Short-term changes in abundance of zooplankton (with notes on a swarm of Appendicularia) in Ambon Bay, Indonesia

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Abstract. Zooplankton has an essential role in estuarine environments and serves as a food source for various fish and other benthic planktivorous organisms. The monsoon has affected the water mass distribution in tropical regions. As planktonic organisms, zooplankton abundance and population structure are potentially driven by water mass circulation and coupling with the seasonal monsoon. This study investigated the zooplankton community structures in two months (February and April). February represents the Northwest Monsoon (NWM), and April represents the Transition I (TI). A total of 47 zooplankton taxa were identified, 19 of which belonged to copepods. The species composition of zooplankton has slightly different taxa during the NWM and TI. Species composition of zooplankton was higher in the outer region of Ambon Bay (OAB) during NWM; on the contrary, the higher value of species composition of zooplankton occurred in the inner of Ambon Bay (IAB) during TI. However, short-term changes in the abundance of zooplankton have been detected during these two periods of monsoons. In NMW, the appendicularian *Thalia sibogae* has a higher abundance, and the opposite, the meroplankton peak has been reached during TI. The swarm of Appendicularia has been detected along the IAB and sill area during NWM. In this area, the highest abundance of *T. sibogae* reached 2×10^3 ind m^{-3} and 9×10^2 ind m^{-3}, respectively. Meanwhile, meroplankton outnumbers abundance during TI. The higher abundance of meroplankton of 8×10^2 ind m^{-3} and 7×10^2 ind m^{-3} in IOB and sill area during TI. The Echinodermata larvae were counted in higher abundance in IAB and sill area during TI.
Key Words: Echinodermata larvae, salp swarm, *Thalia sibogae*, tropical area.

Introduction. The dynamics zooplankton community in coastal and marine waters has been monitored worldwide (Belkahia et al 2021; Mahara et al 2021; Wang et al 2021). Monitoring the zooplankton abundance in the urban coastal area has been conducted using metabarcoding approaches (Song et al 2021). Coastal zooplankton composition, abundance, and distribution are affected by oceanographic parameters, e.g., salinity, temperature, productivity, water mass circulation, and monsoon influence. Vereshchaka et al (2019) explained that temperature and productivity are the main environmental factors that influence the zooplankton in Black Sea coastal waters. Also, it was evident that there were significant intra-monsoonal variations in the zooplankton population on the Sundarbans Estuarine System that were correlated with several hydrological parameters (Nandy et al 2018; Basu et al 2022).

The plankton community in Ambon Bay has been observed since the 1980s (Sutomo & Anderson 1984) and continually monitored in Ambon Bay. Phytoplankton assemblages were investigated (Dwiono & Rahayu 1984; Wagey 2002; Pello et al 2014; Serihollo et al 2015), and the dynamics of toxic species (Mizushima et al 2007; Likumahua 2013; Sidabutar et al 2016; Kesaulya et al 2022). Besides that, the zooplankton populations and abundance in Ambon Bay was determined by Yusuf (1979), Mulyadi (2011), and Mulyadi and Saputra (2019). Furthermore, other studies were focused on coastal primer productivities (Basit et al 2012) and physical oceanography properties (Saputra & Sapulette, 2016). Interestingly, the swarming of appendicularian salp *Thalia sibogae* in Ambon Bay was reported in February 1973 (Troost et al 1976). The present study aimed to reveal the short-term changes in zooplankton abundance in Ambon Bay during Northwest Monsoon (NWS) and Transition I (TI). We conducted sampling during February and April to investigate the dynamics abundance of zooplankton. Thus, we expected that revealing the dynamic abundance of zooplankton in Ambon Bay coastal water will have a significant contribution to support marine pelagic fisheries management.

Material and Method

Description of the study sites. Ambon Bay is located on Ambon Island, consisting of the Inner of Ambon Bay (IAB) and outer of Ambon Bay (OAB) separated by a shallow, narrow sill of approximately 12 meters depth. The study was carried out in February and April 2014 at 17 stations (Figure 1). February represents the Northwest Monsoon (NWM), and April represents the Transition I (TI). Zooplankton samples were collected vertically from 10 meters of depth using NORPAC net (mesh size 330 μm; mouth diameter 45 cm). The samples were preserved at 4% formalin. Zooplankton determination followed the method suggested by Wickstead (1965) under a binocular microscope (Nikon Eclipse) at different magnifications (10x, 20x, 40x, and 100x). The identification of zooplankton samples was done referring to Yamaji (1984), Nishida (1985), Mulyadi (2002), and Mulyadi (2004). Oceanographic features (temperature and salinity) in Ambon Bay were obtained from a monitoring program established by Research Center for Deep Sea (RCDS-LIPI 2014).

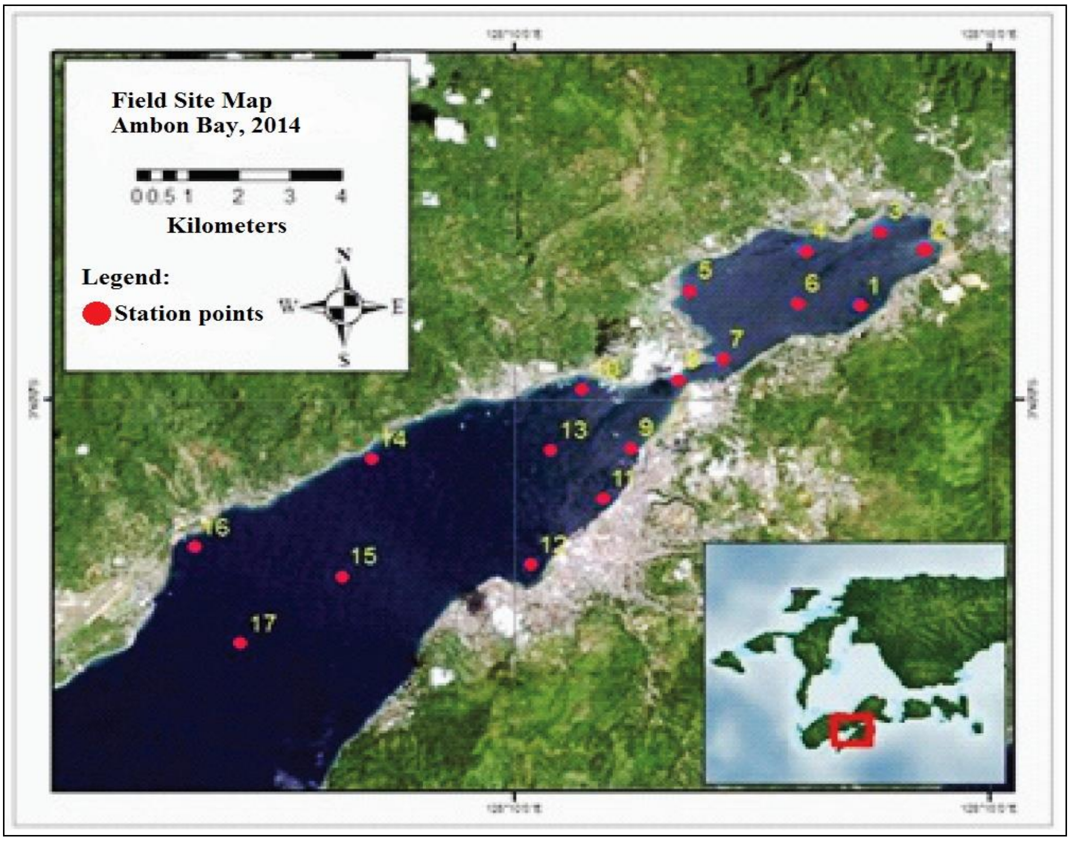

Figure 1. Maps of zooplankton stations in Ambon Bay, Indonesia (map generated using Google Earth and QGIS).

Results. Oceanography properties in Ambon Bay varied in the inner bay (IAB) and in the outer bay (OAB). Sea surface salinity (SSS) in the OAB was higher than in the IAB, while sea surface temperature (SST) in IAB was higher than in OAB. Temperature and salinity during NWM have been shown in Figure 2.

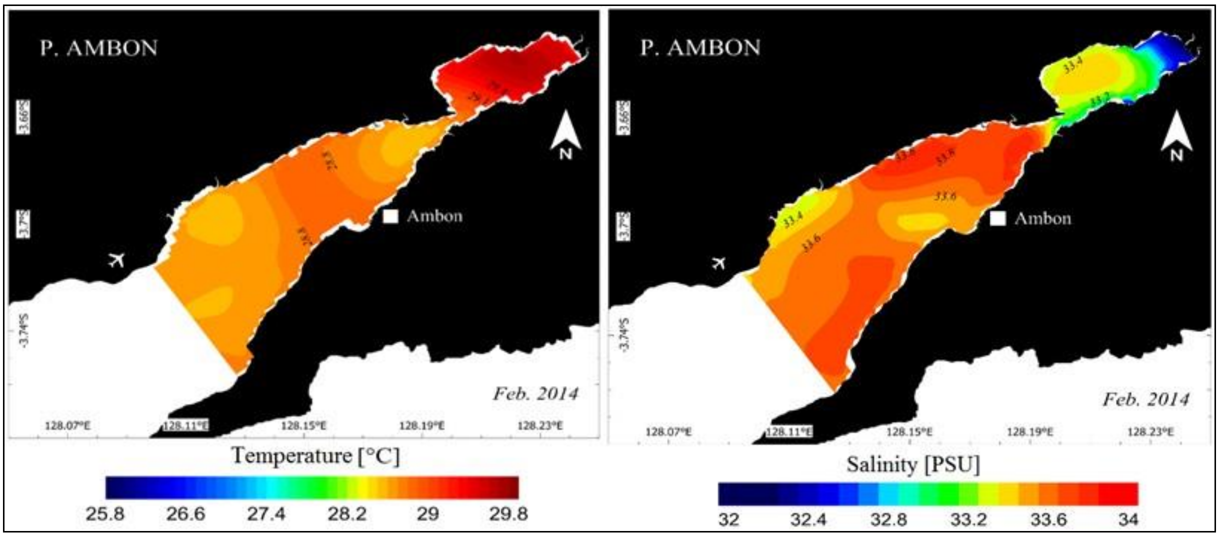

Figure 2. The distribution of temperature and salinity in Ambon Bay during NWM (RCDS-LIPI 2014).

During NWM, SST in IAB ranged from 28.63-29.94°C and 26.79-26.91°C in OAB, respectively. During TI, SST ranged from 26.79-26.91°C in IAB, and 26.31-26.47°C in OAB. Meanwhile, during NWM, SSS reached for 32.56-33.77 psu in IAB and 33.26-33.78 psu in OAB, respectively. During TI, SSS reached for 32.12-32.99 psu in the IAB, and 33.43-33.98 psu in OAB, respectively.

There were 47 species of zooplankton identified, and 19 taxa belonged to copepods. Detailed composition of zooplankton in Ambon Bay is shown in Table 1.

Table 1

Species composition of zooplankton in Ambon Bay, 2014

No			NWM			TI		
			IAB	Sill	OAB	IAB	Sill	OAB
1	Copepoda	*Candacia discaudata*	-	-	●	-	-	●
2		*Centropages brevifurcus*	-	●	●	●	-	●
3		*Acartia amboinensis*	●	●	●	●	●	●
4		*Pontellopsis inflatodigitata*	-	-	●	●	●	●
5		*Canthocalanus pauper*	-	-	●	-	-	-
6		*Temora discaudata*	-	●	●	-	-	●
7		*Tortanus forcipatus*	●	●	●	-	-	●
8		*Labidocera* sp.	●	-	●	●	●	●
9		*Euchaeta* sp.	-	-	●	-	-	●
10		*Paracalanus aculeatus*	-	-	●	-	-	-
11		*Acrocalanus gibber*	●	●	●	●	●	●
12		*Subeucalanus subcrassus*	●	●	●	●	●	●
13		*Copilia quadrata*	-	-	●	-	-	-
14		*Sapphirina* sp.	●	●	●	-	-	-
15		*Oncaea* sp.	-	●	●	●	-	●
16		*Oithona* sp.	●	●	●	●	●	●
17		*Corycaeus* sp.	●	●	●	●	●	●
18		*Macrosetella* sp.	-	-	-	●	-	-
19		*Clytemnestra* sp.	-	●	-	-	-	-
20	Cladocera	*Penilia avirostris*	●	●	-	●	●	-
21		*Evadne tergestina*	●	●	-	●	-	-
22	Ostracoda	*Pyrocypris natans*	-	-	●	-	-	●
23		*Chonchoecia* sp.	●	●	●	-	●	●
24	Decapoda	*Lucifer intermedius*	●	●	●	●	●	-
25		*Acetes* sp.	●	●	-	●	●	●
26		*Mysis* sp.	-	-	●	-	-	-

27		*Hyperia* sp.	●	-	-	●	●	-
28		*Pseudeuphausia* sp.	●	-	-	●	-	-
29	Chaetognatha	*Sagitta enflata*	●	●	●	●	●	●
30		*Krohnitta pacifica*	●	●	●	●	●	●
31	Thaliacea	*Thalia sibogae*	●	●	-	●	●	●
32	Appendicularia	*Oikopleura* sp.	●	●	●	●	●	●
33	Hydrozoa	*Siphonophora* sp.	●	●	●	●	●	●
34	Cubozoa	*Carybdea* sp.	●	●	●	●	●	●
35	Meroplankton	Penaeidae larvae	●	-	-	●	-	●
36		Palaemonidae larvae	●	-	●	●	●	●
37		Cirripedia larvae	●	●	●	●	-	-
38		Stomatopoda larvae	-	-	-	●	-	-
39		Brachyuran (zoea) larvae	●	-	●	●	●	●
40		Brachyuran (megalopa) larvae	-	-	-	-	●	-
41		Echinodermata larvae	●	●	●	●	●	●
42		Gastropoda larvae	-	●	●	●	●	●
43		Bivalvia larvae	-	●	●	●	-	●
44		Annelida larvae	●	●	●	●	●	●
45		Fish eggs	●	●	●	●	●	-
46		Fish larvae	●	-	●	●	-	-
47		Leptochela larvae	●	-	●	-	-	●
	Total		30	28	36	33	25	30

The highest total composition of zooplankton has occurred during NWM in OAB, and the lowest has occurred during TI in the sill area. Several taxa have been identified in all areas (IAB, sill area, and OAB) during NWM and TI period, e.g., *Acartia amboinensis*, *Acrocalanus gibber*, *Subeucalanus subcrassus*, *Oithona* sp., *Corycaeus* sp., *Sagitta enflata*, *Krohnitta pacifica*, *Oikopleura* sp., *Siphonophora* sp., *Carybdea* sp., Echinodermata larvae, and Annelida larvae. Zooplankton taxa, which was present during NWM and absent during TI, was *Sapphirina* sp.

During NWM, zooplankton taxa, e.g., *Acartia amboinensis*, *Tortanus forcipatus*, *Acrocalanus gibber*, *Subeucalanus subcrassus*, *Sapphirina* sp., *Oithona* sp., *Corycaeus* sp., *Chonchoecia* sp., *Lucifer intermedius*, *Sagitta enflata*, *Krohnitta pacifica*, *Oikopleura* sp., *Siphonophora* sp., *Carybdea* sp., Cirripedia larvae, Echinodermata larvae, Annelida larvae and fish eggs were present in IAB, sill area and OAB. Meanwhile, the zooplankton taxa, e.g., *Acartia amboinensis*, *Pontellopsis inflatodigitata*, *Labidocera* sp., *Acrocalanus gibber*, *Subeucalanus subcrassus*, *Oithona* sp., *Corycaeus* sp., *Acetes* sp., *Sagitta enflata*, *Krohnitta pacifica*, *Thalia sibogae*, *Oikopleura* sp., *Siphonophora* sp., *Carybdea* sp., Palaemonidae larvae, Brachyuran (zoea) larvae, Gastropoda larvae, Annelida larvae were identified in IAB, sill area, and OAB during TI.

The total composition of zooplankton taxa was dominated by copepods during the study (Figure 3). Copepods account for 27-47% of total composition of zooplankton, followed by meroplankton (22-34%) in the second position.

During NWM, copepods reached 27-47%, followed by meroplankton which has a value of 22-30% of the total composition of zooplankton. Copepods have a leading position in OAB and sill area while meroplankton takes over the position in IAB. In the third position, decapod constitutes 4-14% of the total composition of zooplankton. Although decapod has a few contributions in OAB and sill area, the composition percentage value was increase in IAB.

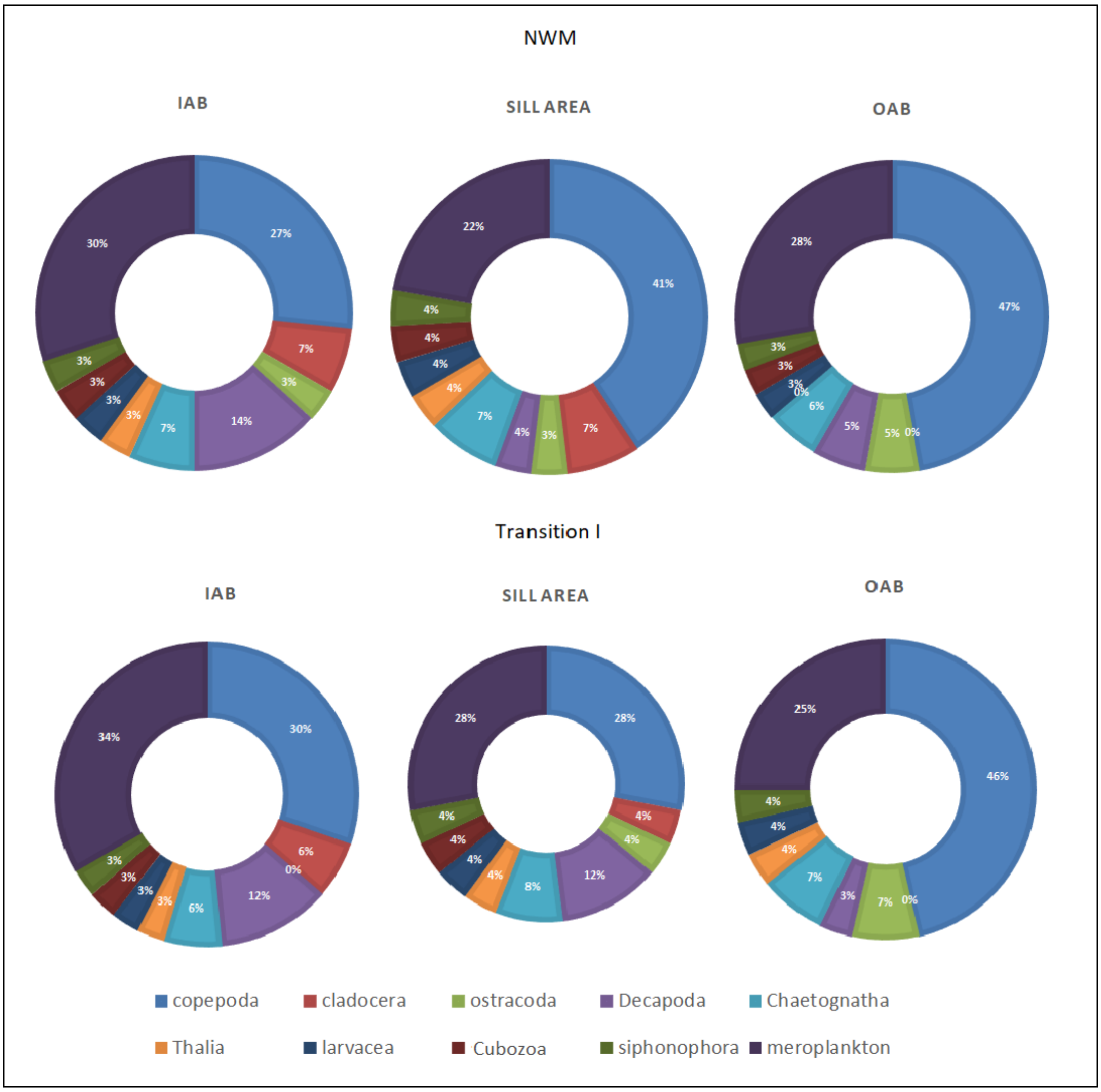

Figure 3. Zooplankton composition (%) in Ambon Bay (NWM and TI).

During TI, copepod accounts for 28-46% in the first position and is followed by meroplankton in the second rank with 25-34% of the total composition of zooplankton. In detail, Copepoda has the leading position only in OAB. At the same time, both copepod and meroplankton shared an equal contribution in the sill area. Meanwhile, meroplankton overtook and became the leading position in IAB. Decapod become the third leading position in the percentage of the total composition of zooplankton (3-12%).

Zooplankton abundance in Ambon Bay during NWM and TI ranged from 474-5981 (1723±997) ind m^{-3}. The detailed total abundance of zooplankton is shown in Figure 4.

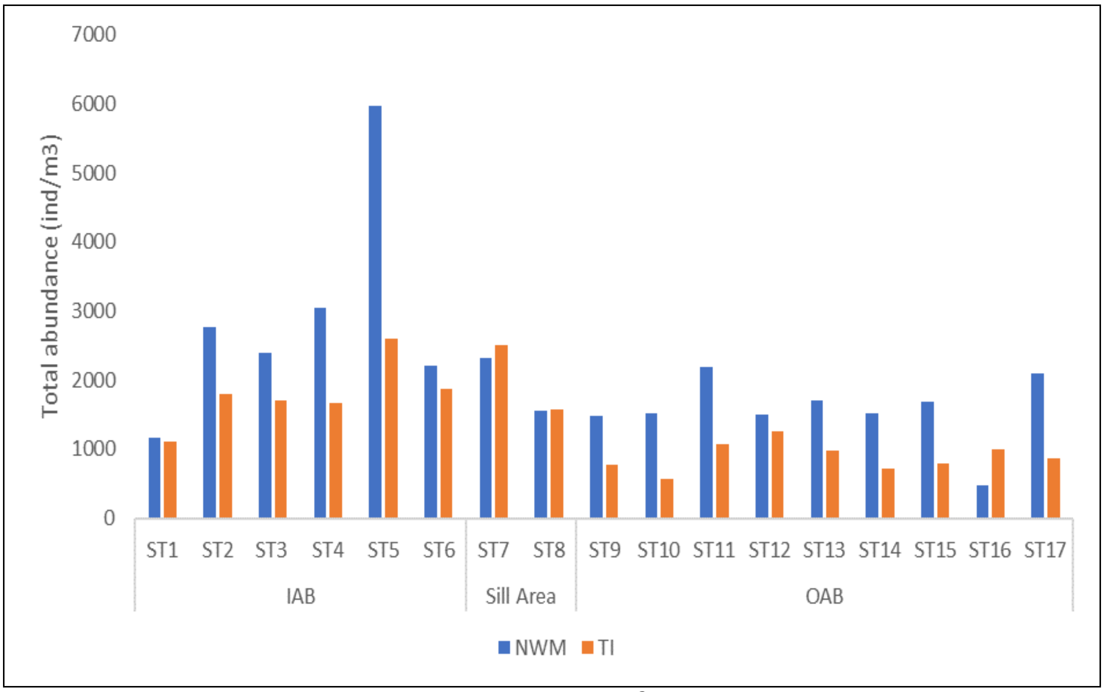

Figure 4. Total abundance zooplankton (ind m^{-3}) in Ambon during NWM and TI.

The total abundance of zooplankton peaked in IAB (Station 5) with a value of nearly 6000 ind m^{-3}, and the lower occurred in OAB (Station 16) with a value under 500 ind m^{-3} during NWM. However, in TI, the total abundance of zooplankton peaked in IAB (Station 5) with a value of nearly 3000 ind m^{-3}. A lower abundance was detected in OAB (Station 10) with a value under 600 ind/m^3.

The appendicularian zooplankton *Thalia sibogae* has a remarkable abundance value in IAB (almost stations, except St 01) and the sill area during NWM (Figure 5). The outnumbers of *T. sibogae* occurred in Station 5, reached 5 $x10^3$ ind m^{-3}, and replaced the predominant taxa position of copepods in IAB and sill area during NWM. However, meroplankton becomes the leading taxa because of the abundance of zooplankton in the IAB and sill area during TI.

Although copepods have a lower abundance in IOB and sill area during NWM and TI, the abundance of copepods in OAB is predominant. During NWM, the abundance of copepods ranged from $1x10^2$ - $3x10^2$ ind m^{-3} in IAB and $2x10^2$ – $5x10^2$ ind m^{-3} in the sill area. While the higher values abundance of copepods in OAB during NMW ranged from $2x10^2$ – $1x10^3$ ind m^{-3}. A slightly similar pattern occurred during TI. The abundance of copepods in IAB and sill area ranged for $1x10^2$ - $3x10^2$ ind m^{-3} and $2x10^2$ – $3x10^2$ ind m^{-3}, respectively. Meanwhile, the abundance of copepods in OAB ranged $2x10^2$ – $6x10^2$ ind m^{-3} during TI.

Discussion. The SST during NWM is higher than SST during the TI period. On the contrary, the SSS during NWM is lower than SSS during the TI period. The water mass condition in Ambon Bay is significantly affected by monsoon (Saputra & Sapulette 2016). Interestingly, the distribution and value of SST in IOB was warmer than in OAB. On the contrary, the SSS in IOB was lower than in OAB during NWM and TI periods. These results indicated that the water mass circulation in IOB and OAB is driven by tides (Wenno & Anderson 1984; Nurfitri & Putri 2019).

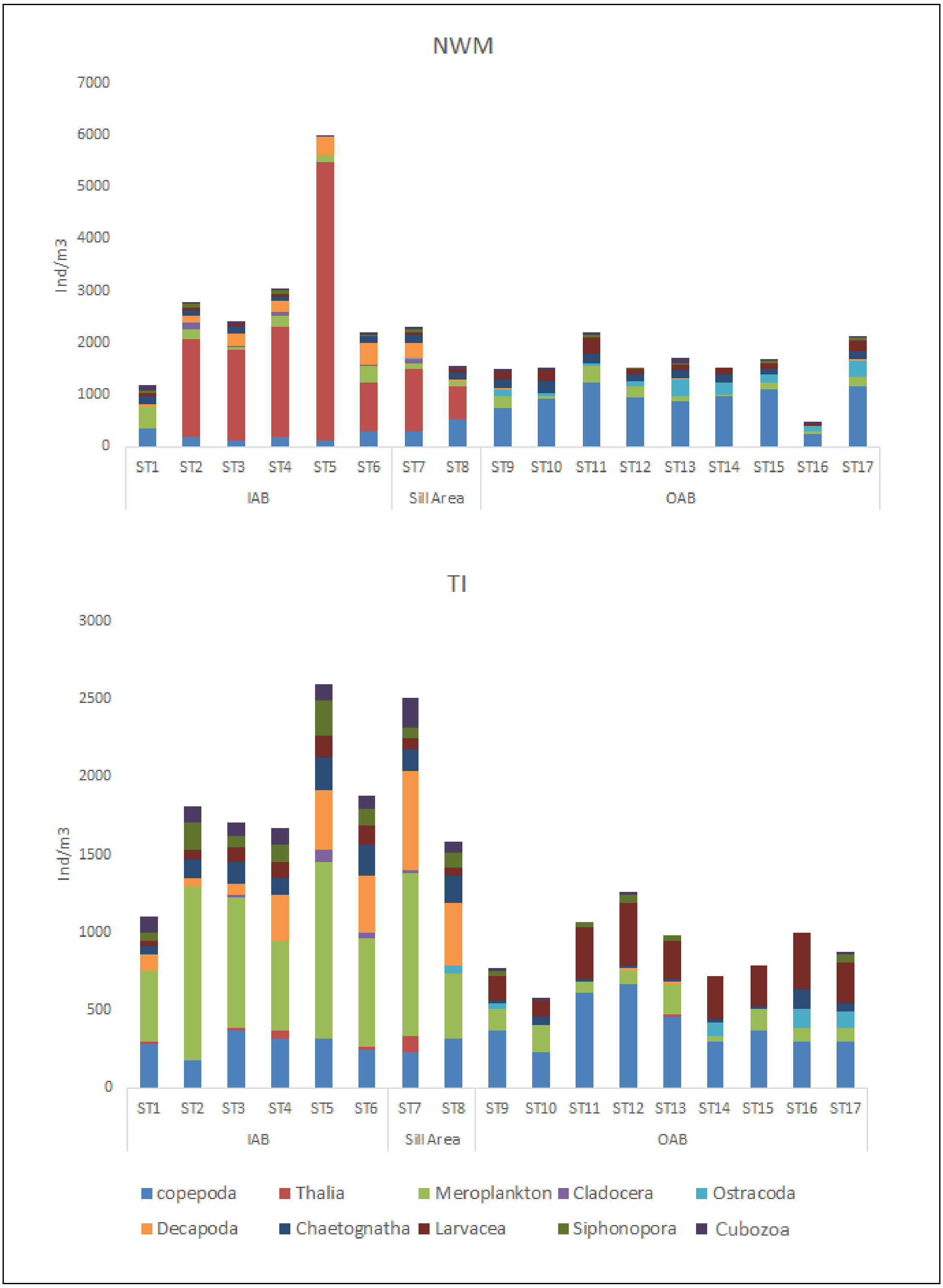

Figure 5. The abundance of zooplankton in each group (ind m^{-3}) during NWM and TI.

Copepoda in Ambon Bay was the predominant taxa in the total composition of zooplankton community structures. Copepods is the most diverse and major group of zooplankton in estuarine envrironments (Li et al 2017). In this study, 47 species or groups of zooplankton were recorded from Ambon Bay, a number which is higher than the number of species (45 sp.) in Malaysia seagrass ecosystem (Ismail et al 2021). Mulyadi and Radjab (2015) identified 43 species of zooplankton in Morella coastal waters, which is located near Ambon Bay. The copepod composition account for 19 species in Ambon Bay which is lower than copepod from Cilacap mangrove and coastal area (36 sp.) (Mulyadi & Murniati 2017) and the diversity of copepod from Sundarbans Estuarine

System (SES), India (41 sp.) (Basu et al 2022). Meroplankton is in the second position in order of species composition. The meroplanktonic organisms were found in the higher number of composition in IAB, indicating that the inner bay has essensial functions. The previous study explained that IAB is the spawning ground or nesting area for several adult nekton or benthic organisms (Mulyadi 2012), which consist of a mangrove ecosystem (Suyadi 2009) and seagrass (Irawan & Nganro 2016).

The mean zooplankton abundance in this study was 1723±997 ind m^{-3} which is higher than the mean abundance of zooplankton in Morella coastal waters (890±128 ind m^{-3}) (Mulyadi & Radjab 2012) and in the Bay of Bengal (33.37±7.19 ind m^{-3}) and 35.08±2.07 ind m^{-3} in the South China Sea (Li et al 2017). The abundance of zooplankton in estuarine was affected by environmental factors, e.g., temperature and salinity (McKinstry & Campbell 2018). Temperature and salinity affect the growth of zooplankton. Several taxa are more tolerant of the wide range of salinity which is known as euryhaline species or short ability to adapt the fluctuation of salinity as stenohaline species.

Figure 6. The abundance of meroplankton in each taxa (ind m^{-3}) during NWM and TI.

The short-term changes in the abundance of zooplankton were detected during NWM. In NMW, the appendicularian *Thalia sibogae* has a higher abundance, and the opposite, the meroplankton peak has been reached during TI. A swarm of Appendicularia has been detected along the IAB and sill area during NWM. In this area, the highest abundance of *T. sibogae* reached 2 x 10^3 ind m^{-3} and 9 x10^2 ind m^{-3}, respectively. The swarming of appendicularian zooplankton in Ambon Bay was reported in a previous study by Troost et al (1976). In another area, outbreaks of appendicularian salp were detected in the Apulian coast and the Otranto Channel in March-May 2013 (Boero et al 2013). Heron and Benhaam (1985) explained that swarms of appendicularian salp in the ocean was initially of low density but increased the growth rate, followed by high density, and the value of growth rate increased to maximum and continued by condition with lack of nutrients or food caused negative growth rate and decreased of density. Environment conditions, e.g., temperature and phytoplankton as a driver of appendicularian salp swarms (Henschke et al 2015). Further, Henschke et al (2016) report the new findings on the crucial functions of salp in the ocean. They argue that miss-interpretation of salp functions in marine food webs due to the difficulties sampling and their gelatinous bodies indicate that salp less-functions in the carbon cycle. In fact, salp is a vital food source for some commercial fishes, turtles, and crustaceans and a significant role in carbon exporters.

In addition, meroplankton outnumbers abundance during TI. The higher abundance of meroplankton 8x10^2 ind m^{-3} and 7x10^2 ind m^{-3} in IOB and sill area during TI (Figure 6). The result of this research was a similar pattern to several meroplanktonic taxa at Jakarta Bay and Seribu Island (Puspasari & Aisyah 2018), in which the author reported that mollusk, shrimp, and fish larvae were in abundance during April. The presence of meroplanktonic organisms in high values indicated the spawning time (Highfield et al 2010), linked to oceanographic factors (Ayata et al 2011). In the Sub-Artic Shelf System, the seasonal pattern of meroplankton was low density and abundance during winter, increased during spring, and outnumbered during summer (Silberberger et al 2016).

Interestingly, the Echinodermata larvae were counted in higher abundance in IAB and sill area during TI (more than 50 percent of total meroplankton abundance) related to the habitat preference of the adult of benthic Echinodermata. The IAB consists of mangrove ecosystem (Suyadi 2009) and seagrass (Irawan & Nganro 2016) which are the favorable habitat for benthic invertebrates. The population of benthic Echinodermata in IAB was conducted (Tuapattinaja et al 2014). The author explained that 16 species of Echinodermata were identified in Tanjung Tiram (IAB), with the higher abundance being *Diadema setosum* and the higher frequency occurrence was *Holothuria scabra*.

Conclusions. This study has successfully investigated the short-term changes in zooplankton abundance during the NWM and TI period in Ambon Bay. In NMW, the appendicularian *Thalia sibogae* has a higher abundance, and meroplankton reached its peak during TI. IOB and sill area have the vital function as habitat preference for adult marine benthic organisms, indicated by outnumbers of their planktonic larvae. Capturing the swarm of salp and planktonic invertebrate larvae in Ambon Bay suggested that monitoring Ambon Bay is essential to supporting Indonesia's marine pelagic fisheries management program.

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Conflict of interest. The authors declare that there is no conflict of interest.

References

Ayata S. D., Stolba R., Comtet T., Thiebaut E., 2011 Meroplankton distribution and its relationship to coastal mesoscale hydrological structure in the northern Bay of Biscay (NE Atlantic). Journal of Plankton Research 33(8):1193-1211.

Basit A., Putri M, R., Tatipatta W. M., 2012 Estimation of seasonal vertically integrated primary productivity in Ambon Bay using the depth-resolved, time-integrated production model. Mar. Res. Indonesia 37(1):47-56.
Basu S., Gogoi P., Bhattacharyya S., Kumar L. K., Das S. K., Das B. K., 2022 Variability in the zooplankton assemblages in relation to environmental variables in the tidal creeks of Sundarbans estuarine system, India. Environ Sci Pollut Res Int. 29(30):45981-46002. doi: 10.1007/s11356-022-19136-8. Epub 2022 Feb 14. PMID: 35157203.
Belkahia N. M., Pagano M., Chevalier C., Devenon J. L., Yahia M. N. D., 2021 Zooplankton abundance and community structure driven by tidal currents in a Mediterranean coastal lagoon (Boughrara, Tunisia, SW Mediterranean Sea). Estuarine, Coastal and Shelf Science 250(2021)107101.
Boero F., Belmonte G., Bracale R., Fraschetti S., Piraino S., Zampardi S., 2013 A salp bloom (Tunicata, Thaliacea) along the Apulian coast and in the Otranto Channel between March-May 2013 [v1; ref status: awaiting peer review, http://f1000r.es/1ok] F1000Research 2013, 2:181. doi: 10.12688/f1000research.2-181.v1.
Dwiono S. A. P, Rahayu D. L., 1984 [Preliminary study of phytoplankton in the inner Ambon Bay]. Oseanologi di Indonesia (18):55-61 [in Indonesian].
Henschke N., Smith J. A., Everett J. D., Suthers I. M., 2015 Population drivers of a *Thalia democratica* swarm: insights from population modelling. Journal of Plankton Research 37(5):1074-1087.
Henschke N., Everett J. D., Richardson A. J., Suthers I. M., 2016 Rethinking the role of salps in the ocean. Trend in Ecology and Evolution 31(9):720-733.
Heron A. C., Benham E. E., 1985 Life history parameters of growth in three salp populations. Journal of Plankton Research 7(3):365-379.
Highfield J. M., Eloire D., Conway D. V. P., Lindeque P. K., Attrill M. J., Somerfield P. J., 2010 Seasonal dynamics of meroplankton assemblages at station L4. Journal of Plankton Research 32(5):681-691.
Irawan A., Nganro N. R., 2016 Distribution of seagrasses in Inner Ambon Bay. Jurnal Ilmu dan Teknologi Kelautan Tropis 8(1):99-116.
Ismail J., Mustafa Kamal A.H., Idris M. H., Amin S. M. N., Hamli H., Sien L. S., Al-Asif A., Abualreesh M. H., 2021 Zooplankton species composition and diversity in the seagrass habitat of Lawas, Sarawak, Malaysia. Biodiversity Data Journal 9: e67449. https://doi.org/10.3897/BDJ.9.e67449.
Kesaulya I., Rumohoira D. R., Saravanakumar A., 2022 The abundance of *Gonyaulax polygramma* and *Chaetoceros* sp. causing blooming in Ambon Bay, Maluku. Ilmu Kelautan: Indonesian Journal of Marine Sciences 27(1):13-19.
Li K., Yin J., Huang L., Tan, Lin Q., 2017 A comparison of the zooplankton community in the bay of Bengal and South China Sea during April-May, 2010. J. Ocean Univ. China. doi: 10.1007/s11802-017-3229-4.
Likumahua S., 2013 Recent blooming of *Pyrodinium bahamense* var. *compressum* in Ambon Bay, Eastern Indonesia. Marine Research Indonesia 38(1):31-37.
Mahara N., Pakhomov E. A., Dosser H. V., Hunt B. P. V., 2020 How zooplankton communities are shaped in a complex and dynamic coastal system with strong tidal influence. Estuarine, Coastal and Shelf Science 249(2021):107103.
McKinstry C. A. E., Campbell R. W., 2018 Seasonal variation of zooplankton abundance and community structure in Prince Willian Sound, Alaska, 2009-2016. Deep Sea Research Part II:Topical Studies in Oceanography 147:69-78.
Mizushima K., Matsuoka K, Fukuyo Y., 2007 Vertical distribution of *Pyrodinium bahamense* var. *compressum* (Dynopeceae) cysts in Ambon Bay and Hutun Bay, Indonesia. Plankton and Benthos Research 2(4):163-174.
Mulyadi, 2002 The calanoid copepods family Pontellidae from Indonesian waters, with notes on its species groups. Treubia. 32(2):167pp.
Mulyadi, 2004 The pelagic calanoid copepods of the families Acartiidae, Aetideidae, Augaptidae, Calanidae, Calocalanidae, Candaciidae, Centropagidae, Clausocalanidae, Eucalanidae, Euchaetidae, Heterorhabdidae, Metridinidae, Paracalanidae,

Phaennidae, Pseudodiaptomidae. Research Center for Biology, Indonesian Institute of Sciences. pp. 1-195.
Mulyadi H. A., 2011 [Distribution and abundance of Cladocera (*Penilia avirostris* DANA, 1852]. Oseanologi dan Limnologi di Indonesia 37(2):191-210.
Mulyadi H.A., 2012 [The urgency of managing the Ambon Bay area is reviewed from the meroplankton aspect]. Prosiding seminar nasional pengelolaan sumberdaya alam dan lingkungan UNDIP 342-348.
Mulyadi H. A., Radjab A. W., 2015 Dynamics of spatial abundance of zooplankton in Morella coastal waters, Central Maluku. Jurnal Ilmu dan Teknologi Kelautan Tropis 7(1):109-122.
Mulyadi H. A., Saputra F. R. T., 2019 Zooplankton sesonal dynamics in Ambon Bay, Maluku. IOP Conf. Series: Earth and Environmental Science 339(2019):012028.
Mulyadi, Murniati D. C., 2017 Diversity, abundance, and distribution of copepods (crustacea) in the mangrove area of Segara Anakan Cilacap. Oseanologi dan Limnologi di Indonesia 2(2):21-31.
Nandy T., Mandal S., Chatterjee M., 2018 Intra-monsoonal variation of zooplankton population in the Sundarbans Estuarine System, India. Environ Monit Assess. 190(10):603. doi: 10.1007/s10661-018-6969-8. PMID: 30242488.
Nishida S., 1985 Taxonomy and distribution of the family Oithonidae (Copepoda, Cyclopoida) in the Pacific and Indian Oceans. Bulletin of the Ocean Research Institute, University of Tokyo. 167p.
Nurfitri S., Putri M., 2019 Water mass exchange at Ambon Bay based on trajectory model: a preliminary study. Journal of Physics Conference Series 1127:012039.
Pello F. S., Adiwilaga E. M., Huliselan N. V., Damar A., 2014 Seasonal variation of the composition and density of phytoplankton in inner Ambon Bay. Aquatic Science and Technology 2(1):31-41.
Puspasari R., Aisyah, 2018 Grouping of meroplankton habitat in Jakarta Bay and Seribu Island. Oseanologi and Limnologi di Indonesia 3(1):49-61.
Saputra F. R. T., Sapulette J. D., 2016 Water mass dynamics in Ambon Bay. Widyariset 2(2):143-152.
Serihollo L. G. G., Yuli E. H., Mohammad M., 2015 The composition and abundance of phytoplankton in Amboina Bay (inside), Indonesia. International Journal of Scientific & technology Research (4):437-439.
Sidabutar T., Toha H., Bayu M. D., Rachman A., Sianturi O. R., Fitriya N., Muawanah, Mulyadi H. A., Likumahua S., Masseret E., 2016 Occurrence of *Pyrodinium bahamense* blooms related to cyst accumulation in the bottom sediments in the bays at Ambon, Lampung and Jakarta, Indonesia. Harmful Algae news, An IOC Newsletter on Toxic Algae and Algal Blooms (52). 2pp.
Silberberger M. J., Renaud P. E., Espinasse B., Reiss H., 2016 Spatial and temporal structure of the meroplankton community in a sub-Arctic shelf system. Marine Ecology Progress Series 555:79-93.
Song C. U., Coi H., Jeon M. S., Kim E. J., Jeong H. G., Kim S., Kim C. G., Hwang H., Purnaningtyas D. W., Lee S., Eyun S. I., Lee Y. H., 2021 Zooplankton diversity monitoring strategy for the urban coastal region using metabarcoding analysis. Scientific Reports (2021)11:24339.
Sutomo, Anderson J. J., 1984 Phytoplankton and zooplankton abundance in Ambon Bay. Marine Research in Indonesia, 23:1–11.
Suyadi, 2009 [Condition of mangrove forests in Ambon Bay]. Berita Biologi, 9(5):481-490.
Troost D. G., Sutomo A. B., Wenno L. F., 1976 Distribution and abundance of major zooplankton groups in Ambon Bay (Maluku, Indonesia) during Salp swarming, with notes on Chaetognatha and Pteropoda species. Mar. Res Indonesia (16):31-44.

Tuapattinaja M, A., Pattikawa J, A., Natan Y., 2014 Community structure of echinoderms at Tanjung Tiram, inner Ambon Bay, Indonesia. AACL Bioflux 7(5):351-356.
Vereshchaka A. L., Anokhina L. L., Lukasheva T. A., Lunina A. A., 2019 Long-term studies reveal major environmental factors driving zooplankton dynamics and periodicities

in the Black Sea coastal zooplankton. PeerJ. 2019 Sep 27(7):e7588. doi: 10.7717/peerj.7588. PMID: 31579575; PMCID: PMC6768059.
Wagey A. G., 2002 Ecology and physiology of phytoplankton in Ambon Bay, Indonesia. *PhD Thesis* the University of British Columbia.185pp.
Wang X., Wang Z., Zhang X., Liu P., 2021 The distribution of zooplankton and the influencing environmental factors in the South Yellow Sea in the summer. Marine Pollution Bulletin 167(2021):112279.
Wenno L. F., Anderson J. J., 1984 Evidence for tidal upwelling across the sill of Ambon Bay. Marine Research in Indonesia 23:13-20.
Wickstead J. H., 1965 An introduction to the study of tropical plankton. Hutchinson Trop. Monogr: 160pp.
Yamaji I. E., 1984 Illustrations of the marine plankton of Japan. Hoikusha Publishing Co., LTD, Japan, 536p.
Yusuf S. A., 1979 [Variation of zooplankton density and composition in Ambon Bay]. Oseanologi dan Limnologi di Indonesia, 12:31-43.
*** Research Center for Deep Sea-Indonesian Institute of Sciences (RCDS-LIPI), 2014 Monitoring of Ambon Bay. 56pp.

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