LIPI COREMAP-CTI Nusa Manggala oceanographic survey, I: oceanic mesozooplankton community from epipelagic zones of North-Eastern part of the Indonesian waters -adjacent to the Southwest Pacific Ocean

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Abstract. During the Indonesia LIPI COREMAP CTI oceanographic survey of RV. Baruna Jaya VIII, at the end of 2018 to the outermost small Islands of the north-eastern part of Indonesia, the mesozooplanktonic community were studied for their structure and distribution along the epipelagic zone of the waters influenced by the movement of the southwest Pacific Oceans water masses. This study aimed at exploring the oceanographic condition of the trophic level of the water’s masses during the end of the dry season in Indonesia. A total of 42 taxonomic groups of mesozooplankton were identified, including general fish larvae and eggs. Calanoida and cyclopoid Copepoda dominated (up to 69%) the structure of all survey points. The composition slightly varied across the survey sites, with the abundance of all groups ranged from 24 to 167 ind. per m³. While the main current follows a pattern of the southwest Pacific Ocean, the planktonic community might highlight the condition of the Ocean.

1. Introduction

Zooplankton generally sits as a primary consumer or major grazer in the marine food web, and serve as a food resource in trophodynamic of a pelagic ecosystem [1,2]. Mesozooplankton (>200 µm) has been recognized to play an important functional role in the food web since it bridges between primary producer, grazer microplankton (<200 µm) to higher trophic levels (e.g. ‘[3,4,5,6,7]’). Marine ecosystem functioning depends on its structure, diversity, and integrity, and it explains the different types of energy flows, e.g., bottom-up control by the planktonic community [8]. It will, in turn, control fish yield as part of the food web, or vice versa (e.g. ‘[9]’).

Epipelagic zone (~100 or 200 m depth) in the Ocean is an area rich with biological and microbiological processes determining, inter alia, the productivity of the Ocean, and efficiency of carbon flux to the deeper Ocean through a biological pump [3,6,10,11]. Buesseler and Boyd, 2009 suggested that the Ocean’s biological pump contributes to carbon flux from the epipelagic, the surface waters a flux of >10 billion tons C yr⁻¹. Abundance and composition of the planktonic community, including zooplankton, phytoplankton, and microbial plankton in the epipelagic zone, determining the relative contribution of particulate carbon flux (fetal pellets, marine snow, and phytodetritus) of the
has been recognized as locally produced fecal pellets [10,11]. Legendre and Rivkin [12] introduced 3 food-web control nodes of the carbon fluxes in the upper Ocean, which one of those is the large zooplankton control transfer POC to large metazoan and downward flux. Zooplankton undergoes diel vertical migration, where they feed at night above the pycnocline and respire by day below the pycnocline [13].

The waters along the north part of Maluku and Papua main islands converged of several regimes of currents, the secondary path of the Indonesia trough flow (ITF) deep current carrying water masses from North Pacific Subtropical Water, and New Guinea Coastal Current (NGCC) at surface moving northerly from the southeast and turned back easterly, and Equatorial Under Current (EUC) drift water masses from South Pacific Subtropical Water (SPSW) characterized by high saline waters [14].

The outermost islands around this area are characterized by the coral and atoll relatively pristine far from anthropogenic influences, mostly not an inhabitant. With regards to the Indonesia fisheries, waters of the northern part of Papua is identified as the Indonesia Fisheries Management Area 717 (FMA) or locally called Wilayah Pengelolaan Perikanan (WPPNRI) 717. It has been recognized as less utilized-fishing areas or not optimally exploited fishing areas in Indonesia, albeit its fisheries potential [15].

Exploring oceanographic conditions and trophic levels at relatively remote, pristine waters of the tropical region such as the northern part of Papua Island is valuable due not only to cost-expensive, but also limited opportunity. This study is a part of the LIPI COREMAP-CTI Nusa Manggala oceanographic survey. This study aimed at exploring the oceanographic condition of the trophic level of the water’s masses during the end of the dry season in Indonesia. In particular, it is to describe the profile of the zooplankton community structure and abundance in the unexplored tropical north-eastern part of the Indonesian waters, as to understand the ecosystem function to its hydrographic profiles.

2. Materials and methods
2.1 Study areas and sampling locations
This study was conducted during the LIPI COREMAP-CTI Nusa Manggala - an oceanographic survey of the P20 LIPI R/V Baruna Jaya VIII (BJ8) to the small outermost islands of the north-eastern part of Indonesia, from waters of the North Maluku province to those of Papua province (Fig.1). Due to the large area of Ocean, numbers of sampling stations were specifically selected to representatively represent the longitudinal spatial of the outermost waters of Indonesia territory, down to waters closed to the mainland of Papua province. The sampling stations were then segmented into outer stations (OS04 – OS10) and inner stations (OS11-OS23) (Table 1). However, for some analysis, OS11, OS19, and OS23 are specifically segregated due to its position very closed to the mainland. All samples were collected onboard during the BJ8 research cruise, at the 2nd transitional east-to-west monsoon in the October to December 2018.

Tabel 1. Detail of the sampling locations of the Nusa Manggala - oceanographic survey for the planktonic study.

| Station | Date      | Time (West Indonesia Time, GMT+7) | Latitude | Longitude | Water Depth (m) |
|---------|-----------|----------------------------------|----------|-----------|-----------------|
| OS-04   | 07-Nov-18 | 20:48                            | 1.25251 N| 130.58122 E| 4120            |
| OS-05   | 08-Nov-18 | 06:28                            | 1.25090 N| 131.19833 E| 2948            |
| OS-06   | 08-Nov-18 | 15:10                            | 1.25096 N| 131.79319 E| 4104            |
| OS-07   | 08-Nov-18 | 23:15                            | 1.25150 N| 132.39438 E| 4362            |
| OS-08   | 09-Nov-18 | 08:44                            | 1.25467 N| 133.00053 E| 3587            |
Figure 1. Map of the sampling locations at the north-eastern part of the Indonesian waters -adjacent to the southwest Pacific Oceans. The transects follow the LIPI Nusa Manggala oceanographic survey in the waters of the outermost islands of Indonesia.

2.2 Oceanographic condition and planktonic sampling
Oceanographic condition including temperature, salinity, density, oxygen, and chlorophyll-a fluorescence of all sampling sites was assessed by SBE 911Plus CTD equipped with SBE 43 dissolved oxygen sensor and WET Labs ECO-AFL/FL fluorescence sensor.

Mesozooplankton samples were collected at the selected sites of BJ8 sampling stations along the cruise. The NORPAC plankton net with a mesh net of 300 µm (45 cm net-mouth diameter, 1.7 m long), equipped with a calibrated flowmeter fix-attached to the mouth of the net, were deployed to vertically haul the samples from up to 500 m depth from the thermocline layer covering plankton undergoing possibly diel vertical migration to the surface of the Ocean. The collected samples were then preserved by formalin 4% and stored at the fridge until further analysis.

2.3 Sample analysis
Samples were microscopically identified and classified following P2O LIPI-commonly-used methods [16]. A high power microscope was used to identify and count the abundance of the sample using a Bogorov disk, with fractionation of the sample. Ecological indexes of species diversity were
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determined by the Shannon Index of Diversity and the Evenness Index as described in [16]. Statistical descriptive analysis and regression are applied to construct variation of the data, and the relationship between water parameters.

3. Results and discussion

3.1 Oceanographical context

The oceanographic profile of the water column was constructed against temperature, salinity, density versus depth for all the sampling stations (Fig. 2a, b). Sea surface temperature (SST) in the OS04 to OS10 ranged from 29.02°C to 30.19°C (av. ± SD: 29.48 °C ± 0.25 °C). While, in the OS 11 – OS 23, the SST ranged from 28.97°C to 30.07°C (av. 29.45 °C ± 0.17 °C). The depth of relatively stable SST varied among the stations. It ranged between 43 m and 77 m depth, with a mean of 66 m depth at OS 04 – OS10, while it varied from 44 m depth to 95 m depth at OS 11 - OS 23, with a mean of 75 m depth. Thermocline in the outer stations ca. 300 m, while inner stations slightly thinner ca. 250 m.

The salinity profile of the epipelagic zone increases over depth from a mean of 33.06 ± 0.12 psu at the surface to a mean of 34.58 ± 0.16 psu at the bottom epipelagic layer in the station OS04 – OS10. While, in the station, OS11 – OS23, the salinity of the epipelagic zone increased over depth from 33.82 psu ± 0.38 psu to 34.53 ± 0.26 psu. Their maximum salinity of the profile of the station transects was respectively 35.52 psu (119 m depth) and 35.6 psu (121 m depth). There is no significant difference in the salinity profile between the two transects indicating the same source of water masses influences the areas of study.

Density ($\rho$) represented by sigma-t profile shows a clear pycnocline layer, an increased density from the bottom of the epipelagic layer up to 400 m depth (Fig. 2). The outer stations have a deeper pycnocline than the inner station. In the epipelagic layer, the $\rho$ ranged from 20.9 to 21.9 (21.4 ± 0.19) kg/m$^3$ in the outer stations, while ranged from 20.4 to 22.03 (21.3 ± 0.23) kg/m$^3$ in the inner stations. In the pycnocline layer, a strong regression was constructed between temperature and salinity ($R^2$, 99.9%). Regression analysis for effective predictors showed that temperature profile contributed to $\rho$ more significant (84.4%) than that of salinity (15.5%), with p<1%.

![Figure 2.](image-url)  
Figure 2. (a) T, S, $\rho$ profile of the sampling locations (OS4 – OS10) offshore far from the mainland indicating thinner epipelagic mixing zone (up to 66 m depth) against stratified vertical temperature profile, warmer mixed layer (CTD data source: LIPI Nusa Manggala 2018).
3.2 Community structure and diversity

A total of 42 taxonomic groups of zooplankton were identified, including general fish larvae and eggs. Calanoida and cyclopoid Copepoda dominated in terms of the density, build up to 69% of the zooplankton structure of all survey points (Fig. 3). In the outer stations OS04 – OS10, there were 30 taxa identified, with other dominant zooplankton taxa including Oikopleura, Ostracoda, Siphonophora, Chaetognatha found >2% of the density of the sample population. In the inner stations OS11 – OS23, it was 42 taxa. The other zooplankton taxa dominated the inner stations included Ostracoda, Chaetognatha, Oikopleura, Gastropoda, and Siphonophora. The remaining taxa were <3% of the density.

In general, Shannon’s diversity and evenness indexes ranged respectively between 1.12 (OS06, OS07) and 1.42 (OS04), with a mean of 1.23±0.13, and 0.37 (OS06, OS07) to 0.48 (OS10), with a mean of 0.42±0.05. While, in the inner stations, those indexes range from 1.44 (OS17) to 2.10 (OS22).
with a mean of 1.69±0.17 for the diversity, and ranged from 0.47 (OS17) to 0.65 (OS22) with a mean of 4.97±0.54 for the evenness. Details for each transect are given in Table 2.

**Table 2. Shannon diversity indexes of the zooplankton community in the waters of the northern part of Papua island (range, mean±SD).**

| Ecological indexes | Outer stations (OS04–OS10) | Inner Stations (OS12–OS22) | Inner Stations closed to mainland (OS11,19,23) |
|-------------------|-----------------------------|-----------------------------|---------------------------------------------|
| **Abundance (ind. m⁻³)** | 24 – 56, 37 ±9.95 | 36 – 141, 74 ±36.6 | 54 – 167, 114 ±56.8 |
| **Shannon diversity** | 1.09 – 1.42, 1.23 ±0.13 | 1.44 – 2.10, 1.67 ±0.19 | 1.61 – 1.78, 1.70 ±0.09 |
| **Evenness** | 0.37 – 0.49, 0.42 ± 0.05 | 0.47 – 0.65, 0.54 ± 0.06 | 0.52 – 0.56, 0.54 ± 0.02 |
| **Species richness** | 4.19 – 5.84, 5.09 ±0.58 | 4.24 – 5.85, 5.04 ±0.46 | 4.38 – 5.67, 5.02 ± 0.64 |

### 3.3 Abundance and distribution
The composition slightly varied across the sampling locations, with the abundance of all groups ranged from 24 to 167 ind. m⁻³. The abundance ranged from 24 to 56 ind. m⁻³ with a mean of 37±9.95 ind. m⁻³ in the outer stations OS4-OS10, while it ranged from 36 to 167 ind. m⁻³, with a mean of 87±42.4 ind. m⁻³ in the inner station OS11 – OS23 (Table 2). An abundance of mesozooplankton was significantly higher in the stations very close to the mainland and in the Cenderawasih Bay.

### 3.4 Discussion
#### 3.4.1. The community and the ecological function
Forty-two different zooplankton groups were identified from all stations. Seven of them in the outer stations and ten of them in the inner station were found more than 1% of the abundance structure. Copepods have been identified as the dominant taxa in the sampling stations. This copepods-dominated structure has been a typical structure of oligotrophic systems, such as [17, 18]. This dominance of the copepod taxa in the mesozooplankton structure explained their key role in the oceanic food web.

As indicated by the ecological indexes, the diversity, evenness, and species richness are relatively similar within and among the transects meaning that the distribution of similarly structured mesozooplankton is extensive (Fig 4). Shannon diversity index ranges between 1.09 and 1.42 in the outer stations, while it ranged from 1.44 to 2.10 in the outer stations (Table 2). The highest diversity was in the OS 22, but in general, the diversity in the inner stations was slightly higher than those in the outer ones. Overall, the tropical and subtropical regions of the oceans commonly have high species diversity [18].

The abundance of mesozooplankton was mostly <100 ind. m⁻³, except in the inner stations at OS11,12,13, 22, 23 where it was >100 ind. m⁻³. The most abundance was in the OS 11 in the Cenderawasih Bay. The higher abundance of the mesozooplankton in the inner stations reflecting whole possible influences of the mainland to the food web. It likely includes the possibility of the availability of cascaded prey, such as microzooplankton [5].

Overall, the abundance of mesozooplankton (>300 µm) was relatively low, but it might not represent the abundance of the overall zooplankton community, which involves those <300 µm. The biomass of the size <300 µm can make up to 80% of the zooplankton community [19]. The abundance of zooplankton from tropical and subtropical Atlantic, Pacific, and Indian Oceans has been reported in other studies [18].
Figure 4. Spider chart of diversity indexes of the mesozooplankton in outer and inner stations showing that diversity, evenness, and species richness are relatively similar within the transects meaning the distribution of relatively the same mesozooplankton structure is quite widespread.

3.4.2. The SPSW influence and the grazing layer. The CTD data shows there is no significant difference in hydrographic profile among stations, except those in the very close to the mainland. It indicates that the water masses are relatively the same. The hydrographic data revealed a transitional east-to-west monsoon profile characterized by a thinner epipelagic mixed layer and pronounced thermocline layer ca. 250 m – 300 m thick at the outer sampling stations. The salinity profile shows a signature of the high salinity the SPSW below the epipelagic layer [14]. The hydrographic profile distinct those of SPSW up to 150 m depth with the cooler, less saline deep-water masses below the thermocline. Chlorophyll-a concentration increased toward the verge of the epipelagic layer, a depth chlorophyll maximum, DCM (Fig. 5). DCM indicates an abundance of chloroporous phytoplankton at the bottom epipelagic layer, where it could function as food barns for the higher trophic level, primarily herbivorous zooplankters such as copepods, herbivorous krill, pteropods, larvae, and chordates.

Figure 5. Chlor-a profile of the sampling stations indicating the primary producers are available max at the bottom epipelagic mixed layer, where it was assumed as the zooplankton feeding zone below the pycnocline.
In the SPSW layer, oxygen and chlorophyll-a depleted gradually against deeper waters. There is a strong correlation between the decreased oxygen and decreased chlor-a, suggesting that the decreasing population of phytoplankton towards the deep-water masses (Fig. 6). The decreasing abundance of phytoplankton can be assumed due mainly to zooplankton grazing (e.g. '[6,20]'). The role of mesozooplankton and microzooplankton in controlling primary phytoplankton production (PP) population by grazing has been discussed in other studies [5,6,3]. It varies proportionally to the PP, which can be up to almost 80% [5]. It decreases exponentially with increasing productivity for mesozooplankton and is estimated for the global Ocean that the effect of the mesozooplankton grazing on primary production is ca. 12% of the oceanic PP per year [3]. However, the estimation can be higher if the consumption of microplankton integrated. The effect on primary production was reported five times higher for micro- than for mesozooplankton [5]. It is, therefore, the SPSW layer is likely to be the potential grazing zone and prey area, which is likely to be a zooplankton relatively rich area. However, zooplankton abundance tends to drop significantly down across the pycnocline has long been recognized in the Ocean (e.g. ‘[21]’).

4. Conclusion
The hydrographic data indicates a clear stratification of the waters, where the oceanographic profile indicates the characters of the SPSW influencing the studied area. The planktonic community highlighted the spatiotemporal condition of the Ocean. The copepods have been found to be the dominant taxa as it has also been recognized globally in oligotrophic systems. The dominance of the copepod taxa in the mesozooplankton structure showed their key role in the food web as bridging the primary producers, microzooplankton to higher trophic levels, or mostly small fishes. The abundance of the mesozooplankton was relatively comparable to other oligotrophic waters. Overall, this exploratory study improves understanding of the nature of the zooplankton community and its ecological function in the oceanic waters influenced by the southwest Pacific Ocean.

Figure 6. A strong linearity-approach correlation between decreasing oxygen and decreasing chlorophyll-a in the layer below the pycnocline in the outer sampling stations, indicating a decrease in oxygen-produced phytoplankton population in the SPSW layer due presumably to zooplankton grazing.

At the OS11 in the Cenderawih Bay, it shows significant depleted-oxygen zone below the epipelagic zone. It indicates that it is likely another oxygen-consumed process occurred coupled with decreased phytoplankton abundance. It is most likely that the sharp decrease in oxygen is due to the decomposition of organic matters (non-phytoplankton), and that could indicate another anthropogenic pressure in the Bay, e.g., organic pollution. The water circulation in OS11 is relatively low compared to other sampling sites (personal communication), and that might facilitate the decomposition of organic matters.
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