The Banda Sea: a hotspot of deep-sea echinoderms diversity in Indonesia

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Abstract. A list of Echinodermata fauna recorded from the Banda Sea has been compiled from the literature published between 1889-1995 as well as from the LIPI-RCO reference collection. To date, 44 species from five extant classes (Asteroidea, Ophiuroidea, Crinoidea, Echinoidea, and Holothuroidea) have been recorded from this area that consisting of the epipelagic (< 200 m depth), mesopelagic (200-1000 m depths) and bathypelagic (> 1000 m depth) species. Research history, taxonomy, and depth distribution are briefly discussed here. However, deep-sea habitats all over the world remain unexplored, including the Banda trench. The opportunity to discover both new records and new species for science from this trench is still wide open since the hitherto record of its marine biodiversity is still a few compared to the discovery on the shallow water. More deep-sea exploration will be needed to improve our knowledge of marine biodiversity.

Keywords: Asteroidea, Ophiuroidea, Crinoidea, Echinoidea, Holothuroidea, Banda trench, research history.

1. Introduction

The Echinodermata group is characterized not only by the spiny integument as its phylum definition, but also by a combination of adult pentaradial symmetric body, a calcite skeleton, and water vascular system. The phylum is an ancient group of exclusively marine invertebrate that was defined for the first time by Herouard in 1899 [1] which includes five extant class i.e. crinoids (feather stars and sea lilies), asteroids (sea stars), echinoids (sea urchins, heart urchins and sand dollars), ophiuroids (brittle stars and basket stars) and holothuroids (sea cucumbers). Echinoderms species are mostly free-living and benthic; the distributions are from tropical to the sub-tropical area with a depth range from shallow water to deep sea.

The Echinodermata is well represented in Indonesian waters. However, the comprehensive lists of its species in Indonesia have never been published. Most of the publications about Indonesian Echinodermata biodiversity were reported partially based on location (figure 1). For example diversity in Anambas waters [2], Seribu Island waters [3], East Java waters [4], Nusa Tenggara waters [5-7], Spermonde waters [8], Lembeh Strait waters [9] and Maluku waters [10-20].

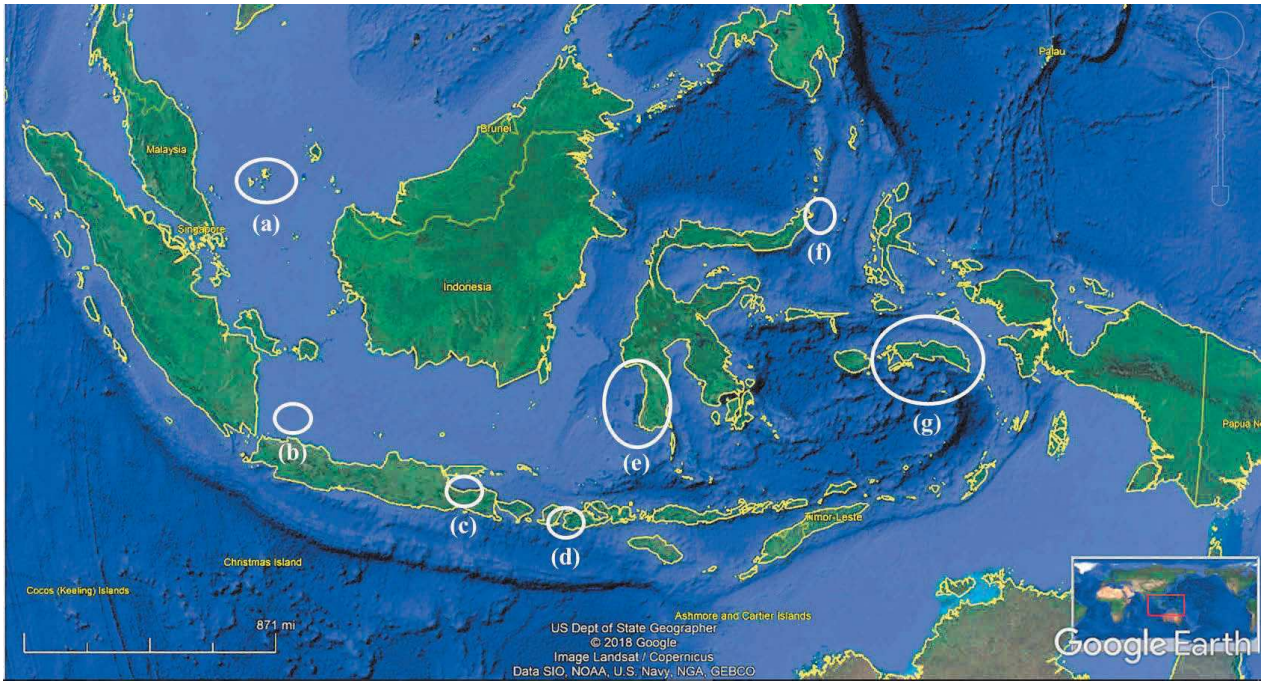

Figure 1. Locations in Indonesia that have taxonomical data of the Echinodermata: a: Anambas Island; b: Seribu Island, West Java; c: East Java; d: Nusa Tenggara; e: Spermonde Island, South Sulawesi; f: Lembeh Strait, North Sulawesi; g: Maluku.

The Indonesian marine life diversity is hard to be precisely reported not only due to the vast area to discover but also to the variety of habitats to be explored. Indonesia comprises of more than 18,000 islands and coastline of about 109,000 km [23]. Indonesia waters composed of many ecosystem varieties from the shallow water to the deep sea i.e. mangrove, seagrass, coral reef, and deep water. The Banda Sea is one of the important deep-sea realm in Indonesia which is not well documented from any viewpoints including its species diversity and energy resources [23].

The study on deep-sea echinoderm in Indonesia has received minor attention for centuries. The most recent overview of the Zoological Catalogue of Australia [1] enlisted several type-species from the Banda Sea that were deposited in the Australian Museum. We used the bibliography noted in this catalog as a reference in tracing the exploration history of the Banda Sea.

2. Data collection

The substance of the discussion in this manuscript was based on the data from any publication which had a topic "Echinodermata and the Banda Sea." Ten publications were successfully traced. They were one overview paper [1] and old taxonomic papers for the rest [24-31]. To comprehend the data, we used also the record of echinoderms specimens from the Banda Sea that were deposited in the LIPI-Recearch Center for Oceanography (RCO) Reference Collection (Refcoll) [32].

3. Results and Discussion

A total of 44 species was collected from the Banda Sea that belongs to five classes. 35 species were successfully listed based on the literature and the rest of nine species were the record from the LIPI-RCO Refcoll database (Table 1). It was comprised of 10 species of Holothuroidea, 12 species of Asteroidea, and 14 species of Ophiuroidea. Echinoidea and Crinoidea possessed four species each respectively (figure 2).

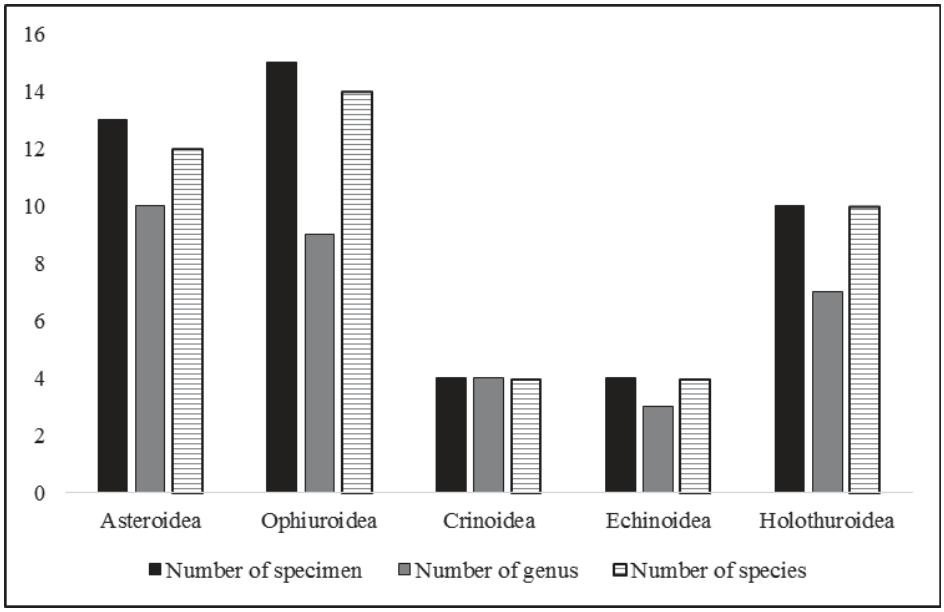

Figure 2. The number of the specimens, genus, and species of Echinodermata class found in the Banda Sea to date.

3.1. Research history

It can be seen from the references [1,24-31] that all species observed from the deepest levels of the Banda Sea were collected from the date far back after G.E. Rumphius exploration [33]. Meanwhile, records from specimens deposited in the LIPI-RCO Refcoll [32] shows that it was from the exploration year 1975, Rumphius Expedition II funded by UNESCO [34]. Sladen [24] through Challenger Expedition describe almost all Asteroidea specimen from the Banda Sea as new species. All species described by him were taken from the seafloor of the Banda Sea using dredging equipment; hence, the depth recorded in the list is remaining constant at a level deeper than 200 meters. Doderlain [28-31] also described the species of Asteroidea, of which some species are the same species found by Sladen [24]. Specimens identified by Doderlain were collected using dredge and corer during the Siboga expedition. He specifically described the starfish specimens. His publication in 1917 was focused on the genus of *Astropecten* [28] and three years later he described the genus of *Luidia* [29]. In 1924, he noted the asteroid species of Pentagonasteridae family [30] and he continued the description of asteroid subfamily of Oreasterinae in 1936 [31]. Holothuroidea and Echinoidea species listed here mostly from the reference of Sluiter [25] and De Meijere [26] which also resulted from Siboga expedition. Meanwhile, Clark [27] re-record one of Holothuroidea species that previously described by Sluiter [25]. Overall, the large number of new species from the deep water of the Banda Trench described by the aforementioned authors in the past is not surprising because the Banda Sea at that time had been wholly unexplored. Moreover, the sampling method using dredge or corer had also never previously been employed.

Table 1. Species list of Banda Sea echinoderms, based on literatures review. e: epipelagic (0-200 m), m: mesopelagic (200-1000 m), b: bathypelagic (> 1000 m)

No	Class/Family	Species present status[a]	Cited as	Depth	Synonim	Ref.
Asteroidea						
1	Benthopectinidae	*Cheiraster (Luidiaster) teres* Sladen, 1889	*Cheiraster teres* (Sladen, 1889)	m	*Pontaster teres* Sladen, 1889	[1,24]
2	Astropectinidae	*Astropecten acanthifer* Sladen, 1883	*Astropecten acanthifer* Sladen, 1883	m	*Astropecten acanthifer* Sladen, 1883	[24,28]
3	Astropectinidae	*Astropecten bandanus* Döderlein, 1917	*Astropecten bandanus* Döderlein, 1917	e, m	*Astropecten bandanus* Döderlein, 1917	[1,28]
4	Astropectinidae	*Astropecten polyacanthus* Müller & Troschel, 1842	*Astropecten polyacanthus* Müller & Troschel, 1842	e	*Astropecten hystrix* Müller & Troschel, 1842	[28]
5	Pseudarchasteridae	*Paragonaster ctenipes* Sladen, 1889	*Paragonaster ctenipes* Sladen, 1889	e, m	*Paragonaster ctenipes* Sladen, 1889	[1,24,30]
6	Goniasteridae	*Rosaster symbolicus* [30]	*Nymphaster symbolicus* var. Breviradiata Sladen, 1889	e, m	*Nymphaster symbolicus* Sladen, 1889	[1,24]
7	Ophidiasteridae	*Tamaria tumescens* Koehler, 1910	*Tamaria tumescens* Koehler, 1910	e, m	*Ophidiaster tumescens* Koehler, 1910; *Tamaria ajax* Livingstone, 1932; *Tamaria propetumescens* Livingstone, 1932	[1]
8	Zoroasteridae	*Pholidaster squamatus* Sladen, 1889	*Pholidaster distinctus* Sladen, 1889	m	*Pholidaster squamatus* Sladen, 1889	[24]
9	Luidiidae	*Luidia avicularia* Fisher, 1913	*Luidia avicularia* Fisher, 1913	e	*Luidia avicularia* Fisher, 1913	[29]
10	Oreasteridae	*Protoreaster nodosus* Linnaeus, 1758	*Oreaster turritus* Gray, 1840	e	*Pentaceros turritus* Gray, 1840	[31]
Ophiuroidea						
11	Asteroschematidae	*Ophiocreas sibogae* Koehler, 1904	*Ophiocreas sibogae* Koehler, 1904	e, m, b	Ophiocreas longipes Mortensen, 1924	[1]
12	Ophiohelidae	*Ophiomyces delata* Koehler, 1904	*Ophiomyces delata* Koehler, 1904	m, b	*Ophiomyces delata* Koehler, 1904	[1]
13	Ophiodermatidae	*Bathypectinura heros* (Lyman, 1879)	*Bathypectinura heros* (Lyman, 1879)	m, b	*Pectinura heros* Lyman, 1879; *Pectinura lacertosa* Lyman, 1883; *Pectinura tessellata* Lyman, 1883; *Pectinura conspicua* Koehler, 1897; *Ophiocrates lenta* Koehler, 1904; *Pectinura modesta* Koehler, 1904; *Ophiocrates secundus* Koehler, 1906; *Pectinura elata* Koehler, 1906; *Athypectinura gotoi* Matsumoto, 1915; *Phiozonella brachyactis* Clark, 1939; *Ophiocrates intervallus* Madsen, 1947	[1]
14	Ophiodermatidae	*Ophiopsammus yoldii* (Lütken, 1856)	*Ophiopsammus yoldi* (Lütken, 1856)	e, m	*Ophiopeza yoldii* Lütken, 1856; *Ophiopeza conjungens* Bell, 1884; *Ophiopeza exilis* Koehler, 1905	[1]
15	Ophiuridae	*Ophiopallas paradoxa* Koehler, 1904	*Ophiopallas paradoxa* Koehler, 1904	e, m		[1]
16	Ophiotrichidae	*Ophiogymna elegans* Ljungman, 1866	*Ophiogymna elegans* Ljungman, 1866	e	*Ophiocampsis inermis* Koehler, 1905	[1]

continue on the next page

Table 1. Continued

No	Class/Family	Species present status[a]	Cited as	Depth	Synonim	Ref.
17	Ophiotrichidae	*Ophiothrix (Acanthophiothrix) armata* Koehler, 1905	*Ophiothrix (Acanthophiothrix) armata* Koehler, 1905	e	*Ophiothrix armata* Koehler, 1905	[1]
18	Ophiuridae	*Amphiophiura insolita* Koehler, 1904	*Amphiophiura insolita* Koehler, 1904	m, b	*Ophiura monaria* Clark, 1949	[1]
Crinoidea						
19	Comatulidae	*Capillaster sentosus* Carpenter, 1888	*Capillaster sentosa* Carpenter, 1888	e	*Actinometra sentosa* Carpenter, 1888	[1]
20	Comatulidae	*Clarkcomanthus littoralis* Carpenter, 1888	*Clarkcomanthus littoralis* Carpenter, 1888	e	*Actinometra littoralis* Carpenter, 1888	[1]
21	Comatulidae	*Phanogenia multibrachiata* Carpenter, 1888	*Phanogenia multibrachiatus* Carpenter, 1888	e	*Actinometra multibrachiata* Carpenter, 1888	[1]
22	Comatulidae	*Stephanometra indica* Smith, 1876	*Stephanometra indica* Smith, 1876	e	*Comatula indica* Smith, 1876; *Antedon spicata* Carpenter, 1881; *Antedon monacantha* Hartlaub, 1890	[1]
Echinoidea						
23	Saleniidae	*Salenocidaris hastigera* A. Agassiz, 1879	*Salenocidaris hastigera* A. Agassiz, 1879	m, b		[1]
24	Cidaridae	*Eucidaris metularia* Lamarck, 1816	*Cidaris metularia* Lamarck, 1816	e		[26]
25	Temnopleuridae	*Temnotrema bothryoides* L. Agassiz in L. Agassiz & Desor, 1846	*Pleurechinus bothryoides* L. Agassiz in L. Agassiz & Desor, 1846	e		[26]
Holothuroidea						
26	Holothuriidae	*Pearsonothuria graeffei* [43]	*Holothuria graeffei* Semper, 1868	e		[25]
27	Holothuriidae	*Holothuria (Theelothuria) kurti* Ludwig, 1891	*Holothuria kurti* Ludwig, 1891	e		[25]
28	Phyllophoridae	*Phyllophorella longipeda* Semper, 1867	*Cucumaria longipeda* Semper, 1867	e		[25]
29	Cucumariidae	*Cucumaria vilis* Sluiter, 1901	*Cucumaria vilis* Sluiter, 1901	e		[25]
30	Sclerodactylidae	*Afrocucumis africana* Semper, 1867	*Pseudocucumis africana* Semper, 1867	e		[25]
31	Synaptidae	*Synaptula reticulata* Semper, 1867	*Chondrocloea reticulata* Semper, 1867	e		[25]
32	Holothuriidae	*Holothuria (Microthele) whitmaei* Bell, 1887	*Mulleria maculata* Brandt, 1835	e		[25]
33	Stichopodidae	*Thelenota ananas* (Jaeger, 1833)	*Stichopus ananas* Quoy & Gaimard, 1833	e		[25]
34	Synaptidae	*Synaptula lactea* (Sluiter, 1887)	*Synaptula lactea* (Sluiter, 1887)	e	*Synapta lactea* Sluiter, 1887	[25, 27]
35	Synaptidae	*Synaptula lamperti* Heding, 1928	*Synaptula lamperti* Heding, 1928	e	*Synaptula membrana* Heding, 1928; *Synaptula purpurea* Heding, 1928	[1]

[a] updated from [35].

3.2. Taxonomy and depth distribution

Several species in the older literature had multiple different synonyms because of uncertain identification and unfixed systematic in the past (Table 2). Systematic problems because of minor classificatory and nomenclatorial changes are unavoidable. More investigations by using advanced identification methods will lead to more invention of species characteristic. Thus will strength the systematics of the taxa. However, at present, by tracing through WORMS [35] (The World Register of Marine Species) as one of the trusted and reputable online sources for marine species systematics, all species enlisted here are now recognized as valid.

The echinoderm species found in the Banda Sea enlisted herein are divided into three major depth (epipelagic, mesopelagic and bathypelagic). Epipelagic depth is species found in the depth less than 200 m. Mesopelagic depth is species found in the depth between 200-1000 m. Bathypelagic depth is species found in the depth more than 1000 m. Almost all of the species described in old taxonomical reference [1], [24-31] (Table 1) were discovered from the zone range of mesopelagic and bathypelagic. On the other hand, all species from the data of RCO Refcoll (Table 2, [32]) were discovered from the epipelagic depth, even shallower. Species of Holothuroidea inhabiting the shallower bottom than other Echinodermata class. Based on a number of Echinodermata species inhabiting the deeper water, Ophiuroidea has the largest species diversity, continue to Asteroidea, Crinoidea, and Echinoidea respectively. It confirms that Echinodermata species has a wide range of depth distribution habitat from shallow water to the deepest sea such as the Banda Trench.

Table 2. Species list of Banda Sea echinoderms, based on specimen collection. Voucher: specimens deposited at LIPI-RCO Refcoll. e: epipelagic (0-200 m), m: mesopelagic (200-1000 m), b: bathypelagic (> 1000 m)

No	Class/Family	Species	Voucher	Depth	Notes	Reference
Asteroidea						
1	Goniasteridae	*Fromia indica* (Perrier, 1869)	ECH 0694, ECH 0961	e		[32]
2	Ophidiasteridae	*Linckia multifora* (Lamarck, 1816)	ECH 0699	e		[32]
Ophiuroidea						
3	Ophiotrichidae	*Ophiothrix* Sp	ECH 0743	e		[32]
4	Ophiotrichidae	*Ophiothrix nereidina* (Lamarck, 1816)	ECH 0768, ECH 1280	e		[32]
5	Ophiotrichidae	*Ophiothrix ciliaris* Müller & Troschel, 1842	ECH 0875	e		[32]
6	Ophiotrichidae	*Ophiothrix rhabdota* H.L. Clark, 1915	ECH 0895	e		[32]
7	Ophiotrichidae	*Ophiothrix deceptor* Koehler, 1922	ECH 1243	e	lay on *Acropora*	[32]
8	Ophiotrichidae	*Macrophiothrix longipeda* (Lamarck, 1816)	ECH 1277	e		[32]
Echinoidea						
9	Echinometridae	-	ECH 1234	e	unfixed identification	[32]

3.3. Foresight of the Banda Trench

The opportunity to explore the Banda Trench as one of the deepest seas of the world is still wide open since the hitherto record of its marine biodiversity remains limited. Our knowledge of echinoderms

biodiversity is inadequate, and knowledge of already described diversity also is limited [36]. More biodiversity survey on the deep sea will improve our knowledge of the benthic invertebrate.

Numerous species remain difficult or impossible to get the accurate identification. This leads us to study more on advanced identification methods. Indonesia only has limited taxonomist, particularly who is a concern on megabenthic invertebrate such Echinodermata. The chance of multinational cooperation on exploring the deep water of Banda Trench will remain wide open in the upcoming year.

4. Conclusion

This review has highlighted the gaps in terms of the deep-sea echinoderms research that awaits to be carried in the future. Research using dredge or corer up to the bathypelagic or abyssopelagic (> 4000 m depth) zone is the attractive issue for the next research methods. Multinational collaboration also should become a necessary thing to do in the upcoming years because discovery surveys remain chaotic for many decades. However, the role of taxonomy study will still become the main subject for the next years. Thus our responsibility together to discover as much as possible species diversity before they got vanish.

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