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Revealing the Biodiversity of Marine Copepods Pontellidae on Small Islands (Jakarta Bay, Sikka Bay, and Ambon Bay), Affected by Anthropogenic Activities

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ABSTRACT

Pontellidae are representatives of the epipelagic marine biota, a community that inhabits the surface layer (SL) of the ocean. In SL habitat, they are exposed to ultraviolet (UV) and are constantly impacted by anthropogenic disturbances. Anthropogenic activities on the small islands could potentially influence the biodiversity and abundance of Pontellidae. This study aimed to reveal the biodiversity of Pontellidae on small islands (Jakarta Bay, Sikka Bay, and Ambon Bay). Datasets were collected from three sites, representatives of the urban small islands of Jakarta Bay and Ambon Bay, and one site of a suburban small island in Sikka Bay, Indonesia. Copepod samples were collected during September-November 2021. Sampling was done using a conical plankton net (mesh size 300mm) by horizontal towing. The result showed that the biodiversity of Pontellidae comprises 12 species belonging to six genera. Genus *Labidocera* has become the richest taxa (6 species). Biodiversity of Pontellidae at Sikka Bay > Ambon Bay > Jakarta Bay. However, the abundance of Pontellidae is slightly different with that at Sikka Bay > Jakarta Bay > Ambon Bay. These findings indicate that antropogenic activities and disturbances may affect the biodiversity and abundance of Pontellidae.

INTRODUCTION

The global species richness of Pontellidae is around 180 species **(Walter & Boxshall, 2023)**. Researchers have conducted a previous study of Pontellidae on several aspects, including taxonomy and ecology. A taxonomy study on Pontellidae has been reported from Singapore by **Othman and Toda (2006)**, a new species of *Labidocera boxshalli* sp. from the Red Sea **(El-Sherbiny & Ueda, 2010)**, and a redescription of *Pontella andersoni* from the Bay of Bengal, India **(Francis *et al*. 2021)**. The ecological perspectives of Pontellidae (*Labidocera* spp.) are potentially vulnerable to ocean acidification **(Smith *et al*.. 2017)**. Moreover, anthropogenic microplastic particles are ingested by neustonic pontellidae *Pontella mediterania* **(Fagiano *et al*., 2024)**.

In Indonesian waters, the biodiversity of Pontellidae consists of 45 species **(Mulyadi, 2002a)**, and there are potentially new species from this coastal area **(Mulyadi, 2002b, 2003, 2011, 2014a, 2014b, 2019, 2021)**. More than fifteen species of Pontellidae have been described as new species from Indonesian waters **(Mulyadi *et al*. 2024)**. It is indicated that Indonesian coastal waters serve as one of the “homes” for Pontellidae in the tropical region. However, antropogenic activities could potentially disturb the coastal habitat and influence marine organisms. Urbanized coastal areas on the small island may have hazardous contaminants and disturbances to the ecosystem due to population growth and antropogenic activities. **Mulyadi and Hernawati (2022)** detected abnormalities in the anal segment of the abdomen of juveniles and adults of the copepods *Acartia erythraea* and *Acartia pacifica* at Jakarta Bay, one of the Indonesia’s urbanized coastal waters. Therefore, revealing the biodiversity of the copepod Pontellidae in an urbanized coastal area on small island is necessary. Thus, we chose Jakarta Bay and Ambon Bay as representatives of urbanized coastal areas and Sikka Bay as representatives of suburban coastal water. This study aimed to investigate the biodiversity of Pontellidae in Indonesian coastal waters’ small islands (Jakarta Bay, Sikka Bay, and Ambon Bay).

MATERIALS AND METHODS

Study sites

Coastal ecosystems have an important role for marine organisms. This area also supports human activites. Anthropogenic activities strongly influence the Jakarta Bay. This area is located in the center of the capital city of Indonesia, which has highly dense human population. The coastal area is bustling with human activity. Ambon Bay is located in the eastern part of Indonesia, specifically on Ambon Island. This area, which is part of Maluku Province, experiences moderate levels of human activity along the shoreline. Hovewer, Sikka Bay, is located in Nusa Tenggara Timur, where human activities cause fewer disturbances (Table 1).

Table 1. Characteristic habitat and anthropogenic activities or contaminants in each sites sampling

No	Site	Ecosystem	Reference	Anthropogenic activities/contaminants	Reference
1	Jakarta Bay	Mangrove, coral reef, and seagrass	**Cleary *et al*. (2006), Baum *et al*. (2015),**	Harbor, industry, coastal tourism, fishing, excessive nutrients, heavy metals, and	**Kunzmann *et al*. (2018), Damar *et al*. (2019), Damar**

			Husodo *et al.* (2017), and **Sari *et al.* (2019)**	microplastics.	***et al.* (2020), Purwiyanto *et al.* (2022), Dwiyitno *et al.* (2024)**
2	Sikka Bay	Mangrove, seagrass, and coral	**CRITC-P2O LIPI (2015), Riniatsih and Munasik (2017), CRRMP-CTI-P2O LIPI (2021)**	Traditional Fishing, and diving spots	**BPS Kab Sikka (2022)**
3	Ambon Bay	Mangrove, seagrass, and coral	**PPLD-LIPI (2016), Suyadi (2009, 2012), Indrabudi and Alik (2017), Irawan and Prayudha (2020)**	Harbor, coastal tourism, excessive nutrients, heavy metals, and microplastics	**Suyadi and Manullang (2020)**

Sampling was carried out in Jakarta Bay, Sikka Bay, and Ambon Bay during September-November 2021 (Fig. 1). Samples were collected using a conical plankton net (mesh size 300µm) by horizontal hauls. A TSK No. 6068 flowmeter was attached to the center of the net aperture to record the exact volume of water sampled. Each tow lasted 10 minutes at 2 knots. Samples were preserved in 4% formalin for further analysis. Oceanographic parameters, including sea surface temperature (SST) and sea surface salinity (SSS), were measured using portable tools.

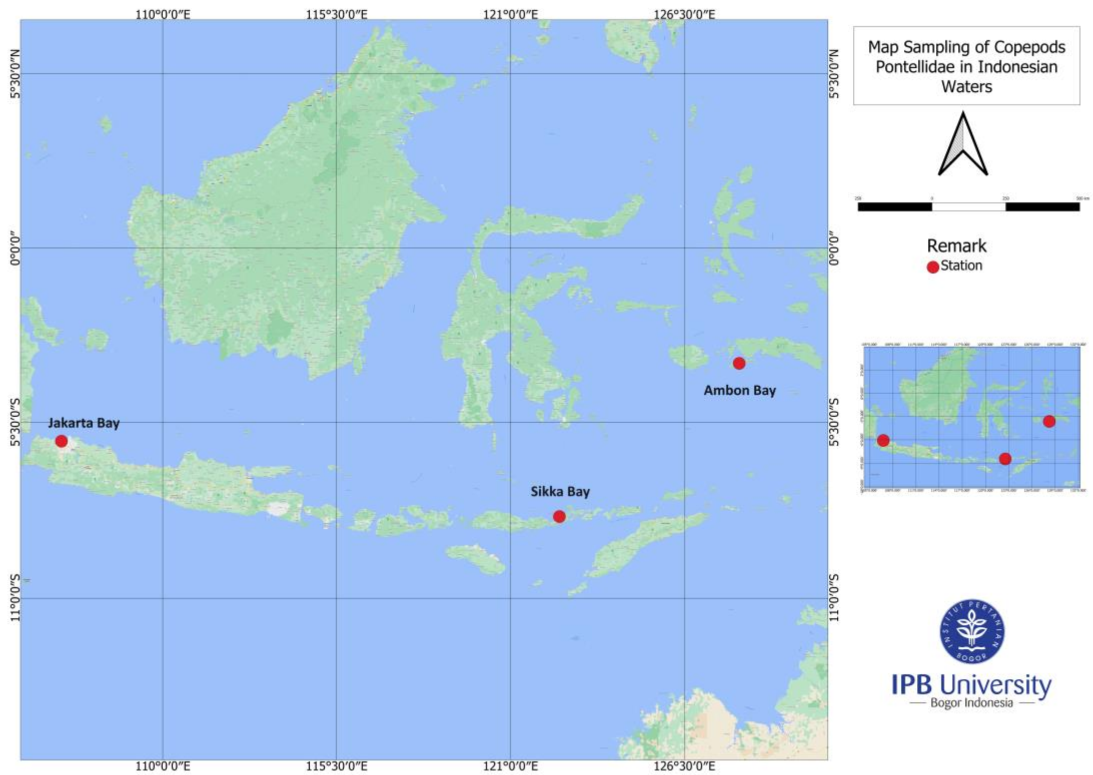

Fig. 1. Map of Indonesian waters showing study sites (Map generated from QGIS)

For further analysis, the biodiversity of the copepods Pontellidae in each area was compared using a Venn diagram **(Heberle *et al*., 2015)**. PAST 4.03 statistical software calculated the statistical analysis diversity index, which includes species diversity (Shannon-Weiner), species evenness (Pielou's), and species richness (Margalef) **(Legendre & Gauthier, 2014)**, multivariate analysis (non-metric dimensional scaling - nMDS, and cluster analysis) to obtain an ordination from any distance measure that summarizes the differences among each pair of Pontellidae copepods **(Clarke, 1993; Paliy & Shankar, 2016)**.

RESULTS AND DISCUSSION

1. Oceanographic features

The oceanographic parameters, such as SST and SSS, were measured during observation (Table 2). The SSS ranged between 22-34psu, and the SST ranged between 31-32°C. This result is slightly different compared to previous studies by **Mulyadi (2002a, 2002b, 2011)**, which found that the SSS ranged between 30psu in the western region and 34psu in the eastern region, while SST ranged between 27°C in the eastern region and 31°C in the western region.

The highest value of SSS was measured at Sikka Bay, and the lowest SST occurred at Jakarta Bay. Estuarine areas near the mainland, such as Jakarta Bay 1, Jakarta Bay 2, and Ambon Bay 1, exhibit lower SSS values; conversely, coastal waters connected to the open sea, such as Sikka Bay 1, Sikka Bay 2, and Ambon Bay 2, exhibit higher SSS values. The topography of Jakarta Bay, which is composed of numerous small islands, specifically "Tousand Island-Kepulauan Seribu" in the surrounding area, along with riverine input from the mainland, may affect the SSS value. The riverine input may also influence the SSS value at Ambon Bay 1, which is located in the inner part of the bay. On the other side, the SST generally has the same value at all stations of observation (Table 2). The physical oceanographic parameters (e.g. salinity and temperature) have a significant role in marine zooplankton **(Toklu-Alicli *et al*., 2021; Wang *et al*., 2021; Zhao *et al*., 2022; Liu *et al*., 2024)**.

Table 2. Oceanographic features (SST and SSS) of small islands (Jakarta Bay, Sikka Bay, and Ambon Bay)

Parameter	Jakarta Bay 1	Jakarta Bay 2	Sikka Bay 1	Sikka Bay 2	Ambon Bay 1	Ambon Bay 2
SST (°C)	31	31	31	32	31	32
SSS (psu)	22	27	34	34	24	30

2. Biodiversity, distribution, and multivariate analysis

In total, the biodiversity of marine copepods Pontellidae on the small islands (Jakarta Bay, Sikka Bay, and Ambon Bay) comprises 12 species belonging to six genera (Table 3). **Mulyadi (1997)** previously described two species, *Labidocera javaensis* and *Pontella vervoorti*, as new species. Genus *Labidocera* is the most rich taxa (6 species), followed by the genus *Pontella* and *Pontellopsis* (2 species). Moreover, genus *Labidocera* is the largest taxa in the family Pontellidae **(Mulyadi, 2020)**. Furthermore, this finding contributed 27% to the total Pontellidae in Indonesian waters **(Mulyadi, 2002a)**.

Table 3. Species composition of copepods Pontellidae on small islands (Jakarta Bay, Sikka Bay, and Ambon Bay)

No	**Species**	**Jakarta Bay**		**Sikka Bay**		**Ambon Bay**		**Geographical distribution**	**Horizontal distribution**
		ST 1	ST 2	ST 1	ST 2	ST 1	ST 2		
A	**Genus *Calanopia***								
1	*Calanopia* sp.						●	nd	nd

B	**Genus *Labidocera***								
2	*Labidocera acuta*			●	●	●		I-P	Neritic
3	*L. bataviae*			●	●			I-P	Neritic
4	*L. minuta*				●		●	I-P	Neritic
5	*L. javaensis*	●	●					Indonesia	
6	*L. bengalensis*		●					Indian ocean	
C	**Genus *Pontella***								
7	*Pontella forficula*				●			Philippina	Neritic
8	*P. vervoorti*		●					Indonesia	
D	**Genus *Pontellopsis***								
9	*Pontellopsis armata*				●			I-P	Neritic
10	*Pontellopsis* sp.				●	●		I-P	Neritic
E	**Genus *Pontellina***								
11	*Pontellina* sp.			●					
F	**Genus *Ivellopsis***								
12	*Ivellopsis elephas*				●			Philippina	NO

Remarks: nd =not documented; I-P =Indo-Pacific; NO =Neritic-Oceanic.

The biodiversity of Pontellidae at Sikka Bay is higher compared to Ambon Bay and Jakarta Bay (Table 3 & Fig. 2). The species composition at Sikka Bay accounted for 66.7% of the total (8 species), followed by Ambon Bay (33%; 4 species) and Jakarta Bay (25%; 3 species).

In terms of species composition similarities, the multivariate analysis (nMDS) in Fig. (2) shows that there are three groups of Pontellidae, e.g., Sikka Bay, Ambon Bay, and Jakarta Bay. Then, according to cluster analysis with single linkage Bray-curtis, the biodiversity at Sikka Bay 1 and Sikka Bay 2 has more than 50 percent of similarities; the biodiversity at Sikka Bay (1,2) and at Ambon Bay 2 has nearly 20 percent of similarities; the biodiversity of Sikka Bay (1,2), Ambon Bay 2 and Ambon Bay 1 has more than 10 percent of similarities; and the biodiversity at Sikka Bay (1,2), Ambon Bay (1,2), and Jakarta Bay is completely different (no similarities).

Interestingly, the biodiversity of Pontellidae species at Jakarta Bay is completely different from that of the two other sites, Sikka Bay and Ambon Bay. Jakarta Bay is located in the western part of Indonesian waters, while Sikka Bay and Ambon Bay are located in the eastern region. The Venn diagram in Fig. (2) reveals that three Pontellidae species, including *Labidocera acuta*, *Labidocera minuta*, and *Pontellopsis* sp., overlap the biodiversity between Sikka Bay and Ambon Bay. Oceanographic factors such as watermass current and circulation, temperature, and salinity drive the distribution of

Pontellidae, resulting in differences in biodiversity between the western and eastern parts of Indonesian waters **(Mulyadi, 2002a)**. In other study, **Hoeksema (2013)** explained about the reasons for the west-east variation in coral biodiversity in Indonesian waters. These include: (1) more species that are only found in eastern Indonesia because of plate tectonics; (2) higher species survival during the last glacial maximum (LGM); (3) more habitat diversity; and (4) interocean currents that flow north to south between the Pacific Ocean and the Indian Ocean. Furthermore, **Marwayana *et al*. (2021)** confirmed that coral reef fish have the highest biodiversity in the eastern part of Indonesian waters (Raja Ampat) and the lowest in the western part of Indonesian waters.

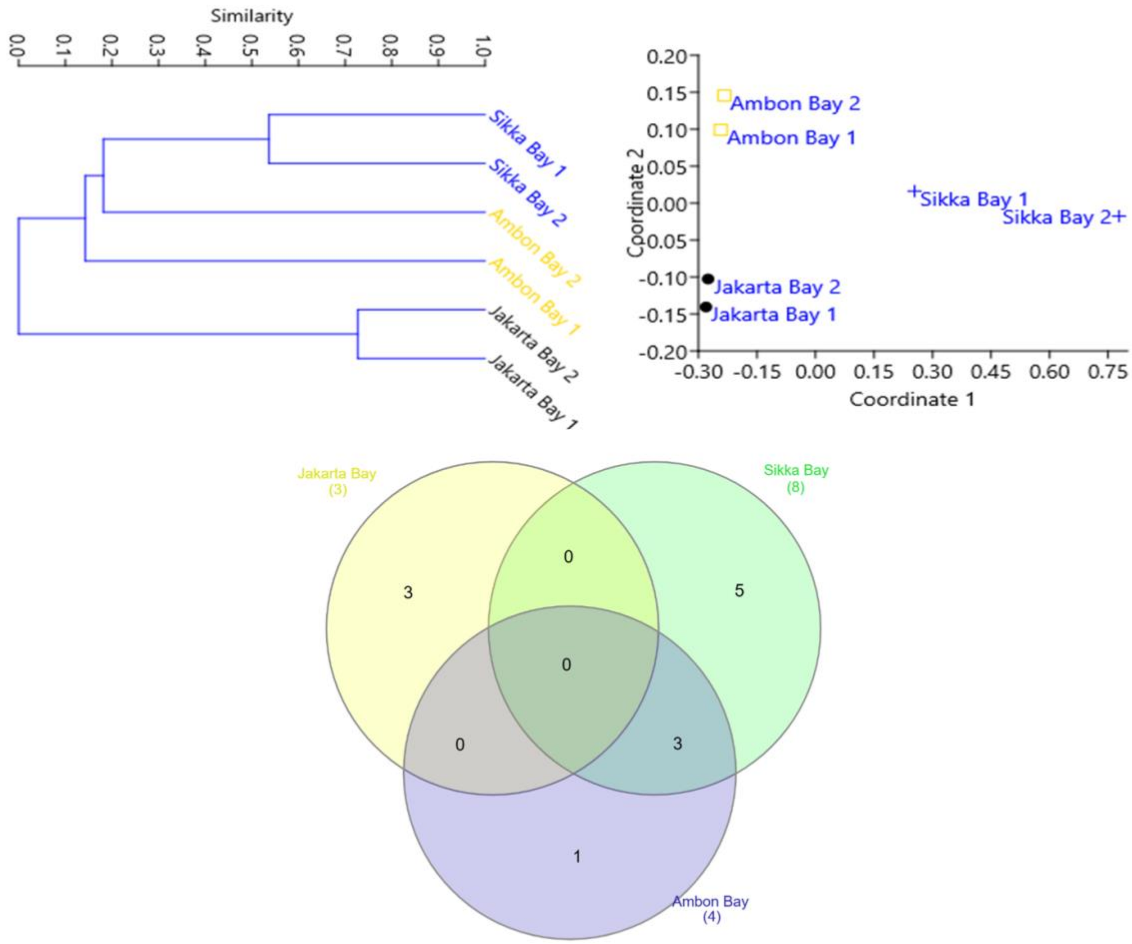

Fig. 2. The biodiversity of Pontellidae across all sites, analyzed using cluster analysis - single linkage Bray-Curtis, nMDS analysis, and Venn diagram

All the species of Pontellidae from these sites were analyzed to clarify their geographical distribution (Table 1). Most of the Pontellidae species are Indo-Pacific; two species, such as *Labidocera javaensis* and *Pontella vervoorti*, were only recorded in Indonesian waters. Then, *Pontella forficula* and *Ivellopsis elephas*, which were previously recorded from Philipina waters, as well as *Labidocera bengalensis*, which was previously recorded in the Indian Ocean, Malaysia, and Australia, represented new records for this region, their horizontal distribution is mostly neritic. The watermass circulation, known as the Indonesian trough flow (ITF), influences the distribution of planktonic copepods in Indonesian waters. **Sprintall and Revelard (2014)** explained that the Indonesian troughflow is the open pathway for interocean exchange between the Pacific and Indian Oceans. Further, the ocean dynamics process in the Indo-Pacific Convergence Zone (IPCZ) has essential impacts on biodiversity by controlling species dispersal and genetic exchange between basins **(Du *et al*., 2023)**.

3. Abundance and diversity index

The total abundance of Pontellidae on the small islands (Jakarta Bay, Sikka Bay, and Ambon Bay) ranged from 2-29ind/ m^3 (Table 4). The copepods Pontellidae in Indonesian waters were rich in terms of biodiversity but never in abundance **(Mulyadi, 2002a)**. The total abundance of the family Pontellidae, starting from the highest to the lowest, occurred at Sikka Bay, Jakarta Bay, and Ambon Bay, respectivelly. Referring their upper-layers habitat, epipelagic Pontellidae in these sites are at risk of being threatened by antropogenic activities and disturbances (Table 2). Microplastics contamination was detected at Ambon Bay **(Suyadi & Manullang, 2020)** and Jakara Bay **(Parwiyanto *et al*., 2022; Dwiyitno *et al*., 2024)**. The presence of microplastics in the ecosystem may have an impact on planktonic organisms. **Fagiano *et al.* (2024)** reported the ingestion of an anthropogenic microplastic particle by the pontellid copepod *Pontella mediterania* in the northern Alboran Sea.

Table 4. The abundance of Pontellidae on small islands (Jakarta Bay, Sikka Bay, and Ambon Bay) of Indonesian waters (ind/m^3).

No	Species	Jakarta Bay		Sikka Bay		Ambon Bay	
		ST 1	ST 2	ST 1	ST 2	ST 1	ST 2
A	**Genus *Calanopia***						
1	*Calanopia* sp.	0	0	0	0	0	1
B	**Genus *Labidocera***						
2	*Labidocera acuta*	0	0	1	1	1	0
3	*L. bataviae*	0	0	10	20	0	0
4	*L. minuta*	0	0	0	3	0	3
5	*L. javaensis*	5	4	0	0	0	0
6	*L. bengalensis*	0	1	0	0	0	0
C	**Genus *Pontella***						
7	*Pontella forficula*	0	0	0	2	0	0
8	*P. vervoorti*	0	0	0	1	0	0
D	**Genus *Pontellopsis***						
9	*Pontellopsis armata*	0	1	0	0	0	0

10	*Pontellopsis* sp.	0	0	1	0	0	0
E	**Genus *Pontellina***						
11	*Pontellina* sp.	0	0	0	1	0	0
F	**Genus *Ivellopsis***						
12	*Ivellopsis elephas*	0	0	0	1	1	0
	Total	5	6	12	29	2	4

Sikka Bay had a higher abundance of Pontellidae than the two other sites. The higher abundance of copepod at Sikka Bay was represented by Pontellidae *Labidocera bataviae* (Table 4). This suggests that the ecosystem at Sikka Bay may have been suitable for Pontellidae's living habitat. According to **CRRMP-CTI-PRO LIPI (2021)**, seagrass coverage is 64.3% and mangrove coverage is 85.74%, with fewer antropogenic activities and contaminants (Fig. 3). Mangrove and seagrass have an essential role in supporting planktonic organisms through marine pelagic food webs. They produce detritus, which is valuable nutrient for marine organisms in the upper tropics.

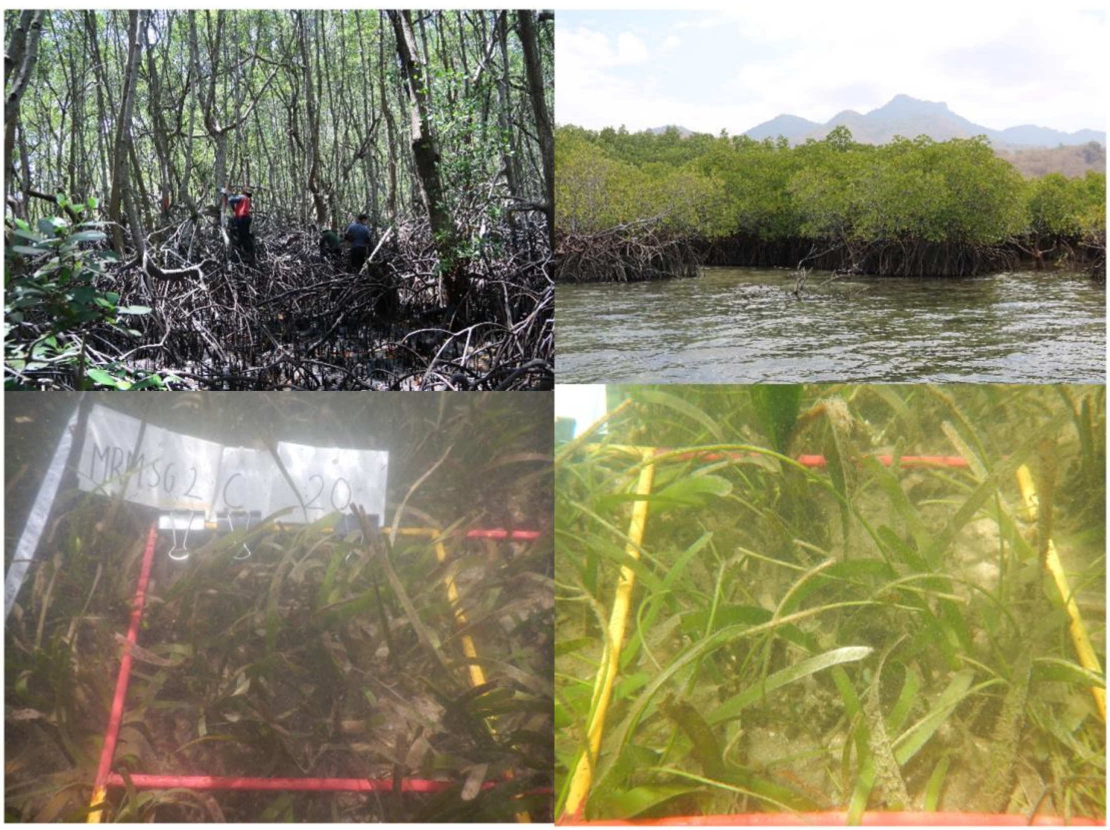

Fig. 3. Ecosystem mangrove and seagrass at Sikka Bay **(CRRMP-CTI-PRO LIPI, 2021)**

On the other side, Pontellidae at Ambon Bay recorded a low abundance. The ecosystem (mangrove, seagrass, and coral) at Ambon Bay was affected by antropogenic activities and contaminants. Mangrove decline **(Suyadi, 2009, 2012)**, coral cover loss **(Indrabudi & Alik, 2017)**, and seagrass bed loss **(Irawan & Prayudha, 2020)** are all signs of this happening in Ambon Bay, which is an area with a lot of human activity. Furthermore, **Suyadi and Manulang (2020)** have detected microplastic contaminants at Ambon Bay. The blooming of phytoplankton is another environmental condition that may affect the abundance of copepods (Pontellidae) at these sites. The occurrence of phytoplankton blooms, also known as harmful alga blooms (HABs), at Ambon Bay has been previously reported **(Likumahua, 2013, Likumahua *et al*., 2019, Kesaulya *et al*., 2022)**. The massive antropogenic activities in the surrounding coastal area (development of hospitals, new docks, and housing) have an impact on Ambon Bay's ecosystem.

A biodiversity index including species richness, evenness, and species diversity index is shown in Fig. (4). The species richness index and species diversity index reached a higher value at Sikka Bay 2, and a lower value at Jakarta Bay 1. However, the species evenness index showed a higher value at Jakarta Bay 1 and Ambon Bay 1, and a lower value at Sikka Bay 2. The higher values of species richness and species diversity indexes illustrated that the environmental conditions are adequate to support copepod pontellid growth. The ecosystem at Sikka Bay is relatively pristine and less antropogenic. On the other hand, the lower values of species richness and species diversity index at Jakarta Bay and Ambon Bay may indicate that the environmental conditions are influenced by antropogenic pressure and contaminants.

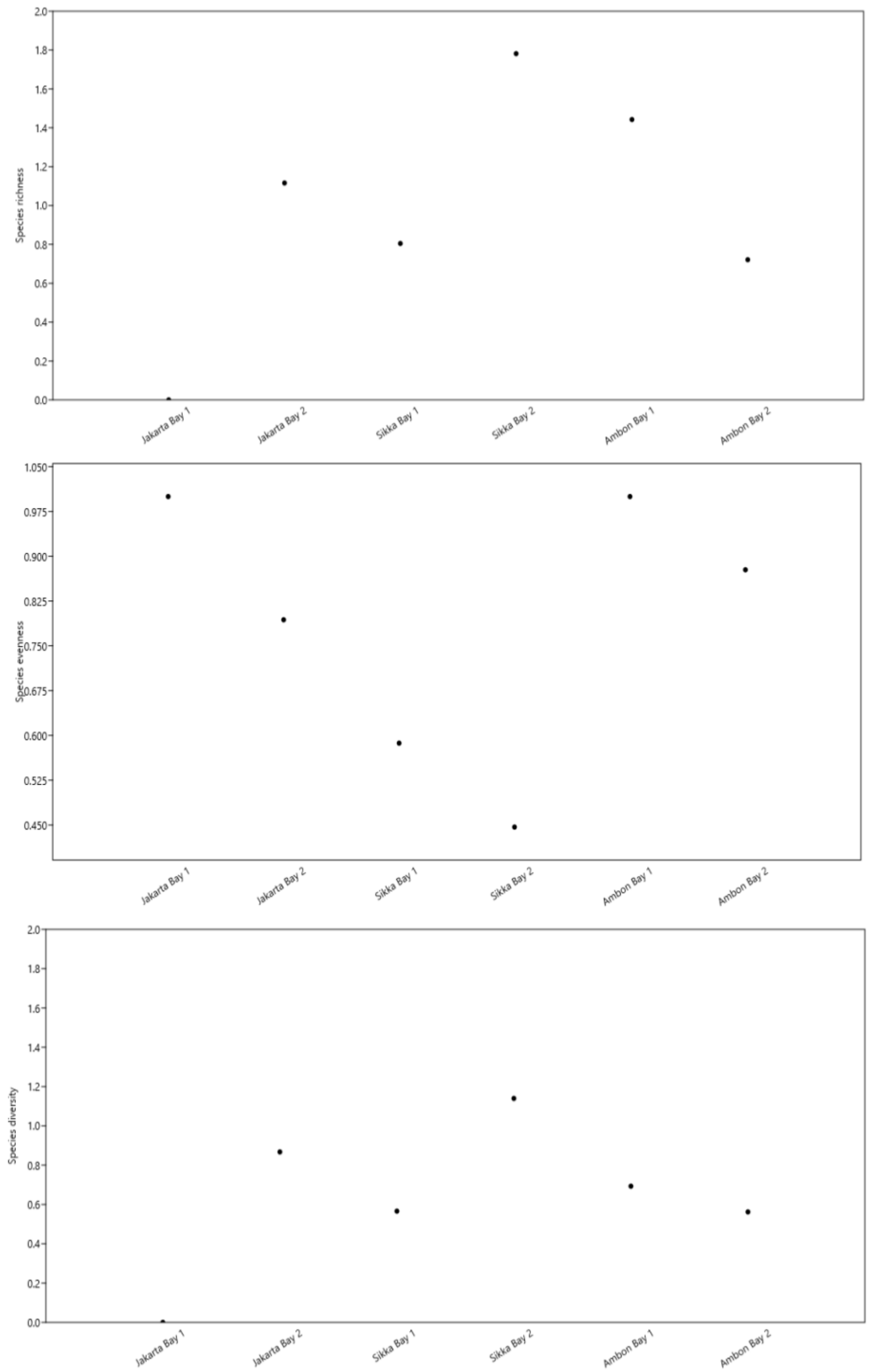

Fig. 4. The small island (Jakarta Bay, Sikka Bay, and Ambon Bay) exhibits variation in the biodiversity index in terms of species richness, species evenness, and species diversity of copepod Pontellidae

CONCLUSION

The study aimed to reveal the biodiversity of marine copepods (Pontellidae) on small islands (Jakarta Bay, Sikka Bay, and Ambon Bay) potentially affected by anthropogenic activities. Therefore, this study concluded that the biodiversity of Pontellidae comprises 12 species belonging to six genera. Biodiversity of Pontellidae at Sikka Bay > Ambon Bay > Jakarta Bay, respectivelly. However, the number of abundance of Pontellidae is slightly different with the following order: Sikka Bay > Jakarta Bay > Ambon Bay. These findings indicate that antropogenic activities and disturbances may affect the biodiversity and abundance of Pontellidae.

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AUTHOR CONTRIBUTIONS

HAM conducted the field sampling and laboratory work, supervised by DGB, M, MK, and HM. HAM drafted the manuscript with review and assistance from DGB, M, MK, and HM. All authors contributed equally to the final version.

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