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Why many Indonesian marine species remain undescribed: a case study using polychaete species discovery

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Abstract. Even though it is a global marine biodiversity hotspot, the contribution of Indonesia to marine species discovery has been disproportionately small, and despite the amount of biodiversity research conducted by local scientists, many species in this country remain undescribed. In this article, we used the discovery rate of Indonesian polychaete species as a case example to investigate the contributory factors leading to the slow rate of marine species discovery in the country. In addition, we evaluated ecological studies on Indonesian polychaetes and enumerated the number of local marine taxonomists along with the number of Indonesian species that they described. We found that throughout Indonesia's history, the country only had a few marine taxonomists and that past marine species discoveries have been largely dependent on overseas scientists. This has been the primary factor causing the slow rate of marine species discovery in the country and has led to limited taxonomic literature on local species, resulting in many species either remaining unidentified or incorrectly identified, as local researchers typically used identification keys written for other geographic regions. We further found that limited access to natural history collections, uneven distribution of research facilities, a lack of collaborative research and funding, and strict requirements for research permits for foreign researchers have also hampered discoveries of marine species new to science in Indonesia. Long term recruitment of local marine taxonomists through the job vacancies regularly offered (annually) by the Indonesian government along with taxonomic training by relevant governmental research institutions are the first immediate actions to address these problems. Moreover, collaborative work and the establishment of Indonesian marine reference collections, databases, and identification keys are other strategies to end taxonomic impediments in the nation. For polychaetes, provided that such actions are made, our model forecasts that between 120 and 270 more Indonesian species will be discovered by the end of this century. Any taxonomic investigations conducted in the Coral Triangle are likely to uncover greater numbers of undescribed marine species compared to any other location in Indonesia or the world.

Key words. Annelida, marine biodiversity, Polychaeta, taxonomy

INTRODUCTION

Indonesia, as the country with the second longest coastline in the world (The World Factbook, 2021) and part of the Coral Triangle (CT), is recognised as one of Earth's marine biodiversity hotspots (e.g., Ekman, 1934; Roberts et al., 2002; Hoeksema, 2007; Asaad et al., 2020). Four sites within this archipelagic country, i.e., the northern tip of Sulawesi, Ambon, the Kei Islands, and the Raja Ampat Archipelago, have even been identified as areas with exceptionally high marine species richness that merit conservation (Asaad et al., 2018).

Knowing the precise number of marine species that have been identified from this nation is nevertheless challenging as the data are generally scattered amongst many publications, and many species either remain unidentified or are incorrectly identified (e.g., Hutomo & Moosa, 2005; Pamungkas &

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Glasby, 2019). However, based on limited data, roughly 800 and 10,000 Indonesian species of marine flora and fauna, respectively, were documented by Hutomo & Moosa (2005), whereas Widjaja et al. (2014) reported about 1,100 and 5,300 species of marine flora and fauna, respectively. Additionally, approximately 8,200 marine species were recorded by Hernawan & Santoso (2021) through Ocean Biodiversity and Information System (OBIS) Indonesia. These species numbers are low, i.e., only around 3–5%, compared to the total number of marine species that have been described so far, i.e., approximately 230,000 species (Bouchet, 2006; Appeltans et al., 2012). The number of marine species described from the country by both local and foreign researchers is also limited. For example, out of about 11,500 polychaete species that have been described worldwide (Pamungkas et al., 2019), only around 300 species (or fewer than 3%) are from Indonesia (Pamungkas & Glasby, 2019). Similarly, in isopods, with around 6,180 accepted marine species known globally to date (Boyko et al., 2008 onwards), only ca. 230 species (3.8%) are either described or known to be distributed in Indonesia (Sidabalok, 2013; Sidabalok & Bruce, 2017, 2018; Sidabalok et al., 2020; Wong & Sidabalok, 2021).

While marine biodiversity studies continue to be conducted by local researchers, the number of new species described over time has remained small. For instance, there were only six polychaete species described from Indonesia over the past two decades, i.e., *Namalycastis rhodochorde* Glasby, Miura, Nishi & Junardi, 2007, *Polymastigos javaensis* Pamungkas, 2015, *Capitella ambonensis* Pamungkas, 2017, *Notodasus celebensis* Lin, García-Garza & Arbi, in Lin et al., 2019, *Caulleryaspis sundaensis* Chuar & Salazar-Vallejo, 2021, and *Pectinaria nusalautensis* Pamungkas & Hutchings, 2023. This slow species discovery rate is concerning as local species may go extinct before being discovered, particularly because Indonesia is at high risk of marine biodiversity loss due to both high anthropogenic impacts—such as overexploitation of living resources, habitat conversion, and pollution—and climate change (e.g., Edinger et al., 1998; Hutomo & Moosa, 2005; Yuwono et al., 2007; Finnegan et al., 2015; Lestari & Trihadiningrum, 2019).

Although some common challenges in conducting biodiversity research in Southeast Asia have been identified by Ng (1998, 2000, 2001), the underlying factors causing the slow rate of Indonesian marine species discovery have not been investigated in detail. In general, an overall review of marine taxonomic studies conducted by Indonesian researchers (e.g., how many local marine taxonomists are present in Indonesia, along with their specialisations, as well as how many and what species have been described by them) has not been conducted before. In the present work, we used species discovery of Indonesian polychaetes as a case example to understand why many Indonesian marine species remain undescribed despite the efforts made by local researchers. Polychaetes were chosen as these animals are ubiquitous in both marine and estuarine environments, and often dominate benthic communities (Hutchings, 1998)—thus, any benthic sampling in those habitats will most likely yield polychaete

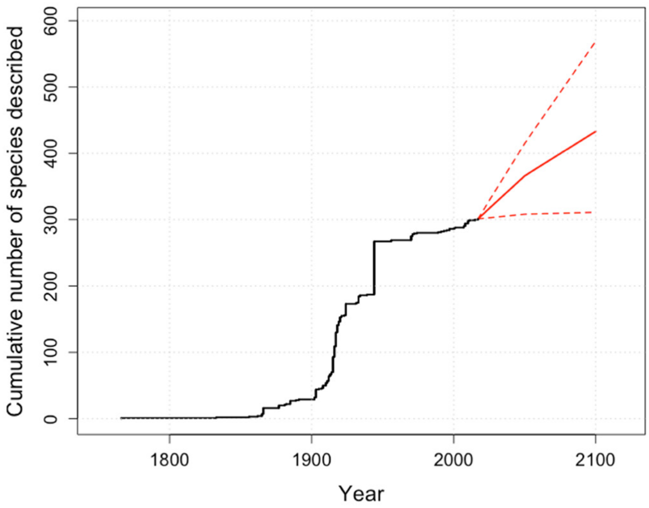

Fig. 1. The cumulative number of Indonesian polychaete species described (the black solid line), projected to the end of the 21st century with a 95% probability. The upper and lower red dashed lines, as well as the red solid line, are the projected species discovery trends assuming great, little, and medium taxonomic efforts, respectively, being made to shift the pre-existing trend.

specimens. Most importantly, polychaete species discoveries and geographic distribution of the species have been reviewed both globally (Pamungkas et al., 2019; Pamungkas et al., 2021) and locally (Pamungkas & Glasby, 2019). Data on Indonesian polychaetes in Pamungkas & Glasby (2019) were used to graph the cumulative number of species described. The non-homogeneous renewal process model of Wilson & Costello (2005) was then used to forecast the future species discovery of the animals (Fig. 1). Using the past species discovery rate with 95% confidence limits, this model has been used to predict the numbers of marine species (Appeltans et al., 2012), total global species (Costello et al., 2012), and global polychaete species (Pamungkas et al., 2019) that will be discovered by the end of the 21st century. This model is considered the most robust compared to the other three approaches commonly used to estimate species richness, i.e., based on (1) expert opinions, (2) species-habitat relationships using the island biogeographic theory, and (3) body size-species richness relationships (Costello & Wilson, 2011). The equation used in the model was:

$$t = \frac{N}{1 + \exp(-\beta(t - \alpha))}$$

where ***t*** is the number of Indonesian polychaete species discovered by a particular year; ***N*** is the total number of Indonesian polychaete species to be discovered; α is the year of the maximum rate of discovery; and β is the overall rate of discovery (a larger β implies a faster rate). In addition, we examined ecological literature on Indonesian polychaetes by local researchers published in the past two decades to document species identification, specimen deposition, as well as the involvement of taxonomists in their studies. To see the present-day composition of Indonesian taxonomists, we updated the directory of Indonesian taxonomists in Rahajoe et al. (2018) by removing inactive retired employees, ecologists, and those who did not consistently publish taxonomic papers, as well as adding new workers. While

Costello et al. (2013) simply defined taxonomists as "the people describing species new to science", and Rahajoe et al. (2018) included ecologists in their list of local taxonomists (apparently because ecologists also identify species), we here define taxonomists as people who have consistently published taxonomic papers throughout their career and, as a result of their persistent work, usually—but not necessarily—described species new to science (thus not all taxonomists describe new species, and not all researchers who describe new species are taxonomists). This is because their work is more than just to identify species by using existing references, but also to clarify, classify, and even when necessary, to reorganise and revise the identity of the organisms (see Ng, 1998, 2000, 2001). A list of Indonesian marine species described by local taxonomists is also provided based on the species name data listed on the World Register of Marine Species (WoRMS) at www.marinespecies.org and was cross-checked with the authors' taxonomic publications.

A SLOW DOWN IN SPECIES DISCOVERY

One approach to determine whether a taxon still has many species remaining to be discovered is by looking at the curve of the cumulative number of species described. That is, whether it is increasing (suggesting that the taxon still has many species awaiting description) or seems to be reaching an asymptote (indicating that most species of the taxon may have been discovered) (e.g., Costello et al., 1996). The curve has been used to estimate the numbers of global (Costello et al., 2012) and marine species (Appeltans et al., 2012). On a global scale, the curve for polychaetes has been increasing (Pamungkas et al., 2019), suggesting that future marine benthic sampling will still yield numerous polychaetes new to science. However, the curve for Indonesian polychaetes (Fig. 1) appears to have been levelling off since the 1940s, and more obviously in the 2000s, reflecting a slow-down in the species discovery rate. Assuming no considerable change in taxonomic effort, this trend is projected to remain the same until the end of this century. This, at first glance, creates an impression that most polychaete species in the region, especially the most conspicuous ones, may have already been discovered. However, this does not seem to be true as the slow-down is actually caused by a decline in taxonomic effort due to the taxonomic impediment, i.e., "The shortage of taxonomic experts, and unequal and limited access to taxonomic information (e.g., taxonomic literature, field guides, species identification aids) and collections of natural history specimens" (Abrahamse et al., 2021). This is indicated by the drop in the number of taxonomic publications on Indonesian polychaetes since the early 20th century (Pamungkas & Glasby, 2019).

The actual number of Indonesian polychaete species is expected to be high. Our model (Fig. 1) demonstrates that between 120 and 270 more Indonesian polychaete species may be discovered by the end of this century provided that local researchers make significant taxonomic efforts to shift the current discovery rate trend. Using the rarefaction method of Hurlbert (1971) to statistically calculate the expected number of polychaete species per 50 occurrence records extracted from the Ocean Biodiversity Information System (OBIS; https://obis.org), Martin et al. (2021) and Pamungkas et al. (2021) also found that polychaete species richness around the Equator, especially Indonesia, is expected to be high. In particular, more endemic polychaete species are anticipated to be discovered from Indonesia, as it has been found to be one of the 11 polychaete biogeographic regions of the world (Pamungkas et al., 2021).

TAXONOMIC IMPEDIMENTS

A shortage of local marine taxonomists

Geographic regions whose polychaete species are well described, such as northern Europe, North America, Australia, and Brazil, typically have a number of active polychaete taxonomists who work either on local fauna or materials obtained during major marine expeditions across the globe (Hutchings & Lavesque, 2020). The case in Indonesia is a completely different story. While on a global scale, the number of polychaete taxonomists generally increased (Pamungkas et al., 2019), Indonesia had no taxonomists working on this group of fauna until the 2000s. From the middle of the 18th century to the 2000s, all polychaete species from this nation were exclusively described by overseas scientists; with all of the material from this group deposited in overseas research institutions, mainly at the Naturalis Biodiversity Center (NBC) in Leiden, Netherlands, reflecting past colonial collecting practices (Bleeker & van der Spoel, 1992; Glasby & Al-Hakim, 2017; Pamungkas & Glasby, 2019). This is in line with the global trend that most taxonomists—as well as biological specimen collections—are generally based in industrialised countries, not in tropical developing countries which are usually high in species richness (Secretariat of the Convention on Biological Diversity, 2006).

Recent data shows that the total number of locals holding an official position as a researcher at Badan Riset dan Inovasi Nasional (BRIN), or in English, the 'National Research and Innovation Agency' (NRIA) was around 5,500 (National Research and Innovation Agency, 2023). However, the number of local marine taxonomists was disproportionately small (we here define 'marine taxonomists' as people who have consistently published taxonomic papers and usually—but not necessarily—described marine species new to science; those who once in a while described new species as a co-author through collaboration with taxonomists and did not consistently write taxonomic papers are thus excluded since their contributions in the paper are usually not on the species description section). We updated the directory of Indonesian taxonomists in Rahajoe et al. (2018) and found only 13 marine taxonomists out of 109 people who currently work on local species (Table 1; Fig. 2; Appendix 1). The number of Indonesian marine taxonomists we found (13) is slightly lower than that identified earlier by Ng (2001), i.e., 16. Along with one retired stomatopod taxonomist (this person was the first Indonesian marine taxonomist), these 13 Indonesian taxonomists have in total described 154 Indonesian marine

Table 1. List of active Indonesian marine taxonomists.

No.	Name[a]	Institution	Taxon[b]	Number of new species described[c]	Number of publications on new species[d]	Year of first species described[e]	Year of last species described[f]
1	Ana Setyastuti	RCO	Holothurians	–	–	–	–
2	Bunjamin Dharma[g]	–	Gastropods & scaphopods	9	7	2001	2023
3	Conni M. Sidabalok	RCBE	Isopods	8	5	2017	2021
4	Dewi C. Murniati	RCBE	Decapods	4	2	2022	2023
5	Dharma A. Nugroho	RCBE	Decapods	7	4	2012	2022
6	Dwi L. Rahayu	RMLB[j]	Decapods	68	37	1993	2022
7	Fahmi	RCO	Marine fishes	8	7	2006	2019
8	Ismiliana Wirawati	RCO	Holothurians	–	–	–	–
9	Joko Pamungkas	RCBE	Polychaetes	3	3	2015	2023
10	Kartika Dewi[h]	RCBE	Parasitic nematodes	3	2	2013	2017
11	Mulyadi[i]	RCBE	Copepods	28	11	1996	2022
12	Romanus E. Prabowo	Jenderal Soedirman University	Cirripeds	1	1	2005	2005
13	Teguh Peristiwady	RCO	Marine fishes	7	7	2005	2020

[a]Additionally, Mohammad K. Moosa (RCO; retired) was the first Indonesian marine taxonomist who described a number of Indonesian marine decapods and stomatopods (see Table 2). Pradina Purwati (RCO; retired) was a holothurian taxonomist. Kasijan Romimohtarto (RCO; deceased) erected the genera *Dorippoides* Serène & Romimohtarto, 1969. Local researchers who intermittently wrote taxonomic papers from collaboration with taxonomists include Armen R. Ngo (gastropods), Aswan (Bandung Institute of Technology; gastropods), Edwin Setiawan (Sepuluh Nopember Institute of Technology; sponges), Ernawati Widyastuti and Rianta Pratiwi (RCO; decapods), Hadiyanto and Inayat Al Hakim (RCO; polychaetes), Indra B. Vimono (RCO; asteroids), John Abbas (gastropods), Junardi (Tanjungpura University; polychaetes), Pipit Pitriana (RCBE; cirripeds), Steven Lie (gastropods), Tri Arfianti (RCBE; amphipods), Ucu Y. Arbi (RCO; molluscs and polychaetes) and Woro W. Kastoro (RCO (deceased); bivalves).

[b]Determined based on the taxon of most species described.

[c, d, e, f] Exclusively on Indonesian marine species.

[g, h] These researchers mostly described non-marine species.

[i]This researcher also described one species of Indonesian jellyfish (see Table 2).

[j]Research Center for Marine and Land Bioindustry was part of RCO.

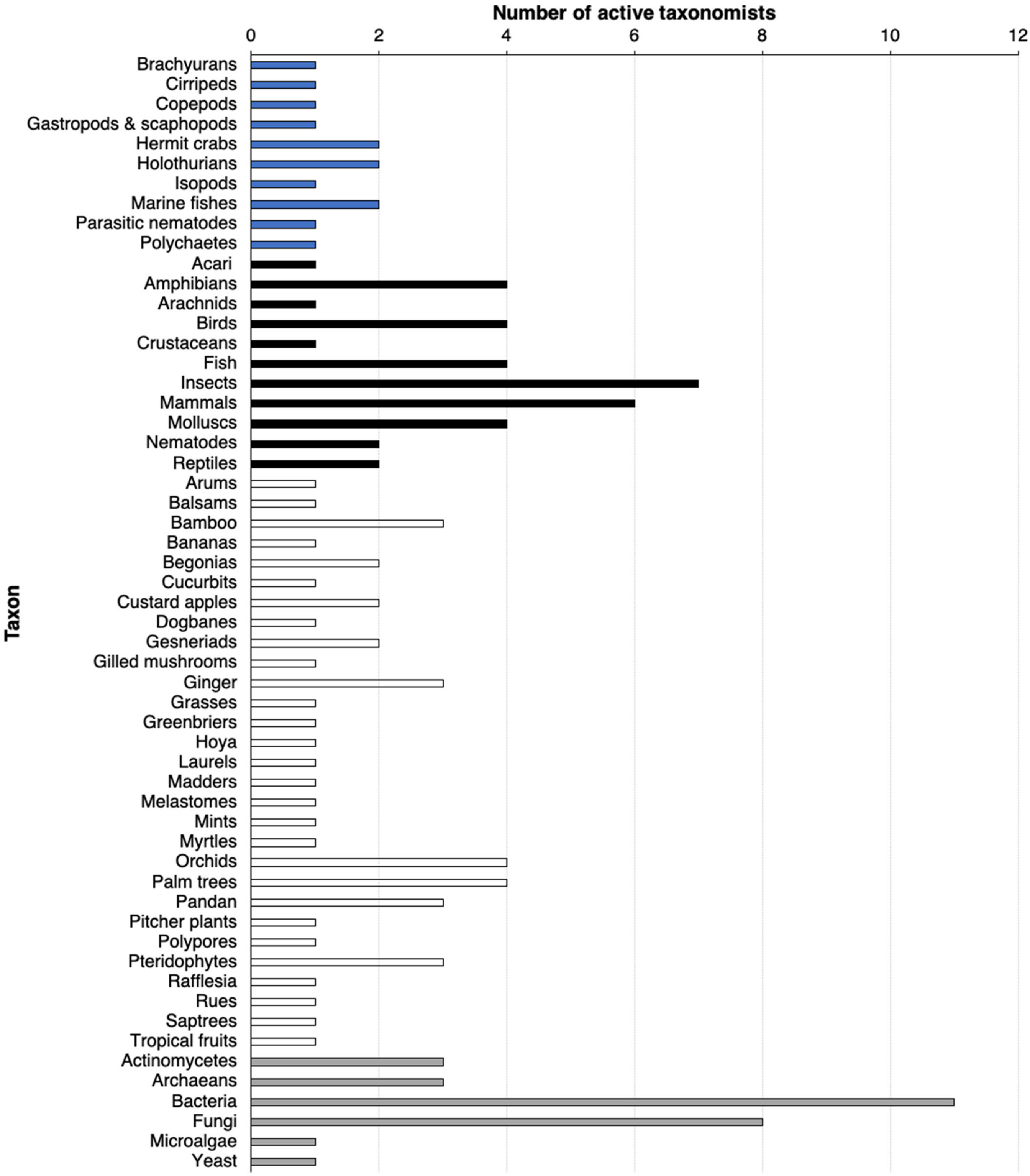

Fig. 2. The composition of active local taxonomists. Blue, black, white, and grey bars indicate marine, faunal, floral, and microbial taxa, respectively (the last three taxa are non-marine). A list of the taxonomists is provided in Appendix 1.

Table 2. List of Indonesian marine species exclusively described by local taxonomists from the 1970s to January 2023. In total, there have been 154 Indonesian marine species described by local researchers in 91 publications. Localities: CI = Central Indonesia (63 species; 41%), EI = Eastern Indonesia (52 species; 34%), WI = Western Indonesia (39 species; 25%).

Taxon	Species	Authority	Locality	General habitat
Cirripeds	*Fistulobalanus sumbawaensis*	Prabowo & Yamaguchi, 2005	Sumbawa, West Nusa Tenggara, CI	Intertidal (mangrove)
Copepods	*Calanopia asymmetrica*	Mulyadi & Ueda, 1996	Sunda Strait, Labuan, West Java, WI	Pelagic
	Candacia ishimarui	Mulyadi, 1997a	Flores Sea, CI	Pelagic
	Hemicyclops javaensis	Mulyadi, 2005	Java Sea, WI	Pelagic
	Hemicyclops minutus	Mulyadi, 2005	Java Sea, WI	Pelagic
	Kelleria indonesiana	Mulyadi, 2009	Cilacap, Central Java, WI	Pelagic
	Kelleria javaensis	Mulyadi, 2009	Surabaya, East Java, WI	Pelagic
	Labidocera baliensis	Mulyadi, 2021	Bali, CI	Pelagic
	Labidocera gagensis	Mulyadi, 2021	Gag Island, West Papua, EI	Pelagic
	Labidocera javaensis	Mulyadi, 1997b	Java Sea, WI	Pelagic
	Labidocera kaimanaensis	Mulyadi, 2014	Arguni Bay, Kaimana, West Papua, EI	Pelagic
	Labidocera muranoi	Mulyadi, 1997b	Java Sea, WI	Pelagic
	Paramacrochiron amboinense	Mulyadi, 2005	Ambon, Maluku, EI	Pelagic
	Pontella bonei	Mulyadi, 2003	Gulf of Boni, South Sulawesi, CI	Pelagic
	Pontella kleini	Mulyadi, 2003	Cilacap, Central Java, WI	Pelagic
	Pontella labuanensis	Mulyadi, 1997b	Sunda Strait, Labuan, West Java, WI	Pelagic
	Pontella papuaensis	Mulyadi, 2014	Arguni Bay, Kaimana, West Papua, EI	Pelagic
	Pontella vervoorti	Mulyadi, 2003	Semarang, Central Java, WI	Pelagic
	Pontellopsis bispinata	Mulyadi, 2018	Gulf of Boni, South Sulawesi, CI	Pelagic
	Pontellopsis celebensis	Mulyadi, 2018	Gulf of Boni, South Sulawesi, CI	Pelagic
	Pontellopsis rajaensis	Mulyadi, 2018	Raja Ampat, West Papua, EI	Pelagic
	Pseudodiaptomus kleini	Mulyadi, 2022	Tanjung Merah, North Sulawesi, CI	Pelagic
	Tortanus (*Atortus*) *bilobus*	Mulyadi, Nishida & Ohtsuka, 2017	Tanjung Merah, North Sulawesi, CI	Pelagic
	Tortanus (*Atortus*) *indonesiensis*	Mulyadi, Nishida & Ohtsuka, 2017	Tanjung Merah, North Sulawesi, CI	Pelagic
	Tortanus (*Atortus*) *lukmani*	Mulyadi, Nishida & Ohtsuka, 2017	Tanjung Merah, North Sulawesi, CI	Pelagic
	Tortanus (*Atortus*) *manadoensis*	Mulyadi, Nishida & Ohtsuka, 2017	Tanjung Merah, North Sulawesi, CI	Pelagic
	Tortanus (*Atortus*) *omorii*	Mulyadi, Nishida & Ohtsuka, 2017	Tanjung Merah, North Sulawesi, CI	Pelagic
	Tortanus (*Atortus*) *processus*	Mulyadi, Nishida & Ohtsuka, 2017	Tanjung Merah, North Sulawesi, CI	Pelagic
	Tortanus (*Atortus*) *sulawesiensis*	Mulyadi, Nishida & Ohtsuka, 2017	Tanjung Merah, North Sulawesi, CI	Pelagic
Decapods	*Amarinus pristes*	Rahayu & Ng, 2004	Timika, Papua, EI	Intertidal (mangrove)
	Areopaguristes breviantennatus	(Rahayu, 2005)	Flores Sea, Komodo Island, East Nusa Tenggara, CI	Subtidal
	Areopaguristes micheleae	(Rahayu, 2005)	Banda Sea, Binongko Island, South East Sulawesi, CI	Deep sea

Taxon	Species	Authority	Locality	General habitat
	Areopaguristes ngochoae	(Rahayu, 2005)	Celebes Sea, Sangihe Island, North Sulawesi, CI	Subtidal
	Calcinus morgani	Rahayu & Forest, 1999	Halmahera, North Maluku, EI	Intertidal
	Chartocinus rarus	Ng & Rahayu, 2022	Kamora, Papua, EI	Estuary
	Clibanarius ambonensis	Rahayu & Forest, 1993	Ambon, Maluku, EI	Intertidal (mangrove)
	Clibanarius antennatus	Rahayu & Forest, 1993	Makassar, South Sulawesi, CI	Intertidal
	Clibanarius bistriatus	Rahayu & Forest, 1993	Ambon, Maluku, EI	Intertidal (mangrove)
	Clibanarius danai	Rahayu & Forest, 1993	Balikpapan, East Kalimantan, CI	Intertidal
	Clibanarius harisi	Rahayu, 2003	Timika, Papua, EI	Estuary
	Clibanarius rubroviria	Rahayu, 1999	Lombok, West Nusa Tenggara, CI	Intertidal
	Clibanarius rutilus	Rahayu, 1999	Lembeh Strait, North Sulawesi, CI	Intertidal (sandy beach)
	Clibanarius serenei	Rahayu & Forest, 1993	Kendari, Sout East Sulawesi, CI	Intertidal (mangrove)
	Clibanarius similis	Rahayu & Forest, 1993	Balikpapan, East Kalimantan, CI	Intertidal
	Clistocoeloma amamaparense	Rahayu & Takeda, 2000	Timika, Papua, EI	Intertidal (mangrove)
	Crossotonotus ceramensis	(Moosa & Serène, 1981)	Seram Island, Maluku, EI	Subtidal
	Cymonomus hakuhoae	Takeda & Moosa, 1990	Flores Sea, CI	Deep sea
	Diogenes berduri	Rahayu, 2021	Sunda Strait, WI	Deep sea
	Diogenes fasciatus	Rahayu & Forest, 1995	Muara Karang, Jakarta, WI	Intertidal
	Diogenes foresti	Rahayu & Hortle, 2002	Timika, Papua, EI	Estuary
	Diogenes klaasi	Rahayu & Forest, 1995	Balikpapan, East Kalimantan, CI	Intertidal
	Diogenes matabiru	Rahayu & Pratiwi, 2022	Lombok, West Nusa Tenggara, CI	Intertidal (mangrove)
	Diogenes moosai	Rahayu & Forest, 1995	Muara Karang, Jakarta, WI	Intertidal
	Diogenes spinicarpus	Rahayu & Forest, 1995	Ambon, Maluku, EI	Intertidal
	Diogenes takedai	Rahayu, 2012	Lombok, West Nusa Tenggara, CI	Intertidal (seagrass)
	Diogenes tumidus	Rahayu & Forest, 1995	Sorong, West Papua, EI	Intertidal & subtidal
	Elamena nara	Rahayu & Nugroho, 2019	Lombok, West Nusa Tenggara, CI	Intertidal
	Elamena similis	Rahayu & Nugroho, 2019	Lombok, West Nusa Tenggara, CI	Intertidal
	Elamena sira	Rahayu & Nugroho, 2019	Lombok, West Nusa Tenggara, CI	Intertidal
	Elamenopsis gracilipes	Rahayu & Ng, 2019	Timika, Papua, EI	Estuary
	Haberma kamora	Rahayu & Ng, 2005	Timika, Papua, EI	Intertidal (mangrove)
	Heteropilumnus satriai	Yeo, Rahayu & Ng, 2004	Laut Island, Natuna, The Riau Islands, WI	Intertidal
	Hexapinus latus	Rahayu & Ng, 2014	Lombok, West Nusa Tenggara, CI	Intertidal
	Hexapinus simplex	Rahayu & Ng, 2014	Lombok, West Nusa Tenggara, CI	Intertidal
	Hexapus timika	Rahayu & Ng, 2014	Timika, Papua, EI	Subtidal
	Indopinnixa kasijani	Rahayu & Ng, 2010c	Lombok, West Nusa Tenggara, CI	Intertidal (seagrass)
	Indopinnixa moosai	Rahayu & Ng, 2010c	Lombok, West Nusa Tenggara, CI	Interidal (sandy beach)

Taxon	Species	Authority	Locality	General habitat
	Leptarma gracilipes	Li, Rahayu & Ng, 2018	Timika, Papua, EI	Intertidal (mangrove)
	Leptarma paucitorum	(Rahayu & Ng, 2009)	Manado, North Sulawesi, CI	Intertidal (mangrove)
	Macrophthalmus fusculatus	Rahayu & Nugroho, 2012	Timika, Papua, EI	Intertidal (mangrove)
	Macrophthalmus (*Macrophthalmus*) *manggala*	Murniati, Asakura, Nugroho, Hernawan & Dharmawan, 2022	Liki Island, Papua, EI	Intertidal (mangrove)
	Mariaplax cyrtophallus	Rahayu & Ng, 2014	Timika, Papua, EI	Subtidal
	Mariaplax pitrai	Rahayu & Widyastuti, 2018	Damar Kecil Island, The Thousand Islands, Jakarta, WI	Intertidal
	Mariaplax sundaica	Rahayu & Widyastuti, 2018	Sunda Strait, WI	Offshore
	Neodorippe simplex	Ng & Rahayu, 2002	Timika, Papua, EI	Estuary
	Neorhynchoplax elongata	Rahayu & Ng, 2004	Timika, Papua, EI	Intertidal (mangrove)
	Neosarmatium bidentatum	Rahayu & Davie, 2006	Timika, Papua, EI	Intertidal (mangrove)
	Neosarmatium papuense	Rahayu & Davie, 2006	Timika, Papua, EI	Intertidal (mangrove)
	Notonyx castroi	Rahayu & Ng, 2010b	Lombok, West Nusa Tenggara, CI	Intertidal (seagrass)
	Notonyx falcatus	Rahayu, 2011	Seram Island, Maluku, EI	Intertidal
	Notonyx guinotae	Rahayu & Ng, 2010a	Lombok, West Nusa Tenggara, CI	Intertidal
	Oreotlos octavus	Mendoza & Nugroho, 2021	Sunda Strait, WI	Subtidal
	Paguristes antennarius	Rahayu, 2006	Arafura Sea, The Kei Islands, Maluku, EI	Deep sea
	Paguristes arostratus	Rahayu, 2006	Makassar Strait, East Kalimantan, CI	Subtidal
	Paguristes brachyrostris	Rahayu, 2006	Makassar Strait, West Sulawesi, CI	Deep sea
	Paguristes rectus	Rahayu, 2021	Indian Ocean, WI	Deep sea
	Pagurus fungiformis	Komai & Rahayu, 2004	Bitung, North Sulawesi, CI	Intertidal
	Paracleistostoma laciniatum	Rahayu & Ng, 2003b	Timika, Papua, EI	Intertidal (mangrove)
	Paracleistostoma quadratum	Rahayu & Ng, 2003b	Timika, Papua, EI	Intertidal (mangrove)
	Parapalicus ambonensis	Moosa & Serène, 1981	Haruku Island, Maluku, EI	Subtidal
	Parapalicus piruensis	Moosa & Serène, 1981	Seram Island, Maluku, EI	Subtidal
	Parasesarma anambas	Yeo, Rahayu & Ng, 2004	Jemaja Island, Anambas, The Riau Islands, WI	Intertidal (mangrove)
	Parasesarma charis	Rahayu & Ng, 2005	Timika, Papua, EI	Intertidal (mangrove)
	Parasesarma cricotum	(Rahayu & Davie, 2002)	Timika, Papua, EI	Intertidal (mangrove)
	Philyra bicornis	Rahayu & Ng, 2003a	Timika, Papua, EI	Intertidal (mangrove)
	Pleurophricus longirostris	(Moosa & Serène, 1981)	Sunda Strait, WI	Subtidal
	Pseudocheles neutra	De Grave & Moosa, 2004	Kaledupa, Sout East Sulawesi, CI	Subtidal (reef rubble)
	Pseudolambrus sundaicus	Ng & Rahayu, 2000	Ayer Island, The Thousand Islands, Jakarta, WI	Intertidal
	Pseudopaguristes asper	Rahayu, 2005	Bali Sea, CI	Deep sea
	Scopimera gordonae	Serène & Moosa, 1981	Manokwari, West Papua, EI	Intertidal
	Takedellus ambonense	(Serène & Moosa, 1971)	Ambon, Maluku, EI	Intertidal

Taxon	Species	Authority	Locality	General habitat
	Thecaplax capillosa	Ng & Rahayu, 2014	Lombok, West Nusa Tenggara, CI	Intertidal (sandy beach)
	Tmethypocoelis celebensis	Murniati, Asakura & Davie, 2023	North Minahasa, North Sulawesi, CI	Estuary
	Tmethypocoelis liki	Murniati, Asakura, Nugroho, Hernawan & Dharmawan, 2022	Liki Island, Papua, EI	Intertidal (mangrove)
	Tmethypocoelis simplex	Murniati, Asakura & Davie, 2023	Donggala, Central Sulawesi, CI	Estuary
	Tritodynamia nontjii	Rahayu & Ng, 2021	Otakwa, Papua, EI	Subtidal
	Typhlocarcinops hadrotes	Ng & Rahayu, 2020	Pelabuhan Ratu, West Java, WI	Deep sea
	Typhlocarcinops hirtus	Ng & Rahayu, 2020	Lombok, West Nusa Tenggara, CI	Intertidal (seagrass)
	Typhlocarcinops raouli	Ng & Rahayu, 2020	Arafura Sea, Papua, EI	Subtidal
	Typhlocarcinops robustus	Ng & Rahayu, 2020	Arafura Sea, Papua, EI	Subtidal
Fishes	*Akheilos suwartanai*	White, Fahmi & Weigmann, 2019	West Seram, Maluku, EI	Pelagic
	Atelomycterus erdmanni	Fahmi & White, 2015	Lembeh Strait, North Sulawesi, CI	Pelagic
	Chelidoperca flavolineata	Matsunuma, Tan & Peristiwady, 2020	Indian Ocean, Java, WI	Pelagic
	Cymatognathus aureolateralis	Kimura, Johnson, Peristiwady & Matsuura, 2017	Bitung, North Sulawesi, CI	Pelagic
	Eubleekeria kupanensis	(Kimura & Peristiwady, 2005)	Savu Sea, Kupang, East Nusa Tenggara, CI	Pelagic
	Okamejei cairae	Last, Fahmi & Ishihara, 2010	South China Sea, West Kalimantan, WI	Pelagic
	Parmaturus nigripalatum	Fahmi & Ebert, 2018	Indian Ocean, Sumbawa, West Nusa Tenggara, CI	Deep sea
	Parupeneus inayatae	Uiblein & Fahmi, 2018	Bali Sea, Tanjung Luar, West Nusa Tenggara, CI	Pelagic
	Pastinachus stellurostris	Last, Fahmi & Naylor, 2010	South China Sea, Pemangkat, West Kalimantan, WI	Pelagic
	Platygobiopsis hadiatyae	Larson, Jaafar, Tan & Peristiwady, 2020	Sunda Strait, WI	Pelagic
	Rhinobatos jimbaranensis	Last, White & Fahmi, 2006	Kedonganan, Bali, CI	Pelagic
	Rhinobatos penggali	Last, White & Fahmi, 2006	Kedonganan, Bali, CI	Pelagic
	Synodus nigrotaeniatus	Allen, Erdmann & Peristiwady, 2017	Lembeh Strait, North Sulawesi, CI	Pelagic
	Upeneus farnis	Uiblein & Peristiwady, 2017	Bitung, North Sulawesi, CI	Pelagic
	Vanderhorstia lepidobucca	Allen, Peristiwady & Erdmann, 2014	Lembeh Strait, North Sulawesi, CI	Pelagic
Gastropods	*Euthria effendyi*	Fraussen & Dharma, 2002	Bali Strait, WI	Subtidal
	Melo gajahmadai	Dharma, 2023	East Java, WI	Subtidal
	Melo nusantara	Dharma, 2023	Riau Archipelago, East Sumatra, WI	Subtidal
	Murex hystricosus	Houart & Dharma, 2001	Indian Ocean near Bengkulu, WI	Depth unknown
	Nassaria nebulonis	Fraussen, Dharma & Stahlschmidt, 2009	Pangandaran, West Java, WI	Subtidal
	Petalopoma indoensis	Dharma, 2011	Karimata Island, West Kalimantan, WI	Subtidal
	Pleuroploca effendyi	Dharma, 2021	Bali Strait, WI	Subtidal
	Tenagodus sundaensis	Dharma, 2011	Natuna, The Riau Islands, WI	Subtidal

Taxon	Species	Authority	Locality	General habitat
Isopods	*Bathynomus raksasa*	Sidabalok, Wong & Ng, 2020	Sunda Strait, WI	Deep sea
	Cirolana bambang	Sidabalok & Bruce, 2018a	Bitung, North Sulawesi, CI	Subtidal
	Cirolana duo	Sidabalok & Bruce, 2017	Lombok, West Nusa Tenggara, CI	Intertidal (reef rubble)
	Cirolana fasfes	Sidabalok & Bruce, 2018b	Raja Ampat, West Papua, EI	Subtidal
	Cirolana lembeh	Sidabalok & Bruce, 2018b	Lembeh Strait, North Sulawesi, CI	Subtidal
	Metacirolana lombok	Sidabalok & Bruce, 2018c	Lombok, West Nusa Tenggara, CI	Subtidal
	Metacirolana mioskon	Sidabalok & Bruce, 2018c	Raja Ampat, West Papua, EI	Subtidal
	Dolichiscus selatan	Wong & Sidabalok, 2021	Panaitan Island, Sunda Strait, WI	Deep sea
Jellyfish	*Crambionella helmbiru*	Nishikawa, Mulyadi & Ohtsuka, 2014	Cilacap, Central Java, WI	Pelagic
Nematodes	*Philometra damriyasai*	Dewi & Palm, 2017	Bali Sea, CI	Parasitic
	Philometra epinepheli	Dewi & Palm, 2013	Bali Sea, CI	Parasitic
	Spirophilometra endangae	Dewi & Palm, 2013	Bali Sea, CI	Parasitic
Polychaetes	*Capitella ambonensis*	Pamungkas, 2017	Ambon, Maluku, EI	Intertidal (mangrove)
	Pectinaria nusalautensis	Pamungkas & Hutchings, 2023	Nusalaut Island, Maluku, EI	Intertidal (sandy beach)
	Polymastigos javaensis	Pamungkas, 2015	Cilacap, Central Java, WI	Intertidal (mangrove)
Scaphopods	*Fissidentalium sahlmanni*	Dharma & Eng, 2009	Arafura Sea, EI	Deep sea
Stomatopods	*Acanthosquilla wilsoni*	Moosa, 1973	The Aru Islands, Maluku, EI	Subtidal
	Clorida javanica	Moosa, 1974	Java Sea, WI	Subtidal
	Clorida seversi	Moosa, 1973	The Kei Islands, Maluku, EI	Subtidal
	Cloridina moluccensis	Moosa, 1973	The Aru Islands, Maluku, EI	Subtidal
	Coronidopsis serenei	Moosa, 1973	The Kei Islands, Maluku, EI	Subtidal

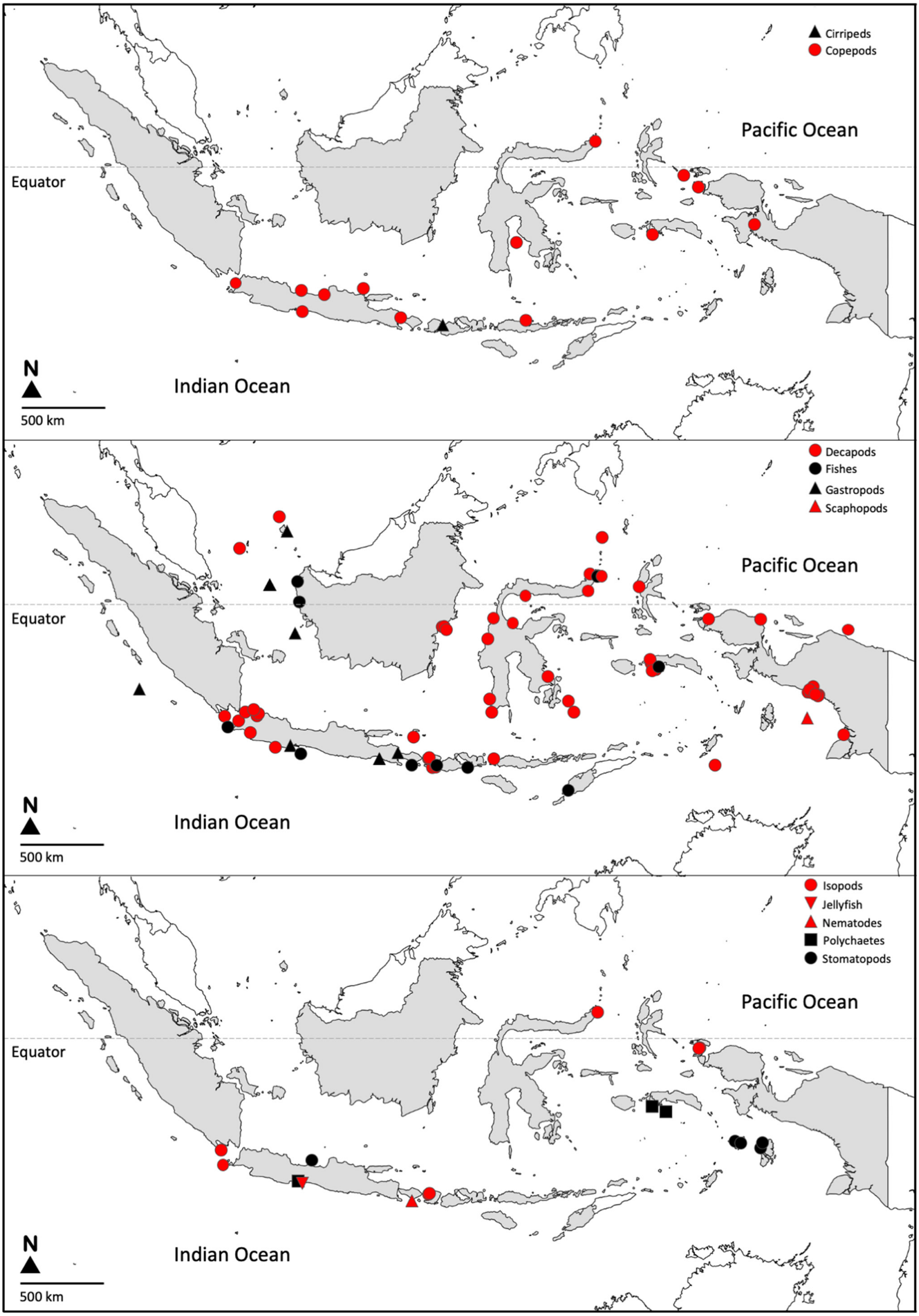

Fig. 3. Distributional map of Indonesian marine species exclusively described by local taxonomists. Grey and white land areas indicate Indonesia and the neighbouring countries, respectively.

Table 3. List of polychaete ecological studies conducted by local researchers in the past two decades[a]. Abbreviations: WI = Western Indonesia, CI = Central Indonesia, EI = Eastern Indonesia; NI = No Information; ZMT = Zentrum für Marine Tropenforschung (Centre for Tropical Marine Research).

Study	Sampling habitat	Location	Identification level	Literature used for identification	Taxonomist involvement	Specimen deposition
Indarjo et al. (2005)	Mangrove	Java, WI	Family	NI	No	NI
Junardi & Wardoyo (2008)	Mangrove	Kalimantan, WI	Family, genus, species[b]	Day (1967), Fauchald (1977), Beesley et al. (2000), Wilson et al. (2003)	No	NI
Widianwari & Widianingsih (2011)	Deep sea	East Nusa Tenggara, EI	Family, genus	NI	No	NI
Hadiyanto (2012)	Seagrass	Java, WI	Family, genus, species[c]	Imajima (1966), Day (1967), Fauchald (1977), Light (1978), Uebelacker (1984), Baoling et al. (1985)	No	NI
Ni'amillah et al. (2012)	Mangrove	Java, WI	Family	NI	No	NI
Prasetyo et al. (2012)	Estuary	Java, WI	Genus	Arnold & Birtles (1989), Day (1967), Fauchald (1977), Gosner (1971)	No	NI
Jauhara (2012)	Estuary	Java, WI	Genus	Arnold & Birtles (1989), Day (1967)	No	NI
Mahfud et al. (2013)	Estuary	Java, WI	Genus	Day (1967), Beesley et al. (2000)	No	NI
Pamungkas (2013)	Mangrove	Java, WI	Genus	Fauchald (1977), Imajima (1990), Beesley et al. (2000), Green (2002), Wilson et al. (2003)	Yes	ZMT
Romadhoni & Aunurohim (2013)	Mangrove	Java, WI	Genus	NI	No	NI
Rahman et al. (2013)	Seagrass	Java, WI	Genus	Day (1967), Beesley et al. (2000)	No	NI
Finishia et al. (2014)	Seagrass	Java, WI	Genus	Imajima (1966), Day (1967), Fauchald (1977), Light (1978), Uebelacker (1984), Baoling et al. (1985)	No	NI
Rahman (2016)	Seagrass	Java, WI	Family	Day (1967), Beesley et al. (2000)	No	NI
Sahidin & Wardiatno (2016)	Coastal waters	Java, WI	Genus, species[d]	NI	No	NI
Priyandayani et al. (2018)	Mangrove	Bali, CI	Genus	Day (1967), Fauchald (1977)	No	NI
Wambrauw et al. (2018)	Muddy, sandy, rocky shores	West Papua, EI	Genus	Day (1967), Fauchald (1977)	No	NI
Katili & Utina (2019)	Mangrove	Sulawesi, CI	Species[e]	NI	No	NI
Nadia et al. (2020)	Sandy beach	Sumatra, WI	Species[f]	NI	No	NI
Rahman et al. (2021)	Seagrass	Lombok, CI	Family	NI	No	NI

[a]Most of the publications were obtained through Garba Rujukan Digital (Garuda; https://garuda.ristekbrin.go.id), the national web portal for local publications.
The species identified along with their locality based on the species' original description include:
[b]*Cirratulus concinnus* and *Notomastus fauvelii* (South Africa), *Nephtys hombergii* (France), *Sternaspis scutata* (Adriatic Sea), *Cossura coasta* (Japan), *Prionospio cirrifera* (Arctic and North Atlantic waters);
[c]*Armandia maculata* (Bermuda), *Cirrophorus branchiatus* (South Africa), *Mediomastus californiensis* (US), *Naineris laevigata* (Mediterranean Sea), *N. hystricis* (Ireland), *Nicon japonicus* (Japan), *Ophelina longicaudata* (Indonesia), *Pista brevibranchia* (Palau), *Platynereis dumerilii* (France), *P. cirrifera* (Arctic and North Atlantic waters), *P. steenstrupi* (Iceland);
[d]*Aphrodita aculeata* (unknown), *Arenicola marina*, *Petta pusilla* and *Rhodine loveni* (Sweden), *Capitella capitata*, *Glycera capitata* & *N. caeca* (Greenland), *Exogone naidina*, *Polyphysia crassa* and *Scoloplos armiger* (Denmark), *Janua heterostropha*, *Myxicola infundibulum* (UK), *Melinna cristata* & *Scalibregma inflatum* (Norway), *Neanthes fucata* (Mediterranean Sea), *Neoamphitrite figulus* and *Owenia fusiformis* (Canada and US), *Ophryotrocha puerilis* (US), *P. dumerilii* (France), *S. scutata* (Adriatic Sea), *Syllis gracilis* (Italy), *Travisia forbesii* (Netherlands);
[e]*Capitella capitata* (Greenland);
[f]*Alitta virens* and *Hediste diversicolor* (Norway), *A. marine* (Sweden), *Bispira brunnea* (Bahamas), *Palola viridis* (Samoa), *Protula bispiralis* (Indian Ocean), *Sabella pavonina* (Mediterranean Sea), *Serpula vermicularis* (Atlantic and Mediterranean waters), *Spirobranchus giganteus* (Caribbean Sea), *Spirorbis (Spirorbis) spirorbis* (France).

species in 91 publications between 1973 and early 2023 (Table 2); most of the species were collected from the CT (Fig. 3). This species number is insignificant compared to the total number of marine species that have been described worldwide, i.e., around 230,000 species (Bouchet, 2006; Appeltans et al., 2012).

Moreover, Table 1 shows that Indonesia at present only has two senior marine taxonomists who have consistently described species from the 1990s to the 2020s; they have described 68 and 28 local species of decapods and copepods, respectively. The other nine workers, meanwhile, initiated marine species description in the 2000s, 2010s, and 2020s—each one of them has described fewer than 10 local species—and two workers have not described species new to science (Table 1). Evidently, this pace of species discovery is too slow and does not meet the challenge of documenting biodiversity before they go extinct due to anthropogenic impacts. In all, these 13 marine taxonomists have studied ten taxa only, i.e., cirripeds, copepods, crabs (including other crab-like decapods), gastropods, holothurians, isopods, marine fishes, parasitic nematodes, scaphopods, and polychaetes (Table 1). Local taxonomists who work on species-rich marine taxa such as bivalves, echinoids, phytoplankton, and sponges are not yet available; exclusively meiofaunal taxa such as free-living nematodes, foraminiferans, and priapulids are, to our best knowledge, completely unstudied.

The direct cause of the marine taxonomist shortage in Indonesia is apparently because explicit job vacancies for them have never existed; such vacancies have never been created by the Research Center for Oceanography (RCO), the country's biggest marine research institution with the most marine scientists. The decision to become a marine taxonomist was usually made later, after a person has already spent years working, often after the completion of their postgraduate studies as well (Augy Syahailatua, 2021, pers. comm.). To our best knowledge, the Research Center for Biology (RCB) was the only institution that, albeit not explicitly, opened vacancies for taxonomists in the past few decades. The institution's research focus was nonetheless on terrestrial and freshwater species, indicated by the research activities, the publications (Pusat Penelitian Biologi – LIPI, 2022), and the fields of expertise of its researchers (Appendix 1). Also, the vast majority of about 1,000 Indonesian species new to science described by local taxonomists over half a century (1967–2017) were in fact non-marine (Ardiyani et al., 2017). Globally, the lack of recruitment into permanent positions of taxonomists has been identified as one of the biggest challenges in taxonomy today (e.g., Britz et al., 2020), and this vagueness in career paths seems to have also hindered local Indonesians who are passionate about marine taxonomy from entering the field.

Limited taxonomic literature and knowledge

The fact that local marine taxonomists are 'rare species' has led to the scarcity of taxonomic literature on local species. As a result, most biological specimens obtained are generally either not identified to species level or incorrectly identified, as we found for polychaetes in the present study (Table 3). The latter case typically occurs because local researchers use identification keys written for other geographic areas that are far away from their study sites—usually because such literature is well illustrated—such as China (Baoling et al., 1985), France (Fauvel, 1923, 1927), southern Africa (Day, 1967), as well as the family and generic identification keys of Fauchald (1977). This has resulted in many polychaete species from European, North American, north Atlantic, and southern African waters being reported to occur in Indonesian waters (Table 3). This practice does not seem to be unique to Indonesia (or polychaetes), but occurs globally across other marine taxa, causing many species to be regarded as cosmopolitan (Hutchings & Kupriyanova, 2018).

To determine whether a species is new to science or not, one needs to carefully compare the morphology of the observed specimens with that of all the species belonging to the same genus (the congeners). Taxonomic literature, which is ideally coupled with comparisons with type specimens loaned from natural history museums, is required. This thorough and long identification process is unfortunately not a priority for ecologists who can often achieve the same outcomes by utilising morphospecies names for statistical analysis purposes; potentially new species consequently remain undiscovered. Although today the use of DNA barcoding based on the mitochondrial cytochrome oxidase 1 (CO1) gene to rapidly identify Indonesian marine species (especially fish) is becoming more popular (e.g., Sembiring et al., 2015; Nuryanto et al., 2017; Wibowo et al., 2018; Fadli et al., 2020), this method alone should not replace the morphological approach to officially describe a new species—although a recent study controversially did do just that (Sharkey et al., 2021).

Furthermore, due to a lack of taxonomic knowledge—in this context the term refers to the awareness of researchers to identify biological specimens properly using all available literature and deposit the specimens in an accessible repository—polychaete species identification is often performed carelessly by only matching the morphology of observed specimens against figures in identification books without reading the species' full description, which results in unreliable species name data (JP, pers. obs.). Polychaete specimens and other biological specimens, especially larger ones, are in the worst cases discarded after the study is published, mainly due to space limitations and partly the fact that biological specimen deposition has never been of concern to local journal editors (e.g., Table 3 shows that almost all of the published ecological papers on Indonesian polychaetes have no information about where the authors deposited their specimens). All these practices have hampered marine species discoveries in Indonesia.

Limited access to natural history collections

The utilisation of reference collections is crucial for species identification, especially when one needs to compare a new species candidate with several congeners that are most morphologically similar to it. Up until the year 2021, reference collections of Indonesian marine species, including polychaetes, could be found at the Museum Zoologicum Bogoriense (MZB), the Research Center for Deep Sea (RCDS), and the RCO (this institution housed the largest marine biological collection in the country). However, following the merger of all national research institutions under the management of NRIA (President of the Republic of Indonesia, 2021), all of these collections are now centralised at the Biodiversity Buildings in Cibinong, Bogor, West Java. Museum Zoologicum Bogoriense, Herbarium Bogoriense (BO), and Indonesian Culture Collection (InaCC), the three national repositories for Indonesian fauna, flora and microorganisms, respectively (Pusat Penelitian Biologi – LIPI, 2017a, b, 2019), will be managing the entire combined collection at these buildings.

While the country does possess national repositories, the number of type specimens of local marine species are quite limited (except perhaps for copepods and decapods whose local taxonomists have consistently described and deposited their specimens at MZB over time). For example, at present there are only 15 polychaete type specimens (from three species) at MZB as most of the Indonesian polychaete type specimens are deposited at NBC (Bleeker & van der Spoel, 1992; Pamungkas & Glasby, 2019). Local researchers who intend to compare their specimens against type specimens consequently need to either conduct a research visit to overseas museums or request specimen loans. While the former action requires significant amounts of funding for Asian taxonomists—this is because most type specimens are kept in European and American museums (Ng, 1998), as well as Australian museums for polychaetes (Pat Hutchings, 2023, pers. comm.)—the latter one, although more practical, is risky for polychaetes and other alcohol-preserved marine specimens. Biological specimens sent from abroad can be received, provided local researchers are able to provide proper documents to the customs authorities, yet the specimens cannot be shipped back—neither by air nor by sea—as the delivery of packages containing liquid, especially alcohol, is prohibited according to the current national postal regulations (Pos Indonesia, 2022). That is why no comparative materials were examined during the identifications of three Indonesian polychaetes described by the author (JP), i.e., *C. ambonensis*, *P. javaensis*, and *P. nusalautensis*. Limited access to natural history collections has, therefore, been a challenge especially for local researchers who require comparative materials to identify their specimens.

A lack of research funding and collaboration

As a country with exceptionally high biodiversity, the local government's budget for taxonomic investigations to reveal the nation's biodiversity is relatively small. In 2022, for instance, NRIA had a total budget of about IDR 6.1 trillion (around USD 400 million), of which IDR 272 billion (around USD 18.1 million) was allocated for research activities (BRIN, 2022). Of these IDR 272 billion, the amount of funds secured for taxonomic research was nearly IDR 11 billion (around USD 733 thousand), which was later reduced by 50% to around IDR 5.5 billion (around USD 366 thousand) due to budget efficiency policy at the institution. There were 75 taxonomic research proposals making use of these funds, the vast majority of which were on non-marine species (Research Organization for Life Sciences, 2021) as the country currently has much more non-marine than marine taxonomists (Appendix 1). Limited funding for conducting taxonomic research also occurs worldwide, and is considered one of the primary impediments in taxonomy (e.g., Britz et al., 2020).

Furthermore, the trend in polychaete ecological investigations in Indonesia over the past two decades demonstrated that in most cases, taxonomists were not involved in species identification (Table 3). In turn, taxonomic publications on the fauna were not co-authored by ecologists (e.g., Pamungkas, 2015, 2017; Pamungkas & Glasby, 2015), indicating that both groups of experts in many cases tend to conduct their own projects separately, which may undermine their research findings. In such case, studies by local polychaete ecologists have rarely revealed the biodiversity of the investigated areas (Table 3), whereas taxonomic investigations have yielded a relatively small number of polychaete specimens. Moreover, the performance of local researchers is evaluated based primarily on publications, and a research article with more co-authors receives less credit than that with fewer ones (Indonesian Institute of Sciences, 2019). This policy has existed for many years and partly caused local scientists to do solo rather than collaborative work.

Uneven distribution of research facilities

The CT is recognised as the centre of marine biodiversity of the world. The area encompasses four Southeast Asian countries (i.e., the Philippines, Malaysia, Indonesia, and Timor-Leste) and two Oceanian countries (i.e., Papua New Guinea and the Solomon Islands). In Indonesia, the CT lies in the central (i.e., Celebes, Flores and Savu Seas, Makassar Strait) and the eastern parts of the country (i.e., Molucca, Halmahera, Ceram, Banda, and Timor Seas). About 75% of Indonesian marine species described by local researchers were discovered in these areas (Table 2 & Fig. 3).

In contrast to the extraordinarily high marine species richness in these areas, research facilities there are quite limited. Most research and higher education institutions, and consequently the majority of local taxonomists (Appendix 1) and research activities, are based outside the CT, especially in Java and Sumatra. For example, about 70% of polychaete ecological studies were carried out in the western part of Indonesia, mostly in Java (Table 3). The three national biorepositories, i.e., MZB, BO, and InaCC, are also located in Java, and out of 3,200 accredited higher education institutions existing in Indonesia, around 1,500 and 800 are situated in Java and Sumatra, respectively (Ministry of Research, Technology and Higher Education, 2019). Meanwhile, several provinces located in the heart of the CT are considered to be remote, and have far fewer universities. The provinces along with their number of universities include East Nusa Tenggara (57), Maluku (30), North Maluku (19), West Papua (21), and Papua (48) (Ministry of Research, Technology and Higher Education, 2019). This lack of research facilities makes biological specimen collection around the CT more challenging as well as costly.

Strict research permit requirements for foreign researchers

The 'golden era' when most Indonesian polychaete species were described was during the early to the mid-20th century, i.e., the period when 236 species (about 78%) out of 301 species were solely described by overseas scientists in 42 taxonomic publications (Pamungkas & Glasby, 2019). That period was one where the regulations for obtaining research permits for conducting biodiversity studies in Indonesia for foreign scientists were not as strict as today. Loose regulations and law enforcement in the past, however, seem to have caused violations of Indonesian regulations concerning international biodiversity research collaboration, such as conducting research without a valid research permit, taking biological materials out of the country without a transfer agreement (biopiracy), publishing scientific papers without the involvement of local researchers, or not depositing type specimens in any Indonesian repository, etc. (e.g., LIPI, 2007; 2012; Pamungkas & Glasby, 2019; Rochmyaningsih, 2019; Grehenson, 2020; Wahyono et al., 2020). These issues have apparently been responsible for the stringent requirements to obtain a research permit in Indonesia (e.g., Rochmyaningsih, 2018, 2019; Grehenson, 2020) and serious penalties for those who violate current regulations. Depending on the types and the levels of violations, failure to comply with these regulations will result in foreign researchers being blacklisted, fined, or even banned from conducting any research activities in Indonesia for five years (Government of Indonesia, 2019—see the translation of some relevant chapters and articles in Appendix 2).

Besides a research proposal that must include Indonesian counterparts (a letter of acceptance from an Indonesian research institute or university whose staff will act as a research counterpart as well as a guarantor is therefore required), either a Memorandum of Understanding (for a multi-year project) or a Letter of Agreement (for a short-term project) must be created in order to apply for a research permit in Indonesia. As biodiversity research projects typically imply transfer of biological specimens, a Material Transfer Agreement (MTA) document is also a must, along with a number of administrative documents. Deposition of holotypes resulting from the proposed studies in Indonesian repositories, along with primary data submission and joint publications, is also mandatory. Joint publications, in particular, have been of concern as between the years 2010 and 2020, there were only about 1,200 joint publications recorded out of around 2,200 publications resulting from about 5,400 international research activities legally carried out in Indonesia (Wahyono et al., 2020). After obtaining the permit, additional permits may still be required if foreign researchers intend to conduct their research activities in a conservation area or using a research vessel. Since 2022, foreign researchers must apply for a research ethics clearance through the information system provided by NRIA to obtain a research permit (BRIN, 2023).

While these strict regulations are claimed to be necessary to protect Indonesian biodiversity from biopiracy—especially because the life sciences have been the most favoured field of collaborative research over the past decade (Wahyono et al., 2020)—and to ensure that both Indonesia and any collaborating countries receive mutual benefits, these strict regulations have the potential to hinder international research collaboration (Grehenson, 2020). In the context of species discovery, the current regulatory climate may have, to some extent, been slowing down the Indonesian marine species discovery rate.

POSSIBLE ACTIONS

Taxonomist recruitment and training

So what immediate actions can be taken to overcome taxonomic impediments in Indonesia? Since it has been shown that the number of local marine taxonomists was and remains low throughout the history of Indonesian species discovery, the recruitment of such workers through the annual job vacancies by relevant governmental research institutions is a direct solution. Additionally, more workers are particularly needed for poorly studied taxa. Since 1 February 2022, nearly all Indonesian taxonomists have been under the management of the Research Center for Biosystematics and Evolution (RCBE). This institution, along with RCO, is therefore most responsible for recruiting the next generation of local marine taxonomists (such recruitment is crucial as most local marine taxonomists in Table 1 are pioneers and have no successors).

In this regard, promoting marine taxonomy through internships and practical training—both activities have been rarely done in the past few years by RCO (Ismiliana Wirawati, 2022, pers. comm.)—can be an initial way to recruit potential scientists, as identifying species correctly based on species morphology requires labourious practice. The training may be best organised through the Regional Training and Research Center on Marine Biodiversity and Ecosystem Health (MarBEST Center) managed by the Indonesian Commision for IOC-UNESCO whose board comprises a number of prominent Indonesian scientists from various relevant research institutions. Normally, as the number of taxonomists increases, so do the numbers of species described, as well as taxonomic literature published. Marine taxonomist recruitment and training are therefore the primary keys to addressing the taxonomic impediments occurring in the country.

Strategic collaboration and funding

International biodiversity research collaboration is another strategy to deal with the nation's taxonomic impediments, especially for studies of taxa for which local experts are not yet available, and because recruiting people who are keen on marine taxonomy takes time. Despite the current strict permitting requirements to conduct such a collaboration (dealing with research permit affairs one year in advance may be necessary), the involvement of overseas scientists in the past has been shown to accelerate polychaete species discovery rate in this geographic region (Pamungkas & Glasby, 2019)—for polychaetes, collaboration with NBC may be of great assistance as the museum houses many Indonesian marine biological specimens collected during the *Siboga* Expedition (Bleeker & van der Spoel, 1992; Pamungkas & Glasby, 2019). In fact, international collaboration has also assisted local taxonomists in describing Indonesian marine species of various taxa (Table 2). Collaboration with overseas researchers based in museums can potentially solve a number of taxonomic impediments as they may be able to provide necessary literature, access to comparative materials, and often, funding.

An excellent example of such work was the collaboration between RCO and the National University of Singapore (NUS) through the South Java Deep-Sea Biodiversity Expedition (SJADES 2018) using RV *Baruna Jaya VIII* in 2018, which led to the discoveries of several Indonesian marine species new to science (Ng & Rahayu, 2021; Rahayu & Tan, 2021), including the deep-sea polychaete species *C. sundaensis* (Chuar & Salazar-Vallejo, 2021). Regional collaboration with Singapore is particularly promising as the nation is the gold standard of taxonomic work in South-East Asia, with the Lee Kong Chian Natural History Museum (LKCNHM), multiple taxonomic experts, and advanced laboratories. Thus, while more funding provided by the Indonesian government to conduct more marine taxonomic investigations is certainly required (this is because marine biodiversity-rich areas are situated in the eastern part of the country, often in remote or offshore areas where the use of a research vessel is necessary), local taxonomists could also either apply for grants from international funding agencies to conduct their research work, or strategically join a more comprehensive research project (e.g., a marine expedition involving a number of scientists with various fields of expertise like SJADES 2018) to obtain samples.

Furthermore, the involvement of taxonomists in an ecological study may also significantly improve the quality of biodiversity studies conducted in Indonesia in terms of the increase in the numbers of both biological specimen collections and species identified/described. For instance, none of the polychaete specimens obtained from the ecological study conducted by Pamungkas (2013) were initially identified to the species level (Table 3). However, a new capitellid species *P. javaensis* was later described in a subsequent paper after intensive communication between the author (JP) and Leslie H. Harris, a polychaete taxonomist from the Natural History Museum of Los Angeles County, Los Angeles, USA. Similarly, a new species candidate of *Paraprionospio* obtained from the same study is awaiting description after the author (JP)'s visit to Karin Meißner, a polychaete specialist from the German Centre for Marine Biodiversity Research, Hamburg, Germany.

Establishment of Indonesian marine reference collections, databases, and identification keys

Deposition of biological specimens, including morphospecies vouchers, in a recognised institution is of critical importance and especially urged for local biodiversity workers (researchers, lecturers and university students). This is because the specimens become national biodiversity physical evidence; it will also allow both local and international scientists to make use of them for future species identification and verification. In this regard, the centralisation of all biological collections, including marine ones, at the Biodiversity Buildings is expected to be a milestone in establishing Indonesian marine reference collections. The three national repositories, i.e., MZB, BO and InaCC, will be managing the entire biological collections at the buildings, which are physically located in the same area as RCBE where most Indonesian taxonomists are based.

While physical collections are being built, databasing Indonesian marine species is also essential—in fact, an annotated checklist of all named Indonesian species is not yet available. In this matter, platforms such as OBIS Indonesia (the last data addition was in 2018 by JP) and Indonesia Biodiversity Information System (IBIS—see http://ibis.biologi.lipi.go.id) can be a good start (the latter platform at present has more data on non-marine species as the website belongs to RCB). The availability of the database is required to answer research questions such as 'How many local species have been identified so far? How many of them are endemic? How are the species distributed across the country? Who described the most species? Where are the specimens deposited? What taxa are best and least studied? Which parts of the country have the most and the least records?' so that future studies can be more concentrated on poorly studied taxa and geographic areas. Following this, and in order to allow local biodiversity workers to identify species correctly, keys to Indonesian marine species need to be created and made publicly available so that they can make use of them rather than keys created for other geographic regions (the latter keys should be used cautiously by taking species geographic distribution into account).

CONCLUSION

A number of taxonomic impediments have been slowing down marine species discovery rate in Indonesia for decades. While such issues also occur in other parts of the world, including other Southeast Asian countries (see Ng, 1998, 2000, 2001), taxonomic impediments at the heart of one of the Earth's marine biodiversity hotspots are a huge obstacle to the global species discovery rate. We highlight that the country currently only has a few marine taxonomists, resulting in discoveries of species new to science being rare for most marine taxa, and past marine species discoveries being largely dependent on overseas taxonomists. It also turns out that despite the existence of biodiversity studies conducted by local scientists, the biological specimens these studies yield are rarely identified to species level due to the limited number of local taxonomists and taxonomic literature on local species. In addition, limited access to natural history collections, uneven distribution of research facilities across the nation, a lack of collaboration and funding, and strict permit regulations for foreign researchers have also contributed to the slow rate of marine species discoveries in Indonesia. To end these impediments, taxonomist recruitment and training are proposed to be the primary solutions. Besides that, obtaining strategic collaboration and funding, as well as the establishment of Indonesian marine reference collections, databases, and identification keys are required. If these strategies are to be applied, our model predicts that between 120 and 270 polychaete species will be discovered from Indonesian waters by the end of this century. Conducting taxonomic studies in the Coral Triangle are likely to uncover greater numbers of undescribed marine species compared to any other location in Indonesia or the world.

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APPENDICES

Appendix 1. List of active Indonesian taxonomists.

No.	Name	Institution	Location	Taxon of interests
Marine taxonomists				
1	Ana Setyastuti	Research Center for Oceanography, NRIA	Java, WI	Holothurians
2	Bunjamin Dharma	–	Java, WI	Gastropods & scaphopods
3	Conni M. Sidabalok	Research Center for Biosystematics and Evolution, NRIA	Java, WI	Isopods
4	Dewi C. Murniati	Research Center for Biosystematics and Evolution, NRIA	Java, WI	Decapods
5	Dharma A. Nugroho	Research Center for Biosystematics and Evolution, NRIA	Java, WI	Decapods
6	Dwi L. Rahayu	Research Center for Marine and Land Bioindustry, NRIA	West Nusa Tenggara, CI	Decapods
7	Fahmi	Research Center for Oceanography, NRIA	Java, WI	Marine fish
8	Ismiliana Wirawati	Research Center for Oceanography, NRIA	Java, WI	Holothurians
9	Kartika Dewi	Research Center for Biosystematics and Evolution, NRIA	Java, WI	Parasitic nematodes
10	Joko Pamungkas	Research Center for Biosystematics and Evolution, NRIA	Java, WI	Polychaetes
11	Mulyadi	Research Center for Biosystematics and Evolution, NRIA	Java, WI	Copepods
12	Romanus E. Prabowo	Jenderal Soedirman University	Java, WI	Cirripeds
13	Teguh Peristiwady	Research Center for Oceanography, NRIA	Java, WI	Marine Fish
Taxonomists working on Indonesian fauna (non-marine)				
14	Amir Hamidy	Research Center for Biosystematics and Evolution, NRIA	Java, WI	Reptiles & amphibians
15	Anang S. Achmadi	Research Center for Ecology and Etnobiology, NRIA	Java, WI	Mammals
16	Awal Riyanto	Research Center for Biosystematics and Evolution, NRIA	Java, WI	Reptiles
17	Awit Suwito	Research Center for Biosystematics and Evolution, NRIA	Java, WI	Insects
18	Ayu S. Nurinsiyah	Research Center for Biosystematics and Evolution, NRIA	Java, WI	Molluscs
19	Cahyo Rahmadi	Research Center for Biosystematics and Evolution, NRIA	Java, WI	Arachnids
20	Daisy Wowor	Research Center for Biosystematics and Evolution, NRIA	Java, WI	Crustaceans

No.	Name	Institution	Location	Taxon of interests
21	Daniel F. Mokodongan	Research Center for Biosystematics and Evolution, NRIA	Java, WI	Fishes
22	Dewi M. Prawiradilaga	Research Center for Biosystematics and Evolution, NRIA	Java, WI	Birds
23	Dhian Dwibadra	Research Center for Biosystematics and Evolution, NRIA	Java, WI	Acari
24	Djuniati Peggie	Research Center for Biosystematics and Evolution, NRIA	Java, WI	Insects
25	Evy A. Arida	Research Center for Biosystematics and Evolution, NRIA	Java, WI	Reptiles
26	Gono Semiadi	Research Center for Ecology and Etnobiology, NRIA	Java, WI	Mammals
27	Gema Wahyudewantoro	Research Center for Biosystematics and Evolution, NRIA	Java, WI	Fishes
28	Hadi Dahruddin	Research Center for Biosystematics and Evolution, NRIA	Java, WI	Fishes
29	Hari Nugroho	Research Center for Biosystematics and Evolution, NRIA	Java, WI	Insects
30	Hari Sutrisno	Research Center for Biosystematics and Evolution, NRIA	Java, WI	Insects
31	Hellen Kurniati	Research Center for Biosystematics and Evolution, NRIA	Java, WI	Reptiles & amphibians
32	Hidayat Ashari	Research Center for Biosystematics and Evolution, NRIA	Java, WI	Birds
33	Ibnu Maryanto	Research Center for Biosystematics and Evolution, NRIA	Java, WI	Mammals
34	Ilham V. Utama	Research Center for Biosystematics and Evolution, NRIA	Java, WI	Fish
35	Irvan Sidik	Research Center for Biosystematics and Evolution, NRIA	Java, WI	Reptiles
36	Maharadatunkamsi	Research Center for Biosystematics and Evolution, NRIA	Java, WI	Mammals
37	Mirza D. Kusrini	Bogor Agricultural University	Java, WI	Amphibians
38	Mohammad Irham	Research Center for Biosystematics and Evolution, NRIA	Java, WI	Birds
39	Mumpuni	Research Center for Biosystematics and Evolution, NRIA	Java, WI	Amphibians
40	Nur R. Isnaningsih	Research Center for Biosystematics and Evolution, NRIA	Java, WI	Molluscs
41	Pungki Lupiyaningdyah	Research Center for Biosystematics and Evolution, NRIA	Java, WI	Insects
42	Raden P. Narakusumo	Research Center for Biosystematics and Evolution, NRIA	Java, WI	Insects
43	Ristiyanti M. Marwoto	Research Center for Biosystematics and Evolution, NRIA	Java, WI	Molluscs
44	Rosichon Ubaidillah	Research Center for Biosystematics and Evolution, NRIA	Java, WI	Insects
45	Sigit Wiantoro	Research Center for Biosystematics and Evolution, NRIA	Java, WI	Mammals
46	Tri Haryoko	Research Center for Biosystematics and Evolution, NRIA	Java, WI	Birds

No.	Name	Institution	Location	Taxon of interests
47	Yuli S. Fitriana	Research Center for Biosystematics and Evolution, NRIA	Java, WI	Mammals
Taxonomists working on Indonesian flora (non-marine)				
48	Abdulrokhman Kartonegoro	Research Center for Biosystematics and Evolution, NRIA	Java, WI	Gesneriads, melastomes
49	Agung Kurniawan	Directorate of Scientific Collection Management, NRIA	Java, WI	Arums
50	Alex Sumadijaya	Research Center for Biosystematics and Evolution, NRIA	Java, WI	Grasses
51	Aninda R. U. Wibowo	Research Center for Biosystematics and Evolution, NRIA	Java, WI	Orchids
52	Arief Hidayat	Research Center for Biosystematics and Evolution, NRIA	Java, WI	Pteridophytes
53	Ary P. Keim	Research Center for Biosystematics and Evolution, NRIA	Java, WI	Palm trees, Pandan
54	Atik Retnowati	Research Center for Biosystematics and Evolution, NRIA	Java, WI	Gilled mushrooms
55	Bayu Adjie	Research Center for Biosystematics and Evolution, NRIA	Java, WI	Pteridophytes
56	Charlie D. Heatubun	State University of Papua	Papua, EI	Palm trees
57	Deby Arifiani	Research Center for Biosystematics and Evolution, NRIA	Java, WI	Laurels
58	Deden Girmansyah	Research Center for Biosystematics and Evolution, NRIA	Java, WI	Begonias
59	Destario Metusala	Research Center for Biosystematics and Evolution, NRIA	Java, WI	Orchids
60	Dewi	Research Center for Biosystematics and Evolution, NRIA	Java, WI	Polypores
61	Diah Sulistiarini	Research Center for Biosystematics and Evolution, NRIA	Java, WI	Orchids
62	Hernawati	University of Andalas	Sumatra, WI	Pitcher plants
63	Himmah Rustiami	Research Center for Biosystematics and Evolution, NRIA	Java, WI	Palm trees
64	I Made Ardaka	Research Center for Plant Conservation, Botanical Garden, and Forestry, NRIA	Java, WI	Begonias, pteridophytes
65	I Putu G. P. Damayanto	Research Center for Biosystematics and Evolution, NRIA	Java, WI	Bamboo
66	Ida B. K. Arinasa	Directorate of Scientific Collection Management, NRIA	Java, WI	Bamboo
67	Inggit P. Astuti	Research Center for Plant Conservation, Botanical Garden, and Forestry, NRIA	Java, WI	Bamboo, ginger, rues
68	Joko R. Witono	Research Center for Biosystematics and Evolution, NRIA	Java, WI	Palm trees
69	Lina S. Juswara	Research Center for Biosystematics and Evolution, NRIA	Java, WI	Orchids
70	Lulut D. Sulistyaningsih	Research Center for Biosystematics and Evolution, NRIA	Java, WI	Bananas, greenbriers
71	Marlina Ardiyani	Research Center for Biosystematics and Evolution, NRIA	Java, WI	Ginger

No.	Name	Institution	Location	Taxon of interests
72	Nanda Utami	Research Center for Biosystematics and Evolution, NRIA	Java, WI	Balsams
73	Nurainas	University of Andalas	Sumatra, WI	Custard apples, ginger
74	Nurhaida Sinaga	State University of Papua	Papua, EI	Pandan
75	Nursahara Pasaribu	University of Sumatera Utara	Sumatra, WI	Pandan
76	R. Hendrian	Deputy for Research and Innovation Utilization, NRIA	Java, WI	Dogbanes
77	Ridha Mahyuni	Research Center for Biosystematics and Evolution, NRIA	Java, WI	Madders, rafflesia
78	Rismita Sari	Bogor Botanical Garden, NRIA	Java, WI	Saptrees
79	Rugayah	Research Center for Biosystematics and Evolution, NRIA	Java, WI	Custard apples, cucurbits
80	Siti Sunarti	Research Center for Biosystematics and Evolution, NRIA	Java, WI	Myrtles
81	Sri Rahayu	Research Center for Plant Conservation, Botanical Garden, and Forestry, NRIA	Java, WI	Hoya, gesneriads
82	Sudarmono	Research Center for Biosystematics and Evolution, NRIA	Java, WI	Mints
83	Tatik Chikmawati	Bogor Agricultural University	Java, WI	Tropical fruits
Taxonomists working on Indonesian microbes (non-marine)				
84	Achmad Dinoto	Research Center for Applied Microbiology, NRIA	Java, WI	Bacteria
85	Antonius Suwanto	Bogor Agricultural University	Java, WI	Archaeans
86	Arif Nurkanto	Research Center for Biosystematics and Evolution, NRIA	Java, WI	Bacteria
87	Ariyanti Oetari	University of Indonesia	Java, WI	Fungi
88	Atit Kanti	Research Center for Biosystematics and Evolution, NRIA	Java, WI	Yeast
89	Dian A. Nurcahyanto	Research Center for Biosystematics and Evolution, NRIA	Java, WI	Archaeans
90	Dwi Susilaningsih	Research Center for Biotechnology, NRIA	Java, WI	Bacteria
91	Evi Triana	Research Center for Applied Microbiology, NRIA	Java, WI	Actinomycetes
92	Fitria T. Oktalira	Research Center for Biosystematics and Evolution, NRIA	Java, WI	Fungi
93	Hani Susanti	Research Center for Applied Microbiology, NRIA	Java, WI	Microalgae
94	I Nengah Sujaya	Udayana University	Bali, CI	Bacteria
95	Iman Hidayat	Research Center for Biosystematics and Evolution, NRIA	Java, WI	Fungi
96	Iman Santoso	University of Indonesia	Java, WI	Bacteria

No.	Name	Institution	Location	Taxon of interests
97	Muhammad Ilyas	Research Center for Biosystematics and Evolution, NRIA	Java, WI	Fungi
98	Nampiah Sukarno	Bogor Agricultural University	Java, WI	Fungi
99	Nilam F. Wulandari	Research Center for Biosystematics and Evolution, NRIA	Java, WI	Fungi
100	Puspita Lisdiyanti	Research Center for Biosystematics and Evolution, NRIA	Java, WI	Bacteria & archaeans
101	Shanti Ratnakomala	Research Center for Biosystematics and Evolution, NRIA	Java, WI	Actinomycetes
102	Sri Listiyowati	Bogor Agricultural University	Java, WI	Fungi
103	Sugiyono Saputra	Research Center for Applied Zoology, NRIA	Java, WI	Bacteria
104	Sulistiani	Research Center for Applied Microbiology, NRIA	Java, WI	Bacteria
105	Titin Yulineri	Research Center for Applied Microbiology, NRIA	Java, WI	Bacteria
106	Wibowo Mangunwardojo	University of Indonesia	Java, WI	Fungi
107	Yantyati Widyastuti	Research Center for Applied Zoology, NRIA	Java, WI	Actinomycetes & bacteria
108	Yulin Lestari	Bogor Agricultural University	Java, WI	Actinomycetes
109	Zahra Noviana	Research Center for Applied Microbiology, NRIA	Java, WI	Bacteria

Appendix 2. Translation of Law Number 11 of 2019 on National System of Science and Technology

Chapter XI
Administrative Sanctions

Article 91

1. Violations of the provisions as referred to in Article 21, Article 40 paragraph 2, Article 76 letters b to g, and Article 82 paragraph 3 are subject to administrative sanctions.
2. Administrative sanctions for violations as referred to in paragraph 1 are in the form of:
   a. written warning;
   b. termination of advisory services;
   c. administrative fines;
   d. inclusion of violators on the blacklist of violations of Research, Development, Assessment, and Implementation; and/or
   e. permit revocation.
3. Further provisions regarding the procedure for imposing administrative sanctions as mentioned in paragraph 2 are regulated by Government Regulations.

Article 92

Every foreigner who conducts Research, Development, Assessment, and Application of Science and Technology in Indonesia without a permit, as referred to in Article 75 paragraph 2, is subject to administrative sanctions in the form of inclusion on the blacklist of foreigners who carry out Research, Development, Assessment activities and Application of Science and Technology in Indonesia.

Chapter XII
Criminal provisions

Article 93

1. In the event that a foreigner, as referred to in Article 92, again commits a violation of conducting Research, Development, Assessment, and Application of Science and Technology in Indonesia without a permit, he or she can be punished with a maximum fine of IDR 4,000,000,000 (four billion Indonesian rupiahs).
2. In addition to the primary punishment as referred to in paragraph 1, the perpetrator may be subject to additional punishment in the form of a ban on obtaining a Research permit in the territory of the Republic of Indonesia for a maximum period of 5 (five) years.

Article 94

1. Any person who without rights or unlawfully transfers local Indonesian specimens abroad, both physically and/or digitally, without being accompanied by a material transfer agreement as referred to in Article 77 paragraph 2, shall be sentenced to a maximum imprisonment of 2 (two) years or a maximum fine of IDR 2,000,000,000 (two billion Indonesian rupiahs).
2. In addition to the primary punishment as referred to in paragraph 1, the perpetrator may be subject to additional punishment in the form of a ban on obtaining a Research permit in the territory of the Republic of Indonesia within a certain period of time.

Article 95

1. Everyone who carries out activities as referred to in Article 85 paragraph 3 without a permit shall be punished with a maximum imprisonment of 1 (one) year or a maximum fine of IDR 2,000,000,000.00 (two billion Indonesian rupiahs).
2. In the event that the act as referred to in paragraph 1 results in damage to goods or objects, the perpetrator shall be sentenced to a maximum imprisonment of 3 (three) years or a maximum fine of IDR 3,000,000,000 (three billion Indonesian rupiahs).
3. In the event that the act as referred to in paragraph 1 results in serious injury to a person, the perpetrator shall be sentenced to a maximum imprisonment of 4 (four) years or a maximum fine of IDR 4,000,000,000 (four billion Indonesian rupiahs).
4. In the event that the act as referred to in paragraph 1 results in the death of a person, the perpetrator should be sentenced to a maximum imprisonment of 7 (seven) years or a maximum fine of IDR 7,000,000,000 (seven billion Indonesian rupiahs).

Article 96

1. In the event that the criminal acts as referred to in Article 93, Article 94 and Article 95 are committed by a Business Entity, the criminal prosecution and punishment shall be filed against the Business Entity and/or its management.
2. The primary punishment that can be imposed on a Business Entity is only a fine, with the maximum penalty as referred to in Article 93, Article 94 and Article 95, each plus 1/3 (one-third).
3. In addition to the fine as referred to in paragraph 2, the Business Entity may be subject to additional punishment in the form of license revocation.