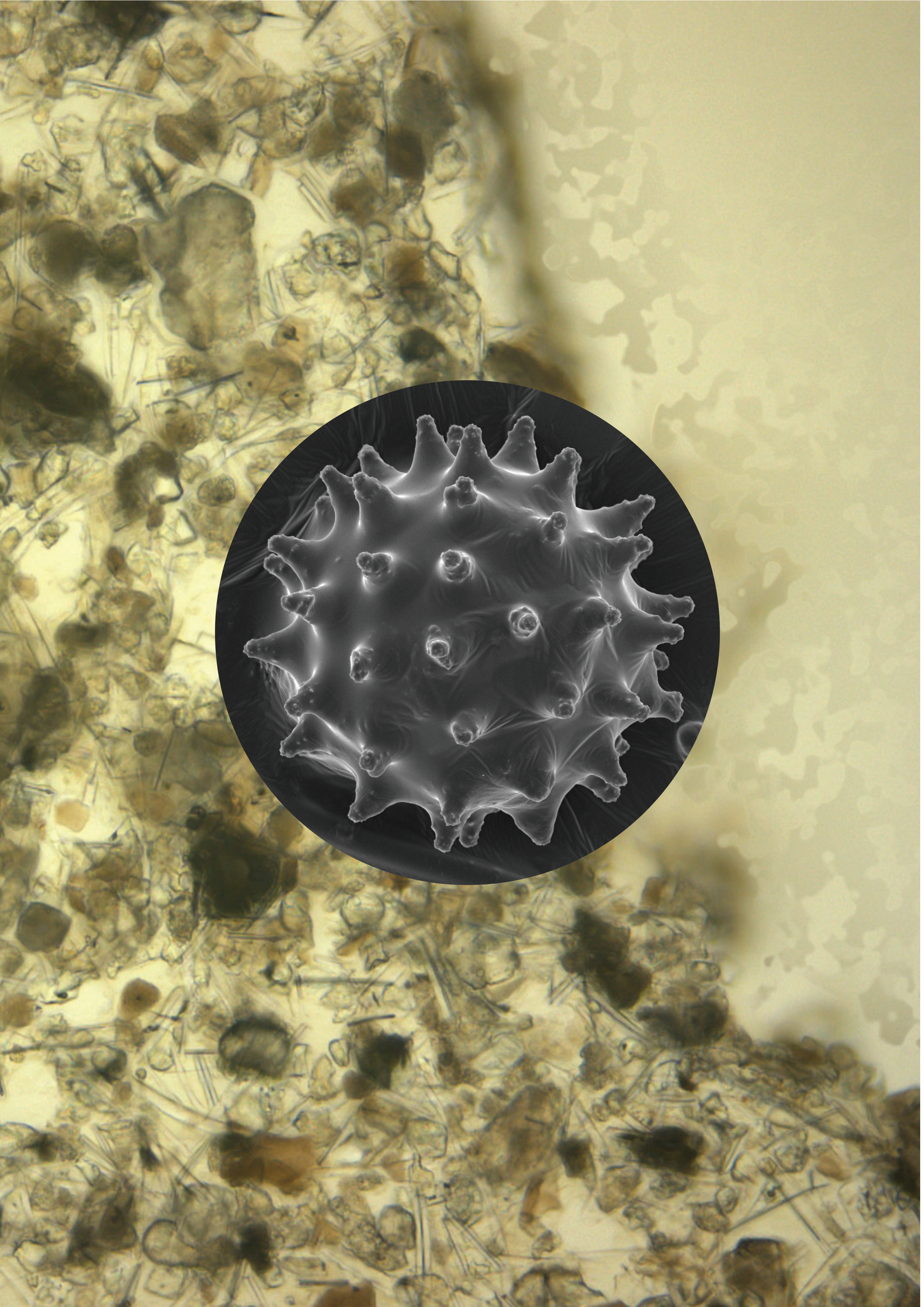

Sponge Biodiversity of Indonesia: Taxonomy and Ecology of Marine Sponge in The Peripheral Spermonde Archipelago

Singgih Afifa Putra
L013191005

SPONGE BIODIVERSITY OF INDONESIA:
TAXONOMY AND ECOLOGY OF MARINE SPONGES IN THE PERIPHERAL SPERMONDE ARCHIPELAGO

BIODIVERSITAS SPONS DI INDONESIA:
TAKSONOMI DAN EKOLOGI SPONS LAUT DI WILAYAH PERIFERAL KEPULAUAN SPERMONDE

SINGGIH AFIFA PUTRA

L013191005

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Prepared and submitted by

SINGGIH AFIFA PUTRA
L013191005

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DISSERTATION

SPONGE BIODIVERSITY OF INDONESIA: TAXONOMY AND ECOLOGY OF MARINE SPONGES IN THE PERIPHERAL SPERMONDE ARCHIPELAGO

SINGGIH AFIFA PUTRA
Student ID. L013191005

The Dissertation has been examined and defended in front of the Dissertation Examination Committee on August 23, 2023, and declare eligible.

Approved by

Supervisor Commission,
Supervisor

Prof. Dr. Ir. Rohani Ambo-Rappe, M.Si.
NIP 196909131993032004

Co-supervisor,

Prof. Dr. Ir. Jamaluddin Jompa, M.Sc.
NIP 196703081990031001

Co-Supervisor,

Prof. Dr. Nicole Joy de Voogd

Head of Study Program,

Prof. Dr. Ir. Musbir, M.Sc.
NIP 196508101989111001

Dean of Faculty of Marine Science and Fisheries,
Hasanuddin University,

Prof. Safruddin, S.Pi., M.P., Ph.D.
NIP 197506112003121003

PERNYATAAN KEASLIAN DISERTASI
DAN PELIMPAHAN HAK CIPTA

Dengan ini saya menyatakan bahwa, disertasi berjudul “Sponge Biodiversity of Indonesia: Taxonomy and Ecology of Marine Sponges in The Peripheral Spermonde Archipelago” adalah benar karya saya dengan arahan dari komisi pembimbing (Prof. Dr. Ir. Rohani Ambo-Rappe, M.Sc. sebagai promotor, Prof. Dr. Ir. Jamaluddin Jompa, M.Sc. sebagai co-promotor-1, dan Prof. Dr. Nicole Joy de Voogd sebagai co-promotor-2). Karya ilmiah ini belum diajukan dan tidak sedang diajukan dalam bentuk apa pun kepada perguruan tinggi mana pun. Sumber informasi yang berasal atau dikutip dari karya yang diterbitkan maupun tidak diterbitkan dari penulis lain telah disebutkan dalam teks dan dicantumkan dalam Daftar Pustaka disertasi ini. Sebagian dari isi disertasi ini telah dipublikasikan di Jurnal (Zootaxa, Vol. 5298, No. 1: 1-74, DOI: 10.11646/zootaxa.5298.1.1) sebagai monografi dengan judul “Two centuries of sponges (phylum Porifera) taxonomic studies in Indonesia (1820–2021): checklist and bibliography”. Apabila di kemudian hari terbukti atau dapat dibuktikan bahwa sebagian atau keseluruhan disertasi ini adalah karya orang lain, maka saya bersedia menerima sanksi atas perbuatan tersebut berdasarkan aturan yang berlaku.

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Makassar, 23 Desember 2023

METERAI ELEKTRONIK 10000 SEPULUH RIBU RUPIAH

SINGGIH AFIFA PUTRA
NIM L013191005

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Author,

Singgih Afifa Putra

ABSTRAK

SINGGIH AFIFA PUTRA. **Biodiversitas Spons di Indonesia: Taksonomi dan Ekologi Spons Laut di Wilayah Periferal Kepulauan Spermonde** (dibimbing oleh Rohani Ambo-Rappe, Jamaluddin Jompa, dan Nicole J. de Voogd).

Latar Belakang. Ekosistem perairan laut secara global diketahui menyimpan beragam bentuk kehidupan yang belum terungkap, hasil riset memperkirakan sebagian besar masih banyak yang belum teridentifikasi. Estimasi termutakhir, khususnya keanekaragaman spons di Indonesia, diperkirakan masih jauh dari ekspektasi. Hal ini memberikan sinyal bahwa bahwa pentingnya peningkatan upaya penelitian di masa depan. Meskipun ekspedisi masa lampau dan kolaborasi internasional telah dilakukan, dan memberikan kontribusi kepada informasi keanekaragaman hewan spons, disparitas informasi terkait taksonomi spons tetap jelas dijumpai. **Tujuan**. Disertasi ini secara umum bertujuan untuk mengisi kesenjangan informasi keanekaragaman hewan spons, menyusun daftar periksa (*checklist*) spesies spons yang komprehensif untuk eko-region laut di Indonesia (*marine ecoregions*), memahami peran spons dalam ekosistem terumbu karang, dan mengevaluasi spons sebagai sentinel untuk kajian polusi plastik mikro. Sedangkan, tujuan khususnya adalah untuk analisis taksonomi dan sistematika spons, mengidentifikasi morfologi fungsional, kaitannya secara ekologis, dan menganalisis kandungan polutan mikro yang terakumulasi di dalam hewan spons pada skala ruang dan waktu. **Metode**. Berbagai metode observasi dan analisis digunakan dalam disertasi ini. Secara umum, spesimen spons dikumpulkan dan diamati dari perairan dangkal Kepulauan Spermonde, tepatnya di antara wilayah intertidal dan sub-tidal, dari tahun 2018 hingga 2022. Namun, untuk kajian terkait polutan mikro, sampel dikumpulkan sejak tahun 1997. Sedangkan, kajian taksonomi dan sistematika spons di Indonesia mengacu kepada data set yang divalidasi dan sumber pustaka yang di depositori oleh World Porifera Database, mencakup periode 1820 hingga 2021. Selanjutnya, observasi lapangan menggunakan teknik *roving* (jelajah), dan setiap spesimen selalu didokumentasi secara *in situ* untuk analisis morfologi makro, kemudian spesimen tersebut diawetkan dengan larutan etanol dan dianalisis di laboratorium. Analisis morfologi mikro menggunakan mikroskop cahaya (LM), dan untuk spesies tertentu, mikroskop elektron (SEM) juga digunakan. Sedangkan analisis untuk kandungan mikro-polutan pada hewan spons menggunakan teknik visual dengan analisis mikroskopi (LM dan SEM), serta teknik analisis dispersi cahaya menggunakan instrumen Spektroskopi Raman. **Hasil**. Disertasi ini mengungkap hasil riset yang berkontribusi pada pemahaman taksonomi dan sistematika yang komprehensif, yaitu secara kolektif mengidentifikasi 27 spesies spons laut dari wilayah perifer di Kepulauan Spermonde, yang didominasi oleh Ordo Haplosclerida. Daftar periksa spesies spons untuk eko-region laut Indonesia tercatat sebanyak 735 spesies, dengan faktor endemik regional yang signifikan, dan juga mengungkap kekurangan data pada beberapa eko-region laut. Sementara itu, hasil analisis klasifikasi morfologi makro spons (Demospongiae) dari 24 spesies menunjukkan ragam variasi, membuktikan kemampuan adaptabilitas hewan ini pada berbagai habitat dan kondisi lingkungan. Selanjutnya, hasil analisis polutan mikro pada beberapa spesies spons menunjukkan variasi kandungan partikel yang mampu diakumulasi oleh hewan spons di laut, dengan variasi temporal yang positif dan faktor spasial yang berkaitan erat dengan wilayah urban. **Kesimpulan**. Disertasi ini menjelaskan riset keanekaragaman spons laut pada ekosistem terumbu karang yang terabaikan. Khusus di wilayah Kepulauan Spermonde, mengungkap informasi keanekaragaman spons dan peran ekologis penting dalam ekosistem terumbu karang. Kegunaan sistem klasifikasi morfologi makro untuk menganalisis faktor lingkungan juga telah dibuktikan dalam disertasi ini. Lebih lanjut, hasil riset juga mengusulkan beberapa spesies hewan spons untuk dapat dimanfaatkan sebagai indikator biologis atau repositori partikulat terkait kajian polusi lingkungan laut, terutama plastik mikro.

Kata Kunci: bentuk pertumbuhan, daftar periksa, polusi laut, Porifera, terumbu karang

ABSTRACT

SINGGIH AFIFA PUTRA. **Sponge Biodiversity of Indonesia: Taxonomy and Ecology of Marine Sponges in the Peripheral Spermonde Archipelago** (supervised by Rohani Ambo-Rappe, Jamaluddin Jompa, dan Nicole J. de Voogd).

Background. The global marine ecosystem harbors a vast array of undiscovered life forms, with estimates suggesting that a significant portion remains unidentified. The estimation of marine species, particularly sponge diversity in Indonesia, is acknowledged as underrepresented, emphasizing the importance of expanding research efforts. Although historical expeditions and international collaborations have contributed to understanding sponge diversity, taxonomic information gaps persist. **Aims**. The general objectives of this dissertation are to fill information gaps in sponge biodiversity, provide a comprehensive checklist of sponge species for the marine ecoregions of Indonesia, understand the roles of sponges in coral reef ecosystems, and evaluate sponges as sentinels for the study of microplastic pollution. Specific objectives include taxonomic and systematic analyses of sponges, identification of functional morphology, ecological relationships, and analysis of micropollutant incorporation in tropical reef sponges over space and time. **Methods**. Various observation and analytical methods were employed in this dissertation's research. In general, sponge specimens were collected and observed from the shallow waters of the Spermonde Archipelago, specifically between intertidal and subtidal zones, from 2018 to 2022. However, for the micropollutant study, samples were collected since 1997. Taxonomic and systematic studies on Indonesian sponges relied on references and datasets validated by the World Porifera Database, covering the period from 1820 to 2021. Field observations utilized roving techniques, with each specimen documented in situ, preserved in ethanol, and analyzed in the laboratory. Micromorphological analyses used light microscopy (LM), and for specific species, scanning electron microscopy (SEM) was also applied. Micropollutant analysis of sponge specimens employed visual techniques with microscopy (LM and SEM) and Foton scattering analysis using Raman spectroscopy. **Results**. This dissertation presented a comprehensive taxonomic and systematic understanding of Porifera in Indonesia, identifying 27 marine sponge species from the peripheral zone of the Spermonde Archipelago, predominantly from the Order Haplosclerida. The sponge species checklist for the marine ecoregions of Indonesia documented a total of 735 species, with significant regional endemism, revealing insufficient data in several marine ecoregions. On the other hand, the analysis of macro-morphological classification of sponges (Demospongiae) from 24 species showcased diverse morphologies, demonstrating the adaptability of these animals to various habitats and diverse environmental conditions. Furthermore, the analysis of micropollutants in several sponges revealed varied particle contents that could be accumulated by tropical reef sponges, with positive temporal variations and spatial factors closely related to urban areas. **Conclusions**. This dissertation uncovered the overlooked diversity of Porifera in the marine ecoregions of Indonesia, particularly in the coral reef ecosystems of the Spermonde Archipelago, emphasizing information on the diversity and important ecological roles of sponges in tropical marine ecosystems. The applicability of the morphological classification system was also demonstrated in this dissertation. Furthermore, this dissertation proposed some sponge species as sentinels or repositories related to the study of marine environmental pollution, particularly microplastics.

Keywords: checklist, coral reef, marine pollution, growth forms, Porifera.

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GLOSSARY

Terminology	Definition
Aquiferous system	A complex network of water canals that allows the sponge to filter and circulate water for feeding and respiration.
Amorphous	Without definitive shape
Anastomosing	The interconnected or branching structure of the water canals within the sponge's body.
Apical	The top or highest point of certain structures within the sponge's anatomy.
Arborescent	Erect, branching habit, tree-like
Asconoid	The aquiferous system within sponges, is characterized by its simple tube-like body structure with a single central opening (osculum) and choanocytes lining the interior, representing the most basic organizational form among sponge body plans.
Boring	Excavating
Caliculate	Cup shaped
Checklist	A systematic list of species, typically within a specific geographical area or habitat, along with their names and often additional information such as classification, distribution, or conservation status.
Choanosomal	The central, choanocyte-lined region within the body of a sponge
Choanocyte	A specialized cell in sponges characterized by a collar surrounding a flagellum, facilitating water circulation and filter feeding by capturing food particles from the water
Clathrate	Resembling open latticework
Clavate	Club shaped
Columnar	Shape of solid, erect cylinder
Cosmopolitan	The wide-ranging nature of the species, showcasing its ability to exist in various ecosystems and geographic locations
Crateriform	Massive shape, with a broad base and large central depression
Cup shaped	Caliculate
Digitate	Deeply devided, finger-like outgrowth from basal mass
Echinating	The process or state of having or developing spines, prickles, or bristles.
Ectosome	The outer layer or region of the sponge's body.
Encrusting	Thin, sheet-like coating of the substrate
Endemic	The ecological phenomenon where a species is restricted to a specific geographic area and is not naturally found anywhere else in the world.

Terminology	Definition
Endolithic	Occupying cavities in hard substrata (excavating)
Endopsammic	Main part of body buried in sand
Erect	General term for having a vertical (away from substrate)
Excavating	Ling in galleries or cavities bored into limestone or other calcareous materials
Ficiform	Fig shaped
Fistulose	Bearing fistules
Flabellate	Fan shaped
Falgelliform	Shaped as a single, very long, erect branch
Foliaceous	In the form of a leaf
Foliose	Foliaceous
Globular	Ball shaped, spherical
Habitus	The overall appearance, form, or structure of a plant, animal, or organism.
Incrusting	Encrusting
Infundibuliform	Funnel shaped
Kladonoid	A more recently described category of aquiferous system, exhibit characteristics similar to leuconoid sponges but with additional complexities in the arrangement of chambers, reflecting an advanced aquiferous system.
Lamellate	Plate-like erect
Lamelliform	Thin, flat, and plate-shaped, resembling lamellae or layers
Leuconoid	A type of aquiferous system; the most complex system, with numerous chambers separated by walls, allowing for extensive surface area and efficient filter feeding.
Massive	Large, compact structure without definable shape
Microplastic	Tiny plastic particles that are less than 5 millimeters in size.
Oligotrophic	An environment, typically a body of water, that has low nutrient levels.
Osculum	A large opening at the top of the sponge's body through which water is expelled after passing through the internal canals.
Ostia	Small openings or pores on the surface of the sponge, (singular: ostium)
Ostium	Singular term for ostia
Ovate	Egg shaped
Palmate	Hand shaped
Papillate	Surface bearing papillae
Pedunculate	Support by a short stalk containing choanosome
Perforating	Excavating
Pinnate	Feather shaped

Terminology	Definition
Platy	Thickly lamellate, usually in horizontal orientation
Polymorphic	Occurring in different shapes
Porocalices	The small pores or openings in the body wall of certain sponges.
Pyriform	Ficiform
Ramose	branching or bushy structure, develops numerous branches or ramifications.
Repent	Growing along or just above the substrate, simple or branching, attaching to the substrate at intervals
Reticulation	Net-like structure or pattern formed by the interconnecting canals or channels within the sponge's body
Sentinel	Stands as a guard, lookout, or monitor, often positioned to provide advanced warning or to keep watch for potential dangers or changes in the environment
Solenoid	A type of aquiferous system; a type of leuconoid, organize their chambers in a tubular fashion, with choanocytes lining the inner surface, contributing to an efficient aquiferous system.
Spicule	Needle-like or spike-like structure that forms part of the skeletal framework within the body of a sponge
Stalked-erect sponges	Have a clear separation of a basal stalk-like portion that does not normally contain any obvious ostiae or oscules, and an apical part that represents the main body with all the functional parts
Stipitate	Supported by a long stalk
Syconoid	A type of aquiferous system; an intermediate level of complexity in their aquiferous system, featuring radial canals that extend from the central cavity, providing increased surface area for filter feeding.
Sylleibid	A type of aquiferous system; a subcategory of leuconoid, distinguish themselves by having an additional layer of choanocytes surrounding the excurrent canals, enhancing their filtration capabilities.
Tubular	Shape of hollow, erect cylinder
Turbinate	Resembling an inverted cone
Type specimens	Individual specimens or examples of a species or a higher taxon that are designated as the reference points for scientific descriptions and names.
Vesicular	Hollow, bladder-like

xxx

CHAPTER 1.

GENERAL INTRODUCTION

1.1. Magnitude of Indonesia Marine Biodiversity

The realm of the global marine ecosystem is a frontier filled with diverse life forms that are largely undiscovered. Recent estimates indicate that a significant portion, ranging from one-third to two-thirds, of marine species remain unidentified (Appeltans *et al.*, 2012). The challenge in revealing this hidden marine biodiversity stems not only from the total number of species but also from the lack of specialized knowledge and dedicated efforts needed for accurate classification, and naming of these organisms (Gaston and May, 1992). This deficiency in taxonomic capacity presents a substantial obstacle to understanding the complete scope of marine biodiversity.

The marine realms, with their vast and complex ecosystems, contain an extraordinary diversity of species, making it challenging to accurately count them due to the numerous and often cryptic life forms in these environments. Several studies propose varied records, creating uncertainty about the total number of marine species, with estimates ranging from less than 200,000 to an astonishing over 10 million species (Briggs, 1994; Benton, 2001). This wide range estimation underscores the inherent difficulty and complexity in determining the true richness of marine life. The disparity in data across studies highlights the ongoing challenge scientists face in precisely quantifying the multitude of species contributing to the rich biodiversity of the marine realm.

Despite the uncertainty in total numbers, current taxonomic knowledge encompasses over 240,000 described marine eukaryotic and prokaryotic species across diverse taxonomic groups. These groups include Animalia, Archaea, Bacteria, Chromista, Fungi, Plantae, Protozoa, and Viruses. However, this represents only about 15% of the globally recognized species (Reaka-Kudla, 1997; Sala and Knowlton, 2006; Appeltans *et al.*, 2012; Ahyong *et al.*, 2023). The incomplete understanding of marine biodiversity is accentuated by the apparent degradation of the marine ecosystem, emphasizing the urgency of addressing potential losses even as our comprehension remains incomplete (Worm *et al.*, 2006).

Indonesia's marine environment boasts a diversity of shallow and deep-water ecosystems, each hosting distinct taxonomic groups (Hutomo and Moosa, 2005). Despite accommodating over 12,000 marine species (

Table 1.1), Indonesia's contribution to the global marine species tally is modest, accounting for only 5% of all recognized species worldwide (Ahyong *et al.*, 2023). The lack of taxonomic records particularly affects less-known marine taxa (e.g., Protozoa, Bacteria, Nematoda, Platyhelminthes), underscoring existing gaps in records and highlighting the need for further exploration to understand the complexities of Indonesia's marine biodiversity.

Since 1955, there has been a consistent increase in the identification rate of global marine species (Appeltans *et al.*, 2012). This is evident, especially in the case of sponges (Porifera), where numerous specimens have been collected, yet many samples and related data await analysis (van Soest *et al.*, 2012a). Plans are in progress to enhance biodiversity exploration and preservation efforts, with advancements in methodology and technology, such as molecular methods, SCUBA diving, and remotely operated vehicles, facilitating the sampling of previously unexplored habitats and the identification of cryptic species. This ongoing surge in discovery provides a promising avenue for uncovering the hidden biodiversity of the marine realm.

Table 1.1. Indonesia marine species diversity. (Notes: *only species number of Crustacea, **recorded from South China Sea region, ***only recorded from Raja Ampat Archipelago, Papua, Indonesia).

Kingdom/ Phylum	Species estimates	Sources
PLANTAE		
Macroalgae	782	(Weber-van Bosse, 1913; Weber-van Bosse, 1921)
Seagrasses	13	(Wafar *et al.*, 2011)
Mangroves	38	(Wafar *et al.*, 2011)
ANIMALIA		
Annelida	713	(Pamungkas and Glasby, 2019)
Arthropoda*	1,512	(Wafar *et al.*, 2011)
Bryozoa**	532	(Gordon, 2016)
Cnidaria	1,150	(Wafar *et al.*, 2011)
Echinodermata	747	(Wafar *et al.*, 2011)
Foraminifera***	421	(Förderer and Langer, 2018)
Mollusca	2,500	(Wafar *et al.*, 2011)
Porifera	830	(van Soest, 1989)
Chordata	3,283	(Wafar *et al.*, 2011)
Total	**12,521**	

1.2. Sponge diversity and distribution in Indonesia

The macro and micro morphological characteristics (e.g., skeleton, aquiferous systems, and spicule morphologies) of sponges, and their ecological adaptations underscore the extensive sponge diversity embedded in the aquatic ecosystem of the planet (including freshwater environment). The skeleton and aquiferous systems of sponges are elaborate complex structures responsible for their filter-feeding behavior. Meanwhile, the spicule morphologies of sponges are diverse. These morphological characteristics reflect the multifarious ecological niches within the aquatic ecosystems. Each sponge species, with its distinctive characters, contributes to the diverse array of aquatic life, emphasizing the need for a deeper understanding and conservation effort to preserve this aquatic biodiversity.

Indonesia stands out as a pivotal focus in the global challenges of biodiversity. The contrast between the richness of Indonesia's marine biodiversity and its global representation highlights broader challenges faced by our planet in comprehending the full scope of marine biodiversity. In this context of marine biodiversity challenges, sponges play a prominent role, representing the complexity in Indonesia's marine ecosystems. With a diverse array of over 9,500 known species, sponges serve as living representatives of the biological aspects (de Voogd *et al.*, 2022).

The study of Indonesia's marine biodiversity has uncovered a diverse array of sponge species, with historical records indicating approximately 830 identified species (van Soest, 1989; de Voogd, 2005; Calcinai *et al.*, 2017a). However, the complete extent of this animal diversity remains uncertain, as a comprehensive annotated checklist is yet to be established. Previous studies, although lacking detailed taxonomic notes, have been compiled from specific locations, providing insights into the diversity of sponges within Indonesia. Efforts to record sponge species have resulted in some annotated checklists for Demospongiae (Calcinai *et al.*, 2017a) and Calcarea (van Soest and de Voogd, 2015), including ecological studies in the Spermonde Archipelago (de Voogd, 2005) and Berau-East Kalimantan (Becking *et al.*, 2013). The accurate identity of several sponge species remains elusive, with numerous entries on the reported lists categorized as unidentified (de Voogd, 2005; Becking *et al.*, 2013; Calcinai *et al.*, 2017a; Marlow *et al.*, 2019).

Several studies have reported on the diversity and distribution of sponges in Indonesia, primarily focusing on reef zones (de Voogd *et al.*, 1999; de Voogd *et al.*, 2004; de Voogd *et al.*, 2006a; Cleary and de Voogd, 2007). In the tropical context, where ecological dynamics exhibit wide variations, there is increasing evidence that different habitats exert distinct influences on sponge diversity, abundance, and composition. Studies indicate that ecological drivers differ not only between various habitats but also within the same habitat (Wulff, 2012; Bachtiar *et al.*, 2022), emphasizing the subtle interactions shaping sponge communities in Indonesian marine ecosystems. On the other hand, despite sponge diversity increasing by depth (Bell *et al.*, 2018), a significant gap exists in our knowledge of the shallow-water zones within Indonesia's marine ecosystems. Given the acknowledged importance of these areas, it becomes imperative to fill this information gap by investigating into the specificities of the sponge community thriving in these peripheral habitats.

The estimation of marine species, particularly the diversity of sponges in Indonesia, is acknowledged as still being underrepresented (Calcinai *et al.*, 2017a). The challenge becomes more pronounced when attempting to conduct sponge studies in specific and ecologically significant habitats, such as seagrass beds, mangroves, and intertidal zones in Indonesia. These peripheral environments pose unique challenges, making it difficult to comprehensively study and record the diversity of sponges present. Recent reports shed light on the complexities of this field, where specific studies in these demanding habitats have successfully described at least more than 50 sponge species, including the identification of a new species (Setiawan *et al.*, 2009; Becking *et al.*, 2013; Calcinai *et al.*, 2017b).

The further studies need, especially in habitat types that have been historically overlooked, carries significant weight. It highlights the importance of expanding research efforts to cover a wider range of locations within Indonesia, filling the existing gaps in our understanding of sponge communities. This expansion is vital not just for academic knowledge but also for the practical implications of effective coastal management and conservation. Emphasizing the need to grasp the baseline diversity of species and provide regular updates, it becomes a crucial aspect in our continuous pursuit of knowledge. Previous studies emphasis the significance of baseline research in guiding effective coastal management strategies (Richards, 2015; Calcinai *et al.*, 2017a), ensuring that conservation efforts are based on accurate and up-to-date information. These studies serve as a foundational pillar for informed decision-making, supporting the sustainable preservation of Indonesia's marine ecosystems.

1.3. Systematics and characteristics of sponges

Sponges, belonging to the phylum Porifera, stand as non-symmetrical metazoan animals predominantly inhabiting marine environments, with only a small representation found in freshwater ecosystems, spanning from the intertidal to the abyssal zone (Hooper, 2008). This diverse phylum comprises four distinct classes, i.e., Calcarea, Demospongiae, Hexactinellida, and Homoscleromorpha (de Voogd *et al.*, 2022). Displaying a wide array of growth forms in various aquatic habitats, sponges primarily function as aquatic filter feeders, adapting to their surroundings with remarkable variation (Bell *et al.*, 2002b; Schönberg, 2021).

Within the phylum Porifera, three classes, i.e., Calcarea, Hexactinellida, and Homoscleromorpha, are exclusively marine, collectively comprising at least 1,643 marine species (de Voogd *et al.*, 2022). In contrast, the Demospongiae class, the largest taxa member in the phylum, not only boasts a significant number of species but also demonstrates cosmopolitanism and adaptation to freshwater environments (Manconi and Pronzato, 2008; van Soest *et al.*, 2012a). Recent phylogenetic research has confirmed the close relationship between Calcarea and Homoscleromorpha, forming a sister group, while Hexactinellida and Demospongiae similarly align as another sister group (Borchiellini *et al.*, 2021).

The organizational details of sponges unfold through the examination of their cell layer, known as the pinacoderm. Comprising flattened cells known as pinacocytes, this layer lines inhalant canals that transport water to choanocytes, or filtering cells, organized within choanoderm chambers. Choanocytes, equipped with flagella, facilitate water flow, and the filtered water exits the sponge through exhalant canals of pinacoderms. This elaborate network of choanocyte chambers and canals collectively forms the complex aquiferous system. Currently, six types of aquiferous systems, i.e., asconoid, syconoid, leuconoid, sylleibid, solenoid, and kladonoid, are recognized, utilized for species identification and classification (Godefroy *et al.*, 2019; Borchiellini *et al.*, 2021; Lopes and Klautau, 2023).

The structural framework of sponges relies heavily on mineral elements known as spicules, playing a pivotal role in the fundamental identification of these organisms (Łukowiak *et al.*, 2022). Within the diverse domain of sponge taxonomy, the Calcarea class stands out with its distinct spicule forms, i.e., diactines, triactines, and tetractines, each exhibiting a variety of derivatives. In contrast, the spicules of the

Demospongiae class primarily manifest as monoaxons and tetraxons (triaenes), categorically excluding the presence of triaxons. On the other hand, the Hexactinellida class produces siliceous spicules characterized by hexactinic or triaxonic (cubic) symmetry. The complex configurations of these spicules are derived from reduction or branching of the primary rays, reflecting the unique adaptations of deep-sea sponges. Meanwhile, the Homoscleromorpha class, dwelling in cryptic to semi-dark and dark habitats, exhibits specific siliceous spicules, which, when present, are small and undifferentiated into mega- and microscleres. Notably, these spicules include tetractines and derivative actines, such as triods and diods, showcasing the diversity and specialization in the skeletal structures of sponges inhabiting different ecological niches (Ereskovsky and Lavrov, 2021).

1.4. Ecological and chemical importance of sponges

Indonesia, situated within the Indo-Pacific marine ecoregion, exhibits the highest population density among its neighboring nations. Approximately 70% of its inhabitants reside in coastal areas, constituting a dynamic interface between human civilization and the marine environment (Tomascik *et al.*, 1997; Spalding *et al.*, 2007; Neumann *et al.*, 2015). This coastal landscape is witnessing rapid urbanization, with growing cities, e.g., Batam, Lampung, Jakarta, Semarang, Surabaya, and Makassar, each accommodating over a million people (Badan Pusat Statistik, 2019). Nonetheless, this urban expansion and other anthropogenic activities are imprinting lasting effects on the marine ecosystem, reshaping ecosystem dynamics, and influencing the distribution patterns of marine species (Guest *et al.*, 2016; Hillmann and Ziegelmayer, 2016; Heery *et al.*, 2018).

The marine and coastal ecosystem encounters disruptions from a multitude of anthropogenic factors. Land-based pollution, destructive fishing practices, and the continuously expanding footprint of urbanization contribute to the challenges faced by this complex ecological system (Cleary *et al.*, 2006; Sawall *et al.*, 2011; Heery *et al.*, 2018). Furthermore, the altering chemistry of water and escalating temperature levels present additional threats, poised to reshape the population structures of marine species. These changes are expected to reverberate through trophic pathways, disrupting energy flow and, consequently, compromising the stability of ecosystem trophodynamics (Mortimer *et al.*, 2023).

In the face of these challenges, the current approach to coastal conservation in Indonesia predominantly centers around coral reef rehabilitation and the protection of charismatic species (Weeks *et al.*, 2014; Clifton and Foale, 2017). However, to formulate effective strategies for coastal conservation, comprehensive baseline data is imperative, encompassing all taxa, including the often-overlooked minor taxa and cryptic species. Unfortunately, quantitative studies on sponges in Indonesia remain scarce, with this community often relegated to the shadows of coral reef community assemblages due to the difficulty in identification and the elusive nature of their cryptic habitats (de Voogd *et al.*, 2009). This highlights the need for a more holistic and inclusive approach to coastal conservation, even in the peripheral of the marine ecosystem.

Sponges, these organisms play a dual role, not only contributing to the ecological function of marine ecosystems but also holding immense potential for pharmaceutical discoveries. For almost half a century, chemists specializing in marine natural products (MNPs) have diligently explored the molecular riches hidden within various marine species, with sponges emerging as a particularly promising source (Higa *et al.*, 1994; Faulkner, 2000). Beyond their medicinal applications, sponges provide invaluable substances crucial for deciphering classification schemes and tracing phylogenetic relationships (Erpenbeck and van Soest, 2007). Despite the variable distribution of chemical compounds across taxa, sponges stand out as the most extensively studied sources for potential MNPs (Carroll *et al.*, 2019). This underscores the importance of baseline studies on sponge diversity, not just for understanding these organisms' ecological roles but also for preserving valuable resources and protecting biodiversity (de Voogd and Cleary, 2008). The misinterpretation of sponge taxa, as highlighted by recent study (Cárdenas *et al.*, 2022), emphasizes the need for accurate evaluations of critical marine species to mitigate potential species loss or misidentification.

In further examining the ecological factors of marine sponges, numerous studies have investigated their spatial and temporal distribution patterns (de Voogd *et al.*, 1999; de Voogd *et al.*, 2006a; de Voogd and Cleary, 2008; de Voogd *et al.*, 2009). However, the complexities of researching sponges are amplified by their often-thin, encrusting, and cryptic nature (Wulff, 2001). The fundamental principle of sponge identification hinges in spicule morphology (Schönberg, 1999), a critical aspect that demands careful macro and micro-morphological observations. Obtaining sponge spicule preparations through acid or bleach digestion is a prerequisite before microscopic observation (Hooper, 2003). Despite the challenges, sponge research remains inadequately represented, holding substantial implications for coral reef conservation and the examination of marine habitats under environmental stress (de Voogd and Cleary, 2008).

1.5. Research thinking framework

In the development of the research thinking framework (Figure 1.1), an exploration is undertaken that spans from the global to the local, with the aim of unraveling the hidden of marine biodiversity. The study begins by considering the global marine biodiversity, indicating the need for intensified taxonomic efforts and expertise (Gaston and May, 1992; Appeltans *et al.*, 2012). Meanwhile, an interesting fact emerges in the marine ecoregions of Indonesia. Although this region is home to more than 12,000 marine species, it only accounts for 5% of the total global count. This emphasizes that there is still much more marine life to be discovered (Ahyong *et al.*, 2023). In the complexity of marine biodiversity, sponges (Porifera) take center stage. Knowledge about Indonesian sponge diversity is currently unclear, lacking updated and comprehensive information on the regional sponge fauna checklist. Despite specific studies focusing on certain classes or parts of the marine ecoregion, a complete overview of sponge diversity in Indonesia's aquatic ecosystems has yet to be achieved (van Soest and de Voogd, 2015; Calcinai *et al.*, 2017a).

The annotated checklist of Porifera in Indonesia is important, emphasizing the scarcity of updated information on sponge fauna, especially in poorly studied peripheral habitats. To address this gap, the investigation extends to the morphological variations of sponge species, with the aim not only to categorize and describe these organisms but also to understand their ecological roles in the diverse marine ecoregions of Indonesia. This diverse approach aligns with the worldwide tendency to enlarge the scope of sponge research, demonstrating an increasing interest in understanding their ecological functions (Schönberg, 2017).

Moreover, focus is shifted to the detailed aspects of marine bio-ecology and the ecological role of sponges as sentinels. Equipped with a deeper understanding of Indonesian marine biodiversity and the specific variations within the Porifera phylum, an analysis is undertaken of the ecological roles played by sponges in the context of diverse marine ecoregions.

The research thinking framework is designed to address key questions:

1. What is the current taxonomic count of sponge species in Indonesia?
2. How can the ecological function of sponges be utilized environmental assessment in coral reef ecosystem monitoring?
3. In what capacity can sponges function as sentinels (bioindicators)?

This interconnected study, spanning from global biodiversity challenges to the ecological functions of sponges in Indonesia, forms a comprehensive framework that seeks to contribute not only to taxonomic knowledge but also to the understanding of marine ecosystems and their conservation.

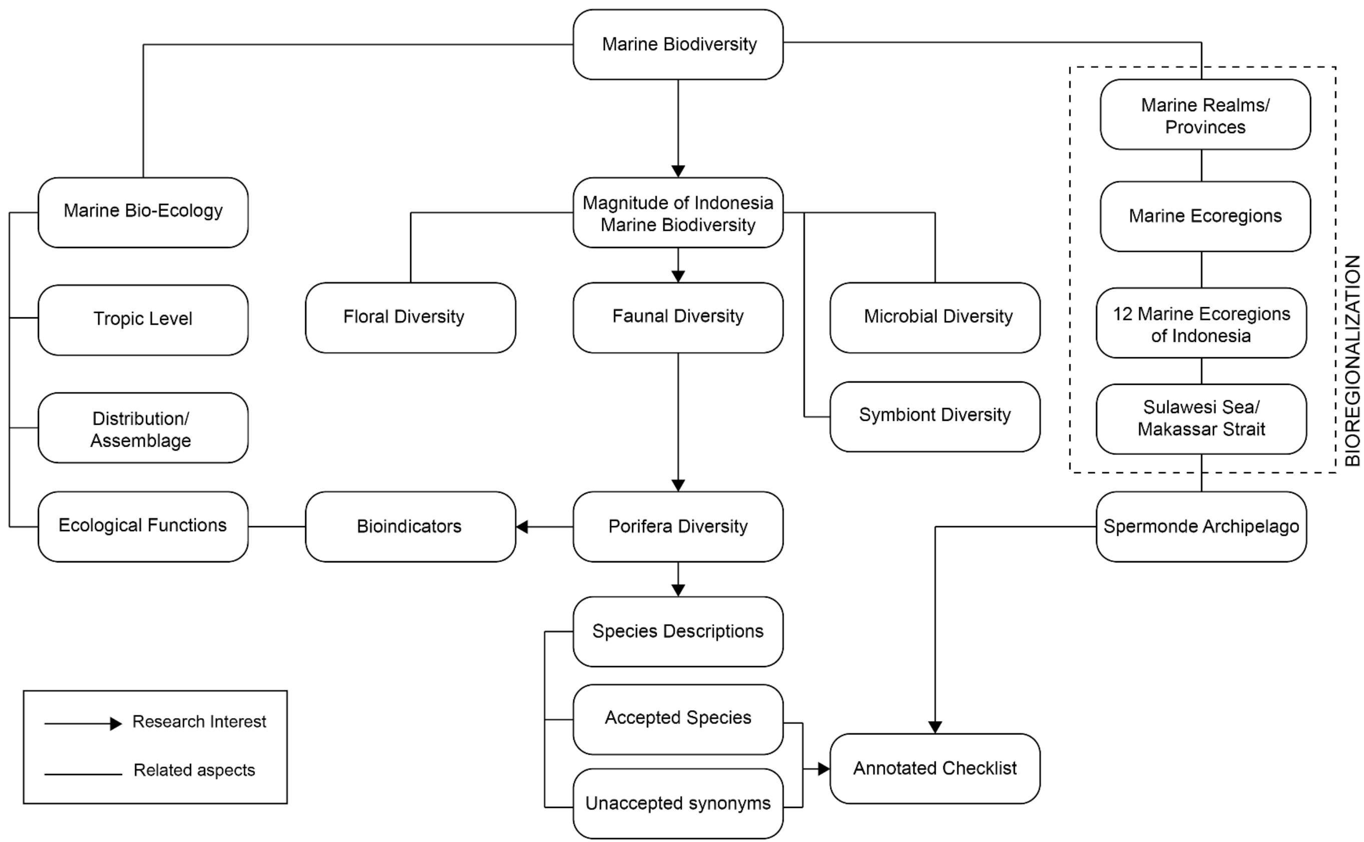

Figure 1.1. Research thinking framework of this study.

CHAPTER 2.

PRELIMINARY STUDY OF MARINE SPONGES (PORIFERA) IN THE PERIPHERAL SPERMONDE ARCHIPELAGO, INDONESIA

Graphical Abstract

2.1. Abstract

Background. The Spermonde Archipelago, located in the Sulawesi Sea/Makassar Strait marine ecoregion, is characterized by diverse coral cays and islands. The coral reef ecosystem, rich in species diversity, is influenced by various environmental factors. Prior ecological studies show higher sponge diversity in the Spermonde Archipelago, SW Sulawesi, Indonesia, compared to the World Porifera Database. Taxonomic studies on sponge diversity in this region are limited, and there is a need for comprehensive understanding. **Aim**. This study aims to provide a preliminary morphological identification of marine sponge species in the peripheral area of the Spermonde Archipelago, addressing the gaps in knowledge regarding marine sponge diversity in Indonesia. The research also seeks to promote sponge taxonomy in Indonesia and update the checklist of sponge diversity in the marine ecoregion. **Methods**. Specimen collection involved observations in the intertidal and subtidal areas of several islands in the archipelago, using roving techniques (i.e., trampling, snorkeling, SCUBA diving). Photographic documentation of living sponges was performed in situ, and specimens were preserved in 96% ethanol. Fragment and skeleton analyses were conducted using light microscopy (LM) and scanning electron microscopy (SEM) at the Naturalis Biodiversity Center, Leiden, following standard procedures. **Results**. Preliminary morphological descriptions of all examined samples are presented. The study identified 27 marine sponge species, primarily from the Order Haplosclerida, in the peripheral area of the Spermonde Archipelago. Notable findings include new records for Indonesia, potentially novel species, and the presence of certain sponges in turbid reefs (peripheral habitat), contrary to their typical habitats. Some species demonstrated preferences for sedimented environments, with potential negative impacts on sponge communities. **Conclusion**. The study contributes to filling a gap in understanding sponge diversity in particular marine ecoregion in Indonesia, providing comprehensive morphological identifications. This study highlights the sponge assemblage growing in a peripheral area, even characterized by a paucity of live corals and a predominant by macroalgae, dead rocks, and rubble.

Keywords: Calcarea, Demospongiae, diversity, Indo-Pacific, taxonomy, turbid sponges

2.2. Introduction

The Spermonde Archipelago is located between the South-Western part of Sulawesi (Indonesia) and the Makassar Strait (Kench and Mann, 2017). This region is placed in the Sulawesi Sea/Makassar Strait (SS/MS) marine ecoregion based on Marine Ecoregions of the World (Spalding *et al.*, 2007). The whole archipelago consists of many coral cays and small islands (Umbgrove, 1928; Kench and Mann, 2017), with the highest coral cover less than 60% (Sari *et al.*, 2021). The coral reef is the richest ecosystem with high species diversity (Cairns, 1999; Williams *et al.*, 2019; Kusumoto *et al.*, 2020b). Every part of the reef is influenced by different regimes of wave actions, light intensity, bathymetric range, and water currents (Kench and Mann, 2017). The sponge community is one of the essential components of the reef environment (Rützler, 2004), and they are commonly appear to have a wide range of distribution across the Spermonde Archipelago (de Voogd *et al.*, 1999). They are also recognized as predominantly niche specialists with marked habitat preferences in coral reef ecosystems (Hooper, 2008).

Various studies have been conducted on this archipelago due to its geological, biodiversity, and ecological interests in marine biology (Polónia *et al.*, 2015). Taxonomic studies on sponge diversity in this region were sporadic. Between areas inside SS/MS, the species checklist was dominated from North Sulawesi compared to other area within this ecoregion, including SW Sulawesi. Only a few papers that wrote a morphological taxonomic study for some new described species or revision of a particular sponge group (e.g., genus, family, order) and mention the Spermonde Archipelago as locality (de Weerdt and van Soest, 2001; de Voogd, 2004; Becking, 2013; Alvarez *et al.*, 2016; van Soest *et al.*, 2021).

Globally, more than 9.000 species sponge species are currently described (de Voogd *et al.*, 2022). However, taxonomic misidentification by non-taxonomist is common when dealing with sponges (Cárdenas *et al.*, 2022). Some comprehensive inventories of the sponge fauna from Indonesia have been reported (van Soest, 1990; Calcinai *et al.*, 2017a), including specific sponge categories-based inventories (de Voogd and van Soest, 2002; Calcinai *et al.*, 2005; van Soest and de Voogd, 2015; van Soest *et al.*, 2021). But, sponge diversity across Indonesian Archipelago is still considered underestimated (Calcinai *et al.*, 2017a).

According to the World Porifera Database (WPD), sponge diversity in the SS/MS marine ecoregion comprises 124 species, i.e., 17 species of Calcarea, 93 species of Demopongiae,13 species of Hexatinellida, and one species of Homoscleromorpha (de Voogd *et al.*, 2022). Class Demospongiae was dominated with Poecilosclerida as the specious order comprises 30 species. However, the latest ecological study shows more sponge species beta diversity in the Spermonde Archipelago. At least 151 species belonging to 68 genera and 37 families were identified in this unit area (de Voogd *et al.*, 2006a). Therefore, taxonomic studies are needed to describe the unregistered sponge species and elucidate sponge alpha diversity in this marine ecoregion.

The current study is focus on the peripheral area of the Spermonde Archipelago. This area is between intertidal and subtidal area, below the lowest tide, including reef flat. Reef flats are the most recent expression of sea-level coral reef growth (Hopley, 2011). This area is extreme for the coral reefs with marginal environmental conditions (Burt *et al.*, 2020). Furthermore, the coral reef ecosystem in this shallow area, particularly in the inner zone of the archipelago was reported as a very poor category, approximately between 5-14 % (Sari *et al.*, 2021; Parenden *et al.*, 2021). This habitat more dominated by dead corals with algae, macroalgae, and sediment cover (Parenden *et al.*, 2021). This study aims as preliminary morphological identifications of the Spermonde Archipelago sponge's specimen to fill the gap of knowledge concerning the marine sponge diversity of Indonesia. This study also tried to promote the study of sponge taxonomy in Indonesia and updated checklist of the sponge diversity of this marine ecoregion.

2.3. Materials and methods

2.3.1. Specimen collection

The specimen collection was conducted through several observations of the peripheral area (between intertidal and subtidal area) in the several islands of the Spermonde Archipelago, SW Sulawesi, Indonesia. Some observations were made by Nicole J. de Voogd in 2018, and by Singgih A. Putra during 2020 and 2021 (Figure 1, Appendix 2.1). The observations were performed using a roving technique (Pattengill-Semmens, 2001) through trampling, snorkelling, or SCUBA Diving. Roving time is about 1-2 hours within approximately 90 m^2 for each site. The timed survey method does not provide density and abundance data but is most useful when the study aims to assess biodiversity (Reimer *et al.*, 2018; Montano *et al.*, 2020).
Photographs of living sponges at the study site (in situ) were captured using an underwater digital camera. The specimens were immediately transferred into 96% ethyl alcohol for preservation during observation (Hooper, 2003), and some of them were deposited in the museum collection of the Naturalis Biodiversity Center, Leiden, the Netherlands.

2.3.2. Specimen identification

Fragments of sponges and hand sections of the skeleton were prepared and then examined using LM (light microscopy) and SEM (scanning electron microscope) at the Naturalis Biodiversity Center, Leiden, following standard procedures for skeleton and spicule analysis (Rützler, 1974; Boury-Esnault and Rützler, 1997; Hooper, 2003). Except for macro morphologies, which were measured with a vernier caliper, microscopic characteristics were assessed using Olympus cellSens Standard or Leica software. Systematic treatment refers to the description of Porifera morphological identification (Hooper and van Soest, 2002c) and the World Porifera Database/WPD (de Voogd *et al.*, 2022). The recording of species names includes as much information as possible, such as valid names, species location, specimen description, and other taxonomic notes.

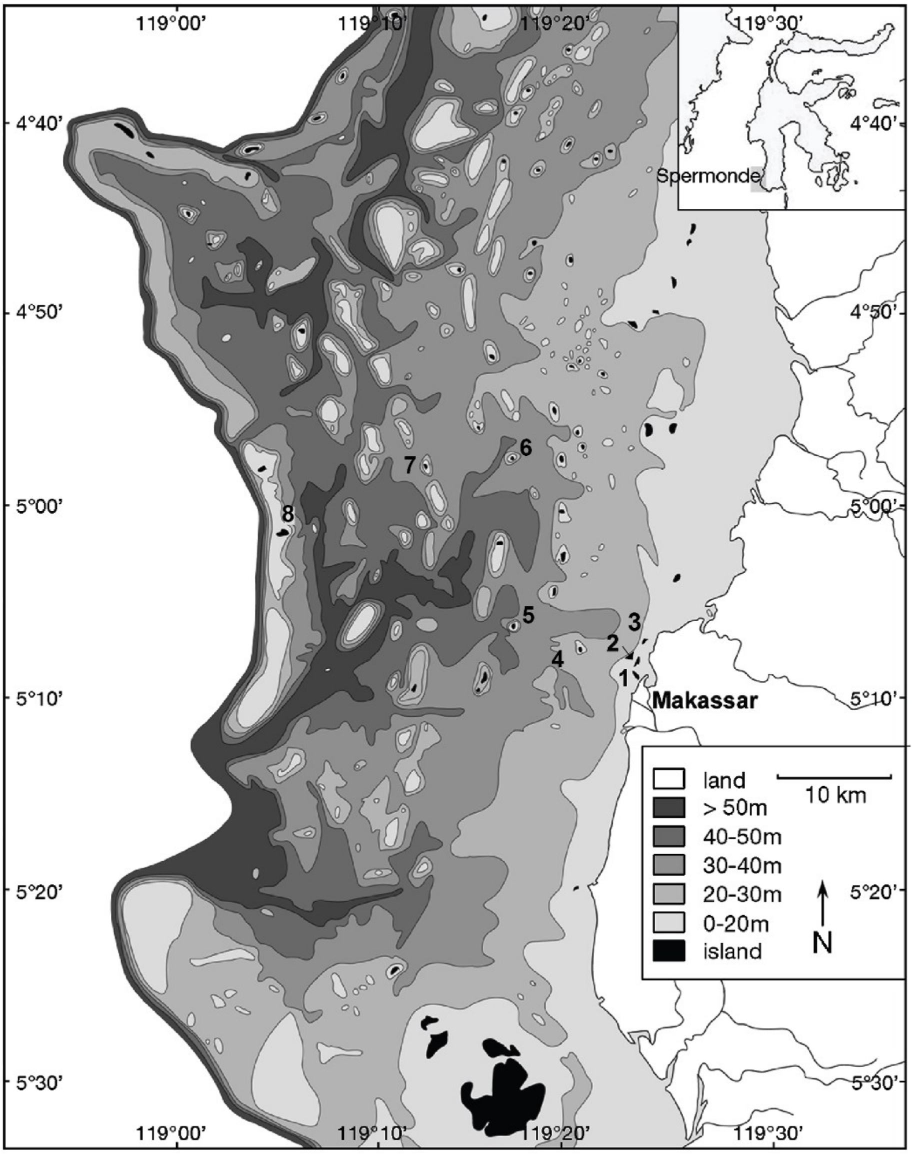

Figure 2.1. The location of sponge observation in the shallow-subtidal area of the Spermonde Archipelago, SW Sulawesi, Indonesia, i.e., 1) Lae-lae, 2) Gusung (as Gusung Tallang), 3) Kayangan, 4) Samalona, 5) Kudingarengkeke, 6) Badi, 7) Lumulumu, 8) Langkai.

2.4. Results

Accepted names, all synonyms and systematics update were referring to the World Porifera Database (de Voogd *et al.* 2022), including all terminology is following updated terms and thesaurus (Boury-Esnault and Rützler, 1997; Łukowiak *et al.*, 2022).

Systematics account

Phylum Porifera Grant, 1835
Class Calcarea Bowerbank, 1862
Subclass Calcinea Bidder, 1898
Order Clathrinida Hartman, 1958
Family Clathrinidae Minchin, 1900
Genus *Clathrina* Gray, 1867

***Clathrina rodriguesensis* van Soest & de Voogd, 2018**
Figure 2.2
Diagnostic features. In its natural environment, the species forms a large, encrusting mass composed of wide, closely linked tubes showing little variation in diameter. According to van Soest & de Voogd (2018), it can spread flatly across wide areas, with the tubes arranged like a ladder. The main tubes often end in an opening slightly raised from the mass. The colour is white with shades of blue, grey, or pink, turning pale beige or brown when preserved. Consistency firm and asconoid aquiferous system. Spicules are only triactines.
Distribution. Previously, this species only recorded from Seychelles, Western Indian Ocean (van Soest and de Voogd, 2018). This is first record for Indonesia (Kudingareng keke, the Spermonde Archipelago).

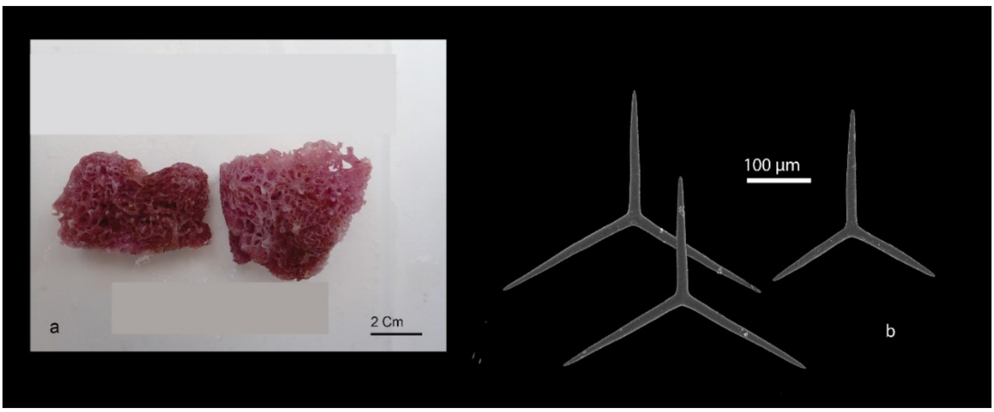

Figure 2.2. *Clathrina rodriguesensis* van Soest & de Voogd, 2018 from Kudingareng keke Island, the Spermonde Archipelago (Sample CEL035), a. Habitus on deck (photo N.J. de Voogd), b, SEM image of the triactines.

Genus *Janusya* Klautau et al. 2021

***Janusya tubuloreticulosa* (van Soest & de Voogd, 2015)**
Figure 2.3
Diagnostic features. An orange flattened mass of short oscular tubes, connected at the substratum by a basal tubular network, the erect tubes maybe divided into one or two side tubes. The walls of tubes are thin with spicules are dominated by triactines. Triactines predominantly equiactinal with size 14.93-120.79 (83.54) x 3.39-6.76 (5.48) µm (n=20). Tetractines are also not rarely found with size 28.04-103.79 (83.77) x 4.98-5.94 (5.48) µm (n=11).
Distribution. Originally reported from Ternate (van Soest and de Voogd, 2015). First record from Samalona Island, the Spermonde Archipelago.

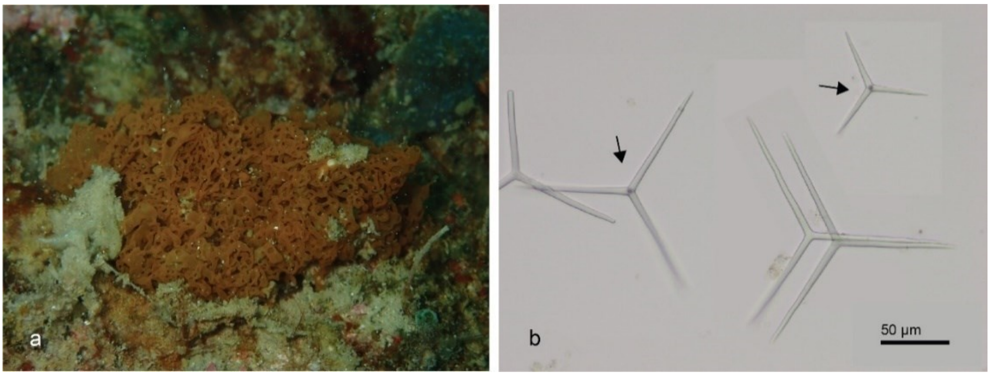

Figure 2.3. *Janusya tubuloreticulosa* (van Soest & de Voogd, 2015) from Samalona Island, the Spermonde Archipelago (Sample CEL001), a. habitus in situ at Samalona reefs (photo N.J. de Voogd), b. LM images of spicules, triactines and tetractines (arrows).

Family Leucaltidae Dendy & Row, 1913
Genus *Laucaltis* Haeckel, 1872

***Leucaltis nodusgordii* (Poléjaeff, 1883)**
Figure 2.4
Diagnostic features. The species forms a clathrate mass of interconnected (anastomosing) tubes with varying lengths and diameters. Individual tubes can reach up to 2.5 cm in length and have diameters of 2-8 mm (van Soest & de Voogd, 2015). The tubes end in oscules, which can be as wide as the tube itself (standing upright) or smaller (flush with the surface), and these oscules are naked. The surface is smooth, and the texture is brittle yet somewhat compressible. The color is white or pinkish white, sometimes lavender-colored, and it turns yellowish white when preserved. Cortical skeleton formed by the basal triradiate system of giant tetractines mixed with giant triactines. Actines of the giant tetractines and triactines protrude into the choanomal skeleton. Next to the actines of the giant tri- and tetractines, the

choanosomal skeleton contains scattered intermediate to small-sized regular triactines and tetractines (see van Soest & de Voogd, 2015 for detail description).

Distribution. *Leucaltis nudusgordii* is a new record for the Spermonde Archipelago (Samalona Island), but this species has been reported previously from North Sulawesi (van Soest and de Voogd, 2015).

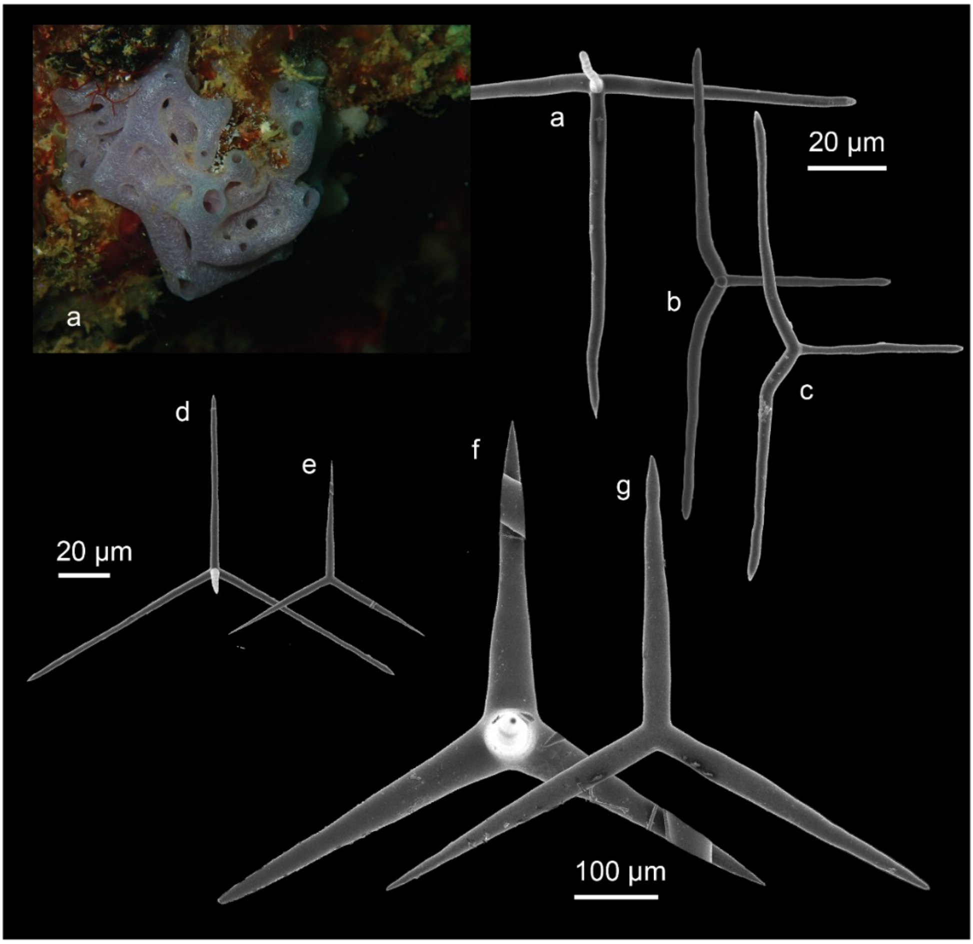

Figure 2.4. a. Habitus *in situ Leucaltis nodusgordii* (Poléjaeff, 1883) (CEL005) from Samalona Island, the Spermonde Archipelago (photo N.J. de Voogd). SEM images of spicules, a. regular equiangular tetractine of the chamber layer, b. 'abruptly angled' tetractines, c. 'abruptly angled' triactines, (b-c) both from the atrial region, d. small regular-shaped tetractines of the chamber layer, e. small regular-shaped triactines of the cortical region, f. giant sized tetractines, f. giant sized triactines, (f-g) both from the cortical region.

Class Demospongiae Sollas, 1885
Subclass Heteroscleromorpha Cárdenas et al., 2012
Order Clionoida Morrow & Cárdenas, 2015
Family Spirastrellidae Ridley & Dendy, 1886
Genus *Spirastrella* Schmidt, 1868

***Spirastrella* aff*. decumbens* Ridley, 1884**
Figure 2.5
Diagnostic features. A thin encrusting sponge with a soft texture and a smooth surface. The living specimens exhibit a salmon-pink or orangish color. The ectosome of the sponge contains numerous microscleres (spirasters), forming a characteristic tangential crust found in this genus. In the choanosome, the megascleres are irregularly arranged tylostyles with well-formed, generally spherical heads (Calcinai *et al.*, 2006a). The specimen shows spirasters with ornamented rays (Figure 2.5d) that not mention in Calcinai report from Vietnam.
Distribution. This species is present in the Australian region, New Caledonia, the Philippines, and Vietnam. In Indonesia is recorded from Ambon, this is first record for the Spermonde Archipelago (Langkai Island).

Order Haplosclerida Topsent, 1928
Family Callyspongiidae de Laubenfels, 1936
Genus *Callyspongia* Duchassaing & Michelotti, 1864
Subgenus *Cladochalina* Schmidt, 1870

***Callyspongia (Cladochalina) johannesthielei* van Soest & Hooper, 2020**
Figure 2.6
Diagnostic features. Massive form and hard surface with numerous cone-shaped projections raised up (lobate). Several large oscula between about 6-7 mm. Pink to red in living and pale yellow in alcohol. Skeleton is reticulate with fiber tract. This species was described as *Spinosella elegans* Thiele, 1899 (junior secondary homonym of *Callyspongia (Cladochalina) elegans* (von Lendenfeld, 1887)) of as a large cup-shaped sponge, about 30 cm high, hollow along its entire length, a light brownish color when dry and very characteristic pointed papillae, often fused into several, on the outer surface (Thiele, 1899). The Thiele species' spicules were shown as rather thin, short-tipped amphioxes that are 90-100 µm x 3-5 µm (van Soest *et al.*, 2020).
Distribution. Kema Bay (1° 23’ N - 125° 04’ E), North Sulawesi (Thiele, 1899); and North-West of Samalona Island; reef flat; attached on dead rock.

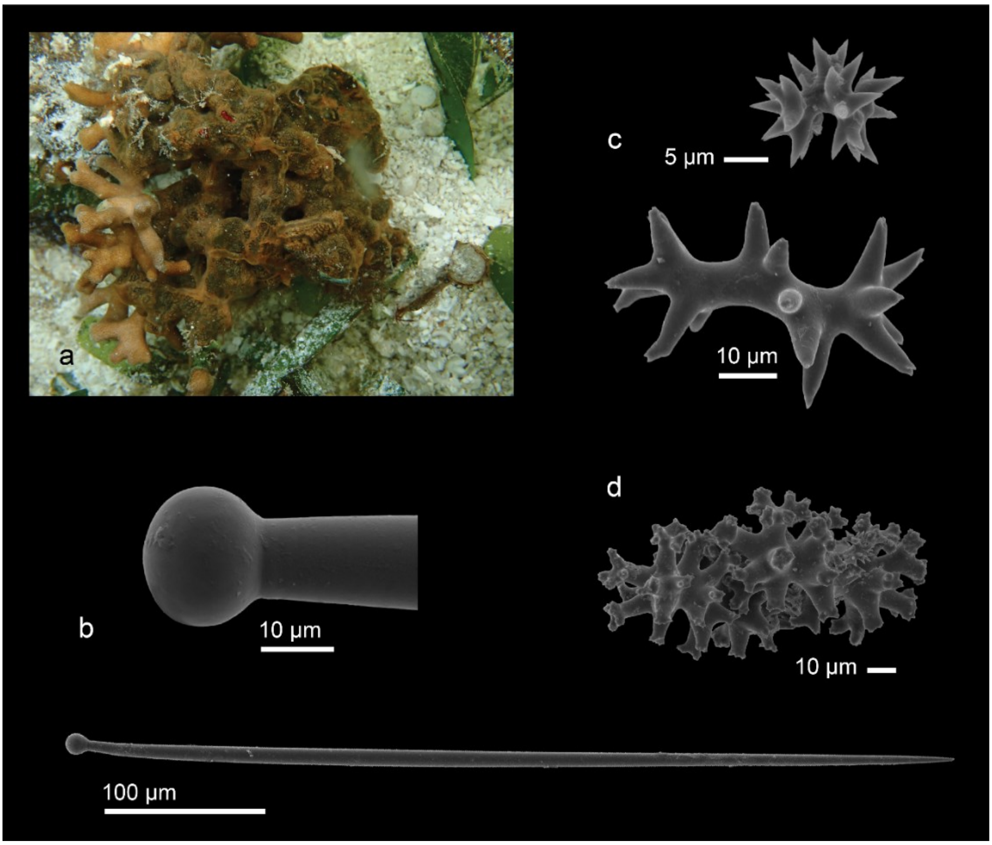

Figure 2.5. *Spirastrella* aff. *decumbens* Ridley, 1884, a. habitus *in situ* (CEL007) from seagrass bed of Langkai Island, the Spermonde Archipelago (photo N.J. de Voogd), b. SEM images of tylostyle with close up of the head, c. spirasters, d. spirasters with ornamented rays.

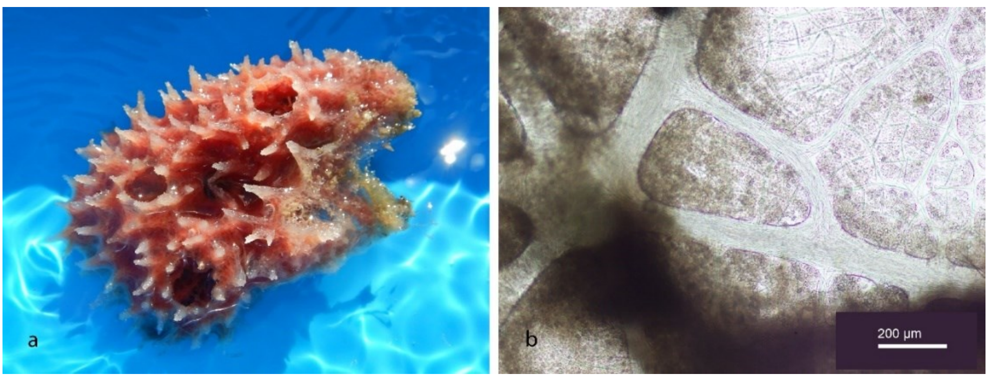

Figure 2.6. *Callyspongia (Cladochalina) johannesthielei* van Soest & Hooper, 2020, a. habitus on deck, b. skeleton.

Family Chalinidae Gray, 1867
Genus *Haliclona* Grant, 1841
Subgenus *Gellius* Gray, 1867

***Haliclona (Gellius) cymaeformis* (Esper, 1806)**
Figure 2.7
Diagnostic features. The appearance is thickly encrusting to repent and majorly arborescent (bushy). The specimen is hard and smooth on the surface, erected wide at the base with short branches. The color in life is dark greyish pink (dark purple) with desaturated dark green on tips. After preservation, the color is pale pink to yellow. Ectosomal skeleton shows unispicular tract and covering the associate branching microalgae (Figure 2.7c). Spicules are oxeas, 109-154 (129.7) x 2.3-5.2 (3.9) µm (n = 27) and microscleres are sigmas. *H. (Gellius) cymaeformis* (Esper, 1806) was abundant in turbid water near Makassar City. This species is known to be associated with the rhodophyte *Ceratodictyon spongiosum* Zanardini, 1878 (Azzini *et al.*, 2007a). Morphological appearance is possibly similar with *H. (H) cartilaginea* and *C. (C) samarensis*.
Distribution. This species has been recorded from marine karts lake from Vietnam (Azzini *et al.*, 2007a), Taiwan (Li, 2013), shallow water of South China Sea (Huang *et al.*, 2016; Lim *et al.*, 2016), Andaman (Immanuel *et al.*, 2015), India (George *et al.*, 2020), across Indonesia Archipelago (de Voogd and Cleary, 2008), and northwest Australia (Fromont and Sampey, 2014). Ous samples collected from North-West of Samalona Island, overgrowing corals (*Seriatopora* sp. and *Acropora* sp.), Kayangan Island and Gusung Tallang, turbid reef environment.

Subgenus *Reneira* Schmidt, 1862

***Haliclona (Reniera) venusta* (Bowerbank, 1875)**
Figure 2.8
Diagnostic features. Specimen form tube, soft and delicate. Color yellowish in live and yellow pale-white in alcohol. Skeleton forming isotropic reticulation of single line spicules. All spicules on this specimen are oxea, 88-109 (95.2) x 4.3-6.5 (5.7) µm (n = 20).
Distribution. WPD checklist only shows four species of subgenus *Reniera* were recorded from marine ecoregions of Indonesia with two as doubtful species, i.e., *Haliclona (Reniera) cinerea* (Grant, 1826) (doubtful species), *Haliclona (Reniera) fascigera* (Hentschel, 1912), *Haliclona (Reniera) infundibularis* (Ridley & Dendy, 1887) (doubtful species), and *Haliclona (Reniera) venusta* (Bowerbank, 1875), but none of these species registered to the Spermonde Archipelago (de Voogd *et al.*, 2022). This report registered a new record of *H. (R) venusta* (Bowerbank, 1875) from the Spermonde Archipelago (Samalona Island). Previously, this species has been only reported from Malacca Strait (Bowerbank, 1875).

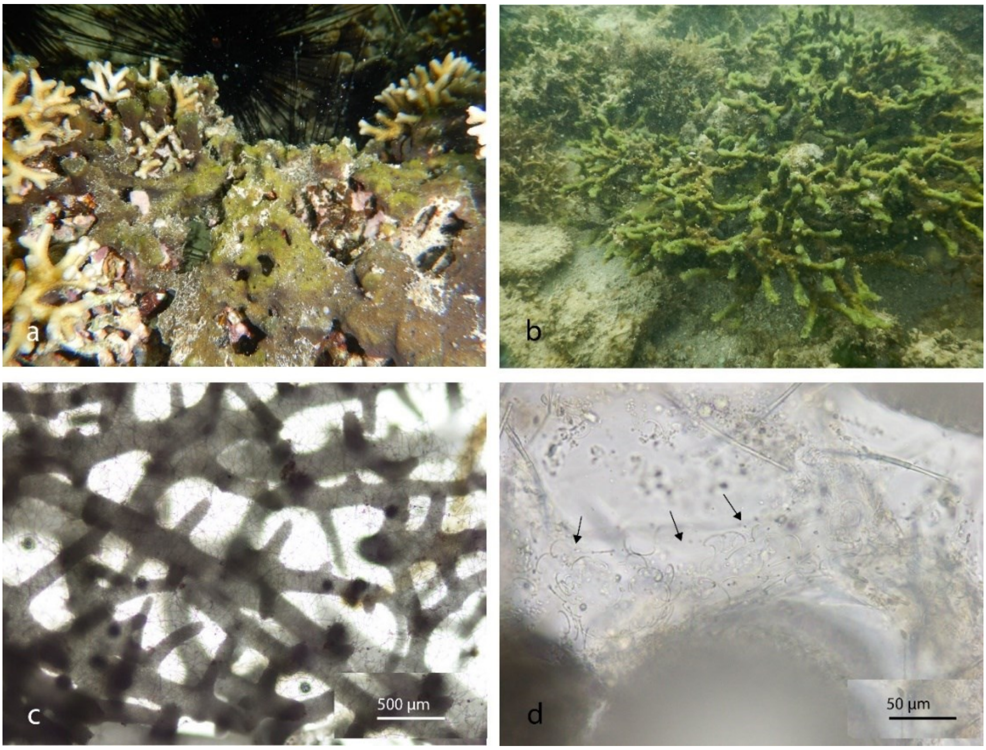

Figure 2.7. *Haliclona (Gellius) cymaeformis* (Esper, 1806), a-b. habitus *in situ* at Samalona Island and Kayangan Island (respectively), the Spermonde Archipelago, b. LM images of tangential section showing Rhodophyta symbiont, d. sigmas (arrows).

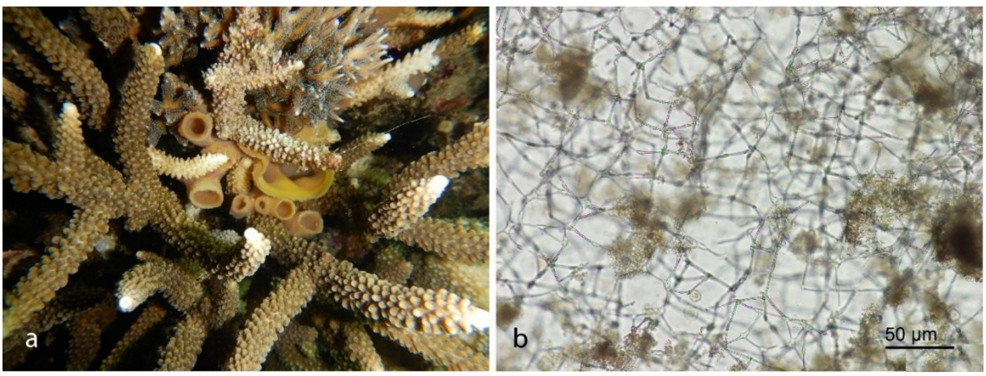

Figure 2.8. *Haliclona (Reniera) venusta* (Bowerbank, 1875), a. habitus in situ at Samalona Island, the Spermonde Archipelago, b. LM images of spicules reticulation.

Subgenus *Soestella* de Weerdt, 2000

***Haliclona (Soestella) elegantia* (Bowerbank, 1875)**

Figure 2.9 a, d, e

Diagnostic features. Small specimen (l x w x h; 46 x 34 x 30 mm) and fragile, found growing in turbid water near coastal city Makassar. Massive shape (amorphous) with large oscula (3-4 mm in diameter). Color in life is deep blue and pale white in alcohol. The choanosomal skeleton is paucispicular tracts. Spicules are oxeas, larger oxeas 163.9-196.2 (163.9) x 7-9.9 (8) µm (n = 20) and thin oxeas 92-156.1 (127.5) x 0.8-5.7 (3) µm (n = 26). Microscleres are sigmas. Subgenus *Haliclona (Soestella)* consists of 25 species, and only *H. (S.) elegantia* are registered from marine ecoregions of Indonesia (de Voogd *et al.*, 2022). This species is poorly studied. I have found no study after its original description. Bowerbank description had not included the illustration. The specimen described as small appearance and small spicules (short and stout) with light and elegant uni, bi, and tri-spiculous reticulation on the dermal structure (Bowerbank, 1875).

Distribution. Previously was recorded from Malacca Strait (Bowerbank, 1875). This is also first record for the Spermonde Archipelago (at Kayangan Island, and Gusung Tallang Island).

***Haliclona (Soestella)* sp1. nov.**

Figure 2.9 b

Diagnostic features. The specimen is fragile and shapeless (amorphous), the surface is slick and smooth, the colour in life mostly black, also in alcohol. Oscula present with 1-3 mm in diameter. The spicules arrangement is oxeas 101-162 (128.8) x 1.5-7 (4.9) µm, n = 21.

Distribution. North-West Samalona Island, reef flat.

***Haliclona (Soestella)* sp2. nov.**

Figure 2.9 c, f

Diagnostic features. Small specimen (l x w x h, 45 x 32 x 25 mm) with magenta color in live and pale white in alcohol. Massive shape with large osculum. Ectosomal skeleton shows multispicular fiber tracts. Spicules are oxea, larger oxeas 102-130.9 (116.1) x 3.8-6.5 (5) µm (n = 24) and thin oxeas 78.4-114.4 (96.8) x 1.3-4.1 (2.5) µm (n = 20). Rounded meshes formed by the spicula characterized those species as subgenus *Soestella*. But, due to different color and variation of macro-morphology they distinguished from identified species of *H. (S.) elegantia.*

Location. West Kayangan Island and Gusung Tallang Island, turbid environment.

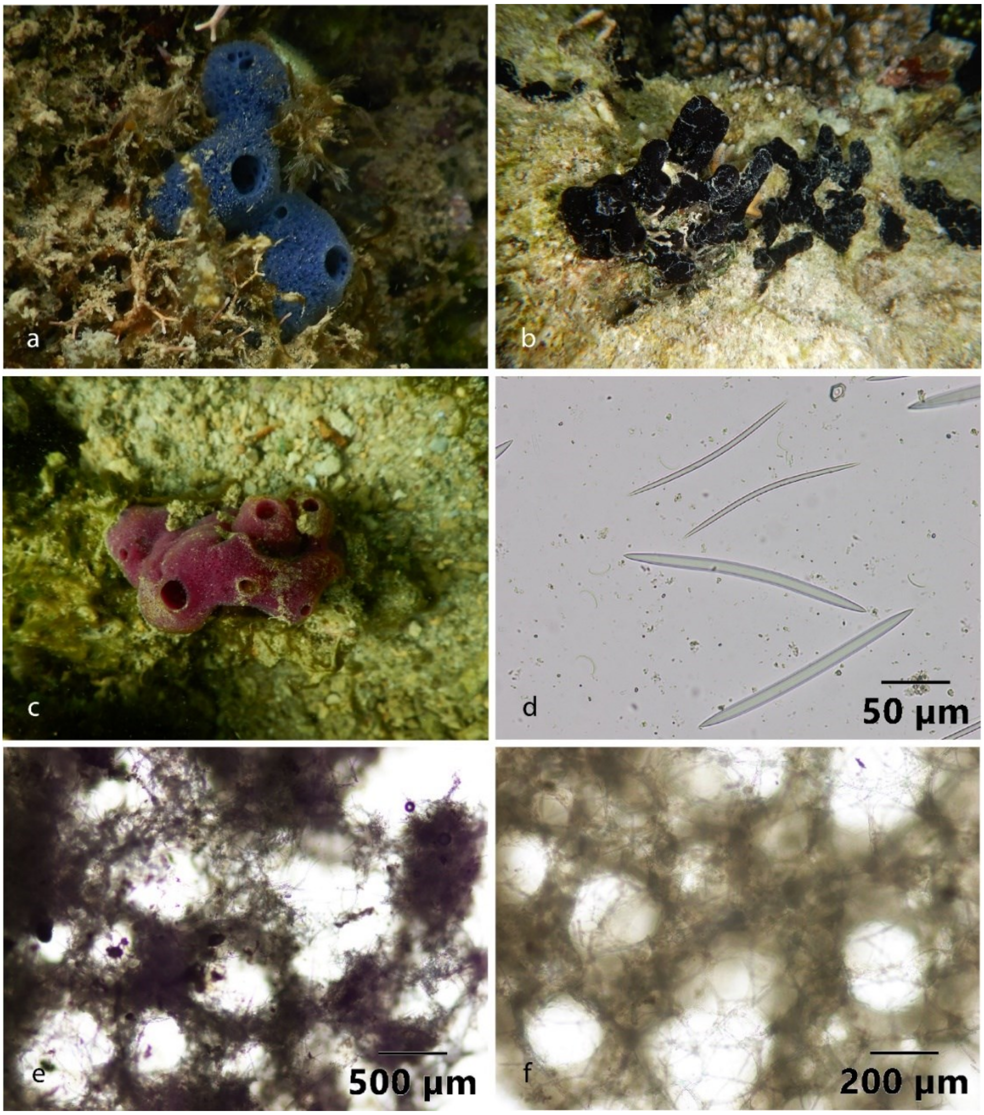

Figure 2.9. Habitus in situ, a. *Haliclona (Soestella) elegantia* (Bowerbank, 1875) at Kayangan Island, the Spermonde Archipelago, b. *Haliclona (Soestella)* sp1. nov. at Samalona Island, the Spermonde Archipelago, c. *Haliclona (Soestella)* sp2. nov. at Samalona Island, the Spermonde Archipelago (all photo by S. A. Putra), d. two sizes of oxeas. e. *Haliclona (Soestella) elegantia* spicules reticulation, f. *Haliclona (Soestella)* sp2. nov. spicule reticulation.

Family Niphatidae van Soest, 1980
Genus *Amphimedon* Duchassaing & Michelotti, 1864

***Amphimedon paraviridis* Fromont, 1993**
Figure 2.10
Diagnostic features. Encrusting and soft, with small oscula and scattered ostia on the surface. Pale green in life and turn brown in alcohol. Skeleton isotropic reticulation arranged by oxeas 155-194 (173.5) x 5.9-8.1 (7.2) µm. *Amphimedon paraviridis* has similarity with *Amphimedon viridis* Duchassaing and Michelloti, 1864 from the Caribbean Sea, where the holotype of *A. paraviridis* (from Great Barrier Reef) have thicker spicules than the Caribbean has much greater spongin component, thicker fibers, and larger mesh spaces (Fromont, 1993). Only three species of *Amphimedon* have been reported from the marine ecoregions of Indonesia (de Voogd *et al.*, 2022), including *Amphimedon anastomosa* Calcinai, *et al.*, 2017, *Amphimedon zamboangae* (Lévi, 1961), and *Amphimedon denhartoogi* de Voogd, 2003.
Distribution. Previously was reported from Australia (Fromont, 1993). This is first record of *Amphimedon paraviridis* collected from Samalona Island, the Spermonde Archipelago. Reef flat area, overgrowing other sponge *Clathria (Thalysias) reinwardti* Vosmaer, 1880.

Genus *Niphates* Duchassaing & Michelotti, 1864

***Niphates nitida* Fromont, 1993**
Figure 2.11
Diagnostic features. Repent and elongate form. Bluish green in life, pale white in alcohol. Oscules are small 2-4 mm in diameter. Ectosomal shows reticulation fiber tract. Oxea slightly curve, larger oxeas 120.3-171.3 (139.4) x 4.8-9.3 (6.1) µm (n = 22), thin oxeas 109.3-132.7 (121) x 2.4-5.3 (3.5) µm (n = 14). Microscleres are C shape sigmas. This specimen characterized as *N. nitida* due to reticulation fiber tract on the skeleton and the present of sigmas. Previously, only two species of *Niphates* recorded from Indonesia (de Voogd *et al.*, 2022). *Niphates laminaris* Calcinai *et al.*, 2017 is charachterized by a non-spiny, rather irregular, microconulose surface and chaonosomal skeleton with primary and secondary reticulation fiber tracts, also numerous microscleres (Calcinai *et al.*, 2017a). *Niphates olemda* (de Laubenfels, 1954) is tubular sponges with small oxeas (de Laubenfels, 1954). *N. nitida* is a new record for Indonesia.
Distribution. Previously was reported from Magnetic Island, Australia (Fromont, 1993). This is first record for the Spermonde Archipelago (at Kayangan Island).

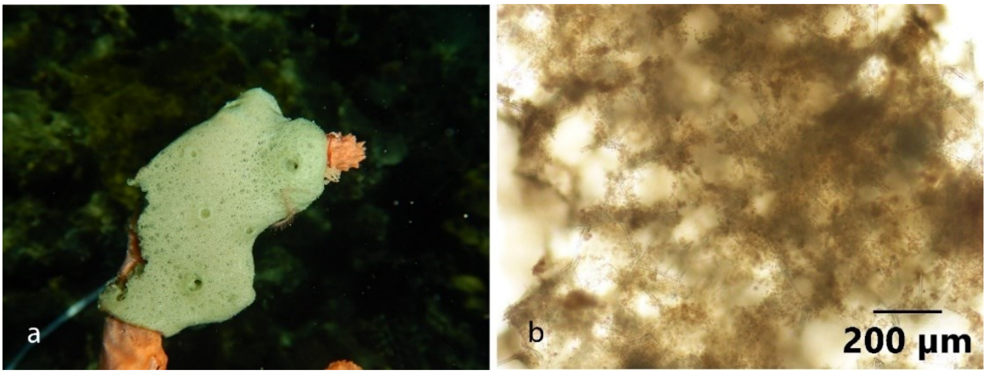

Figure 2.10. *Amphimedon paraviridis* Fromont, 1993, a. habitus *in situ* over growing *Clathria (Thalysias) reinwardti* Vosmaer, 1880 at Samalona Island, the Spermonde Archipelago, b. LM image of cross section of the skeleton shows isotropic reticulation of oxeas.

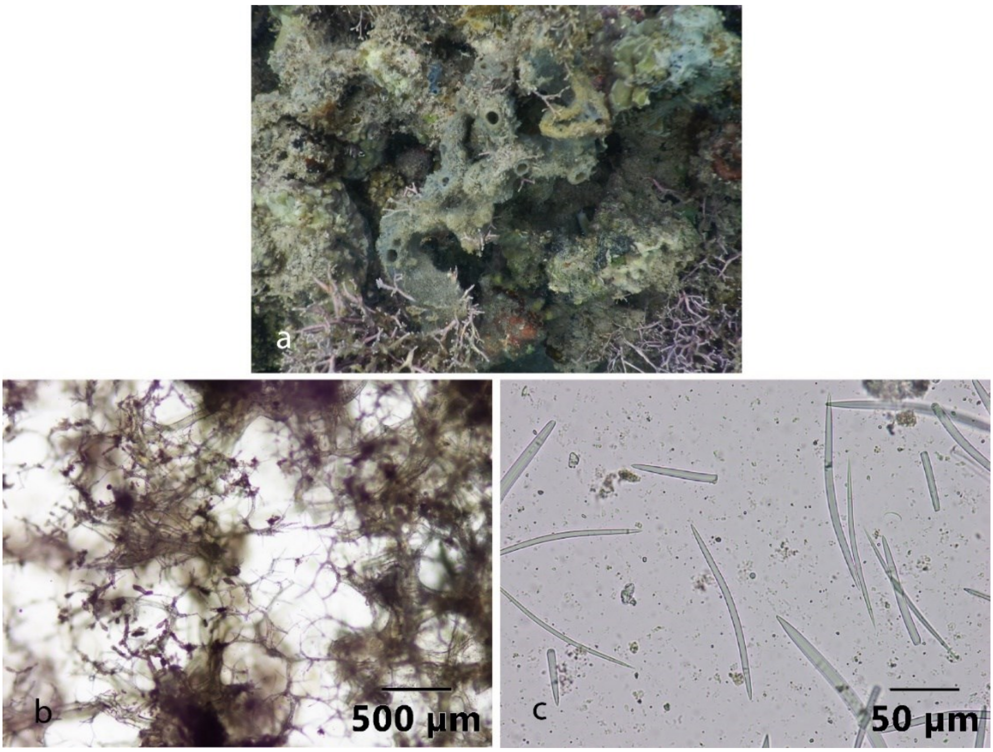

Figure 2.11. *Niphates nitida* Fromont, 1993, a. habitus in situ at Kayangan Island, b. ecotosmal skeleton, c. spicules.

Family Petrosiidae van Soest, 1980
Genus *Petrosia* Vosmaer, 1885
Subgenus *Petrosia* Vosmaer, 1885

***Petrosia (Petrosia) hoeksemai* de Voogd & van Soest 2002**
Figure 2.12
Diagnostic features. The sponge is thick, massive, and encrusting with rugose surface. Color brown outside, cream inside, and turn blackish brown after preserved. Choanosomal skeleton shows pauci-multispicular spicule tracts. Three sizes of oxeas, primary oxeas 182.3-272.9 (219.6) x 10.8-19.2 (14.6) µm (n = 28), secondary oxeas 126.4-221.7 (173.6) x 6.7-11.4 (8.7) µm, n = 32, and tertiary oxeas 58-123.9 (83.1) x 5.6-10.5 (7.5) µm (n =28). Seven species of *Petrosia* have been reported from the Spermonde Archipelago, i.e., *Petrosia (Petrosia) hoeksemai* de Voogd & van Soest, 2002, *Petrosia (Petrosia) alfiani* de Voogd & van Soest, 2002, *Petrosia (Petrosia) lignosa* Wilson, 1925, *Petrosia (Petrosia) nigricans* Lindgren, 1897, *Petrosia (Petrosia) plana* Wilson, 1925, *Petrosia (Strongylophora) cortica* (Wilson, 1925), *Petrosia (Strongylophora) strongylata* (Thiele, 1903), two species are originally description from this area (de Voogd and van Soest, 2002), i.e., *Petrosia (Petrosia) alfiani* and *Petrosia (Petrosia) hoeksemai*. The specimen here shows slightly bigger secondary dan tertiary oxeas compare to de Voogd & van Soest (2002) specimen. Comparison of spicules measurement between Indonesian *Petrosia* specimen shows on Table 2.1.

Table 2.1. Comparison of spicule measurements (µm) in specimens of *Petrosia (Petrosia)* and *Petrosia (Strongylophora)* from Indonesia (de Voogd and van Soest, 2002).

Species	**Oxea/ Strongyles 1**	**Oxea/ Strongyles 2**	**Oxea/ Strongyles 3**	**References**
Petrosia (Petrosia) hoeksemai	182.3-272.9 x 10.8-19.2	126.4-221.7 x 6.7-11.4	58-123.9 x 5.6-10.5	This study
Petrosia (Petrosia) hoeksemai	240-305 x 10-20	90-130 x 7-12	40-75 x 5-9	(de Voogd and van Soest, 2002)
Petrosia (Petrosia) alfiani	183-253 x 10-15	106-153 x 7-14	60-70 x 6-7	(de Voogd and van Soest, 2002)
Petrosia (Petrosia) lignosa	230-300 x 14-18	75-150 x 10-13	35-65 x 7-10	(de Voogd and van Soest, 2002)
Petrosia (Petrosia) nigricans	240-305 x 8-16	120-188 x 9-10	57-85 x 5	(de Voogd and van Soest, 2002)
Petrosia (Petrosia) plana	190-290 x 7-14	95-130 x 7-9.5	43-75 x 5-9	(de Voogd and van Soest, 2002)
Petrosia (Strongylophora) cortica	300-360 x 11-14	80-200 x 11-14	21-50 x 3-9	(de Voogd and van Soest, 2002)
Petrosia (Strongylophora) strongylata	326 x 18	95-145 x 10-12	44-60 x 8-12	(de Voogd and van Soest, 2002)

Distribution. Samalona Island, the Spermonde Archipelago, attached vertically, reef flat; also reported from North Sulawesi (de Voogd and van Soest, 2002).

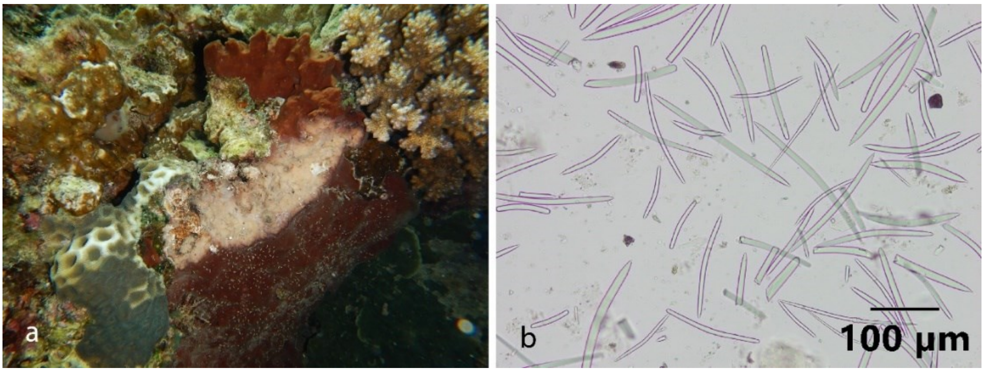

Figure 2.12. *Petrosia (Petrosia) hoeksemai* de Voogd & van Soest, 2002, a. habitus in situ at Samalona Island, the Spermonde Archipelago, b. oxeas.

Order Poecilosclerida Topsent, 1928
Family Coelosphaeridea Dendy, 1922
Genus *Lissodendoryx* Topsent, 1892
Subgenus *Waldoshmittia* de Laubenfels, 1936

***Lissodendoryx (Waldoschmittia) schmidti* (Ridley, 1884)**
Figure 2.13
Diagnostic features. According to Hofman & van Soest (1995), ectosome is tangentially arranged tylotes and ascending bundles in plumose arrangement. Main skeleton is an irregular reticulation of oxeas, with triangular meshes of spicules. Microscleres are isochelas and sigmas (Hofman and van Soest, 1995).
Distribution. This species also known from mesophotic zone. Previously recorded from Cochin-China, East Africa, Hawaii, Read Sea, Syechelles, and South Australia. In part of Indonesia was recorded from Ternate, Banda Sea, Aru Island (Arafura Sea), Flores, Jedan Island, East Java, Sumba (Hofman and van Soest, 1995). This specimen is first record for the Spermonde Archipelago.

Family Iotrochotidae Dendy, 1922
Genus *Iotrochota* Ridley, 1884

***Iotrochota baculifera* Ridley, 1884**
Figure 2.14
Diagnostic features. Black, thin, encrusting with rough surface, and boring. Choanosomal skeleton show multispicular reticulation. Spicule arrangements are styles 157.9-212.5 (191.7) x 7.4-15.9 (11.4) µm (n = 25), strongyles 248-287.6 (266.6) x 3.6-7.8 (6.7) µm (n = 25), with microsclere birotulate chelae, 13.9-17.3

(15.4) µm (n=21). *I. baculifera* have similar coloration with *I. purpurea* and *Iotrochota nigra* (Baer, 1906). Table 2.2 shows comparison of the spicule measurements within these species from several studies (Ridley, 1884b; Baer, 1906; Bergquist, 1965; Thomas, 1973; Thomas, 1991; Núñez Pons *et al.*, 2017; Samaai *et al.*, 2019).

Distribution. Widespread from West Indian Ocean to Hawaii (Núñez Pons *et al.*, 2017). Only two species of *Iotrochota* have been recorded from Spermonde Archipelago, *Iotrochota baculifera* Ridley, 1884 and *Iotrochota purpurea* (Bowerbank, 1875) (de Voogd, 2005). This current study specimen found in the North-West of Samalona Island; reef flat.

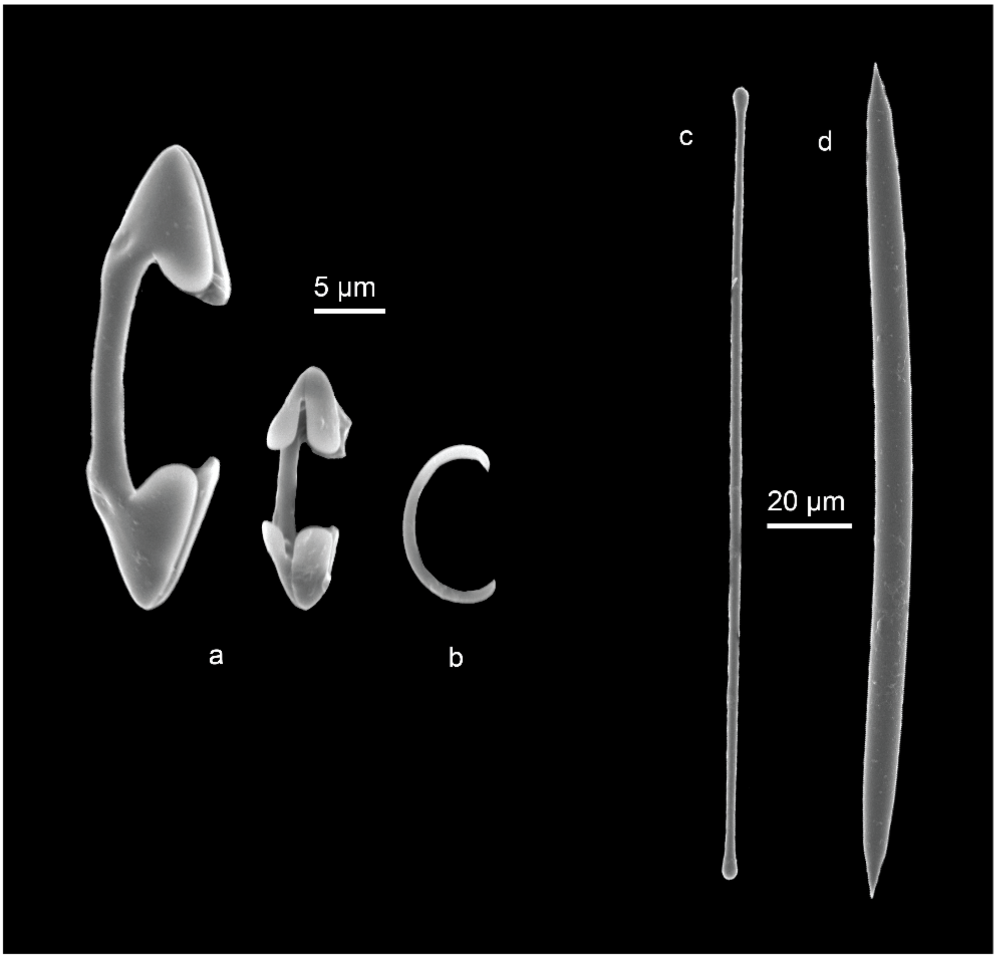

Figure 2.13. *Lissodendoryx (Waldoschmittia) schmidti* (Ridley, 1884) (CEL079), a. SEM images of isochelae, b. sigma, c. tylote, and d. oxea.

Table 2.2. Comparison of spicule measurements (µm) in specimens of *Iotrochota baculifera*, *Iotrochota pupurea,* and *Iotrochota nigra*.

Species	Styles	Strongyles	Birotulates	References
I. baculifera	157.9-212.5 (191.7) x 7.4-15.9 (11.4)	248-287.6 (266.6) x 3.6-7.8 (6.7)	13.9-17.3	This study
I. baculifera	200 x 9.5-12.7	220-280 x 6.3	16	(Ridley 1884)
I. baculifera	125-180 x 5.5-7.5	225-255 x 3.5-5	13-16.5	(Bergquist 1965)
I. baculifera	168-189 (175) x 4-8 (6)	201-243 (225) x 4-6 (4)	12	(Thomas 1973)
I. baculifera	145-170 (160) x 5-8.7 (7.5)	205-230 (220.9) x 2.5-5 (4)	12	(Núñez Pons et al. 2017)
I. purpurea	146-180(163) x 4-8(5)	-	16	(Thomas 1973)
I. purpurea	168x8	-	-	(Thomas 1991)
I. nigra	170 x 6	-	-	(Baer 1906)
I. nigra	230-269 (251) x 5 (5)	163-193(184) x 7(7)	17(17)	(Samaai et al. 2019)

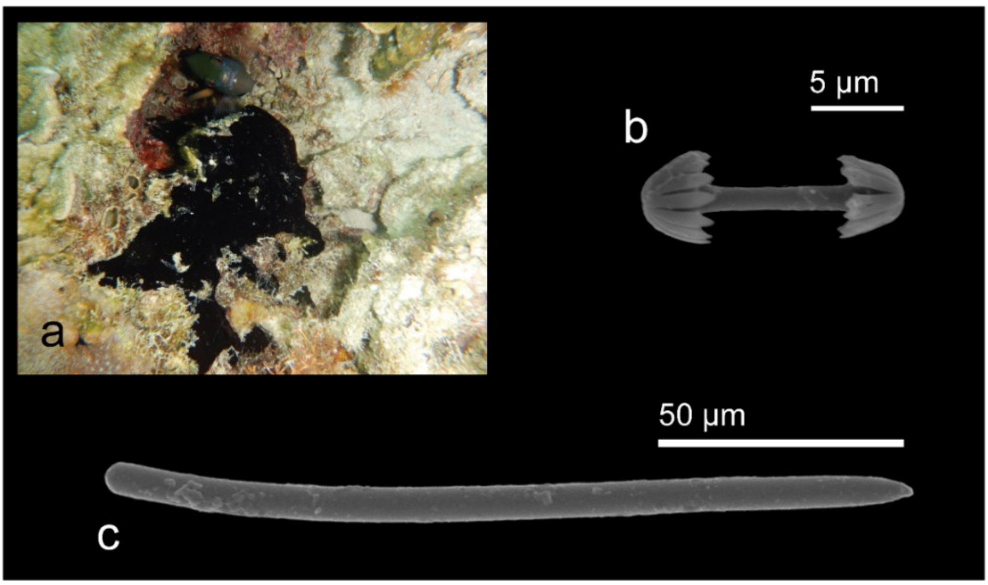

Figure 2.14. *Iotrochota baculifera* Ridley, 1884, a. habitus in situ at Samalona Island, the Spermonde Archipelago (photo by S. A. Putra), b. birotulate chelae, and c. styles.

Family Microcionidae Carter, 1875
Genus *Clathria* Schmidt, 1862
Subgenus *Thalysias* Duchassaing & Michelotti, 1864

***Clathria (Thalysias) reinwardti* Vosmaer, 1880**
Figure 2.15
Diagnostic features. Elongate, branching, and majorly repent appearance with many small oscula. Bright to dark orange in living, and brown in alcohol. Reticulate skeleton with two class size of styles and echinating acanthostyles. Principal styles slightly curve with strongylote point, 151-312 (205.5) x 5.3-10.85 (7.4) µm (n=28), auxiliary tyles straight and slightly curve, 72-163 (106.5) x 1.5-4.7 (3.4) µm (n=37), and enchinating acanthostyle short and rounded point with heavies' spines on point and base, 51.9-81.5 (67.1) x 6.2-8.7 (7.3) µm (n=31). This species can be differentiated form other similar *Thalysias* by its characteristic acanthostyle morphology, growth form, size and geometry of toxas, including ectosomal-subectosomal features (Hooper, 1996). Hooper specimen shows microscleres as palmate isochelae in two size classes and oxhorn toxas.
Distribution. Central Indian Ocean (Thomas, 1986), Indo-Pacific (van Soest, 1990; Lim *et al.*, 2016), and Australia (Hooper, 1996). Commonly found in coral rubble or dead coral and hard substrate. This current study specimen found in the North-West of Samalona Island, reef flat and Gusung Tallang, turbid reef.

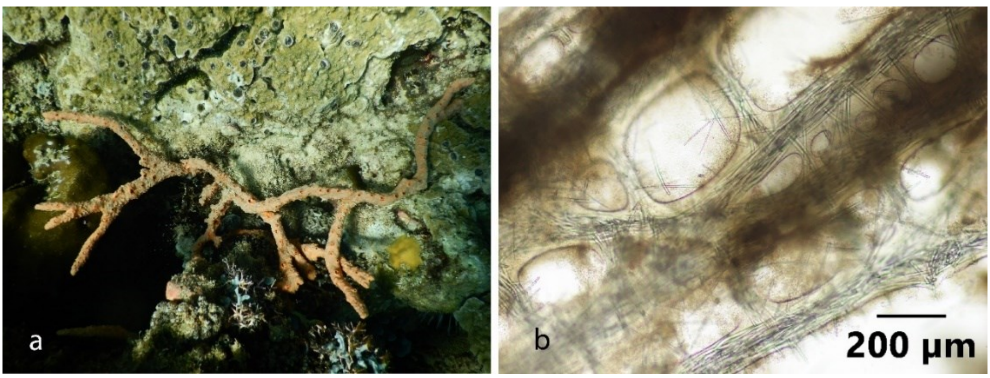

Figure 2.15. *Clathria (Thalysias) reinwardti* Vosmaer, 1880, a. habitus in situ at Samalona Island, the Spermonde Archipelago (photo by S. A. Putra), b. longitudinal section of the skeleton.

Order Scopalinida Morrow & Cárdenas, 2015
Family Scopalinidae Morrow *et al.,* 2012
Genus *Stylissa* Hallmann, 1914

***Stylissa massa* (Carter, 1887)**
Figure 2.16 a
Diagnostic features. Massive, soft, and friable with rough surface and medium oscula appear on top of the ridge. Yellow-orange in life and turn brown in alcohol. Spicules arrangement are styles, strongyle.
Distribution. *S. massa* is widely distributed in Indo-Pacific (Erpenbeck *et al.*, 2017). Since *S. massa* distribution are known to be widespread, recent study with molecular technique shows probability of distinct cryptic lineages of this species in Indo-Pacific (Erpenbeck *et al.*, 2017). Location: South-West of Samalona Island, reef flat, attached to rubbles and dead coral skeletons.

Order Suberitida Chombard & Boury-Esnault, 1999
Family Halichondriidae Gray, 1867
Genus *Halichondria* Fleming, 1828
Subgenus *Halichondria* Fleming, 1828

***Halichondria (Halichondria) cartilaginea* (Esper, 1797)**
Figure 2.16 b
Description. Arborescent and sometimes massive-creeping growth form with upright branches. The branches are irregular, forming mats that cover the substrate. The color is bright green, and the texture is flexible/cartilaginous. This species lives in association with Chlorophyta *Cladophoropsis vaucheriiformis* (Areschoug) Papenfuss, 1958 (van Soest, 1990). Spicules are only oxeas, 125.46-252.45 (197.40) x 4.03-7.40 (5.25) µm (n=20).
Distribution. Currently this species was recorded from China, Vietnam, Malacca Strait, Banda Sea, and East African Coral Coast. According to WPD checklist, this is first record from the Spermonde Archipelago.

Genus *Topsentia* Berg, 1899

***Topsentia indica* Hentschel, 1912.**
Figure 2.17
Description. Only two species of *Topsentia* distributed in Indonesia, i.e., *Topsentia dura* (Lindgren, 1897), *Topsentia indica* Hentschel, 1912, one of them had further illustrations and spicule measurements provided by previous study (Alvarez and Hooper, 2011). These species are massive, of hard consistency with skeletons made of a confused mass of oxeas of similar dimensions, not clearly differentiated into size classes. The current study specimen shows similar characteristics with Hentschel specimen (Hentschel, 1912).

Distribution. Previously recorded from Aru Islands. This is first record from the Spermonde Archipelago.

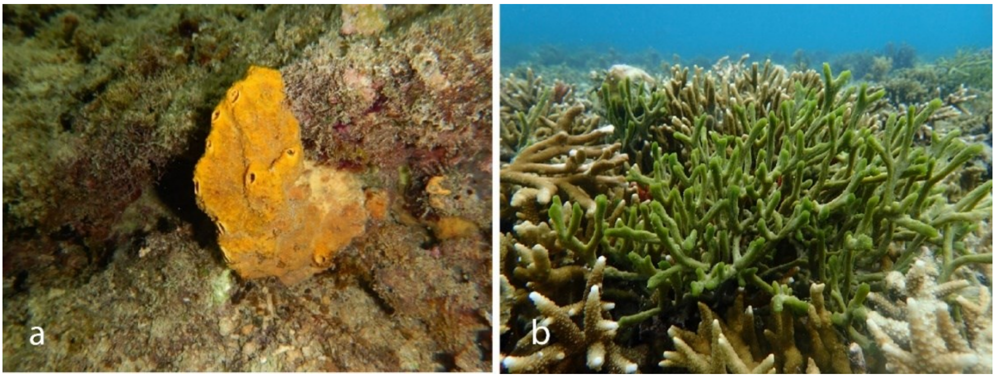

Figure 2.16. Habitus in situ, a. *Stylissa massa* (Carter, 1887) at Samalona Island, the Spermonde Archipelago (photo by S.A. Putra), and b. *Halichondria (Halichondria) cartilaginea* (Esper, 1797) (CEL025), (photo by N.J. de Voogd).

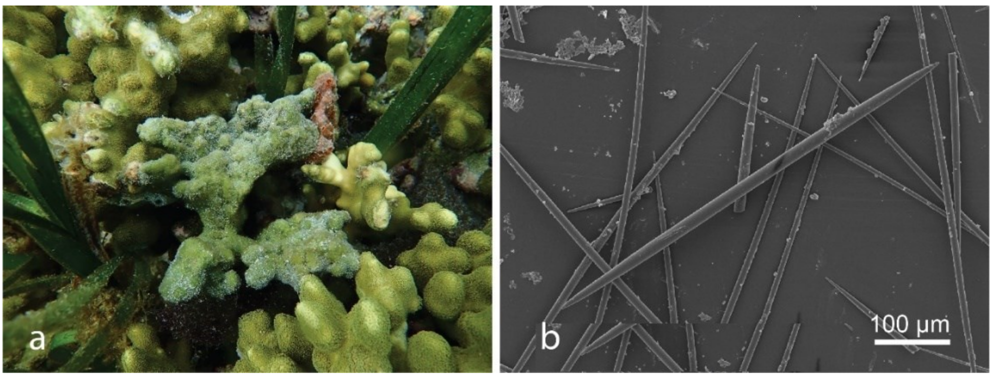

Figure 2.17. *Topsentia indica* Hentschel, 1912, a. habitus in situ at Langkai Island, the Spermonde Archipelago (photo by N.J. de Voogd), b. SEM images of the spicules.

Family Suberitidae Schmidt, 1870
Genus *Suberites* Nardo, 1833

***Suberites* sp. nov.**
Figure 2.18 a
Diagnostic features. Ficiform with orange (almost red) color and fragile. Oscula found on top of the fig-like shape. Aquiferous network can be seen from ectosomal skeleton of living specimen, small ostia also visible. Spicules are tylostyles (total length x width) 204.3-324.5 (278.4) x 3.5-8.6 (5.5) µm (n=31). Tylostyle heads are oval shape with indistinct neck (head length x head width x neck width) 8.8-15.9

(12.3) x 4.2-8.8 (6) x 3.2-8 (4.5) µm (n=25). Only three *Suberites* species have been recorded from Indonesia, *Suberites radiatus* Kieschnick, 1896, *Suberites diversicolor* Becking & Lim, 2009, including deep-sea *Suberites perfectus* Ridley & Dendy, 1886 (Becking and Lim, 2009; de Voogd *et al.*, 2022).
Distribution. North-West of Samalona Island, reef flat, scattered across shallow water area, growth on dead rock, plastic PVC, and sometimes competing with Scleractinian.

Genus *Terpios* Duchassaing & Michelotti, 1864

***Terpios hoshinota* Rützler & Muzik, 1993**
Figure 2.18 b
Diagnostic features. Thin (< 1 mm thick), encrusting, and excavating form overgrowing host coral skeletons (*Acropora* sp.). Dark grey to black, sometime light grey in the upper surface. Original description of *T. hoshinota* show spicules as only tylostyles (Rützler and Muzik, 1993). In this study spicules arrangements are tylostyles (total length x width) 132.9-252 (206.9) x 2.6-7.8 (4.4) µm (n=52), and variation of heads (head length x head width x neck width) 3.7-7.4 (5.4) x 4.8-9 (6.5) x 1.8-5 (3.3) µm (n=27). Spicule dimension measurement comparison show on Table 2.3. The morphology of *T. hoshinota* is similar to *Terpios granulosus* Bergquist, 1967 from Hawaiian reefs. The difference is this species is greyish brown, lobed head tylostyles, and has a cyanobacterial symbiont (Rützler and Muzik, 1993). This species known as a coral-killing sponge, but recently study shows *T. hoshinota* could be also grown on glass slide, plastic sheets, and rubber tires. The competency interaction with the coral host is only for substrate rather than food or nutrients (Syue *et al.*, 2021).

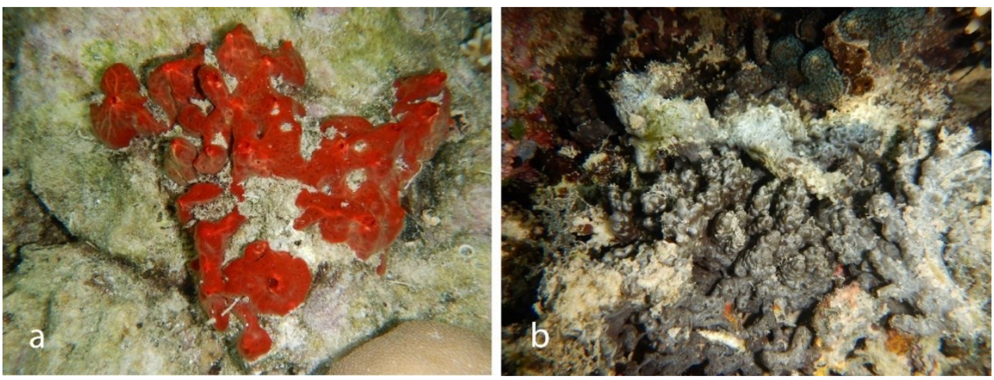

Figure 2.18. Habitus in situ, a. *Suberites* sp. nov., and, b. *Terpios hoshinota* Rützler & Muzik, 1993 (photo by S.A. Putra).

Distribution. North-West of Samalona Island, reef flat, overgrowing branching *Acropora* sp. This species has been recorded widespread from North-western Pacific, Indian Ocean, and Australia (Fromont *et al.*, 2019). *T. hoshinota* originally described from the Ryukyu Archipelago, Japan (North-west Pacific).

Table 2.3. Spicule (tylostyles) dimensions (µm) comparisons for *Terpios hoshinota*.

Total length	Shaft width	Neck width	Head width	Head length	Reference
132.9-252 (206.9)	2.6-7.8 (4.4)	1.8-5 (3.3)	4.8-9 (6.5)	3.7-7.4 (5.4)	This study
180-290 (251.6)	3-4 (3.5)	2-3 (2.7)	5.5-7 (6.1)	4.5-6 (5.2)	(Rützler & Muzik 1993)

Order Tetractinellida Marshall, 1876
Family Ancorinidae Schmidt, 1870
Genus *Ecionemia* Bowerbank, 1862

***Ecionemia acervus* Bowerbank, 1862**
Figure 2.19
Description. Massive or thickly encrusting sponges without a distinct cortex. Megascleres are triaenes of different types and large oxeas. Microscleres include spiny microrhabds in addition to euasters. Microrhabds usually form a dermal layer (Uriz, 2002).
Distribution. West Pacific, Indian Ocean, Indo-Pacific, Australia, New Zealand. This species is common in the Indo-Pacific (Uriz, 2002).

Family Geodiidae Gray, 1867
Genus *Geodia* Lamarck, 1815

***Geodia* sp. nov.**
Figure 2.20
Diagnostic features. Twelve species of *Geodia* spp. was described from Indonesia (de Voogd *et al.*, 2022). The current study specimen has oxeas; 1079.43-1820.54 (1507.20) x 18.17-33.67 (25.21) µm (n=11), dichotriaene, anatriaene, protriaene, sterrasters; width, 49.05-77.40 (59.98) µm (n=20), strongylasters, and oxyasters. Further analysis is needed to examine and give a new name to this specimen.
Distribution. This group is distributed across Indonesia, i.e., Halmahera, Arafura Sea, Southern Java, Sunda Shelf/Java Sea, Banda Sea, Palawan/North Borneo (Sollas, 1888; Kieschnick, 1896; Topsent, 1897; Lindgren, 1898; Thiele, 1900; von Lendenfeld, 1903; Hentschel, 1912; Wilson, 1925; van Soest *et al.*, 2020).

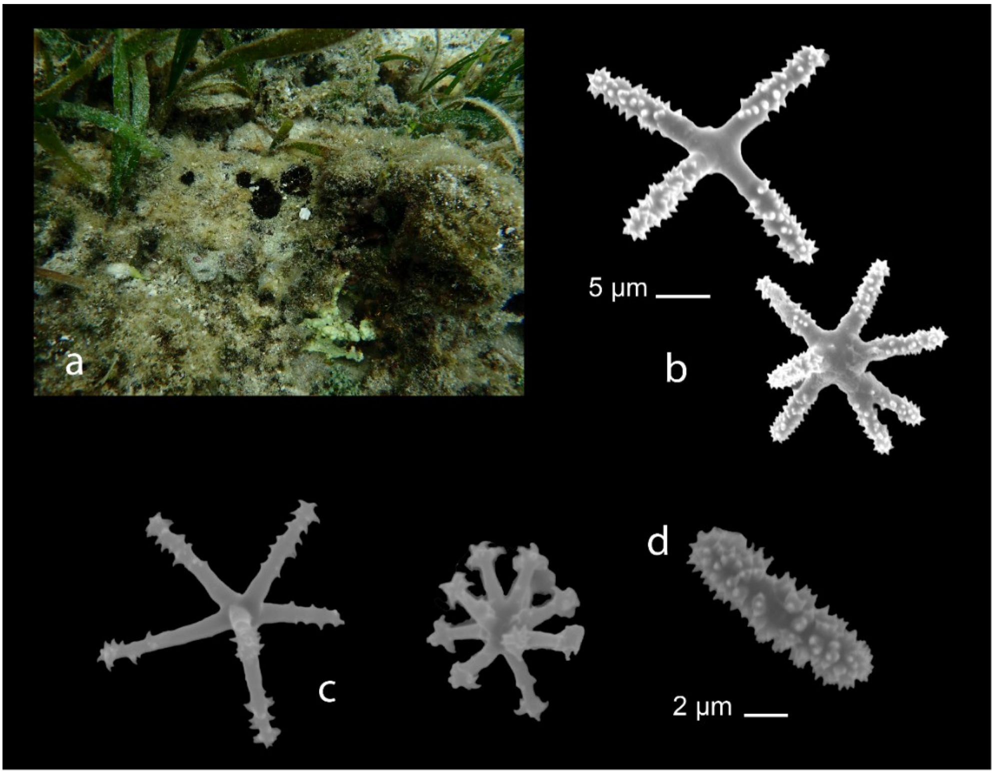

Figure 2.19. *Ecionemia acervus* Bowerbank, 1862, a. habitus in situ at Langkai Island, the Spermonde Archipelago (photo by N.J. de Voogd) (CEL016), and SEM images of spicules, b-c. somal chiasters/ strongylasters, d. cortical rough microrhabds/ microstrongyle.

Family Tetillidae Sollas, 1886
Genus *Paratetilla* Dendy, 1905

***Paratetilla bacca* (Selenka, 1867)**
Figure 2.21 a
Diagnostic features. Globular sponges, specimen approx. 64 x 47 mm (l x w) in diameter. Porocalices are abundant circular to oval apertures. Color generally bright yellow alive with brownish appearance in situ due to algae and sediment cover. Skeleton composed of oxea and triaenes radiating from a central core. Megascleres are oxeas, anatriaenes, and calthrops-like. Microscleres are sigmaspires, C - S shape. A complete redescription of *P. bacca* was described recently (Santodomingo and Becking, 2018). This species had a considerable variation in spicules sizes among the different localities and significant intra-specific variation. This variation could be a response to different environmental conditions, a consequence of genetic selection, or synergetic between ecological and genetic factors.

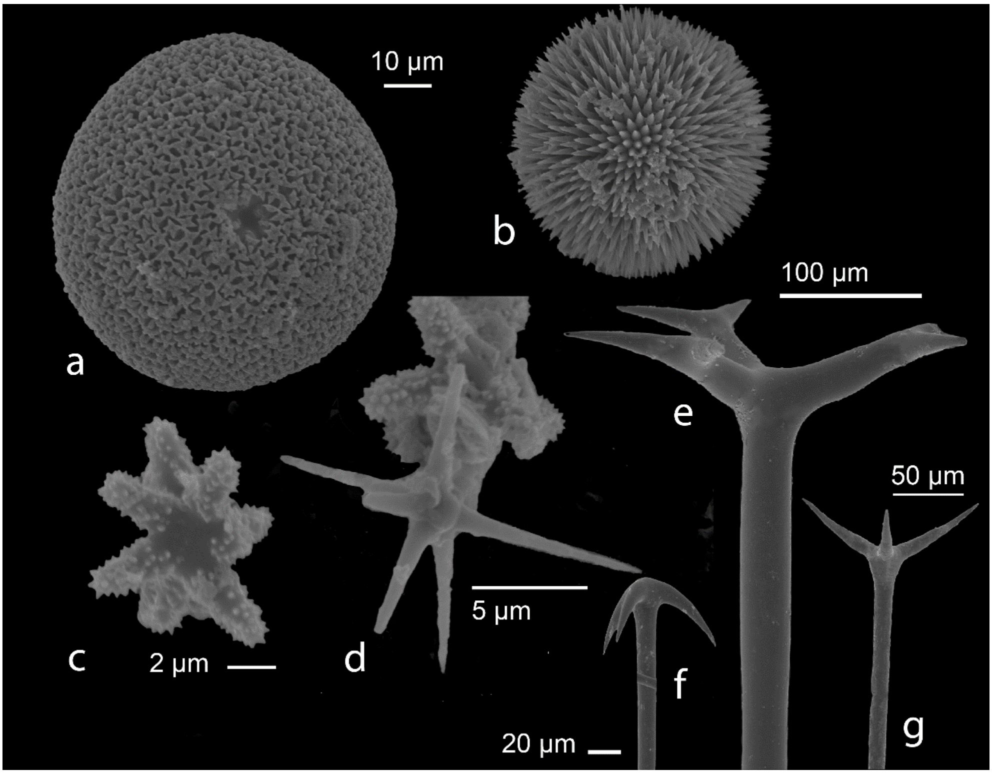

Figure 2.20. SEM images of spicules of *Geodia* sp. nov. (CEL174), a-b. Sterrasters (b. developmental stage), c. strongylaster, d. oxyaster attached to strongylasters, e. dichotriaene, f. anatriaene, g. protriaene.

Distribution. Seychelles Islands (Thomas, 1973), Southwest Madagascar (Vacelet *et al.*, 1976), Zanzibar (Pulitzer-Finali, 1993), Thailand (Putchakarn, 2007), Singapore (Lim *et al.*, 2012b), Philippines (Longakit *et al.*, 2005), Indonesia (Santodomingo and Becking, 2018). According to Santodomingo & Becking (2018), this species distribution is common in Indonesia also located in the Spermonde Archipelago.

Subclass Keratosa Grant, 1861
Order Dictyoceratida Minchin, 1900
Family Dysideidae Gray, 1867
Genus *Lamellodysidea* Cook & Bergquist, 2002

***Lamellodysidea herbacea* (Keller, 1889)**
Figure 2.21 b
Diagnostic features. Life specimen found in white to light green color, and grey after preserved. This species habitus is soft, fragile, slick, thin (<1 cm thick), and encrusting basal plate with complex labyrinthine wall-like pattern or papillate.

Skeleton structure forming interconnected reticulate fibers with several adjacent spicules. Various of microsymbionts (cyanobacteria) are found inhabiting. Currently there only two species of *Lamellodysidea*, i.e., *L. herbacea* (Keller, 1889) and *L. chlorea* (de Laubenfels, 1954). They both are confused to each other. *L. herbacea* is known to be common in the sub-intertidal zone of the coral reef, which is exposed to sunlight (Putchakarn, 2007). Molecular analysis shows *L. herbacea* is a diverse group and consists of several distinct lineages of the alleged single species, and probably misidentified in the past between undescribed lineages due to its superficially resemble (Erpenbeck *et al.*, 2012).

Distribution. Red Sea (Row, 1911), India (George *et al.*, 2020), Thailand (Putchakarn, 2007), The Spermonde Archipelago (de Voogd *et al.*, 2006a), and Great Barrier Reef – Australia (Hooper, 2008). **Family Irciniidae Gray, 1867**

Genus *Ircinia* Nardo, 1833

***Ircinia schulzei* (Dendy, 1905)**

Figure 2.21 c

Diagnostic features. Specimen attached to hard substrate as digitate or cylindrical with irregular short or club-shaped branches and rugose surface. Color in life is light green and pale white in alcohol. Small oscula are found in every branch, sometimes on the tip. Skeleton is laminated fiber. Irciniidae Gray, 1867 is massive, or occasionally encrusting sponges, which display a wide range of forms, e.g., caliculate, lamelliform, lobate, and digitate. The genera of *Ircinia* possess pithed and laminated with primary and secondary fibers (de C. Cook and Bergquist, 1999).

Distribution. First description from Ceylon or Sri Lanka (Dendy, 1905). Also recorded from Papua New Guinea (Pulitzer-Finali and Pronzato, 1999). *I. schulzei* first description is from Ceylon, Sri Lanka (Dendy, 1905). A previous record from Papua New Guinea (Pulitzer-Finali and Pronzato, 1999) and new record in the Spermonde Archipelago shows this species could be widespread in Indo-Pacific region. The current study specimen found living between anemone and other sponges on top of dead rock in the reef flat of North-West of Samalona Island.

Family Thorectidae Bergquist, 1978

Genus *Phyllospongia* Ehlers, 1870

***Phyllospongia foliascens* (Pallas, 1766)**

Figure 2.21 d

Diagnostic features. Specimen form is foliaceous and irregular flabellate branches, pale white colour in life and preserved, and less than 0.5 mm thick. Numerous small oscula (< 1 mm) are scattered in the surface. Skeleton consist of reticulate fibers interconnected. This species is recently transferred from genus *Carteriospongia* Hyatt, 1877 due to the result of molecular phylogenetic analysis shows *C. foliascens* as a clade member of *Phyllospongia bergquistae* Abdul Wahab & Fromont, 2020. The original diagnosis described a verrucose surface is characteristic for *P. foliascens*, then fine and meandering surface patterning for *P. bergquistae* (Bergquist *et al.*, 1988; Abdul Wahab *et al.*, 2020). *P. foliascens* is phototrophic species that mainly rely on their symbiotic cyanobacteria for nutrient cycle. This species also enables to endure high energy of environments (Cleary *et al.*, 2005).

Distribution. Numerous individuals were found during survey. *P. foliascens* is widely distributed and high density in the Spermonde Archipelago (de Voogd *et al.*, 2006a). The current study specimen found at South-West of Samalona Island, reef flat; Gusung Tallang, turbid reef. This species has been recorded from shallow water of Red Sea, Indian Ocean, Easter to Western Australia, and Fiji (Abdul Wahab *et al.*, 2020).

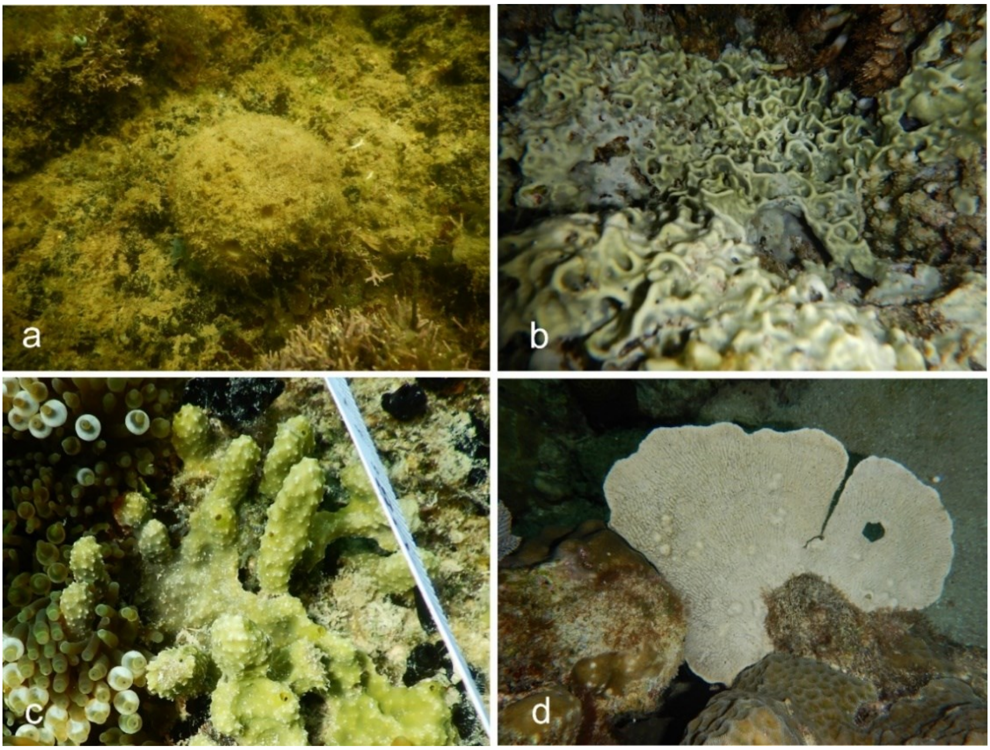

Figure 2.21. Habitus in situ photographs (photos by S.A. Putra), a. *Paratetilla bacca* (Selenka, 1867) at Gusung Tallang, b. *Lamellodysidea herbacea* (Keller, 1889), c. *Ircinia schulzei* (Dendy, 1905), d. *Phyllospongia foliascens* (Pallas, 1766).

2.5. Discussions

Twenty-seven species of marine sponges (Class Calcarea and Demospongiae) have been identified from the peripheral area of the Spermonde Archipelago, Indonesia. The Order Haplosclerida, with nine species, dominates this type of habitat. According to the WPD checklist, some of the sponges found here, such as *Clathrina rodriguesensis, Amphimedon paraviridis, Niphates nitida*, and *Ircinia schulzei*, are newly recorded for Indonesia. Several others are new records for the SS/MS marine ecoregion, including *Janusya tubuloreticulosa, Spirastrella* aff*. decumbens, Haliclona (Reniera) venusta, Haliclona (Soestella) elegantia, Lissodendoryx (Waldoschmittia) schmidti, Halichondria (Halichondria) cartilaginea*, and *Topsentia indica* (see Appendix 2.3). Four potentially new species to science are also preliminarily described, i.e., *Haliclona (Soestella)* sp1. nov., *Haliclona (Soestella)* sp2. nov., *Suberites* sp. nov., *Geodia* sp. nov. Therefore, further examination and registration of voucher specimens are needed to accurately describe all the species.

In relation to extreme habitats, several species such as *Pyllospongia foliascens, Stylissa massa, Clathria (Thalysias) reinwardti*, and *Haliclona (Gellius) cymaeformis*, are frequently found in this habitat. For instance, the foliose sponge *P. foliascens* and *H. (G) cymaeformis* were highly abundant in the turbid reef near Makassar city (personal observation). This behaviour is unusual for phototropic species. Studies in other areas (e.g., Northwest Java, the Great Barrier Reef) have shown that they are typically found in oligotrophic environments, characterized by low concentrations of organic nutrients (Wilkinson, 1988; de Voogd and Cleary, 2008). Conversely, several variables could be influencing the presence of these species in this unique environment. This could also be altered by algal symbionts that provide all the required carbon through photosynthesis, and the nitrogen comes from heterotrophic sources like ultra-plankton (Davy *et al.*, 2002; Pile *et al.*, 2003).

Several species mention above, including *Paratetilla bacca, Spirastrella decumbens*, and *Petrosia (Petrosia) Hoeksemai* (see Appendix 2.2) have demonstrated preferences for sedimented environments (Putchakarn, 2011; Schönberg, 2021). Although psammobiotic species typically exhibit an affinity for sedimented habitats (Schönberg, 2016), sediment presence can exert negative pressures on sponge communities. Specifically, when subjected to elevated concentrations of suspended sediment, sponge taxa can exhibit diminished pumping activity and reduced feeding efficiency (Lohrer *et al.*, 2006). Moreover, there may be alterations in their respiration rates (Pineda *et al.*, 2017) and tissue abrasion (Nava and Carballo, 2013). Such physiological stressors can culminate in partial mortality and compromised survival rates. A decline in sponge abundance, biomass, and species diversity has the potential to instigate cascading effects on broader marine ecosystems (Bell, 2008).

The observed marginal diversity and dominance of specific sponge taxa in the peripheral area of the Spermonde Archipelago, Indonesia, stem from a complex interplay of environmental factors. As warm, nutrient-rich waters flow through the archipelago (Makassar Strait) via the Indonesian Throughflow (ITF), they contribute to temperature regulation, providing a stable and warm environment essential for the growth and sustenance of coral reefs in the shallow-water subtidal areas (Kool *et al.*, 2011; Iskandar *et al.*, 2023). The nutrient influx from the ITF enhances the overall nutrient availability in these waters, supporting the photosynthetic processes of corals and associated organisms, fostering a conducive environment for marine life (Limmon *et al.*, 2023). Therefore, this condition creating a hydrodynamic environment that favours certain sponge species adapted to specific temperature, salinity, sedimentation, and nutrient conditions (Bell and Barnes, 2000; Conway *et al.*, 2006; Powell *et al.*, 2014). The strategic geographic position of the archipelago, coupled with localized influences such as the turbid reef near Makassar City (Parenden *et al.*, 2021), contributes to the selective ecological niche. Coral reef health, intricately linked to sponge diversity, further shapes the composition of the community, with alterations in reef conditions affecting the availability of suitable habitats. The shallow-water microenvironments, influenced by coastal geography, sedimentation, and water quality, create ecological niches that support specific sponge taxa. Remarkably, certain sponge species exhibit behaviours contrary to their typical associations, indicating unique adaptations to the local environment influenced by the interplay of physical oceanographic variables and shallow water conditions. Further research is imperative to unveil the specific mechanisms governing this ecological selectivity and to comprehend its broader implications for the marine ecosystem in the Spermonde Archipelago.

2.6. Conclusions

The study provided a comprehensive morphological description of 27 marine sponge species from the peripheral Spermonde Archipelago, Indonesia, filling a gap in understanding sponge diversity in the Sulawesi Sea/Makassar Strait marine ecoregion. Noteworthy findings included the identification of 11 new records for the marine ecoregion, bringing the total to 135 species on the checklist, not including four potentially novel species. The unusual behavior of certain sponges thriving in turbid reefs, contrary to their typical habitat preferences, was also observed. This study emphasized the need for further examination and registration of voucher specimens for accurate species description. Moreover, the observed sponge diversity in the Spermonde Archipelago was presumably attributed to the complex interaction of physical oceanographic variables and habitat conditions. The geographical position of the archipelago, combined with localized influences like the turbid reef near anthropogenic activity, contributed to ecological selectivity, influencing the composition of the sponge community.

2.7. Appendices

Appendix 2.1**.** Sampling sites of sponge collections from shallow-subtidal habitat of the Spermonde Archipelago, Indonesia. * NJ de Voogd collections.

Locality	**Coordinates**	**Survey time**
Kayangan Island (West)	05°06'51.40" S, 119°23'50.80" E	2020
Gusung Tallang	05°07'20.33" S, 119°23'37.19" E	2021
Samalona (Northwest)	05º07’21.00” S, 119º20’29.70” E	2020
Samalona (Southwest)	05º07’36.69” S, 119º20’24.46” E	2020
Samalona*	05º07’21.17” S, 119º20’21.22” E	2018
Kudingareng Keke*	05°06'28.00" S ,119°17'09.90" E	2018
Barangbaringan*	05°03'15.20" S, 119°25'22.90" E	2018
Lumulumu*	04°58'25.70" S, 119°12'43.80" E	2018
Badi*	04°58'09.10" S, 119°16'58.80" E	2018
Langkai*	05°01'44.58" S, 119°05'08.79" E	2018

Appendix 2.2. List of sponge species examined in this study with locations and environmental condition in the Spermonde Archipelago, Indonesia.

Species	**Location**	**Environments**
Clathrina rodriguesensis van Soest & de Voogd, 2018	Kudingareng Keke	clear
Janusya tubuloreticulosa (van Soest & de Voogd, 2015)	Samalona	clear
Leucaltis nodusgordii (Poléjaeff, 1883)	Samalona	clear
Spirastrella aff. *decumbens* Ridley, 1884	Langkai	clear
Callyspongia (Cladochalina) johannesthielei van Soest & Hooper, 2020	Samalona	clear
Haliclona (Gellius) cymaeformis (Esper, 1806)	Samalona, Kayangan, Gusung Tallang	turbid
Haliclona (Reniera) venusta (Bowerbank, 1875)	Samalona	clear
Haliclona (Soestella) elegantia (Bowerbank, 1875)	Kayangan, Gusung Tallang	turbid
Haliclona (Soestella) sp1. nov	Samalona	clear
Haliclona (Soestella) sp2. nov	Kayangan, Gusung Tallang	turbid
Amphimedon paraviridis Fromont, 1993	Samalona	clear
Niphates nitida Fromont, 1993	Kayangan	turbid
Petrosia (Petrosia) hoeksemai de Voogd & van Soest 2002	Samalona	Clear
Lissodendoryx (Waldoschmittia) schmidti (Ridley, 1884)	Lumulumu	clear
Iotrochota baculifera Ridley, 1884	Samalona	clear
Clathria (Thalysias) reinwardti Vosmaer, 1880	Samalona, Gusung Tallang	turbid
Stylissa massa (Carter, 1887)	Samalona	clear
Halichondria (Halichondria) cartilaginea (Esper, 1797)	Badi	clear
Topsentia indica Hentschel, 1912.	Langkai	clear
Suberites sp. nov	Samalona	clear
Terpios hoshinota Rützler & Muzik, 1993	Samalona	clear
Ecionemia acervus Bowerbank, 1862	Langkai	clear
Geodia sp. nov	Barangbaringan	turbid
Paratetilla bacca (Selenka, 1867)	Gusung Tallang	turbid
Lamellodysidea herbacea (Keller, 1889)	Samalona	clear
Ircinia schulzei (Dendy, 1905)	Samalona	clear
Phyllospongia foliascens (Pallas, 1766)	Samalona, Gusung Tallang	turbid

Appendix 2.3. A checklist of Porifera from Sulawesi Sea/Makassar Strait marine ecoregion with updates based on the current study.

No.	Taxa	Sources
	CALCAREA	
	Calcaronea	
	Leucosolenida: Amphoriscidae	
1	*Leucilla australiensis* (Carter, 1886)	(van Soest and de Voogd, 2015)
	Leucosolenida: Heteropiidae	
2	*Heteropia minor* Burton, 1930	(van Soest and de Voogd, 2015)
3	*Sycettusa sibogae* (Burton, 1930)	(Burton, 1930b)
	Leucosolenida: Jenkinidae	
4	*Anamixilla torresi* Poléjaeff, 1883	(van Soest and de Voogd, 2015)
5	*Uteopsis argentea* (Poléjaeff, 1883)	(van Soest and de Voogd, 2015)
	Calcinea	
	Clathrinida: Clathrinidae	
6	*Clathrina chrysea* Borojevic & Klautau, 2000	(van Soest and de Voogd, 2015)
7	*Clathrina macleayi* (Lendenfeld, 1885)	(Burton, 1930b)
8	*Clathrina purpurea* Van Soest & De Voogd, 2015	(van Soest and de Voogd, 2015)
9	*Clathrina stipitata* (Dendy, 1891)	(van Soest and de Voogd, 2015)
10	*Clathrina rodriguesensis* Van Soest & De Voogd, 2018	**This Study**
11	*Ernsta indonesiae* (Van Soest & De Voogd, 2015)	(van Soest and de Voogd, 2015)
12	*Janusya tubuloreticulosa* (Van Soest & De Voogd, 2015)	**This Study**
	Clathrinida: Leucaltidae	
13	*Ascandra chrysops* (Van Soest & De Voogd, 2015)	(van Soest and de Voogd, 2015)
14	*Leucaltis nodusgordii* (Poléjaeff, 1883)	(van Soest and de Voogd, 2015)
	Clathrinida: Leucascidae	
15	*Leucascus flavus* Cavalcanti, Rapp & Klautau, 2013	(Cavalcanti *et al.*, 2013a)
	Clathrinida: Leucettidae	
16	*Leucetta chagosensis* Dendy, 1913	(Cavalcanti *et al.*, 2013a); (van Soest and de Voogd, 2015)
17	*Leucetta microraphis* Haeckel, 1872	(van Soest and de Voogd, 2015)
18	*Pericharax orientalis* van Soest & De Voogd, 2015	(van Soest and de Voogd, 2015)

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Appendix 2.3. (Continued)

No.	Taxa	Sources
	Clathrinida: Levinellidae	
19	*Burtonulla sibogae* Borojevic & Boury-Esnault, 1986	(van Soest and de Voogd, 2015)
	DEMOSPONGIAE	
	Heteroscleromorpha	
	Axinellida: Axinellidae	
20	*Axinella aruensis* (Hentschel, 1912)	(Alvarez *et al.*, 2016)
21	*Phakellia atypica* Lévi, 1961	(Alvarez *et al.*, 2016)
22	*Phycopsis pesgalli* Alvarez, de Voogd & van Soest, 2016	(Alvarez *et al.*, 2016)
23	*Ptilocaulis spiculifer* (Lamarck, 1814)	(Alvarez *et al.*, 2016)
	Axinellida: Raspailiidae (Echinodictyinae)	
24	*Echinodictyum cavernosum* Thiele, 1899	(Thiele, 1899)
	Biemnida: Rhabderemiidae	
25	*Rhabderemia acanthostyla* Thomas, 1968	(van Soest and Hooper, 1993)
	Bubarida: Dictyonellidae	
26	*Acanthella cavernosa* Dendy, 1922	(Dendy, 1922)
	Clionaida: Clionaidae	
27	*Cliona albimarginata* Calcinai, Bavestrello & Cerrano, 2005	(Calcinai *et al.*, 2005)
28	*Cliona favus* Calcinai, Bavestrello & Cerrano, 2005	(Calcinai *et al.*, 2005)
29	*Cliona liangae* Calcinai, Bavestrello & Cerrano, 2005	(Calcinai *et al.*, 2005)
30	*Cliona mucronata* Sollas, 1878	(Calcinai *et al.*, 2005)
31	*Cliona utricularis* Calcinai, Bavestrello & Cerrano, 2005	(Calcinai *et al.*, 2005)
32	*Cliothosa dichotoma* (Calcinai, Cerrano, Sarà & Bavestrello, 2000)	(Calcinai *et al.*, 2005)
33	*Spheciospongia inconstans* (Dendy, 1887)	(Thiele, 1899)
34	*Spheciospongia purpurea* glaebosa (Vosmaer, 1911)	(Vosmaer, 1911)
	Clionaida: Placospongiidae	
35	*Placospongia melobesioides* Gray, 1867	(Thiele, 1899); (Vosmaer and Vernhout, 1902)
	Clionaida: Spirastrellidae	
36	*Spirastrella* aff. *decumbens* Ridley, 1884	**This Study**
	Haplosclerida: Callyspongiidae	
37	*Callyspongia (Cladochalina) johannesthielei* van Soest & Hooper, 2020	(Thiele, 1899)
38	*Callyspongia (Euplacella) biru* de Voogd, 2004	(de Voogd, 2004)
	Haplosclerida: Chalinidae	
39	*Chalinula nematifera* (de Laubenfels, 1954)	(Rossi *et al.*, 2015)
40	*Haliclona (Flagellia) hamata* (Thiele, 1903)	(Calcinai *et al.*, 2013)

…Continued on the next page

Appendix 2.3. (Continued)

No.	Taxa	Sources
41	*Haliclona (Flagellia) indonesiae* Van Soest, 2017	(van Soest, 2017)
42	*Haliclona (Halichoclona) vanderlandi* de Weerdt & van Soest, 2001	(de Weerdt and van Soest, 2001)
43	*Haliclona (Reniera) venusta* (Bowerbank, 1875)	**This Study**
44	*Haliclona (Soestella) elegantia* (Bowerbank, 1875)	**This Study**
	Haplosclerida: Niphatidae	
45	*Amphimedon anastomosa* Calcinai, Bastari, Bertolino & Pansini, 2017	(Calcinai *et al.*, 2017a)
46	*Amphimedon denhartogi* de Voogd, 2003	(de Voogd, 2003)
47	*Amphimedon paraviridis* Fromont, 1993	**This Study**
48	*Gelliodes spinosella* Thiele, 1899	(Thiele, 1899)
49	*Niphates laminaris* Calcinai, Bastari, Bertolino & Pansini, 2017	(Calcinai *et al.*, 2017a)
50	*Niphates nitida* Fromont, 1993	**This Study**
	Haplosclerida: Petrosiidae	
51	*Acanthostrongylophora ingens* (Thiele, 1899)	(Thiele, 1899)
52	*Neopetrosia chaliniformis* (Thiele, 1899)	(Thiele, 1899)
53	*Neopetrosia contignata* (Thiele, 1899)	(Thiele, 1899)
54	*Neopetrosia rava* (Thiele, 1899)	(Thiele, 1899)
55	*Petrosia (Petrosia) alfiani* de Voogd & van Soest, 2002	(de Voogd and van Soest, 2002)
56	*Petrosia (Petrosia) hoeksemai* de Voogd & van Soest, 2002	(de Voogd and van Soest, 2002)
57	*Petrosia (Petrosia) lignosa* Wilson, 1925	(de Voogd and van Soest, 2002)
58	*Petrosia (Petrosia) nigricans* Lindgren, 1897	(de Voogd and van Soest, 2002); (Thiele, 1899)
59	*Petrosia (Petrosia) plana* Wilson, 1925	(de Voogd and van Soest, 2002)
60	*Petrosia (Strongylophora) corticata* (Wilson, 1925)	(de Voogd and van Soest, 2002)
61	*Petrosia (Strongylophora) strongylata* Thiele, 1903	(de Voogd and van Soest, 2002)
	Haplosclerida: Phloeodictyidae	
62	*Oceanapia media* (Thiele, 1899)	(Thiele, 1899)
63	*Siphonodictyon maldiviense* (Calcinai, Cerrano, Sarà & Bavestrello, 2000)	(Calcinai *et al.*, 2007)
64	*Siphonodictyon microterebrans* (Calcinai, Cerrano & Bavestrello, 2007)	(Calcinai *et al.*, 2007)
	Poecilosclerida: Acarnidae	
65	*Acarnus bicladotylotus* Hoshino, 1981	(van Soest *et al.*, 1991)

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Appendix 2.3. (Continued)

No.	Taxa	Sources
	Poecilosclerida: Chondropsidae	
66	*Chondropsis subtilis* Calcinai, Bavestrello, Bertolino, Pica, Wagner & Cerrano, 2013	(Calcinai *et al.*, 2013)
	Poecilosclerida: Coelosphaeridae	
67	*Coelosphaera (Coelosphaera) navicelligera* (Ridley, 1885)	(Thiele, 1899)
68	*Lissodendoryx (Lissodendoryx) similis* Thiele, 1899	(Thiele, 1899)
69	*Lissodendoryx (Lissodendoryx) ternatensis* (Thiele, 1903)	(Hofman and van Soest, 1995)
70	*Lissodendoryx (Waldoschmittia) schmidti* (Ridley, 1884)	**This Study**
	Poecilosclerida: Desmacididae	
71	*Desmapsamma vervoorti* van Soest, 1998	(van Soest, 1998)
	Poecilosclerida: Esperiopsidae	
72	*Esperiopsis challengeri* (Ridley, 1885)	(Ridley, 1885)
	Poecilosclerida: Hymedesmiidae	
73	*Hymedesmia (Hymedesmia) spinata* Calcinai, Bavestrello, Bertolino, Pica, Wagner & Cerrano, 2013	(Calcinai *et al.*, 2013)
74	*Hymedesmia (Stylopus) perlucida* Calcinai, Bavestrello, Bertolino, Pica, Wagner & Cerrano, 2013	(Calcinai *et al.*, 2013)
	Poecilosclerida: Iotrochotidae	
75	*Iotrochota baculifera* Ridley, 1884	(Thiele, 1899)
	Poecilosclerida: Isodictyidae	
76	*Coelocarteria agglomerans* Azzini, Calcinai & Pansini, 2007	(Azzini *et al.*, 2007b)
	Poecilosclerida: Microcionidae (Microcioninae)	
77	*Clathria (Thalysias) erecta* (Thiele, 1899)	(Thiele, 1899)
78	*Clathria (Thalysias) reinwardti* Vosmaer, 1880	(Thiele, 1899)
79	*Clathria (Thalysias) topsenti* (Thiele, 1899)	(Thiele, 1899)
80	*Clathria (Thalysias) vulpina* (Lamarck, 1814)	(Hooper, 1996)
	Poecilosclerida: Mycalidae	
81	*Mycale (Aegogropila) furcata* Calcinai, Bavestrello, Bertolino, Pica, Wagner & Cerrano, 2013	(Calcinai *et al.*, 2013)
82	*Mycale (Aegogropila) orientalis* (Topsent, 1897)	(van Soest *et al.*, 2021)
83	*Mycale (Arenochalina) regularis* Wilson, 1925	(van Soest *et al.*, 2021)
84	*Mycale (Carmia) fungiaphila* Van Soest, Aryasari & De Voogd, 2021	(van Soest *et al.*, 2021)
85	*Mycale (Carmia) lissochela* Bergquist, 1965	(van Soest *et al.*, 2021)
86	*Mycale (Carmia) phyllophila* Hentschel, 1911	(van Soest *et al.*, 2021)
87	*Mycale (Carmia) tubiporicola* Van Soest, Aryasari & De Voogd, 2021	(van Soest *et al.*, 2021)

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Appendix 2.3. (Continued)

No.	Taxa	Sources
88	*Mycale (Kerasemna) humilis* (Thiele, 1903)	(Calcinai *et al.*, 2006b) (van Soest *et al.*, 2021)
89	*Mycale (Mycale) crassissima* (Dendy, 1905)	(van Soest *et al.*, 2021)
90	*Mycale (Mycale) dendyi* (Row, 1911)	(van Soest *et al.*, 2021)
91	*Mycale (Mycale) grandis* Gray, 1867	(van Soest *et al.*, 2021)
92	*Mycale (Naviculina) cleistochela* Vacelet & Vasseur, 1971	(van Soest *et al.*, 2021)
93	*Mycale (Naviculina) obscura* (Carter, 1882)	(van Soest *et al.*, 2021)
94	*Mycale (Paresperella) sceptroides* Van Soest, Aryasari & De Voogd, 2021	(van Soest *et al.*, 2021)
95	*Mycale (Zygomycale) parishii* (Bowerbank, 1875)	(van Soest *et al.*, 2021)
	Poecilosclerida: Podospongiidae	
96	*Podospongia colini* Sim-Smith & Kelly, 2011	(Sim-Smith and Kelly, 2011a)
	Scopalinida: Scopalinidae	
97	*Stylissa massa* (Carter, 1887)	(Thiele, 1899)
98	*Svenzea devoogdae* Alvarez, van Soest & Rützler, 2002	(Alvarez *et al.*, 2002)
	Suberitida: Halichondriidae	
99	*Axinyssa valida* (Thiele, 1899)	(Thiele, 1899)
100	*Halichondria (Halichondria) cartilaginea* (Esper, 1797)	**This Study**
101	*Topsentia indica* Hentschel, 1912	**This Study**
	Suberitida: Suberitidae	
102	*Aaptos lobata* Calcinai, Bastari, Bertolino & Pansini, 2017	(Calcinai *et al.*, 2017a)
103	*Terpios hoshinota* Rützler & Muzik, 1993	(van der Ent *et al.*, 2016)
	Tethyida: Hemiasterellidae	
104	*Liosina paradoxa* Thiele, 1899	(Thiele, 1899)
	Tethyida: Tethyidae	
105	*Tethytimea tylota* (Hentschel, 1912)	(Calcinai *et al.*, 2017a)
	Tetractinellida (Astrophorina): Ancorinidae	
106	*Dercitus (Stoeba) bangkae* Calcinai, Bastari, Makapedua & Cerrano, 2017	(Calcinai *et al.*, 2017b)
107	*Ecionemia acervus* Bowerbank, 1862	(Thiele, 1899)
108	*Rhabdastrella distincta* (Thiele, 1900)	(Calcinai *et al.*, 2017a)

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Appendix 2.3. (Continued)

No.	Taxa	Sources
	Tetractinellida (Astrophorina): Geodiidae (Erylinae)	
109	*Melophlus sarasinorum* Thiele, 1899	(Thiele, 1899)
	Tetractinellida (Astrophorina): Theonellidae	
110	*Theonella swinhoei* Gray, 1868	(Thiele, 1899)
	Tetractinellida (Spirophorina): Tetillidae	
111	*Acanthotetilla celebensis* de Voogd & van Soest, 2007	(de Voogd and van Soest, 2007)
112	*Cinachyrella australiensis* (Carter, 1886)	(Thiele, 1899)
113	*Tetilla disigmata* Lévi, 1964	(Lévi, 1964)
	Keratosa	
	Dictyoceratida: Irciniidae	
114	*Ircinia colossa* Calcinai, Bastari, Bertolino & Pansini, 2017	(Calcinai *et al.*, 2017a)
115	*Ircinia schulzei* (Dendy, 1905)	**This Study**
116	*Psammocinia alba* Calcinai, Bastari, Bertolino & Pansini, 2017	(Calcinai *et al.*, 2017a)
	Dictyoceratida: Thorectidae (Phyllospongiinae)	
117	*Phyllospongia palmata* Thiele, 1899	(Thiele, 1899)
118	*Phyllospongia papyracea* (Esper, 1806)	(Thiele, 1899)
	Dictyoceratida: Thorectidae (Thorectinae)	
119	*Dactylospongia elegans* (Thiele, 1899)	(Thiele, 1899)
120	*Hyrtios reticulatus* (Thiele, 1899)	(Thiele, 1899)
	Verongimorpha	
	Verongiida: Pseudoceratinidae	
121	*Pseudoceratina purpurea* (Carter, 1880)	(Brøndsted, 1934) (Thiele, 1899)
	HEXACTINELLIDA	
	Amphidiscophora	
	Amphidiscosida: Hyalonematidae	
122	*Hyalonema (Oonema) trifidum* Lévi, 1964	(Lévi, 1964)
	Amphidiscosida: Pheronematidae	
123	*Ijimalophus reflexus* (Ijima, 1894)	(Ijima, 1927)
124	*Pheronema barbulosclera* Lévi, 1964	(Lévi, 1964)
125	*Pheronema pilosum* Lévi, 1964	(Tabachnick and Lévi, 2000)
126	*Semperella similis* Ijima, 1927	(Ijima, 1927)
	Hexasterophora	
	Lyssacinosida: Euplectellidae (Bolosominae)	
127	*Bolosoma cavum* Ijima, 1927	(Lévi, 1990)

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Appendix 2.3. (Continued)

No.	Taxa	Sources
	Lyssacinosida: Euplectellidae (Corbitellinae)	
128	*Regadrella cylindrica* Ijima, 1927	(Ijima, 1927)
	Lyssacinosida: Rossellidae (Acanthascinae)	
129	*Staurocalyptus celebesianus* Ijima, 1927	(Ijima, 1927)
	Lyssacinosida: Rossellidae (Rossellinae)	
130	*Crateromorpha (Aulochone) pedunculata* (Ijima, 1927)	(Ijima, 1927)
	Sceptrulophora: Euretidae (Euretinae)	
131	*Pararete baliense* Ijima, 1927	(Ijima, 1927)
132	*Pararete kangeanganum* Ijima, 1927	(Ijima, 1927)
	Sceptrulophora: Farreidae	
133	*Aspidoscopulia furcillata* (Lévi, 1990)	(Lévi, 1990)
134	*Farrea occa ouwensi* Ijima, 1927	(Ijima, 1927)
	HOMOSCLEROMORPHA	
	Homosclerophorida: Plakinidae	
135	*Plakortis bergquistae* Muricy, 2011	(Muricy, 2011)