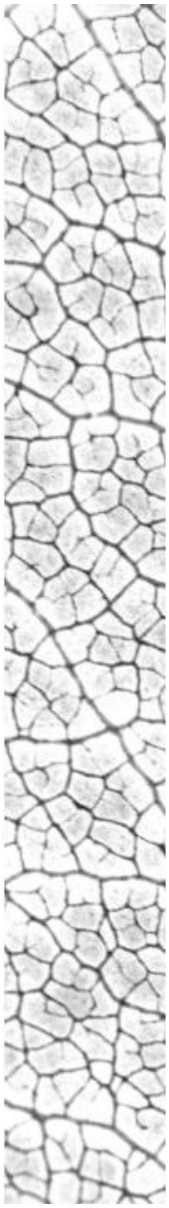

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Distribution of zooplankton abundance and diversity in the vicinity of Maspari Island, Bangka Strait, South Sumatra, Indonesia

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Abstract
Zooplankton species composition has an important role in the food chain that can be used as water fertility indicator. It is strongly influenced by physical-chemical parameters, especially in the strait waters due to the discharge of freshwater as well as strong mixing. This study is aimed to analyze zooplankton distribution and diversity, and their correlation to physical-chemical parameters in the strait water of Maspari Island. The results showed that the zooplankton in the vicinity of Maspari Island can be grouped in 10 taxa, which are dominated by Calanoid (47%) and Harpacticoid (19%). Other taxa (e.g. Cyclopoid, Chaetognatha, Euphausia, Fish egg, Lensia, Ostracod, Brachyura and Polychaeta) only account for less than 10% for each taxa. The abundance of zooplankton obtained in range of 18 to 3205 Ind.L^{-1}, which is mainly found in a high Calanoid. Note that the distribution of zooplankton abundance in these waters found almost at all observation stations. Zooplankton diversity considered as low to moderate categories, with H' index was 0.51<H'<1.66, and there was no type of zooplankton dominates (C<0.5). PCA Analysis shows the correlation between physical-chemical parameters with the zooplankton distribution and diversity is identifier by density, temperature, salinity, pH, current speed, nitrate, phosphate and turbidity.

Keywords: biodiversity, calanoid, plankton, straits water, zooplankton distribution

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INTRODUCTION

Dynamics of strait waters occurred very clearly, which can be easily seen from the changes of water color in certain seasons which is influenced by water mass discharge from the mainland. Likewise, strong currents have a role in the fast mixing process, which has an impact on the distribution of suspended materials and fluctuations in other parameters. Ecologically, this process is highly needed by marine biota to increase dissolved oxygen and nutrients in water (Wang et al. 2016, Afonina and Tashlykova 2018, Banerjee et al. 2019).

Maspari Island waters, located in the southern Bangka Strait, have very high physical-chemical dynamics parameters. They are influenced by the water mass of the Malacca Strait and the Natuna Sea during the northwest monsoon season (December-February), and by the water mass of the Java Sea during the southeast monsoon season (June-August). The advection of water mass has an impact on the suspended material distribution and also the zooplankton abundance. Freshwater mass input from large rivers of the mainland Sumatra such as the Musi River, Banyuasin River, and Lumpur River had caused high turbidity in the Bangka Strait. This condition makes the study of structure and distribution of plankton especially zooplankton is more interesting and challenging. In addition, zooplankton species information in the vicinity of Maspari Island has never been investigated and reported before. It was well known for the local people that this location is one important fishing ground for local fishermen.

Zooplankton abundance has an important role in the food chain, which it can be a water fertility indicator. Its existence is known to be strongly influenced by the dynamics of physical-chemical parameters due to their limited movement. Structure and distribution of zooplankton are also affected by sampling time because

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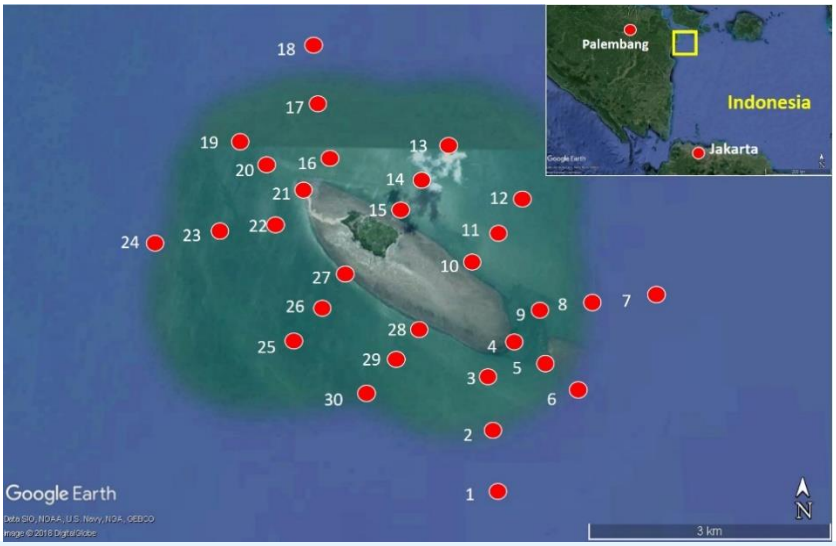

Fig. 1. Map of sampling site

it is negative phototaxis or avoids light. This is closely related to the predation system in the aquatic food chain, where phytoplankton as primary producers and zooplankton as predators (El-Naggar et al. 2019, Stefanoudis et al. 2019, Wu et al. 2019, Shalloof et al. 2020). It was suggested that zooplankton are at the tropic level in the food chain before fish, corals, and other marine biota (Stibor et al. 2019; Al–Taai, 2016).

The dynamics of Maspari Island waters was reported to be highly varying. The current speed is about 0.0 - 1,418 $m.s^{-1}$, while the turbidity is about 17.5 - 90.5 FTU. The dissolved oxygen was reported in the range 3.78 ± 0.18 to 6.18 ± 0.15 $mg.L^{-1}$. Nutrient concentrations (NO_3) is about 0.28 $mg.L^{-1}$, and the Phosphate (PO_4) was reported to be about 0.2 $mg.L^{-1}$, while the other parameters have slight variation (Rozirwan et al. 2019). This study, for the firt time, describes the distribution and diversity of zooplankton in the Maspari Island waters and their correlation with dynamics of physical-chemical parameters..

MATERIAL AND METHODS

Study site

Maspari Island is a very small island about 3 km^2, located in the southern part of Bangka Strait, and it is not inhabited by humans. The dynamics of Maspari Island waters is determined by two seasons, namely the northwest monsoon and the southeast monsoon seasons. During the northwest monsoon season from December to February, the Maspari Island waters are influenced by the water masses from Malacca Straits and the Natuna Sea. Meanwhile, during the southeast monsoon season from June to August they are influenced by the water masses from the Java Sea. Seasonal change is believed to have a strong impact on the dynamics of the physical-chemical parameters in the Maspari Island waters such as turbidity, current velocity, density, salinity, pH, temperature and nutrients (NO_3 and PO_4).

In addition to the seasonal changes driven by the monsoonal wind system, the Maspari Island waters are also influenced by freshwater masses from the mainland of Sumatra Island through large rivers such as the Musi River, Banyuasin River and Lumpur River which are end up in the Bangka Strait. The freshwater discharges from those rivers transport high suspended-sediment indicated by turbid water color. These water masses through the mixing process also have a direct impact on decreasing salinity, increasing suspended material, turbidity and nutrients. In this study, data collection in the Maspari Island waters was carried out during the southeast monsoon season in August 2018, with a total of 30 stations (**Fig. 1**).

Data and zooplankton sampling

Data collection for the physical-chemical parameters of the waters is conducted at 30 stations, which includes current speed, temperature, salinity, pH, turbidity, NO_3 and PO_4 content. Note that the current speed is measured by the current meter, while Conductivity Temperature Depth (CTD) is used for temperature, salinity, pH, turbidity. The NO_3 and PO_4 content are measured using a spectrophotometer. Physical-chemical data are analyzed and displayed using Surfer 9 software.

The zooplankton samples were collected on the surface of the water using 40-micron plankton net. Samples were obtained by filtering 100 L of water with a final volume of 110 mL preserved with 4% formalin. Observation of zooplankton species was carried out under a light microscope and identification refers to (Yousif et al. 2011a, Yousif et al. 2011b).

Date Analysis

Zooplankton abundant analysis

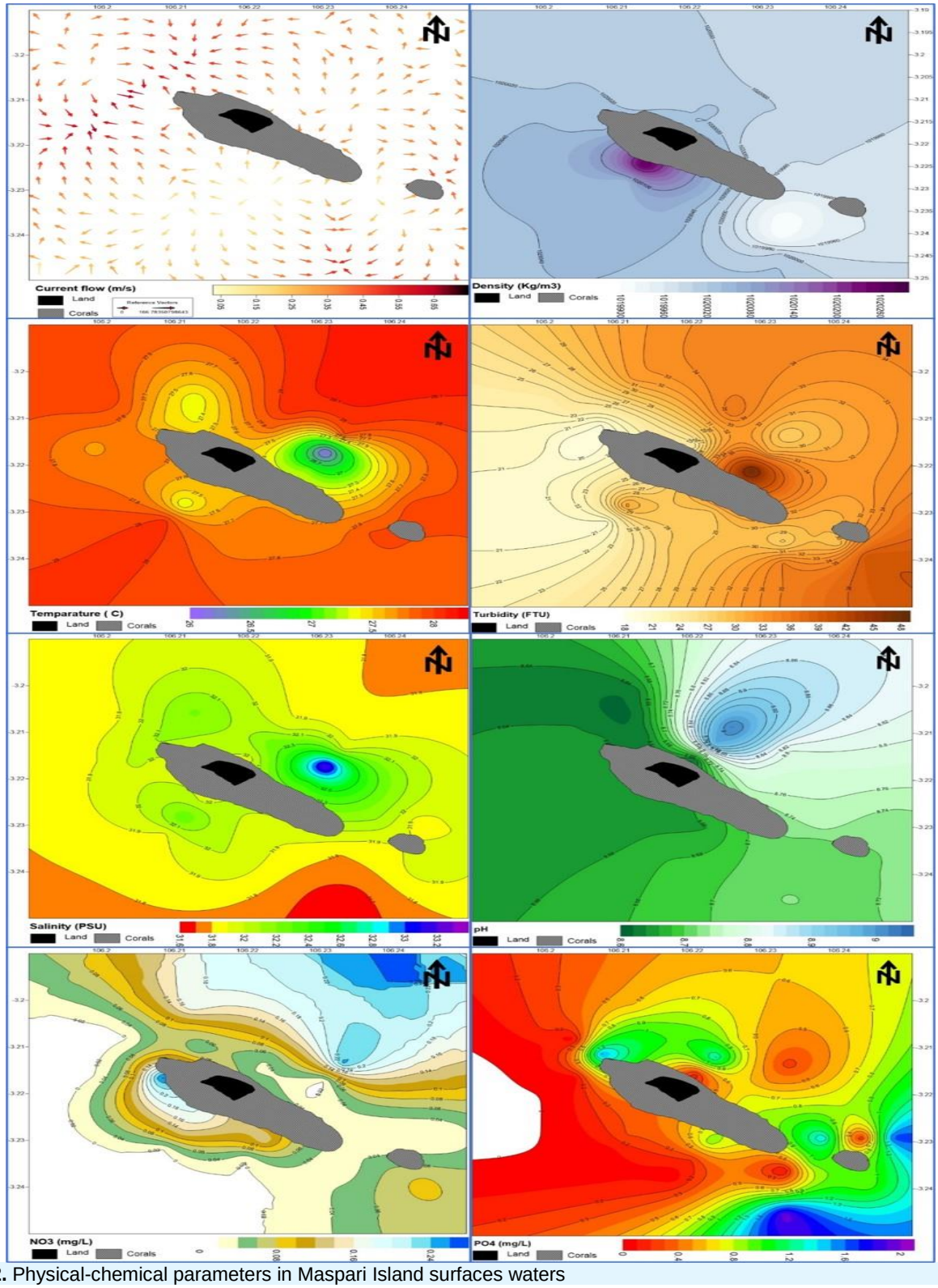

Fig. 2. Physical-chemical parameters in Maspari Island surfaces waters

Zooplankton abundant calculated in Ind.L^{-1} (A) following (APHA 1998) as;

$$A = \frac{1}{Vo} \times \frac{Vf}{Vs} x\ P\ x\ 1000 \qquad (1)$$

Here, *Vo* is a volume of filtered water in liters, *Vf* is a volume of filtered water in ml, *Vs* is a volume of water in the Sedgwick Rafter counting cell, and *P* is individual found zooplankton.

Zooplankton diversity

Zooplankton diversity analyzed using the Shannon-Wiener index (H') following (Shannon and Wiener 1949),

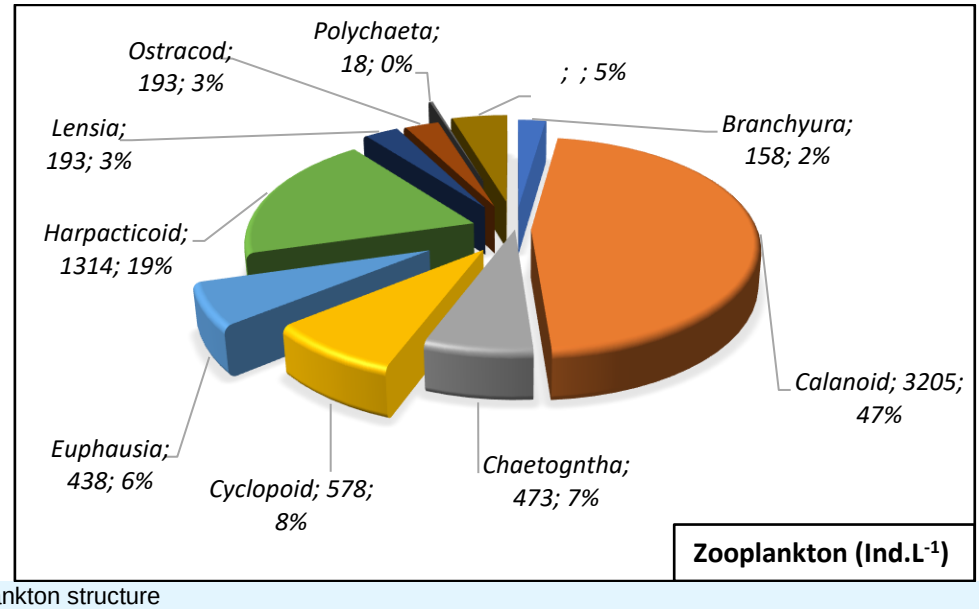

Fig. 3. Zooplankton structure

and the Sampson Index (C) for domination species (Odum 1971), with formula as;

$$H' = -\sum_{i=1}^{s}(\frac{ni}{N})(\ln\frac{ni}{N}) \quad (2)$$

$$C = -\sum_{i=1}^{s}[\frac{ni}{N}]^2 \quad (3)$$

Here, *ni* is total of individual species i, *N* is total of individual per station

Principal components analysis (PCA)

PCA is used to correlation between the physical-chemical parameters (current speed, density, temperature, turbidity, salinity, pH, nitrate and phosphate) with the zooplankton distribution and diversity. This analysis to determined identifier parameters to the zooplankton distribution and diversity of whole observation stations, which is calculated using the XLSAT 2020 software.

RESULTS

Physic-chemical parameters

The surface currents direction in the Maspari Island waters had shown to be dominant towards the northwest with a speed of around 0.05 to 0.65 m.s^{-1}, which is categorized as weak. It has shown that there are indications of tides, due to the current moving in the northwest. For overall water density, It is found almost at all distributed in observation stations, and only a few variated of the island western part (**Fig. 2**).

In general, temperature distribution is indicated in the normal category for zooplankton growths of tropical waters with a range of 26-31^{o}C, but are found slightly warmer of near the island due to its shallow effect. The turbidity level was shown be very high, especially the island eastern part with a range of values between 18-48 FTU. These conditions will certainly affect the photosynthetic layer becomes thin, so the impacted of the phytoplankton growth as primary producers in the aquatic food chain.

Salinity distribution described that be high of shallow waters due to it is affected by warmer water, with a value of around 31.61 to 33.27 PSU. This condition was found generally in Indonesia waters. For pH value was shown in good categories with a range of 8-9, which there is no significant difference between observation stations.

Nutrient content such as nitrate and phosphate in Maspari Island waters was found to be in good condition for zooplankton growth, where nitrate is range of 0.02 to 0.24 mg.L^{-1} and phosphate 0.01 to 2 mg.L^{-1}. The freshwater masses from the main land of Sumatra Island were found not significant impact of increasing nutrient level in Maspari Island waters, due to there is role of currents in the mixing proses to distributed of the organic materials, so that it is still in normal conditions.

Zooplankton taxa structure

Structure zooplankton found that various, which there were 10 taxa such as: *Calanoid*, *Harpacticoid, Cyclopoid, Chaetogntha, Euphausia, Fish egg, Lensia, Ostracod*, *Branchyura* and *Polychaeta* (**Fig. 3**). The *Calanoid* obtained the highest around 47% (3205 ind.L^{-1}), which It is included in *Copepod* class, while the lowest taxa was *Polychaeta* around 0.25% (18 ind.L^{-1}).

Distribution and biodiversity zooplankton

Zooplankton density distribution is shown evenly distributed, except in the southwest, north and east sides of the island found higher abundance. The dominant density of zooplankton has shown a range between 180 to 300 ind.L^{-1}, where it is spread evenly throughout the waters of the island. The lowest distribution is found in southern waters and getting closer to the island ranges from <150 ind.L^{-1} (**Fig. 4**).

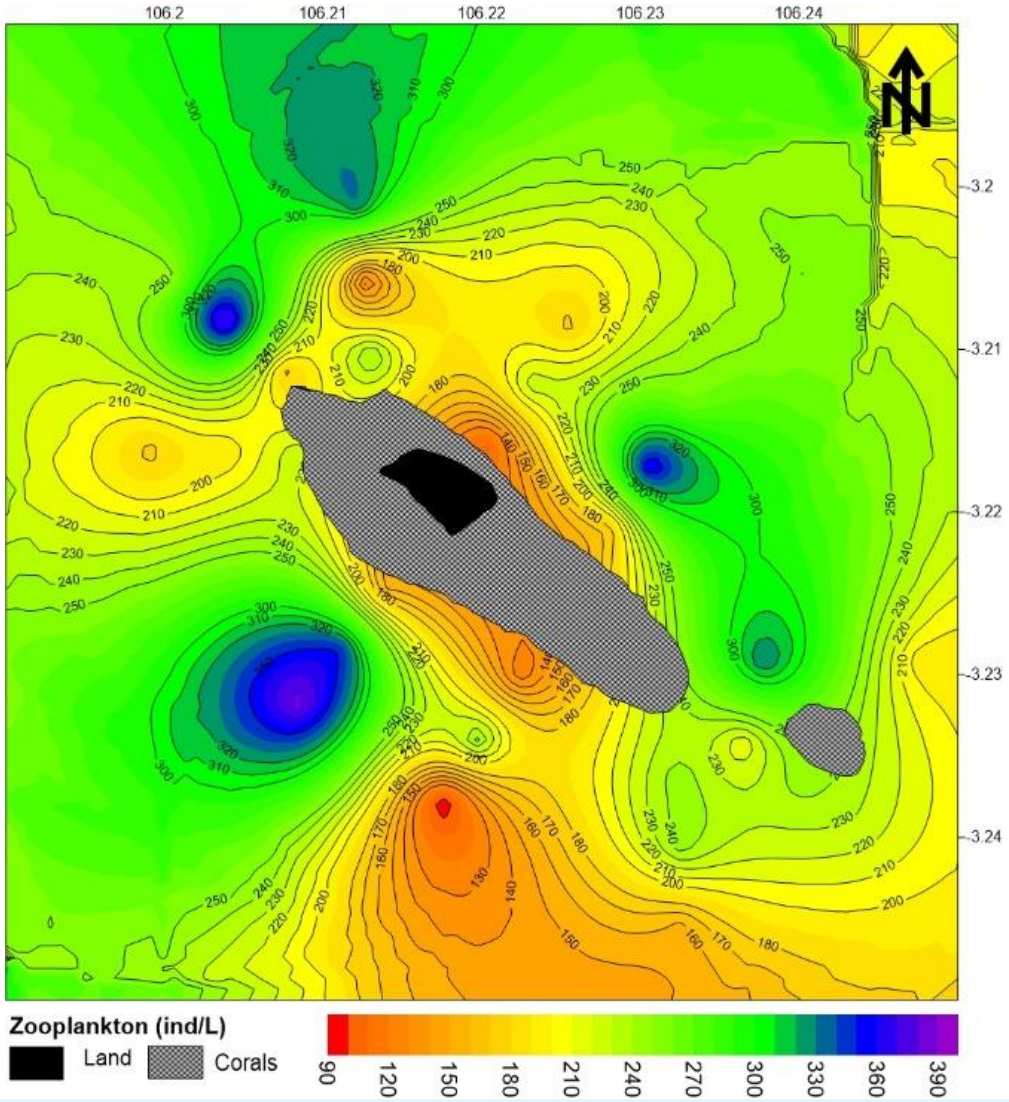

Fig. 4. Distribution of zooplankton abundance in Maspari Island waters

The zooplankton abundance of 10 taxa was obtained in the range of 18 to 3205 Ind.L^{-1}. The *Calanoid* groups found in whole observation samples. with equitable distribution throughout the waters between 35 to 195 Ind.L^{-1}. Then followed by *Harpacticoid* taxa distribution showed quite evenly, but the abundance was relatively low with a range between 18 to 87 Ind.L^{-1}. The lowest distribution is shown *Polychaeta* taxa with the number 18 Ind.L^{-1}, where it is found in only one station (i.e. station 11) (**Table 1**).

Zooplankton species diversity (H') of Maspari Island waters were categorized low to moderate, where H' index value of 0.51<H<1.66. There were 11 observation stations that categorized low, with value of H'<1, while others were moderate. This was supported by dominance index (C) found that generally in low categories (C<0.5), except for 9 stations i.e.: 5, 6, 14, 16, 17, 23, 24, 28 and 30 which it is more than slightly high (0.52<C< 0.66) (**Fig. 5**).

Correlation between zooplankton density with physical-chemical parameters

Based on principal component analysis (PCA), cumulative eigenvalues total was 88% and a minimum cosine squared variable value of 0.5 is shown formed four groups of relationships with each identifier. Groups 1, 2 and 3 were formed on the relationship between the F1 and F2 axes and the fourth group formed on F1 axis and F3 axis (**Fig. 6**).

Based on **Fig. 6**, that *first group* formed on the positive F1 axis, it has described at stations 2, 4, and 8 with the identifiers of density and temperature more than high, which it is followed by an increasing of zooplankton abundance. *The second group* formed on the negative F1 axis, which indicates stations 29 and 30 with the identifiers of higher salinity, pH, current speeds and nitrate. This parameters values found more than high caused there is occurred the strong mixing proses of the waters.

Table 1. Zooplankton taxa distribution of observation stations

Station	Taxa									
	Branchyura	*Calanoid*	*Chaetogntha*	*Cyclopoid*	*Euphausia*	*Harpacticoid*	*Lensia*	*Ostracod*	*Polychaeta*	*Fish egg*
1	-	++	-	++	+		-	-	-	-
2	-	++	-	-	++	++	-	+	-	-
3	-	+++	-	+	-	++	-	-	-	-
4	-	++	+	+	-	++	-	-	-	-
5	-	++++	++	-	-	-	-	-	-	-
6	-	++++	+	+	-	-	-	-	-	-
7	-	++	-	-	-	++	-	-	-	++
8	-	++	+++	-	-	++	-	-	-	-
9	-	+++	-	-	++	++	-	-	-	++
10	-	++	++	+	-	+	-	-	-	-
11	-	+++	-	++	+	++	+	-	+	-
12	-	++	+	-	-	+	++	-	-	++
13	-	++	-	-	+	+	-	+	-	+
14	-	++++	-	-	-	++	-	-	-	-
15	-	++	-	-	-	+	+	-	-	-
16	-	++++	-	-	-	++	-	-	-	-
17	-	++	-	+	-	-	-	-	-	-
18	++	++++	-	++	+	-	-	-	-	-
19	-	++	-	++	-	++	-	-	-	-
20	-	+	-	++	++	++	-	+++	-	+
21	+	++	-	-	-	++	-	-	-	-
22	+	++	-	++	-	+	-	-	-	-
23	-	+++	-	-	-	++	-	-	-	-
24	-	+++	-	-	-	-	-	-	-	++
25	-	+++	+	+	+++	+	-	-	-	-
26	+	+++	++	-	+	++	++	-	-	-
27	-	++	-	-	-	++	-	-	-	+
28	-	++	-	++	+	+	-	-	-	-
29	-	+++	-	-	-	++	-	-	-	+
30	-	+	++	-	-	-	-	-	-	-

Note: (-): 0 Ind.L^{-1}; (+): <50 ind.L^{-1}; (++): 51 to 100 Ind.L^{-1}; (+++): 101 to 150 Ind.L^{-1}; (++++): >150 Ind.L^{-1}

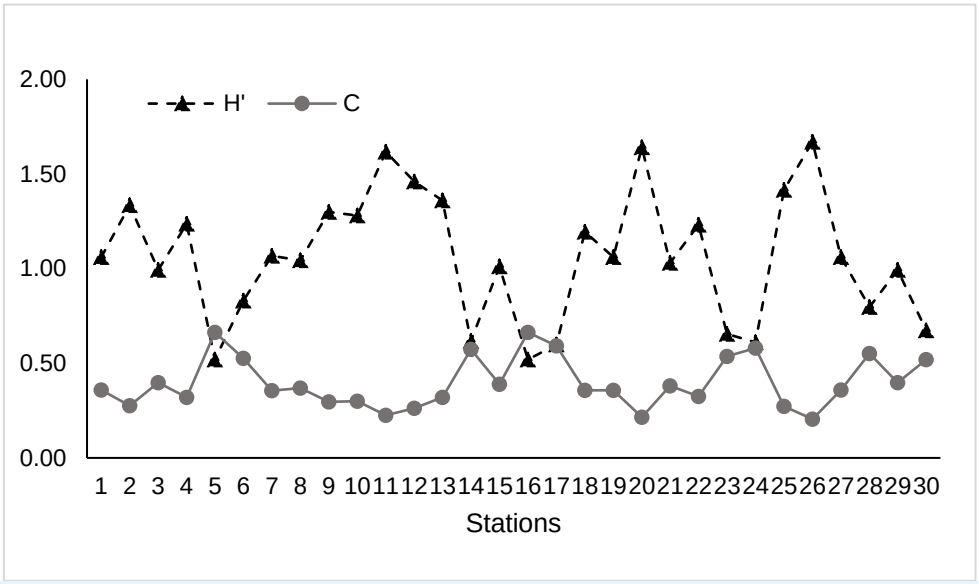

Fig. 5. Zooplankton diversity index

The third group formed on the positive F2 axis, depicted stations 1, 7, 14, and 17 with the identifier of higher phosphate content, due to phosphate carried out by water mass from mainland of Sumatra. *The fourth group* on the positive F3 axis illustrated that station 10 with the identifiers of turbidity and species dominance. The turbidity waters is shown correlated with increasing of zooplankton species domination.

DISCUSSION

The distribution of physical-chemical parameters of Maspari Island waters such as density, temperature, current velocity, salinity, pH, nitrate, turbidity and phosphate shown almost all distributed of the waters, where it is found in good condition for zooplankton growths (Zakaria et al. 2019). This parameters were relatively the similar as previously reported by (Rozirwan et al. 2019), where there is a strong correlation between

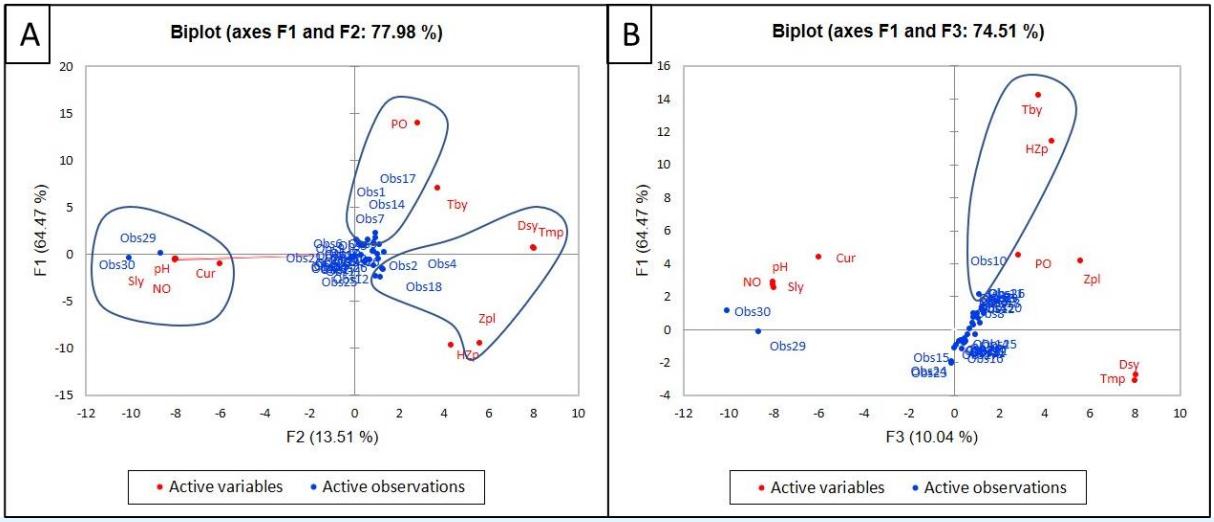

Fig. 6. Principle Component Analysis (PCA) Correlation between physical-chemical parameters with diversity and zooplankton abundance, A) F1 and F2 axes; B) F1 and F3 axes

these parameters with phytoplankton abundance and diversity. This was showed that variable environmental conditions strongly affect the distribution of zooplankton species (Dauvin et al. 1998).

There are 10 zooplankton groups is found in Maspari Island waters, dominated by *Calanoid* in *Copepod* subclass. This number is higher than reported by (Abdul et al. 2016), which only found there were 4 zooplankton groups in tropical coastal estuary that impounds the Bight of Benin in South-west, Nigeria. But is lower than noted by (Zakaria et al. 2019), found that 66 species of zooplankton of Abu Qir Bay, Alexandria, Egypt. The *Copepods* are found be dominant, being able to withstand changes in high salinity. The high *Copepod* abundance has also been reported at Mida Creek, Kenyan coast (Osore et al. 2004), Izmit Bay of the northeastern Marmara Sea (Isinibilir et al. 2008), at the mouth of the Gambia River (Ndour et al. 2018), northeast and southwest of Bermuda (Stefanoudis et al. 2019), Gulf of Gdańsk and in its inner part-Puck Bay (Koszarowska et al. 2019), Cintra Bay of Northwest Africa (Berraho et al. 2019), Senegal-Guinea maritime zone (Ndour et al. 2018), the northern part of the Persian Gulf (Izadi et al. 2018).

Zooplankton abundance in the Maspari Island waters were around 18 to 3205 Ind.L^{-1}. This value were higher than recorded by (Osore et al. 2004, Paturej et al. 2017, McKinstry and Campbell 2018, Berraho et al. 2019, Zakaria et al. 2019), but lower than reported by (Echaniz et al. 2006). This may be caused the research area was in a strait. *Copepods, Protozoa*, and *Mollusca* are zooplankton commonly found in waters. Same as reported by (Osore et al. 2004, Izadi et al. 2018, Berraho et al. 2019, Koszarowska et al. 2019, Zakaria et al. 2019). Mixing high water masses causes high turbidity, this will impact on the ability of zooplankton species to survive (Banerjee et al. 2019). The zooplankton diversity level in Maspari Island water can categorized as low to moderate. The same as recorded by (Okogwu 2010). This condition is thought be caused in the strait area, which it is influenced by the discharge of freshwater masses from the mainland of Sumatra. In addition, it is thought be related to relatively low diversity of phytoplankton as the primary producer of the waters food chain (Afonina and Tashlykova 2018, El-Naggar et al. 2019, Rozirwan et al. 2019, Shalloof et al. 2020, Wu et al. 2019, Zaghloul et al. 2020).

Based on PCA analysis that there was correlated between water parameters with the zooplankton abundance and diversity. The density parameter influenced by depth of waters, which is the increasing of depth correlated increasing of waters density. The numbers of zooplankton species found varies at each depth, which due to impacted by density (Khalifa et al. 2015, Stefanoudis et al. 2019). Temperature was closely related to the evaporation process, which it is caused an increasing of waters salinity and pH. Naturally, temperatures tropical waters have influenced by waters depth, which the temperature will increase with decreasing depth, this is the effect of the evaporation process, and followed by increasing of salinity and pH. In this study, there was a positive correlation between temperature and zooplankton abundance. The same found in a tropical coastal estuary, South-west, Nigeria (Abdul et al. 2016), in the Gulf of Gdańsk (southern Baltic Sea) (Koszarowska et al. 2019).

Salinity, pH, current speed and nitrate showed a negative correlation with zooplankton abundance. This had contradicted by (Abdul et al. 2016) salinity showed a positive correlation with the number of zooplankton species, while phosphate and brightness were negative. Strong current speeds has made salinity, pH and nitrate scattered which is shown at low zooplankton quantities (Abdulwahab and Rabee 2015).

The waters turbidity level was found high, was an indicated that there was an influenced by the freshwater masses discharge from main land of Sumatra Island. It has a negative impact with zooplankton abundance (Koszarowska et al. 2019). The abundance correlated significantly with the water transparency, but not with salinity (Echaniz et al. 2006). There were sediments with high phosphate and nitrate contents, which have an impact on the increasing of zooplankton abundance. This was due to increasing of phytoplankton as primary producer of water (Nuccio et al. 2003, Pilkaitytė and Razinkovas 2007, Paczkowska et al. 2019).

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