified in the current study). Morphological descriptions are provided for the specimens comprising taxa new to Singapore records (i.e., *Enneagonum hyalinum*, *Nanomia bijuga* and *Solmundella bitentaculata*) while a list of existing records of hydromedusae previously reported in Singapore can be found in Table 2.

Table 1. Hydromedusae collected from Siloso and Palawan beach lagoons from 11 Jan to 1 Feb 2021. #: number of individuals.

Order	**Family**	**Identity**	**Location**	
			Siloso (#)	**Palawan (#)**
Leptothecata	Aequoreidae	Aequoreidae spp.	3	0
	Eirenidae	*Eirene hexanemalis*	12	0
		Eirene spp.	3	44
Limnomedusae	Geryoniidae	*Liriope tetraphylla*	2	2
Narcomedusae	Solmundaeginidae	*Solmundella bitentaculata*	2	13
Siphonophorae	Abylidae	Abylidae sp.	0	3
		Enneagonum hyalinum	0	7
	Agalmatidae	*Nanomia bijuga*	7	0
	Diphyidae	*Diphyes bojani*	4	107
		Diphyes chamissonis	0	2
		Lensia sp.	0	1
Trachymedusae	Rhopalonematidae	Rhopalonematidae sp.	0	106
Total			33	285

Table 2. List of existing literature and type of reference pertaining to hydrozoan jellyfishes previously reported in Singapore. Species in **BOLD** have been taxonomically described in this report. Adapted from Yap & Ong (2012) and Schmoker et al. (2014).

Class HYDROZOA				
Family	**Species**	**References**	**Reference Type**	**Remarks**
Subclass HYDROIDOLINA				
Order ANTHOATHECATA				
Suborder FILIFERA				
Bougainvilliidae	*Thamnostoma macrostomum*	Haeckel, 1879	Primary scientific literature	Taxonomic description.
Order LEPTOTHECATA				
Aequoreidae	*Aequorea conica*	Stiasny, 1928	Primary scientific literature	Taxonomic description.
	Aequorea parva	Stiasny, 1928	Primary scientific literature	As *Aequorea parva* var. *buitendijki* (see Schuchert, 2023a for synonymy information), taxonomic description.
	Aequorea pensilis	Yap & Ong, 2012	Primary scientific literature	Taxonomic description.
Campanulariidae	*Clytia* sp.	Schmoker et al., 2014	Primary scientific literature	–
Eirenidae	*Eirene hexanemalis*	Stiasny, 1928	Primary scientific literature	As *Irenopsis hexanemalis* (see Schuchert, 2023b for synonymy information), taxonomic description.
Malagazziidae	*Malagazzia carolinae*	Stiasny, 1928	Primary scientific literature	As *Phialucium mbenga* (see Schuchert, 2023c for synonymy information), taxonomic description.
Order SIPHONOPHORAE				
Suborder CALYCOPHORAE				
Abylidae	*Ceratocymba leuckartii*	Schmoker et al., 2014	Primary scientific literature	–
	Enneagonum hyalinum	Present study	Primary scientific literature	New record in Singapore.
Diphyidae	*Diphyes bojani*	Yap & Ong, 2012	Primary scientific literature	Taxonomic description.
	Diphyes chamissonis	Wickstead, 1958	Primary scientific literature	Brief mention on its occurrence in Singapore.
		Chuang, 1961	Book chapter	Erroneous identification by Chuang (1961).
		Ng et al., 2011	Encyclopedic entry	Brief mention on its occurrence in Singapore.
		Schmoker et al., 2014	Primary scientific literature	–
	Diphyes spp.	Ng et al., 2011	Encyclopedic entry	Brief mention on its occurrence in Singapore.
	Lensia spp.	Ng et al., 2011	Encyclopedic entry	Brief mention on its occurrence in Singapore.
	Lensia sp.	Schmoker et al., 2014	Primary scientific literature	–

Suborder CYSTONECTAE				
Physaliidae	*Physalia physalia*	Sharma, 1973	Book chapter	As *Physalia utriculus* (see Pugh, 2019 for synonymy information), brief mention on its occurrence in Singapore.
Suborder PHYSONECTAE				
Agalmatidae	***Nanomia bijuga***	Present study	Primary scientific literature	New record in Singapore.
Subclass TRACHYLINAE				
Order LIMNOMEDUSAE				
Geryoniidae	*Liriope tetraphylla*	Wickstead, 1958	Primary scientific literature	Brief mention in a single sentence as *Liriope sp*., likely *Liriope tetraphylla*.
Order NARCOMEDUSAE				
Solmundaeginidae	*Solmundella* spp.	Wickstead, 1958	Primary scientific literature	Brief mention on its occurrence in Singapore, no mention of the type of species encountered.
	Solmundella bitentaculata	Present study	Primary scientific literature	Apparently common to Singapore, but not previously recorded.
Cuninidae	*Cunina duplicata*	Haeckel, 1879	Primary scientific literature	As *Cunissa polyporpa* (nomen dubium), taxonomic description.

TAXONOMY

Order Narcomedusae Haeckel, 1879

Family Solmundaeginidae Lindsay, Bentlage & Collins, 2017

Solmundella Haeckel, 1879

Solmundella bitentaculata (Quoy & Gaimard, 1833)

Carybdea bitentaculata Quoy & Gaimard, 1833: 295, pl. 25, figs. 4–5.
Aeginopsis mediterranea Müller, 1851: 272.
Aeginella dissonema Haeckel, 1879: 340, pl. 20, fig. 16.
Solmundella muelleri Haeckel, 1879: 352.
Solmundella bitentaculata var. *mediterránea* – Mayer, 1910: 456, pl. 54, figs. 1–3, pl. 55, fig. 4.
Solmundella bitentaculata – van der Land, 2001: 119; Bouillon et al., 2004: 233, figs. 144B, 144F; Lindsay et al., 2017: 506; Verhaegen et al., 2021: 12–13, fig. 4.

Material examined. 2 ex. preserved in 70% ethanol (ZRC.CNI.2835), Palawan beach, Sentosa, Singapore Strait, coll. Iesa I & Ling MK, 1 February 2021; 2 ex. preserved in 10% formalin (ZRC.CNI.2834), Siloso beach, Sentosa, Singapore Strait, coll. Iesa I & Ling MK, 18 January 2021; 10 ex. preserved in 10% formalin (ZRC.CNI.2836), Palawan beach, Sentosa, Singapore Strait, coll. Iesa I & Ling MK, 1 February 2021; 1 ex. preserved in 10% formalin (ZRC.CNI.2833), Palawan beach, Sentosa, Singapore Strait, coll. Iesa I & Ling MK, 1 February 2021.

Description. Rounded apex, keel-shaped along axis leading to tentacles. Thick mesoglea near the apex, with thin lateral walls; well-developed velum. Has short, lenticular manubrium comprising of eight manubrial pouches with rounded edges. Simple circular mouth. One vestigial marginal tentacle located between each stomach pouch, total of two primary tentacles originating from opposite ends of the umbrella above the manubrium, close to the apex. (Description adapted in part from Bouillon et al., 2004: 233; Lindsay et al., 2017: 506; Verhaegen et al., 2021: 12–13).

Remarks. Samples have an average umbrella width of 3.3 mm, (1.9–4.4 mm; n = 15). Presence of two tentacles in all specimens, originating from opposite ends of umbrella near the apex (Fig. 2).

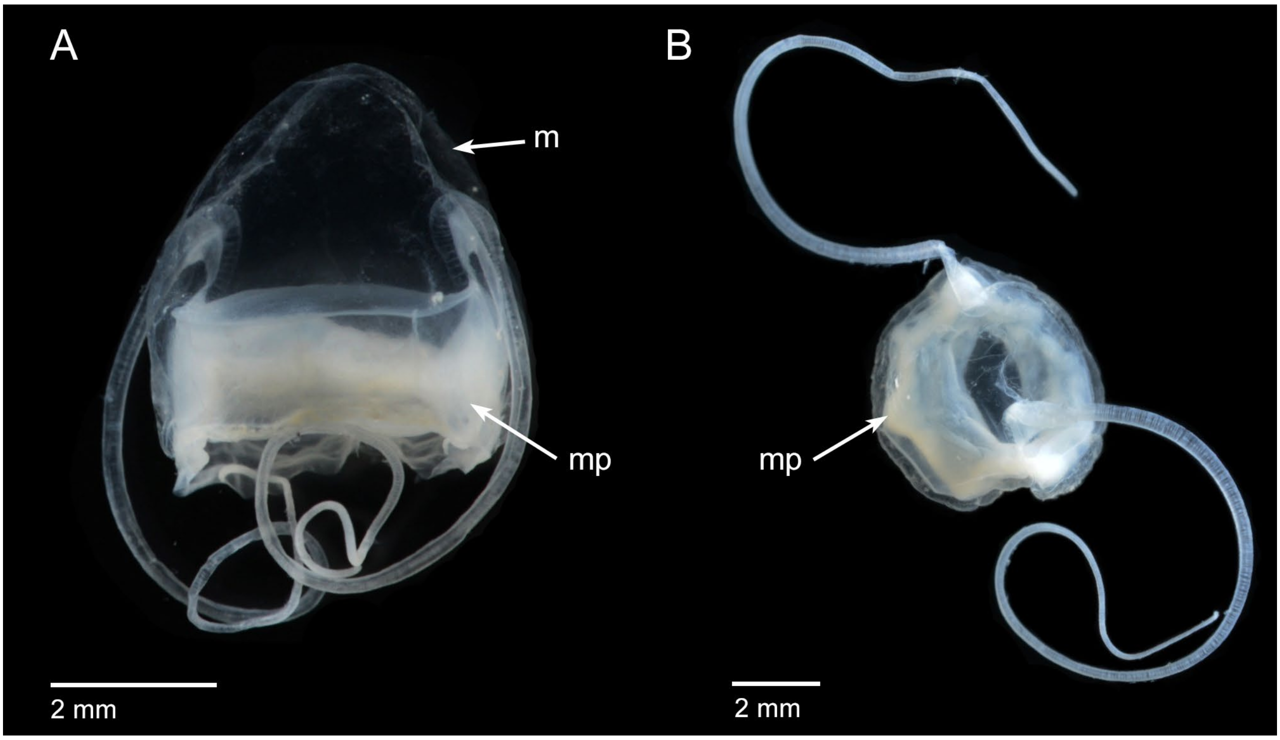

Fig. 2. External morphology of *Solmundella bitentaculata*. Two individuals in lot ZRC.CNI.2834 photographed: A, Lateral view. Presence of thick mesoglea (m) near apex, as well as tentacles originating from opposite ends of the umbrella above the manubrium. Manubrial pouches (mp) slightly visible. Scale bar = 2 mm. B, Subumbrellar view. Manubrial pouches with rounded edges visible. Scale bar = 2 mm. (Photographs: Ling Min Kang).

Order Siphonophorae Eschscholtz, 1829

Suborder Calycophorae Leuckart, 1854

Family Abylidae L. Agassiz, 1862

Enneagonum Quoy & Gaimard, 1827

Enneagonum hyalinum Quoy & Gaimard, 1827

Enneagonum hyalinum Quoy & Gaimard, 1827: 18, pl. 2D, figs. 1–6.
Cuboides vitreus Quoy & Gaimard, 1827: 19, pl. 2E, figs. 1–3 (eudoxid stage).
Cymba cuboides Eschscholtz, 1829: 134.
Abyla vogtii Huxley, 1859: 46, pl. 2, fig. 3.
Cuboides adamantina Chun, 1888: 227–229.
Halopyramis adamantina Chun, 1888: 1155.
Cuboides crystallus Haeckel, 1888b: 122, pl. XLII, figs. 9–17.
Cymba crystallus Haeckel, 1888a: 138, pl. XLI, figs. 1–8.
Cymba vogtii – Haeckel, 1888a: 138, 362.
Cuboides vogtii – Haeckel, 1888a: 360.
Enneagonum searsae Alvariño, 1968: 340.

Material examined. 7 ex. preserved in 10% formalin (ZRC.CNI.2832), Palawan beach, Sentosa, Singapore Strait, coll. Iesa I & Ling MK, 1 February 2021.

Description. Eudoxid stage: Cuboidal bract up to 4.0 mm high. Five-sided comprising of an apical, upper, lower and two lateral surfaces. Large hydroecial opening. Swollen phyllocyst comprising of two lateral and apical processes. Apophysis occupies almost one-third of the gonophore. Polygastric stage: Single, pyramid-shaped nectophore up to 4.0 mm wide. Presence of a median ridge running across the equivalent of the upper surface in other Abylopsinae. Both upper surfaces and the two apico-lateral surfaces can be seen when viewing specimen from the apex. Base of upper surfaces triangle-shaped, both baso-lateral surfaces and lower surfaces visible when viewed basally. Slightly serrated ridges and basal margins. Carrot-shaped somatocyst, an apical diverticulum and no descending upper segment. Presence of a blind diverticulum in the arc along the lateral radial. (Description adapted in part from Bouillon et al., 2004: 217–218).

Remarks. Eudoxid stage (Fig. 3A): Average length of 3.5 mm, width of 4.4 mm and height of 3.9 mm (*n* = 4). Box-shaped, with wider base than apex. Somatocyst oval-shaped, tapered at the apex, occupying about a third of the nectophore. Presence of oil droplets in all specimens. Gonophore present in one specimen. Polygastric stage (Fig. 3B): Average length of 5.2 mm and height of 3.9 mm (n = 3). Carrot-shaped somatocyst located above diverticulum; presence of oil-droplets in diverticulum. Nectosac roughly cylindrical, with narrower ends.

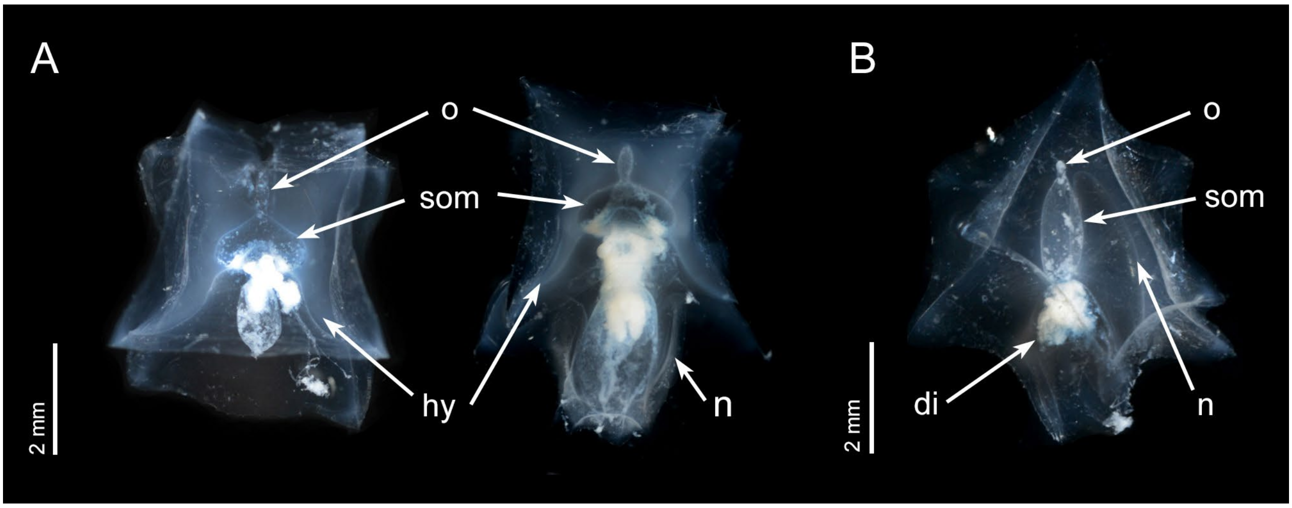

Fig. 3. Exterior morphology of different stages of *Enneagonum hyalinum*: A, Eudoxid stages of *Enneagonum hyalinum*, lower views (both specimens) (ZRC.CNI.2832). Somatocyst (som) oval-shaped, tapered at the apex, located above the hydroecium (hy). B, Polygastric stage of *Enneagonum hyalinum*, lateral view (ZRC.CNI.2832). Scale bars = 2 mm. Carrot-shaped somatocyst located above diverticulum (di); nectosac (n) roughly cylindrical, with narrow ends. Oil droplet (o) present in all specimens. (Photographs: Ling Min Kang).

Suborder Physonectae Haeckel, 1888b

Family Agalmatidae Brandt, 1834

***Nanomia* A. Agassiz, 1865**

***Nanomia bijuga* (Delle Chiaje, 1844)**

Physsophora bijuga Delle Chiaje, 1844: pl. 181, figs. 3–6.
Anthemodes canariensis Haeckel, 1869: 18, figs. 3–10.
Halistemma pictum Metschnikoff & Metschnikoff, 1871: 306, pl. 2, figs. 1–11.
Stephanomia picta – Metschnikoff, 1874: 61, pl. 12; Garstang, 1946: 112.
Stephanomia pictum – Metschnikoff, 1874: 61, pl. 12, figs. 1–9.
Halistemma tergestinum Claus, 1878: 1, pl. 1 figs. 1–11, pl. 2, figs. 1–10, 12–15, pl. 4 fig.
Agalmopsis fragile Fewkes, 1882: 267, pl. 5 fig. 2, pl. 6, figs. 16, 17, 23–25.
Anthemodes picta – Haeckel, 1888b: 40.
Cupulita canariensis – Haeckel, 1888a: 367.
Cupulita picta – Haeckel, 1888a: 367.
Cupulita tergestina – Haeckel, 1888a: 367.
Cupulita bijuga – Schneider, 1898: 123 (in part).
Anthemodes moseri Agassiz & Mayer, 1902: 167, pl. 12 figs. 49–57.
Nanomia bijuga – Leloup, 1956: 475.
Stephanomia bijuga – Bigelow, 1991: 284, pl. 19 figs. 5–11, pl. 20 figs. 1–3.

Material examined. 5 ex. preserved in 70% ethanol (ZRC.CNI.2854), Siloso beach, Sentosa, Singapore Strait, coll. Ling MK, 11 January 2021.

Description. 4-sided, L-shaped nectophores flattened in the abaxial-adaxial plane, up to 2.3 mm high. Lateral wings twisted. Nectophore has well-developed ostial mouth and a broad ostial velum. No ostial pigmentation observed. Looped lateral radial canals found on nectosac. Long pedicular canal. Leaf-shaped bracts with variable morphology, usually with three processes on the distal end with an occasional cross ridge. (Description adapted in part from Bouillon et al., 2004: 212).

Remarks. Specimens obtained from zooplankton haul were all nectophores, 2.3 mm long, and 1.5 mm wide on average (n = 5). Presence of well-developed ostial mouth surrounded by distinct velum. Two "wings" present in all specimens, one on each side of the nectophore, ending in a twist near the upper part of the nectophore (see Fig. 4).

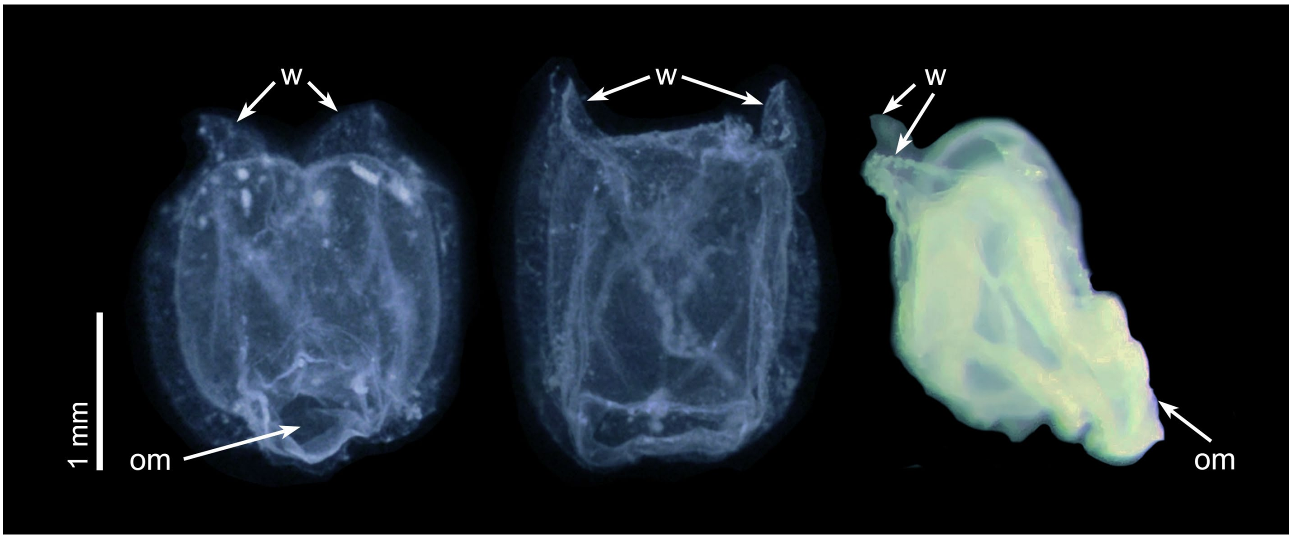

Fig. 4. External morphology of a nectophore of *Nanomia bijuga* (ZRC.CNI.2854), scale bars = 1 mm. Left: upper view. Presence of well-developed ostial mouth (om) with broad ostial velum, as well as two wings (w) on each side of the nectophore, ending in a twist near the upper region of the nectophore. Middle: lower view. Right: side view. (Photographs: Ling Min Kang (left and middle) & Iffah Iesa (right)).

RESULTS AND DISCUSSION

A total of 318 hydrozoan specimens (311 from seining, seven from hauls) from eight families (Abylidae, Aequoreidae, Agalmatidae, Diphyidae, Eirenidae, Geryoniidae, Rhopalonematidae and Solmundaeginidae) were collected. We were able to sort the samples into 16 distinct morphotypes from eight families, seven of which could be identified to species (see Table 1).

Three new records of hydromedusa jellyfishes in Singapore were discovered, namely *Enneagonum hyalinum*, *Nanomia bijuga* and *Solmundella bitentaculata*. The Siphonophorae *Enneagonum hyalinum* and *Nanomia bijuga* were previously reported in the Celebes and Sulu Sea (Du et al., 2012; Grossmann et al., 2015), with the former being distributed around the tropic-equatorial region (Alvariño, 1971). *Solmundella bitentaculata* is widely distributed across all oceans and is particularly common in the southern hemisphere (Kramp, 1955). On top of the current specimens of *Solmundella bitentaculata* obtained in the current study at both Siloso and Palawan beach, Sentosa, a brief mention of *Solmundella* in Singapore was previously made and noted to be “common at times” by Wickstead (1958). Additionally, the figure of *Solmundella bitentaculata* without details in Anonymous (2017) was collected from Lazarus Island, Singapore, in 2012 (I. Iesa, unpub. data), suggesting the species is relatively abundant in Singapore. This would be the first taxonomic description of locally collected *Solmundella bitentaculata*.

Impact of zooplankton net mesh sizes on point haul samples. Existing literature suggests that mesh sizes affect both the amount and type of zooplankton sampled through hauls. Larger meshes tend to retrieve larger-sized species but underrepresent smaller species. Additionally, larger nets retrieve specimens from more evenly distributed size classes while smaller nets generally capture smaller size-classed organisms, with the average species richness of smaller nets being higher (Miodeli et al., 2015). Due to the limited availability of nets of larger mesh sizes, we employed a 25 µm zooplankton net for our point hauls. In comparison, nets of 200–500 µm were used in Miodeli et al. (2015).

Taxonomic resolution among hydromedusae. There is currently a lack of taxonomic resolution among the hydromedusa groups, including the orders Leptothecata (see Maronna et al., 2016), Limnomedusae, Narcomedusae and Trachymedusae (see Collins et al., 2008). As Maronna et al. (2016) notes, the identification and classification of hydromedusae are largely based on their morphology. However, morphological identification of Leptothecata remains challenging at lower taxonomic levels, given that the order exhibits great morphological diversity both at the intraspecies and interindividual levels. Furthermore, as several groups within the order lack the medusae stage altogether, the classification of the Leptothecata by different studies has varied greatly, depending on whether the studies focus on the polyp or medusa stage when carrying out classification (e.g., Allman, 1864; Calder, 2009). Moreover, even after carrying out genetic analysis on the 16S, 18S and 28S rRNA gene sequences of the Leptothecata, Maronna et al. (2016) could not conclusively determine a well-supported sister group for the order, suggesting that much work is needed before the taxonomic relationships among hydromedusae can be conclusively elucidated. In a similar vein, molecular evidence provided by Collins et al. (2008) suggests that both the existing classifications for the orders Trachymedusae and Limnomedusae must be revised to incorporate molecular evidence from the study, further reinforcing the notion that the taxonomy of hydromedusae remains relatively unresolved. Available identification guides, such as Bouillon et al. (2006), allow for identification down to the genus level at best, and the polyphyletic nature of many higher taxa (Maronna et al., 2016) lowers the confidence in identification of hydromedusa at the species levels. Consequently, while the identification and classification of the specimens are based on the taxonomic classifications available at the time of writing, they may have to be reviewed if there are any relevant changes in hydromedusa taxonomy in the future.

CONCLUSION

This study provides a preliminary characterisation of the hydrozoan diversity in the lagoons of Sentosa Island, Singapore. We found new records of three species: *Enneagonum hyalinum, Nanomia bijuga* and *Solmundella bitentaculata*. While the study has shed light on the hydrozoan biodiversity at Sentosa, more long-term studies ought to be conducted to obtain a clearer picture of Sentosa’s medusozoan biodiversity, especially given the general lack of research on jellyfish in Singapore waters.

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