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Composition, density and spatial distribution of zooplankton on wet season (June-August) in Inner Ambon Bay

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Composition, density and spatial distribution of zooplankton on wet season (June-August) in Inner Ambon Bay

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Abstract. Inner Ambon Bay is part of Ambon Bay, it is semi closed area and is a small pelagic fish fishing ground, especially anchovy. The anchovy is zooplankton predator therefore existence of anchovy is affected by abundance of zooplankton. The aim of the research are to know composition, density and spatial distribution of the zooplankton during wet season (June to August). Data of zooplankton composition were obtained from sampling by using plankton net at 10 observation stations, meanwhile, data of densities were collected using scientific hydroacoustic system, BioSonic DTX, on six parallel transect lines and one cross-parallel transect line. Geostatistical analyses technique was used to describe horizontal distributions of zooplankton and vertical distributions were plot in the graphs. The result shows that zooplankton community dominated by Copepod and meroplankton. Highest density was found on August (9393/m^2), while lowest density was on June (903 ind./m^2). Vertical distribution of zooplankton shows that highest density was found near surface and decrease to deeper water coloumn. On the horizontal distribution, lower densities (0 – 400 ind./m^2) occupy wider space, they evenly distributed in western, middle (north to south) and east, on the contrary, higher densities (3000- 5000 ind./m^2) occupy smaller space i.e in the south-west, south and east to north-east of Inner Ambon Bay

1. Introduction

Ambon Bay consist of Inner Ambon Bay and Outter Ambon Bay. The area of Inner Ambon Bay is 11.03 km^2, as semi closed waters and a narrow basin. According to depth detection using hydroacoustic device, known Inner Ambon Bay has 45m maximum depth [1]. This waters is a small pelagic fish fishing ground especially anchovy (*Stolephorus* spp.) in Ambon island. Anchovy resources in Inner Ambon Bay comprises *Stolephorus heterolobus*, *S. indicus*, and *S. buccannieri* [2]. These species are predator of zooplankton and best live baits used in skipjack pole and line fishery in Ambon City.

The previous results of the research of the zooplankton community in Ambon Bay found 53 genera of zooplankton which were dominated by subclass of *Copepoda* comprising *Evadne*, *Calanus*, *Parucalonus*. *Psedocalarus*, *Centropages*, *Acartia*, *Oithona*, *Lucifer*, *Oikopleura*, *Sagitta* dan fish egg. *Stolephorus* spp is the main omnivore group of phytoplankton and zooplankton [3]. Young *Stolephorus heterolobus* fish with a length of 40 mm eat small phytoplankton and zooplankton, while adult S. *heterolobus* fish eat Calanoid, Leptochela, polychaeta larvae, Lucifer, Brachyuran and larvae from other large decapods and eggs of *Stolephorus* spp. [4] and [5] found that Copepoda is the dominant zooplankton in the Inner Ambon Bay.

From the description above, it is clear that the zooplankton community plays an important role as food for anchovy, which is used as live bait to support the operation of the skipjack pole and line fishery in Ambon City. Previous studies on zooplankton as described above only include species composition and density, but have not shown the spatial distribution of these densities.

It is complicated to estimate the abundance and distribution of biomass using sampling methods with plankton net because of the small sample size, large variation, high costs and high bias also inconvenient [6]. Fortunately, in situ hydroacoustic techniques are now available that can quickly and easily estimate the abundance, distribution and behavior of plankton, necton and pelagic fish [7, 8, 9, 10, 11, 12]. The application of hydroacoustic technique in zooplankton research has been carried out by [13, 14, 15, 16, 17].

This research aiming to determine the composition, density and spatial distribution of zooplankton in Inner Ambon Bay in the East Season (June to August).

2. Research Method

2.1. Research Instruments

This research was carried out in Inner Ambon Bay waters from June to August. Research location, the positions of zooplankton sampling stations and transect designs for acoustic raw data acquisition presented in Figure 1.

The equipment used in this study were a speed boat with a size of length x width x depth 11 x 1.8 x 0.8 m, a plankton net with a mouth diameter of 45 cm and a mesh size of 0.33 mm, a scientific hydroacoustic system BioSonic DTX with an operational frequency of 206 kHz. and a half power point beam angle of 6 degrees, global positioning system (GPS) JRC (Japan Radio Cooperation) standard marine survey receiver, Visual Acquisition software to control all operational settings and functions of the echosounders and transducers connected to the acoustic system [18] in acquiring acoustic data, Visual Analyzer software to estimate zooplankton density from echo integration results [19] and a Panasonic Tough Book laptop to run both software, store acoustic data and analysis results.

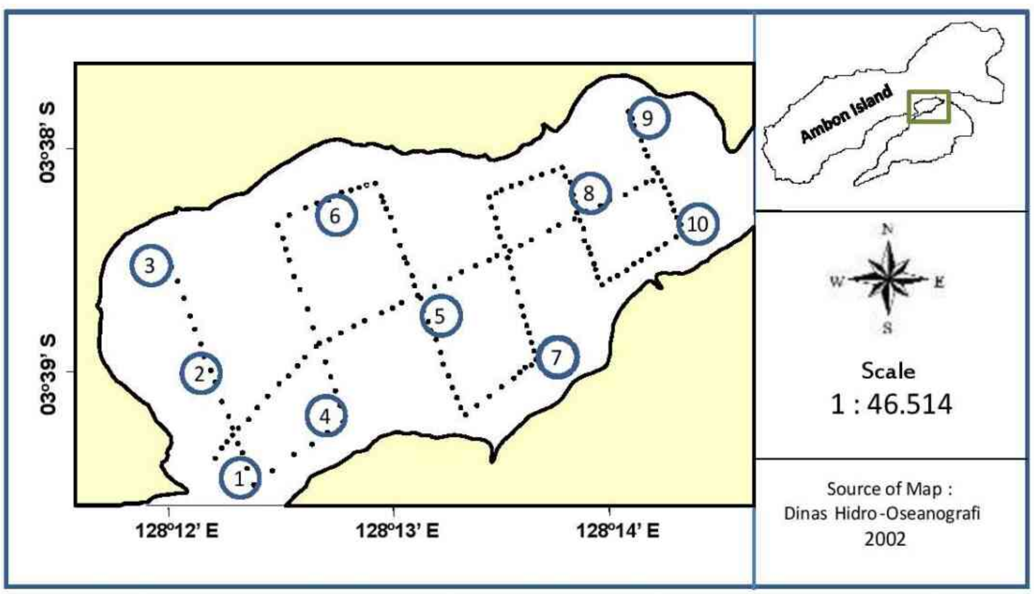

Figure 1. Map of Survey Location. Black dot showing recording positions of zooplankton densities where distance between the two black dots is the elementary sampling distance unit (ESDU) of echo integration. Number 1 to 10 in the circle are the sampling stations of zooplankton using plankton net.

2.2. Data acquisition method

Zooplankton sampling was carried out vertically from a depth with a light intensity of 1% to the surface of the waters at each station at 10 sampling stations (Figure 1), using a plankton net with a net mouth diameter of 45 cm, a length of 1.0 meter and a mesh size of 0,33 mm. This zooplankton sampling is for the purpose of verifying the types of zooplankton detected by the hydroacoustic device during acoustic data collection. The filtered seawater sample was put into a sample bottle given a 4% formaldehyde solution.

Acoustic data acquisition in this research was carried out on 6 parallel transects and one transect that crosses the six parallel transects (Figure 1). In acquiring the acoustic data, the transducer was immersed to a depth of 1.0 meter on one side of the speed boat and dragged with an average speed of 5 (five) knots along the transect data acquisition. The acoustic system parameters we set for zooplankton acoustic data acquisition in this research presented in Table 1.

The duration of the echo integration was set for one minute with the elementary sampling distance unit (ESDU) with the speed of speed boat was 5 knots, which was approximately 125 meters long.

Table 1. Parameter values of hydroacoustic system set during acoustic data acquisition in the field.

Parameter	Value
Data Threshold	-130.00 dB
Ping Rate	3.0 ping per second
Collection Range	1 to 50 m
Pulsa Width	0.1 µsecond

Adjustment of the position and direction of the ship's cruise to the position and direction of the transect lines that have been designed, controlled using JRC GPS (Japan Radio Cooperation) standard marine survey. The position and time of data acquisition in each ESDU were recorded simultaneously and automatically, so that the output of the echo integration obtained was equipped with the position and time data for it, which were automatically saved on the computer hard disk. Zooplankton and acoustic data were sampled at the same time, from the early morning 08.00 AM to noon 12.00 PM local time

2.3. Data analyzes method

The types of zooplankton were identified by identifying samples of zooplankton obtained with plankton nets. The identification of zooplankton types was carried out using identification guidelines from [20] and [21]. Zooplankton densities from vertical hydroacoustic data in each ESDU was estimated using the following formula [19]:

$$ZPCM = \frac{S_v}{\bar{\sigma}_{BS}} \tag{1}$$

where ZPCM is zooplankton density/m^3 (Zooplankton Per Cubic Meter), S_v is *volume back-scattering strength* and $\bar{\sigma}_{BS}$is mean backscattering cross section from individuals of detected zooplankton. S_v obtained by the formula :

$$S_v = 10 * log\left[\rho_c * \left(\frac{\sum P}{\sum samples}\right)\right] \tag{2}$$

where P is gain of sound intensities samples corrected and ρ_c is system scaling constant. ρ_c obtained by the formula:

$$\rho_c = \frac{1}{\pi * pw * c * \left(10^{\left(\frac{SL}{10}\right)}\right)^2 * \left(10^{\left(\frac{RS}{10}\right)}\right)^2 * E[b^2]} \tag{3}$$

where π = 3.14159..., pw is pulse width (s), c is sound speed (m/s), SL is Source Level (dBµPa), RS is receiving sensitivity of transducer (dB), and $E[b^2]$ is beam pattern factor. Zooplankton density analysis was carried out in each interval thickness 1 meter from transducer surface. Zooplankton density horizontally in each ESDU estimated [19] as follow:

$$ZPUA = \sum AD_i * IT_i * \frac{\%_i}{100} \tag{4}$$

where ZPUA is the density of zooplankton per m^2 (zooplankton per unit area) which is the sum of the absolute density vertically (AD, zooplankton per cubic meter or ZPCM) and *i* is strata index.

Zooplankton vertical distribution data is plotted on a graph to see the vertical distribution pattern using the Excel 2007 program, while horizontal distribution data is analyzed using the gridding method used on two-dimensional ordinary kriging techniques [22] as follows:

$$D_i(x) = \sum_{\alpha=1}^{n} \lambda_\alpha D_i(x_\alpha)$$

$$\sum_{\beta=1}^{n} \lambda_\beta \gamma(x_\alpha, x_\beta) + \mu = \gamma(x_\alpha, x) \tag{5}$$

$$\forall \alpha = 1, \dots, n$$

$$\sum_{\alpha=1}^{n} \lambda_\alpha = 1$$

where x = the position of the estimated location in a two-dimensional system, x_α = the position of a sample in a two-dimensional system, λ = kriging weight, n = number of adjacent samples used for kriging, γ = variogram of fish density, μ = distance *lag* parameter, while the variogram is obtained by the formula [23]:

$$\gamma(h) = \{(F - F')^2/2\} \tag{6}$$

where h is distance between sample locations, F, F' = set of paired samples for a certain distance.

3. Result and Discussion

3.1. Composition of zooplankton

The identification results show that in general the zooplankton community at the 10 sampling stations during the wet season is dominated by copepods (72.25% to 85.15%), followed by meroplankton (11.5% to 13.0%). Copepods are dominated by Acrocalanus, Eucalanus and Oithona, while meroplankton consists of Peneidae larvae, Cirripedia larvae, Annelida larvae, Echinodermata larvae and Gastropod larvae. Except in June, Bivalvian larvae were not found at station 1 and 6, Brachyura larvae were only found at station 10, fish larvae at station 2 and fish eggs at station 8. In August, fish larvae were found at station 9, while fish eggs and larvae located at stations close to mangrove forests. The composition of zooplankton in the Wet Season is different from the composition in the Dry Season. Latumeten and Pello (2019) found that in the Dry Season zooplankton was dominated by copepods but had a lower percentage (42.85% to 61.95%) than Wet Season, followed by meroplankton (30.79% to 51.17%) which was higher. Copepods were dominated by Oithona, Acrocalanus and Eucalanus, while Meroplankton consists of Peneidae larvae, Palaemonidae larvae, Ciripedia larvae, Stomatopoda larvae, Brachyura larvae, Echinoderm larvae, Gastropod larvae, Bivalvian larvae, Annelida larvae, fish larvae and fish eggs. While the groups that are present in few numbers are Medusa, Siphonophora, Urochordata, Chaetognata, Amphopoda, Mysis, Sergestida, Ostracoda and Cladocera.

3.2. Density of zooplankton
Statistics of zooplankton density from hydroacoustic data during the east season in Inner Ambon Bay presented in Table 2. The data in Table 2 shows that the zooplankton mean density values vary from month to month during the wet season. The lowest zooplankton mean density was found in June (903 ind./m^2), while the highest density was found in August (9,393 ind./m^2). The standard deviation value shows that the high variation of zooplankton density between Elementary Sampling Distance Units (ESDU) occurred in August (43,627 ind./m^2) while the lowest variation between ESDU was found in June (1,112 ind./m^2). The occurrence of high zooplankton density variations at different times is due to the high variation in phytoplankton density.

Table 2. Statistical of zooplankton densities on wet season in Inner Ambon Bay.

Month	Minimum	Maximum	Mean	Std. Deviation
June	119	4,969	903	1,112
July	139	142,581	2,880	16,144
August	120	357,822	9,393	43,627

3.3. Vertical distribution
The vertical distribution of zooplankton densities in June shows that zooplankton is spread from the surface layer up to 44 meters with a fluctuating pattern between depth layers, with a high density found at the 37 meter depth layer. In the surface layer (0-5 meters), zooplankton are found with a low density (100 ind./m^2) presented in Figure 2.

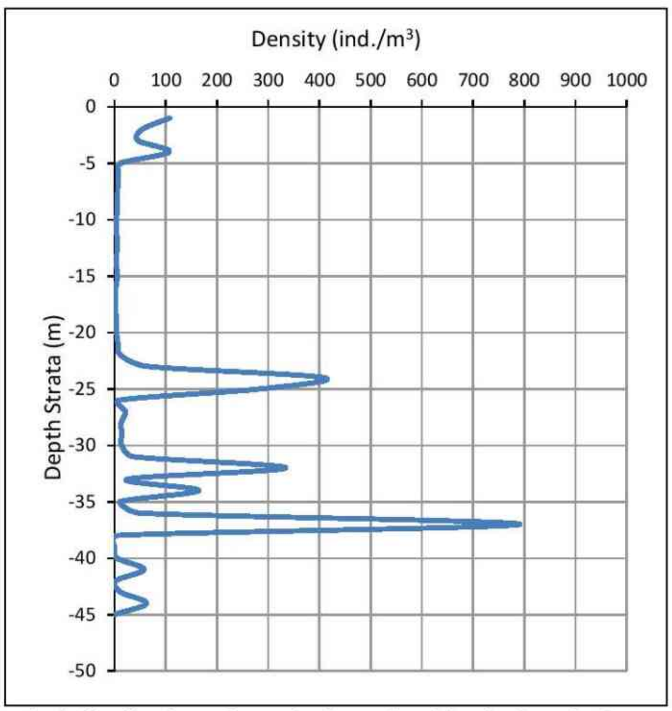

Figure 2. Vertical distribution of zooplankton densities in June in Inner Ambon Bay.

The vertical distribution of zooplankton density in July is from the surface of the water to a depth of 24 m, also with a fluctuating pattern between the layers of depth, where high density is found at the 17 meter depth layer (Figure 3).

The vertical distribution of zooplankton density in June and July is different from the vertical distribution of zooplankton density in the dry season (December - February). In the dry season, a high density of zooplankton is found in the near-surface layer (0-5 meters), while in the wet season the density of zooplankton is low in the surface layer while the high density is spread far below the surface layer of the water. In June and July in the wet season, high zooplankton densities were found in both of the depth were 37 meters and 17 meters, respectively (Figure 2 and Figure 3), indicating there was a large migration of zooplankton from the surface to the deeper layers in both of that months. This migration is the avoidance reaction of low salinity on the surface layer to a deeper water layer which are higher and stable salinity. The low salinity of the surface layer in June and July is due to the fact that in these months the rainfall is usually higher than that of the other months. During this time the input of fresh water from several rivers with large volumes into Inner Ambon Bay due to lower salinity in the surface layer (Table 3).

Tabel 3. The range and average salinity (psu) in the surface layer of Inner Ambon Bay during the Wet and Dry Season, Source : [24].

Value	Wet Season			Dry Season		
	June	July	August	December	January	February
Maximum	32.85	32.99	33.61	32.76	33.34	33.53
Minimum	20.21	25.95	28.63	30.46	31.77	32.42
Average	26.52	29.93	31.65	31.40	32.73	32.81
Std. Deviation	3.91	1.94	1.65	0,82	0.52	0.37

It was also seen in July that zooplankton with density of 500 ind./m^3 were near the surface layer (Figure 3), which is alleged that group of zooplankton species can adapt to lower salinity.

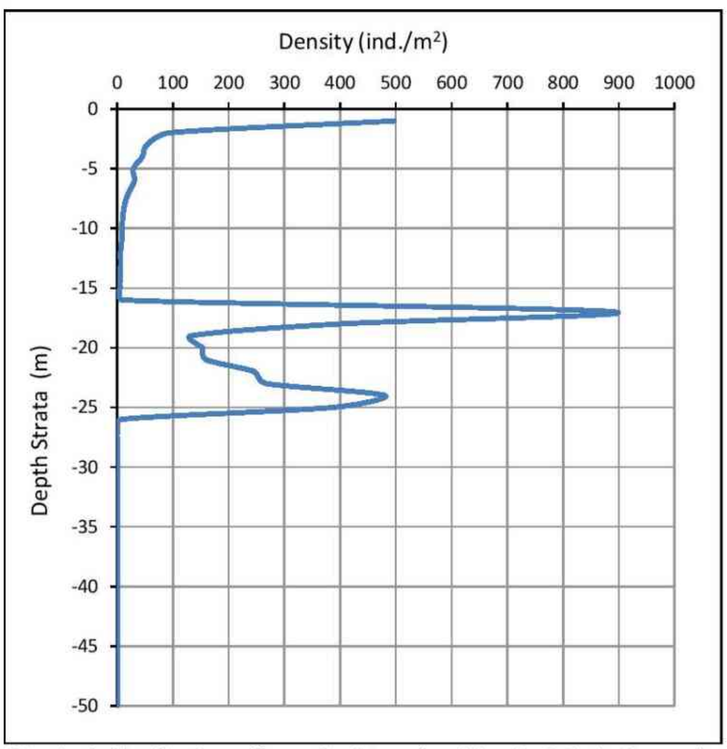

Figure 3. Vertical distribution of zooplankton densities in July in Inner Ambon Bay.

In contrast to the vertical distribution of zooplankton density in June and July, the vertical distribution of zooplankton density in August indicates high density was found in the surface layer at a depth of 4m, then decreases to a depth of 17m, and from this 17m depth to 45m depth there was no zooplankton found, the vertical distribution pattern of zooplankton density in August (Figure 4) was almost the same as the vertical distribution pattern of zooplankton density in the dry season where high zooplankton density was found in the surface layer of the water and decreases in the deeper water layers [1].

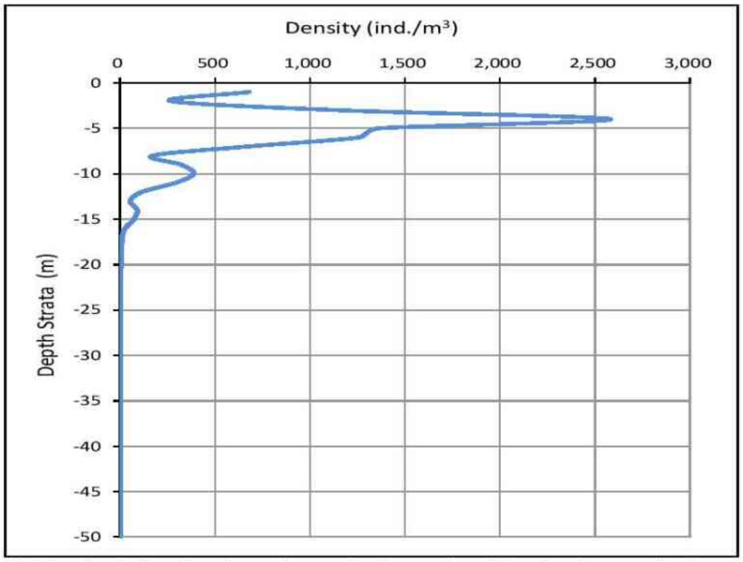

Figure 4. Vertical distribution of zooplankton densities in August in Inner Ambon Bay.

The high density of zooplankton in near the surface layer in August is alleged to be due to the lower rainfall that occurs this in month which causes the salinity of the surface layer to be higher than the salinity in June and July (Table 3). The high density of zooplankton in the surface layer is also related to the high intensity of sunlight which causes the high abundance of phytoplankton which is the food of zooplankton. The results of the research by Huliselan *et al* (2015) in Ambon Bay indicated a high abundance of phytoplankton was followed by a high abundance of zooplankton, where Copepods always dominate the zooplankton community.

3.4. Horizontal distribution

The horizontal distribution of zooplankton density in June shows that low density (0–100 ind./m^2) was spread over the West, North, East and South, namely in a space with an area of about 25% of the total area of Inner Ambon Bay. Compared with a density of 0-100 ind./m^2, zooplankton with a density of 200-400 ind./m^2 was spread over a wider water area, about 60% of the total area of Inner Ambon Bay and spread in the southwest to the northeast, while high density (1000 - 2000 ind./m^2) only occupied a narrow water area of about 15% and were scattered in the Southwest and Northeast in Inner Ambon Bay (Figure 5).

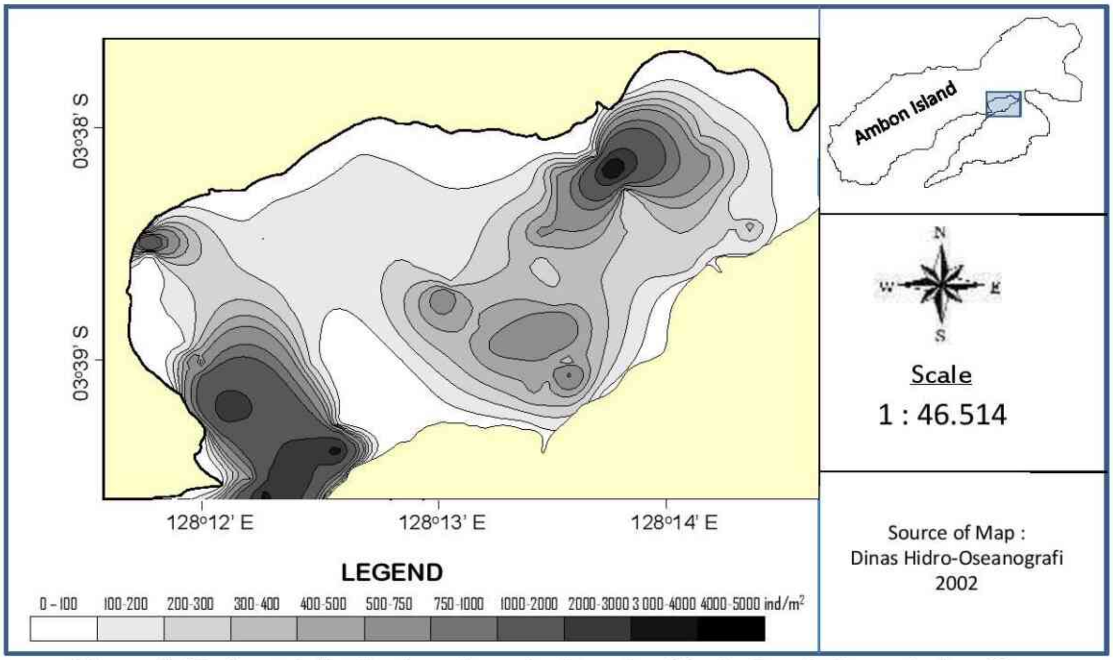

Figure 5. Horizontal distribution of zooplankton densities in June in Inner Ambon Bay.

In contrast to June, the horizontal distribution of zooplankton density in July as shown in Figure 6 shows low density (0–100 ind./m^2) was spread over a fairly large area (30% of the total area of Inner Ambon Bay) from the west, southwest, north and east to northeast. Densities of 200-400 ind./m^2 occupy a wider area of water, which is about 60% in the middle of the bay, from the north to the south, while the high density (4000-5000) had a narrow distribution area (10%) which was only found in the the East and southwest part, namely on the border between the Inner Bay and Outer Bay.

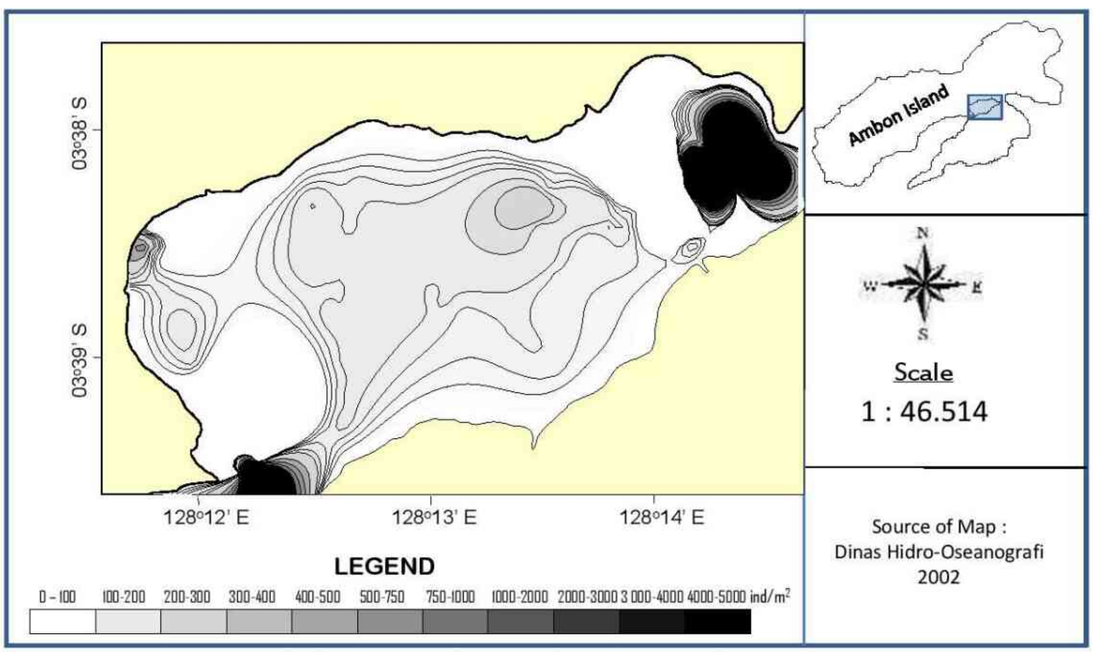

Figure 6. Horizontal distribution of zooplankton densities in July in Inner Ambon Bay.

The horizontal distribution of zooplankton density in August is shown in Figure 7. The contours of zooplankton density in the figure show that low densities (0-100 ind./m^2) were distributed in the North, Northeast, East and South, which occupy approximately 30 % of the total area of the Inner Ambon Bay waters. Compared to the density of 0-100 ind./m^2, the density of 200-500 ind./m^2 occupied a wider space, which was approximately 40% of the total area of Inner Ambon Bay and was spread across the Southwest, West to the central of the bay. In contrast to the high zooplankton density distribution in June and July which occupied a narrow space, the high zooplankton density (4000-5000 ind./m^2) in August occupied a wider space, which was approximately 30% of the total area of Inner Ambon Bay. Within, which were spread over the Northwest, South and East.

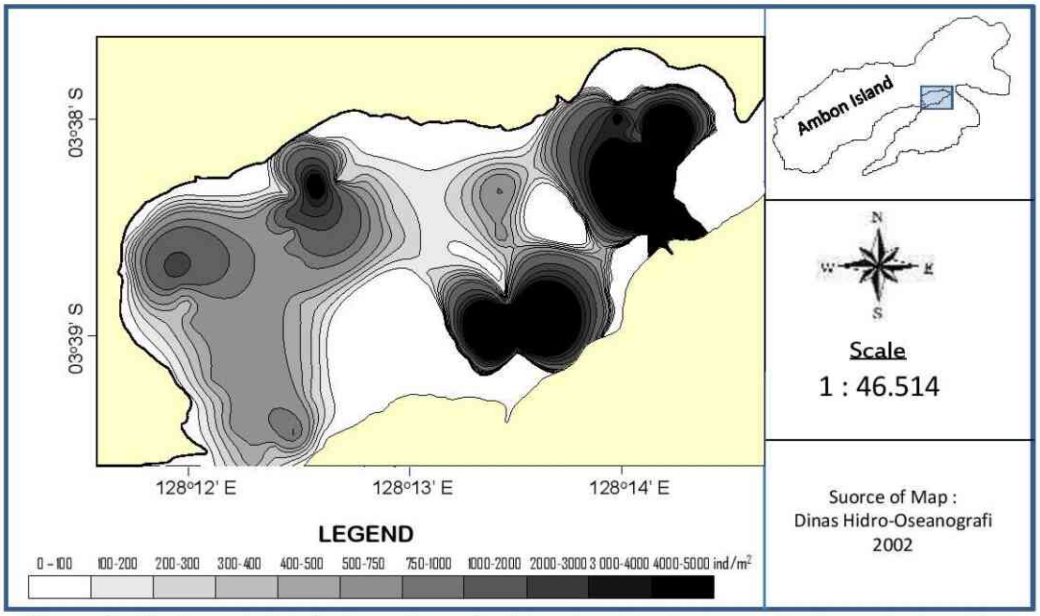

Figure 7. Horizontal distribution of zooplankton densities in August in Inner Ambon Bay.

The difference in the distribution of zooplankton density between locations and times in the Inner Ambon Bay shows the horizontal zooplankton density distribution pattern in occupying space in the sea is not by random, but is grouped. The distribution of animals in a waters is not random, but is well organized by physical, chemical and biological factors that control their activities. These activities include: foraging for food, avoiding predators, migration, reproduction and habitat selection [25]. However, in this research no observations were made on these environmental factors so that the contribution of their influence to the spatial distribution of zooplankton density in the waters of Inner Ambon Bay is unknown.

4. Conclusions

Based on the results of this research, it can be concluded as follows:

(1) The composition of zooplankton in Inner Ambon Bay during the Dry Season was dominated by copepods (72.25% to 85.15%), followed by meroplankton (11.5% to 13.0%). Copepods were dominated by Acrocalanus, Eucalanus and Oithona, while meroplankton consists of Peneidae larvae, Cirripedia larvae, Annelida larvae, Echinodermata larvae and Gastropod larvae. Also were found Brachyura larvae, Bivalvian larvae, as well as fish eggs and larvae but in small number and not scattered in all sampling stations.

(2) The highest average density of zooplankton was found in August, while the lowest density was in June

(3) In the vertical distribution, high zooplankton density were found in August near the surface water (4 meters) and continues to decrease in the deeper water, while in June and July high zooplankton density were found in the water column. which were deeper (June at a depth of 37 m and July at a depth of 17 m), this is an avoidance reaction of low salinity in the layer of surface water.
(4) The horizontal distribution of zooplankton in June and July, it was found that low zooplankton density (0 - 400 ind./m^2) occupied in very large space, namely 85 - 90% of the total area of the Inner Ambon Bay waters, while the high zooplankton density (1000 - 5000 ind./m^2) occupy a narrow space of 10 - 15%, on the other hand in August the high density of zooplankton (4000-5000 ind./m^2) was spread over a wider space, which was approximately 30% of the total area of Inner Ambon Bay.

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