Variability of zooplankton in surrounding five small islands of Kotania Bay, Western Seram, Maluku, Indonesia

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Abstract. This study was conducted on March, July and October 2017 in Kotania Bay at 6 fixed stations surrounding five small islands namely Island of Marsegu, Osi, Burung, Buntal, Tatumbu and station off the coast. Those islands have a complexity of biological communities, such as, on Marsegu, Osi, Buntal and Burung, were dominated by mangrove, seagrass and coral reef communities. While the island of Tatumbu dominated by the community of mangrove and seagrass. This bay is a very potential and has considerable fisheries resources. Zooplankton organism were collected by towing zooplankton net horizontally and the samples were preserved using formaldehyde. Zooplankton abundance showed the peak abundance at station of Marsegu (2297 ind m$^{-3}$), it was in the third period and the lowest was at the station of Osi, and it was during the first period (52 ind m$^{-3}$). The zooplankton composition was highest during the third period (21 genera) at off-coast station, while the lowest was in the first period and second period (10 genera) at station Osi and station Burung, respectively. The highest similarity indices were between stations off-coast and Buntal at the value of 93.02% and the lowest was between station Buntal and Marsegu (61.90%). There were no correlations between the abundant of zooplankton and the hydrology parameters such as DO, temperature, salinity, pH and water clarity. However, the positive significant correlation between composition and the hydrological parameters during the first and third period ($R^2$=0.53 and 0.65 respectively). It highlighted the differences in composition and abundance of zooplankton figured out the type of waters of those islands during period of study.

1. Introduction

The location of Kotania bay, is in the western part of the island of Seram, Maluku. The bay has five small islands in varying sizes, namely the island of Marsegu, Osi, Buntal, Burung and Tatumbu. Those islands have a complexity of biological communities and each island has their own ecosystem and unique characteristics. Those islands namely, Marsegu, Osi, Buntal and Burung dominated by mangrove, seagrass and coral reef communities. While the island of Tatumbu dominated by mangrove and seagrass communities. Under these conditions, the waters of Kotania bay contain diverse marine resources, especially some group of fish that have a high economic value such as grouper (Family Serranidae), Acanthuridae, Scaridae, Lutjanidae, Siganidae and others [1]. Although, coastal marine waters surrounding Kotania bay are under increasing of anthropogenic activities, but according to [2], Kotania bay waters has a variety of fish resources and this bay act as a spawning, nursery and feeding grounds of economically finfish. Kotania bay surrounding waters were influenced by monsoons, when southeastern winds prevailing between April and November and northwestern winds between December and March [3], therefore, the hydrological parameters of Kotania bay waters will be changed according to seasons.

Zooplankton assemblages have the potential to respond and reflect event-scale and seasonal variation in environmental conditions [4] and zooplankton play an important role in supporting the live of marine organisms (plankton feeders) from the surface to the depth waters, since they act as a
medium in transferring energy to benthic organisms. The other important contribution of zooplankton communities in food web are the organic matter fluxes as well as nutrient recycling [5]. The Calanoid of copepods are the most numerous and play an important role in both the transfer of energy to higher trophic levels and the export of carbon from euphotic layer [6]. In addition, copepods are mainly used to predict ecological changes because they appear as the dominant zooplankton group, where they make up over 80-90% of the total zooplankton abundance [7]. The presence of zooplankton organisms especially copepods can cause an abundance of zooplankton predators, such as Chaetognaths, fish larvae, and others zooplankton feeder organisms [8]. The abundance of copepods comprised the prey economically important predators, such as Stolephorus spp [9]. While, zooplankton abundance is depends very much on the condition of waters, as well as the composition. Coastal waters tend to richest of nutrients than oceanic, hence currents of fresh and marine waters bring the high level of nutrients, therefore, the abundance and composition of zooplankton may vary between coastal waters and oceanic. As well as, the similarity indices of zooplankton will differ from the type of water to another [8]. Moreover, some of zooplankton organisms are known to be indicators of water mass. The goals of this study are to analyze the variation of abundance, composition and similarity of zooplankton during the period of study, as well as study on the stations clustering which based on the abundance, composition and similarity of zooplankton organisms.

2. Materials and Methods

2.1. Field work
This research conducted inter-seasonally, on transition season between dried to rainy season and transition season between rainy to dried season. The research carried out on March (first period), July (second period) and October (third period) in 2017, in the surrounding waters of the five small islands in Kotania bay, namely the islands of Marsegu, Osi, Buntal, Burung and Tatumbu but only Osi island is inhabited and off-coast station (Figure 1).

![Map of Study Sites in The Waters of Kotania Bay](image)

**Figure 1.** Map of study site in Kotania bay
This study carried out primarily to analyze the variations of zooplankton abundance and hydrological parameters inter-seasonally, such as, chemical parameters were measured in-situ using multi-parameters tools analyzer, while physical parameters i.e. salinities were measured using refractometer, the waters clarity were determined using a secchi disk (diameter of 30 cm) and temperatures measured using a multi-parameters tool analyzer. The hydrology parameters of waters of Kotania Bay is influences by the monsoons, with southeastern wind prevailing between the months of April to November, while, the northwestern wind occur between the months of December to March [3]. All zooplankton samples were taxonomically analyzed by using [10].

2.2. Data analysis
Prior to data analyses, logarithmic transformation [11], counted by the equation:

$$\log_{10}(x + 1)$$

where: $x$ is the observed abundance of zooplankton.

Numbers of zooplankton are counted by computing the number cubic meter of sea water entering the zooplankton net ($V$) and is analyzed based on formula developed by [12] as below:

$$A = \pi r^2 \cdot L$$

Further, the abundance of zooplankton organisms calculated followed the formula as follow:

$$D = \frac{Nf \cdot V_p}{V}$$

where $D$ is the abundance of zooplankton, $Nf$ is the number of zooplankton in a drop of sample and $V_p$ is the numbers of a total drop in the sample, while, $V$ is the filtered of sea water entered the zooplankton net.

The similarity indices ($S$) determined by using Sorenson’s index [13] as followed:

$$S = \frac{2C}{A+B}$$

where $C$ is the numbers of zooplankton species/genera in the two communities have in common, while $A$ is the total numbers of zooplankton species/genera found in A community, and $B$ is the total numbers of zooplankton species/genera found in B community [13].

Non-metric Dendrogram and Multi-Dimensional Scaling were applied to examine the hierarchical relationship between the abundance of zooplanktons in each period and clusters were combined, using the software package of SPSS version 23.

3. Result and Discussion
3.1. Abundance of zooplankton
Commonly, it can be said that the abundance of zooplankton during the first period was not equally the same numbers of abundance to other periods, as well as to the hydrological parameters along the periods observed. On the first period, the numbers of zooplankton abundance varied from the lowest was 52 ind/m$^{-3}$ and the highest was 524 ind/m$^{-3}$, compared to other periods (second and third), the lowest were 190 and 69 ind/m$^{-3}$ and the highest were 628 and 2297 ind/m$^{-3}$ (Table 1). From rainy to transition seasons, the zooplankton abundance increased slowly.
Table 1. The abundance of zooplankton from six fixed stations in Kotania bay (Individual/m$^{-3}$)

| No. | Stations   | 1$^{st}$ Period | 2$^{nd}$ Period | 3$^{rd}$ Period |
|-----|------------|-----------------|-----------------|-----------------|
| 1   | Marsegu    | 228             | 190             | 2297            |
| 2   | Off-coast  | 367             | 600             | 386             |
| 3   | Buntal     | 524             | 313             | 324             |
| 4   | Tatumbu    | 516             | 425             | 259             |
| 5   | Burung     | 57              | 628             | 93              |
| 6   | Osi        | 52              | 507             | 69              |

Table 2, showed the hydrological parameters changed due to the change of season. The high temperature was in first and third periods (30 °C), while the lowest was in the second period (28 °C). On the other hand, the salinity was higher in the first and second periods (36 and 35 ppt respectively). In addition, the water clarity reached the high values in the first and third periods (13.5 and 16 meter), respectively and the highest value of pH was in the third period (8).

Table 2. Hydrological parameters of six stations in Kotania bay during the study

| Station | Temperature (°C) | Salinity (ppt) | Clarity (meter) | pH | DO (mg/l) |
|---------|------------------|----------------|-----------------|----|-----------|
|         | 1$^{st}$ | 2$^{nd}$ | 3$^{rd}$ | 1$^{st}$ | 2$^{nd}$ | 3$^{rd}$ | 1$^{st}$ | 2$^{nd}$ | 3$^{rd}$ | 1$^{st}$ | 2$^{nd}$ | 3$^{rd}$ |
| Marsegu  | 28.5     | 28.5    | 29.5     | 35    | 32.5    | 31.5    | 13.5    | 9     | 16     | 6      | 6      | 7.99    | 2.8    | 5.89    | 3.25    |
| Off-coast| 29       | 28.3    | 30       | 34    | 33     | 30      | 10      | 9     | 10     | 6.3    | 6.3    | 7.99    | 3.3    | 2.8     | 3.3     |
| Buntal   | 29       | 28.5    | 28       | 32.5  | 32.5   | 29      | 4       | 7     | 6.5    | 6      | 6      | 7.92    | 3.5    | 3.1     | 3.45    |
| Tatumbu  | 30       | 28      | 29       | 31.5  | 30.5   | 30.5    | 4       | 5.5   | 4.5    | 6      | 6      | 7.91    | 2.9    | 3.35    | 3.5     |
| Burung   | 30       | 28      | 27       | 35    | 35     | 31      | 7       | 7     | 9      | 6      | 6      | 7.93    | 3.7    | 2.8     | 3.4     |
| Osi      | 30       | 28      | 30       | 36    | 35     | 31      | 3       | 3     | 3      | 6      | 6      | 7.93    | 3.7    | 2.8     | 3.4     |

By using Multi-Dimensional Scaling (MDS), it was found that there were different clusters formed between the abundance of zooplankton and the hydrological parameters during the three periods of study. Figure 2 showed that on first period (transition season between dried to rainy season), there were 2 groups of clusters separating the high and low abundance of zooplankton. The station of Osi and Burung were clustered, and another cluster was combined by stations at the islands of Buntal, Tatumbu, Marsegu and off-coast station. The first cluster occurred as they had the lowest abundance of zooplankton (52 and 57 ind/m$^{-3}$ respectively), whilst the second cluster was combined at stations of Buntal, Tatumbu, off-coast and Marsegu, which were formed as the zooplankton abundance was high (524, 516, 367 and 228 ind/m$^{-3}$ respectively).

There were no correlations between the abundance of zooplankton and the hydrological parameters, such as, temperature, salinity, clarity, DO and pH encountered from the first to third period of sampling. In the first period, the high temperature were at stations of Burung and Tatumbu islands (30 °C), the highest salinity was at station of Osi (36 ppt), the high value of clarity was at station of Marsegu (13.5 meter), the value of pH was high at station off-coast and the DO was high at station of Osi (Table 2).
In the second period (rainy season), the two clusters were combined by the abundance of zooplankton (Figure 3). The first cluster was combined of stations of Burung, off-coast, Osi, and Tatumbu. This first combined clusters formed due to the higher abundance of zooplankton at those stations were nearly the same in numbers (628, 600, 507 and 425 ind/m³ respectively). While the other cluster combined by stations of Buntal and Marsegu, which had lower abundance of zooplankton (313 and 190 ind/m³ respectively). Dissolved oxygen during the second period reached the highest value (5.89 µm/l) and the lowest was at the stations of Osi and off-coast (2.8 mg/l), however, there were no significant correlation between the abundance of zooplankton and DO and others hydrological parameters.
Figure 4 shows that during the third period (transition between rainy to dried season), the first clustered by combined of the abundance of zooplankton at the stations of off-coast, Buntal, Tatumbu, Burung and Osi (386, 324, 259, 93 and 69 ind/m$^3$ respectively). The other was a single cluster happened as the abundance of zooplankton at the station of Marsegu reached a very high numbers (2297 ind/m$^3$) in this period and during the study. It was due to the overwhelming contribution of *Acartia* spp, *Oncaea* sp, *Calanus* spp, *Corycaeus* sp, *Oithona* sp and *Evadne* sp. The copepods (*Acartia* spp and *Calanus* spp) were present at all stations and at each period of study. Among the copepods, *Acartia* spp has a wide distribution, are the most numerous and they are common in marine to estuarine waters [14, 15].

![Dendrogram using Centroid Linkage](image)

**Figure 4.** Dendrogram and MDS of the abundance of zooplankton and hydrological parameters during the third period.

Figure 2, 3 and 4 revealed that the abundance of zooplankton in Kotania bay varied from period to period especially between stations, therefore, the group of clusters showed the different combination of stations. The Month of July is the wettest while the November is the driest season, therefore the hydrological parameters surrounding Banda Sea is change considerably [3]. Beside the abundance of zooplankton, the composition at the station of Buntal and Tatumbu always showed closely same in number. This condition occurred because the hydrological parameters values of two stations were almost the same and the position two stations closed to each other.

3.2. Composition of zooplankton

Total numbers of 30 genera of zooplankton were recorded from the surrounding waters of Kotania bay, of these 17 genera were copepods. During the study, off-coast station and station at the island of Tatumbu respectively had 22 genera of zooplankton, although, they had different composition of the zooplankton genera. The genera of *Pseudocalanus* spp and *Globigerinella* sp occurred only at the station of Tatumbu. *Salpa* sp was only present at the station of Osi and some genera were only present at the station of Marsegu, i.e. *Undinula* sp, Larvae of *Cyphonaetes* sp, and *Chonchoecia* spp. The lowest number of genera occurred at station of Burung, and it was only 15 genera. Overall, there were 12 genera of zooplankton present at all stations, namely *Calanus* spp, *Centropages* sp, *Acartia* spp,
Oithona sp, Oncaea spp, Corycaeus sp, Thysanoessa sp, Lucifer renaudi, Creseis sp, Oikopleura spp, Stegosoma sp and Sagitta spp, meanwhile, the occurrence of Salpa sp was only at station of Osi.

Based on the period of study, the composition of zooplankton was highest at the station of Off-coast (20 genera) in the third period while the lowest was at the islands of Osi and Burung (10 genera) in the first and second periods, respectively (Table 3).

Table 3. The composition of zooplankton from six fixed stations in Kotania bay

| No | Station | 1st Period | 2nd Period | 3rd Period | All Period |
|----|---------|------------|------------|------------|------------|
| 1  | Marsegu | 16         | 20         | 17         | 21         |
| 2  | Off-coast| 19         | 17         | 21         | 22         |
| 3  | Buntal  | 15         | 16         | 17         | 21         |
| 4  | Tatumbu | 16         | 14         | 16         | 22         |
| 5  | Burung  | 12         | 10         | 12         | 15         |
| 6  | Osi     | 10         | 20         | 12         | 20         |

Dendrogram and Multi-Dimensional Scaling analyzes showed that there were the different cluster combined between composition of zooplankton genera and hydrological parameters during the study periods. Figure 5a and 5b, revealed that there two clusters combined being formed as they have high numbers of zooplankton genera (stations at off-coast, Tatumbu and Marsegu). The others stations were clustered which consisted of stations at Buntal, Osi and Burung). The hydrological parameters varied between stations, temperature were between 28.5 to 30 °C, the highest was at station Tatumbu, Burung and Osi, while the lowest was at station Marsegu. Water clarity was between 3 to 13.5 meter and the highest was at station Marsegu and the lowest at station of Osi. Allhough, the value of pH did not show much variation during this period (6 to 6.3), and DO varied between 2.8 to 3.7 mg/l. The highest was at station Osi and the lowest was at station of Marsegu. However, there were a positive significant correlation between composition and the hydrological parameters in the first period and it was at the value of $R^2=0.53$.

Figure 5. Dendrogram and MDS of the composition of zooplankton and hydrological parameters in the first period.
Figure 6, revealed that station of Marsegu and Osi clustered as the number of zooplankton genera were 20 respectively, while the others cluster combined of stations of off-coast, Buntal, Tatumbu and Burung that had the varying numbers from 17 to 10 genera (Table 3). In this case, the salinities of stations Osi, and station of Burung were the highest (35 ppt), Marsegu and Buntal were 32.5 ppt respectively, off-coast was 33 ppt and the lowest was at Tatumbu (30.5 ppt). Meanwhile, the temperatures were between 28 to 28.5 ºC. Contrastingly, the value of DO reached the highest (5.89 mg/l), and the lowest value was at 2.8 mg/l and it was at stations Osi and off-coast. However, there was no significant correlation between the numbers of genera occurred in this period and the hydrological parameters.

Table 2 showed that the hydrological parameters in this period increase slowly, compared to those in the second period, since it was entering the dried season. The high temperature was at station of Osi and off-coast (30ºC), the lowest was at station of Burung (27ºC). The high value of water clarity was at station Marsegu (16 meter and it was the highest during the study, and the lowest was at station of Osi. The value of pH was also reached the highest and its ranged between 7.92 to 8, the highest value was at station Burung and the lowest was at station of Buntal. However, it revealed that there was a positive significant correlation between composition and the hydrological parameters in the third period (R²=0.65).
Figure 7. Dendrogram and MDS of the composition of zooplankton and hydrological parameters during the third period.

The analyses of Dendrogram and the Multi-Dimension Scaling were done on the abundance and composition of zooplankton during the study showed the different of clusters combined and the separating station on MDS. It was only in the first and third period that revealed there was no significant correlation between the abundance of zooplankton and the hydrological parameters during the study. In the other hands, there was a significant correlation between the composition of zooplankton genera occurred and the hydrological parameters.

3.3. Similarity

Total numbers of zooplankton genera encountered during the study periods, however, not all of them recorded in each station. Based on the genera composition of zooplankton, during the study periods, there was a relative similarity between stations, the maximum similarity occurred between station of Buntal and off-coast and it was at the value of 93.2% (Table 4).

Table 4. Percentage of similarity of zooplankton genera between stations

| Stations | Marsegu | Osi | Burung | Tatumbu | Buntal | Off-coast |
|----------|---------|-----|--------|---------|--------|----------|
| Marsegu  | 73.13   |     |        |         |        |          |
| Osi      | 74.29   | 74.29 |        |         |        |          |
| Burung   | 65.12   | 71.43 | 75.68  |         |        |          |
| Tatumbu  | 61.90*  | 82.93 | 77.78  | 76.67   |        |          |
| Buntal   | 76.19   | 85.71 | 81.08  | 90.91   | 93.03**|          |
| Off-coast|         |       |        |         |        |          |

The total numbers of 23 genera encountered at the stations of Buntal and off-coast, it was about 20 genera were present at the two stations. While the lowest similarity indices occurred between stations of Marsegu and Buntal and it was at the value of 61.90%, as the total numbers of zooplankton genera from the waters was 28 and the similarity genera of the two stations was only 15. While, in the first stations. During the second period, *Calanus* spp, *Paracalanus* sp, *Centropages* sp *Acartia* spp, *Sagitta* spp, *Thysanoessa* sp and *Stegosoma* sp found. Whilst, during the third period *Calanus* spp, *Acartia*
spp, *Oithona* sp, *Corycaus* sp, *Oikopleura* sp. The genera of *Acartia* spp and *Calanus* spp occurred in a high density from all stations during the study, since they are the common zooplankton, which, have a wide distribution [13 and 14]. Overall, this study highlighted that the differences of abundance and composition of zooplankton figured out the type of waters of stations at those islands during the period of study.

4. Conclusion
There were variations in abundance and composition of zooplankton between stations and periods, therefore, the cluster groups during the study periods varied in combination of stations. The highest abundance of zooplankton was in the third period, and it was at station of Marsegu (2297 ind/m$^{-3}$), the lowest was at station of Osi (52 ind/m$^{-3}$). Whilst, the highest number of zooplankton genera composition was at station off-coast (21) and the lowest was at station of Osi (10) in the first period and station of Burung in the second period, respectively. Similarity Indices was highest between station Buntal and Off-coast and the lowest was between stations of Buntal and Marsegu. There was correlation between the composition of zooplankton and temperature and salinity in the first and third periods ($R^2=0.52$ and $R^2=0.65$ respectively). This study highlighted that the differences number of abundance and composition of zooplankton figured out the type of Islands (waters) and seasons during the study.

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