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Composition, density, and spatial distribution of zooplankton on 1st transition season (March to May) in Inner Ambon Bay Waters, Indonesia

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Abstract. Inner Ambon Bay is part of Ambon Bay that covered an area about 11.03 km². It is semi-closed and become a small pelagic fish fishing ground, especially anchovy. The anchovy is a zooplankton predator, hence, the abundance of anchovy is dependent on the abundance of zooplankton. The research aims to analyze the composition, density, and spatial distribution of the zooplankton during the 1st transition season (March to May). Data of zooplankton composition were attained from sampling by using plankton net at ten observation stations, meanwhile, data of densities were obtained using a scientific hydroacoustic system on six parallel transect lines and one cross-parallel transect line. The study shows that the zooplankton community is dominated by Copepod and meroplankton. The highest density was found in March, while the lowest density was in April. Vertical distribution of zooplankton shows that the highest density was found near the surface (0-4 m) and decrease to a deeper water column. On the horizontal distribution, lower densities (0 – 400 ind./m²) occupy a wider area, they are evenly distributed in western, middle, and eastern, in the contrary, higher densities (3,000-4,000 ind./m²) occupy smaller space viz. in the southwest and east of Inner Ambon Bay.

1. Introduction

The Indonesian waters is an area where the wind monsoon system passing through. This wind system appears to have two reversal directions for each year. Surface water current in Indonesia is strongly affected by this wind, therefore the current water pattern is also strongly influenced by the monsoon. During June to August (Easter monsoon), blow the eastern wind with surface current direction move from east to west, while from December to February (Western monsoon) blow the western wind with surface current direction from west to east. From March to May and from September to November the transition monsoon takes place where surface current movement takes an irregular pattern [1].

The abundance and distribution of pelagic fish are closely related to the change and dynamic of oceanographic conditions. Geographically the Ambob Bay is affected by the monsoon climate. Ambon Bay is one of the potential fishing areas in Maluku, especially for small pelagic fish. The area used to be the main live bait (anchovy) fishing ground for skipjack tuna fishery in early 1970 to mid-1980. Some of the pelagic fishes commonly caught are sardines (*Sardinella* sp.), mackerel (*Rastreliger* sp.), mackerel scads (*Decapterus* sp.), and bigeye scad (*Selar* sp.) [2]



The Ambon Bay is divided into two parts namely Outer Ambon Bay (OAB) and Inner Ambon Bay (IAB). The width of the IAB is approximately 11.04 km². This bay is considered as a semi enclosed area with a shallow basin. Based on depth detection with a hydroacoustic device in 2010, it was detected that the maximum depth of this area amount to 45m [3]. This area is a small pelagic fishing ground in particular the anchovy. The anchovy fish commonly caught are *Stelophorus heterolobus*, *S. Indicus*, and *S. bucanieri* [4].

Zooplankton is the first consumer of the aquatic food chain. The abundance of zooplankton in one area will be followed by the abundance of small fishes, the big fishes, and later will form a fishing ground. The anchovy is the group of fishes that feed on zooplankton and the best live baitfish for skipjack pole and line fisheries in Ambon Island.

Research on the zooplankton community in Ambon Bay had revealed as much as 53 genera of zooplankton dominated by the sub-class of Copepoda namely Eudaeidae, Calanus, Paracalanus, Psedocalanus, Centropages, Acartia, Oithona, Lucifer, Oikopleura, Sagitta and fish egg [5]. *Stolephorus* spp are a major omnivore group towards phytoplankton and zooplankton [5]. The young *S. heterolobus* fish with the size of 40mm long feed on small phytoplankton and zooplankton, while the adult one feed on Calanoid, Leptochela, polychaete larvae, Lucifer, Brachyuran and other large includes their eggs [6]. The copepod was found to be the dominant zooplankton in IAB [7].

Estimation of abundance and biomass distribution of plankton using plankton net as a sampling method is considered difficult. This is due to the small sample size, large variety, high cost, and enormous bias [8]. With the invention of the hydroacoustic appliance, the in situ estimation of plankton abundance, distribution, plankton and nekton behavior, pelagic fish can be conducted [9, 10, 11, 12, 13,]. The use of the hydroacoustic instrument in zooplankton research has been performed by several authors [14, 15, 16, 17, 18, 19].

The research was conducted in Inner Ambon Bay between March to May 2012 (the first transition monsoon) to study the zooplankton abundance and its spatial distribution.

2. Materials and Method

2.1. Materials

The research was conducted in IAB waters from March to May 2012. The research location, zooplankton sampling sites, and transect design for acoustic raw data are shown in Figure 1. Materials used in this research covers:

1. One unit of a speed boat with the size of 11x1.8x0.8 m;
2. One unit of plankton net with mouth size of 45 cm and net mesh size of 33 mm;
3. One set of scientific hydroacoustic system BioSonic, frequency operational of 206 kHz, and a beam angle of six degrees;
4. One unit of global positioning system (GPS) receiver JRC (Japan Radio Cooperation) standard marine survey;
5. Visual Acquisition software to control all operational setting and echosounder and transducer functions which connected to the acoustic system during acoustic data collection [20];
6. Visual Analyzer software to estimate zooplankton abundance from echo integration result [21];
7. One unit of Panasonic Tough Book laptop to run the two software, saving acoustic data, and analysis result.

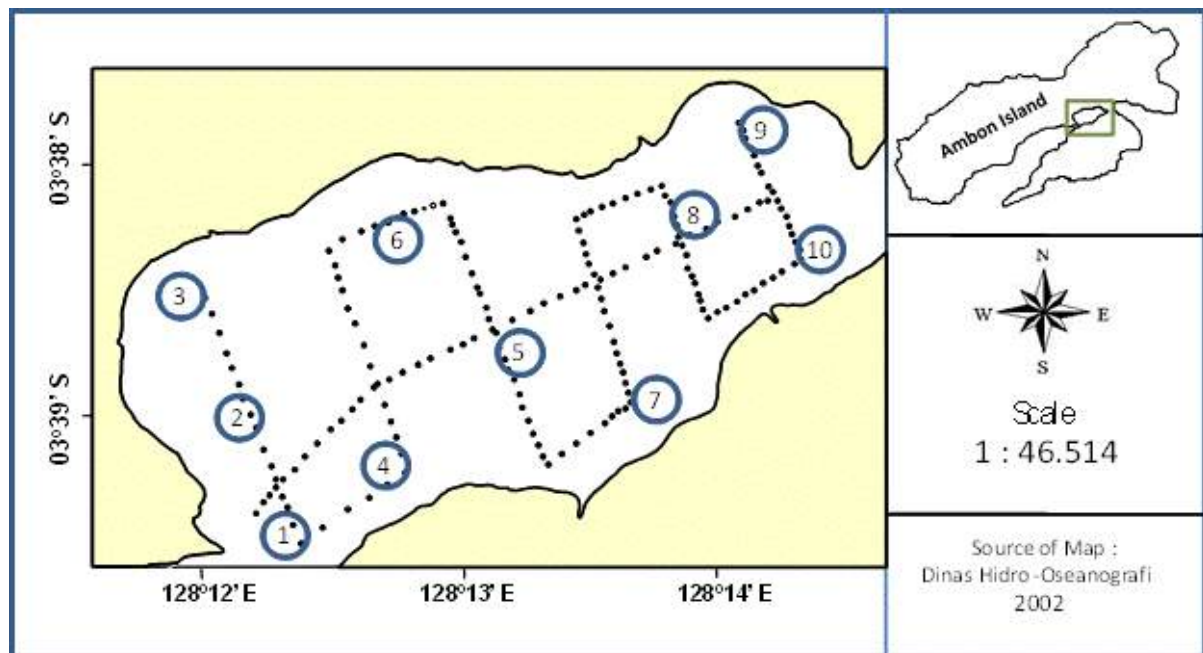


Figure 1. Map of survey location. Black disc showing recording positions of zooplankton densities where the distance between the two black discs is the elementary sampling distance unit (ESDU) of echo integration. Numbers 1 to 10 in the circle are the sampling stations of zooplankton using a plankton net.

2.2. Data collection

The zooplankton sample was collected vertically with a plankton net from the depth with 1% light intensity to the seawater surface. The sampling was done at all 10 stations (Figure 1). The plankton sampled was intended to verify plankton species detected during acoustic data collection. The filtrate water sample was poured into a sample bottle already filled with 4% formaldehyde.

The acoustic data collection was performed at six parallel transects and one transect which cross the six parallel transects (Figure 1). During acoustic data collection, the transducer was laid at 1m depth at one side of the speed boat and was pulled with approximately 5 knots along the transect line. The acoustic system parameter for zooplankton data collection was set as shown in Table 1.

The length of the echo integration period was set to 1 minute with an elementary sampling distance unit (ESDU) at a speed boat speed of 5 knots at approximately 125 m length.

Table 1. Parameter values of hydroacoustic system setting 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
Pulse Width	0.1 milisecond

Positioning adjustment and speed boat course with the position and line transect direction assigned was controlled using standard marine survey GPS JRC. Position and time of data collection at each ESDU were simultaneously and automatically recorded. The echo integration result obtained was compiled with positioning data and collection time. All the data was automatically saved in the

computer hard disk. Zooplankton sampling and acoustic data collection were done concomitant started from 08.00 to 12.00.

2.2. Data analysis

The zooplankton sampled was then identified according to [22, 23]. Zooplankton density from vertical hydroacoustic sampling from each ESDU was estimated following [22] as follows:

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

where ZPCM is a zooplankton density per m³, S_v is the volume of back-scattering strength, and BS is the mean back-scattering cross-section (cross-section of zooplankton size assessed acoustically) from detected zooplankton. The S_v value was calculated using the following formula:

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

where P is a gain of sound intensity samples corrected and ρ_c is a System Scaling Constant that obtained from the following formula:

$$\rho_c = \frac{1}{\pi * pw * (10^{(SL/10)})^2 * (10^{(RS/10)})^2 * E[b^2]}$$

where $\pi = 3.14159$, pw = pulse width (second), c = sound speed (m/second), SL = source level (dB μ Pa), RS = receiver sensitivity of transducer (dB), and $E[b^2]$ beam pattern factor. Zooplankton density analysis was conducted at each 1 m water thickness from transducer surface according to [21] with the following formula:

$$ZPUA = AD_i * (IT_i * \%_i / 100)$$

where ZPUA is the zooplankton density per m² (unit area) which is the sum of vertical absolute density, AD, and zooplankton per cubic meter (ZPCM). The vertical zooplankton distribution data was plotted on the graph to observe a vertical distribution pattern. The plot was done in Microsoft Excel 2007. The horizontal distribution data were analyzed using the gridding method through two-dimensional ordinary technics [24] with the following formula:

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

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

$$\beta = 1, \alpha = 1, \dots, n, \sum \lambda_{\alpha} = 1$$

where : x = site position estimated in two dimensional system

x_{α} = the position of a sample in two dimensional system

λ = kriging mass

n = number of nearest sample that used in kriging

γ = variogram fish density

μ = lag distance parameter

The variogram was obtained according to [25] with the following formula:

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

where : h = distance between the sampling station

F, F' = group of pair of samples for particular distance

3. Result and Discussion

3.1. Zooplankton composition and abundance

The result shows that in general zooplankton community in the 10 sampling stations during the first transition monsoon is dominated by a group of copepod (48.40% to 82.47%), followed by the meroplankton (12.20% - 42.27%). The copepod percentage at this transition monsoon is higher than the copepod percentage in west monsoon in IAB which amounted 42.85% to 61.95% [3]. The copepod was dominated by Oithona, Acrocalanus, Eucalanus dan Macrosetella, while meroplankton consists of the larvae of Peneidae, Cirripedia, Stomatopoda, Brachyura, Echinodermata, Gastropoda, Bivalvia, Annelida, and fish egg. The group with low number is Medusa, Siphonophora, Labidocera, Candacia, Temora, and Acetes. .

There are differences between zooplankton abundance on monthly and station based during the study period. In March, the highest zooplankton abundance was found at station 2 followed by stations 9 and 5. In April, the highest abundance was found at station 5, followed by 10 and 9, whilst in May the highest zooplankton abundance was found at stations 9 and 10. From the total zooplankton abundance found on March, 23.67 % was meroplankton that consists of the larvae of Peneidae, Cirripedia, Brachyura, Echinodermata, Gastropoda, and Bivalvia which distributed at all stations. In April the meroplankton amounted to 12.20% that consists of the larvae of Peneidae, Cirripedia, Stomatopoda, Echinodermata, Bivalvia, and Annelida. All of it was found to distribute in all the stations. The meroplankton abundance in May amounted to 42.27% that consists of the larvae of Peneidae, Cirripedia, Brachyura, Echinodermata, Gastropoda, Bivalvia, Annelida, and fish egg. The meroplankton percentage of occurrence on 1st transition season was lower (12.20% until 42.27%) than the percentage occurrence in west monsoon (30.79% until 51.17%) [3].

3.2. Zooplankton density

Zooplankton density from acoustic data in Inner Ambon Bay during the first transition monsoon is presented in Table 2. This table shows that mean zooplankton density vary from month to month. The lowest zooplankton mean density was found in April (208 ind./m³), whilst the highest mean density was found in March (936 ind./m³). From deviation standard value, it was found that there is a variation in zooplankton density in the Elementary Sampling Distance Unit (ESDU). The highest one was found in March (4.433 ind./m³), whilst the lowest variation between ESDU was found in April (157 ind./m³). The highest zooplankton density at a different time could be due to phytoplankton density variation.

Table 2. Zooplankton densities during 1st transition season in Inner Ambon Bay.

Month	Minimum	Maximum	Mean	Std. Deviation
March	111	43,400	936	4,433
April	72	4,180	208	157
May	157	6,860	600	813

3.3. Vertical distribution

Zooplankton density vertical distribution on March shows that the highest density was found to be on the surface layer (0 – 3 m), decrease to 5 – 10 m depth, increase again at the depth of 17 – 19 m, and decrease again at the more deep water column (Figure 2).

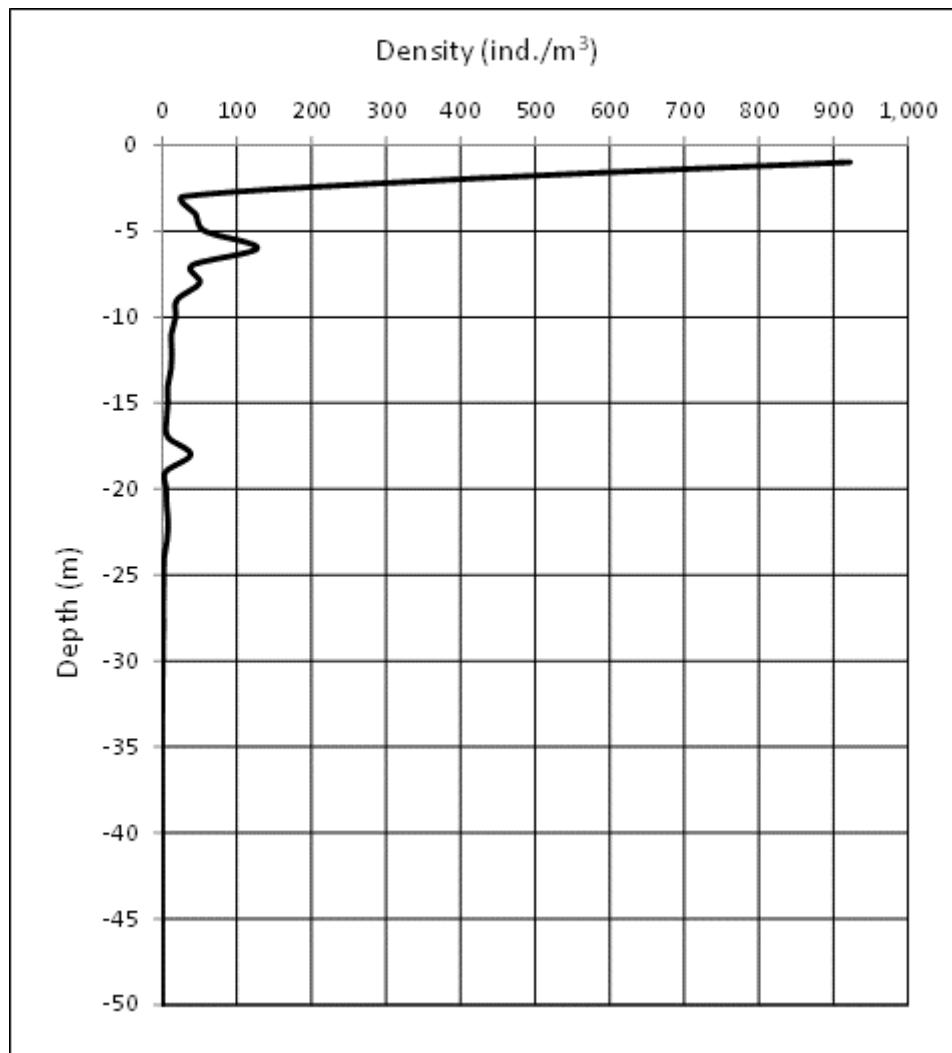


Figure 2. Vertical distribution of zooplankton densities in Inner Ambon Bay on March.

Vertical distribution of zooplankton density on March started from the water surface down to 26 m depth. The highest density was found at the near-surface layer (0 – 4m). The zooplankton density then decreased with high fluctuation between deeper water columns (Figure 3A).

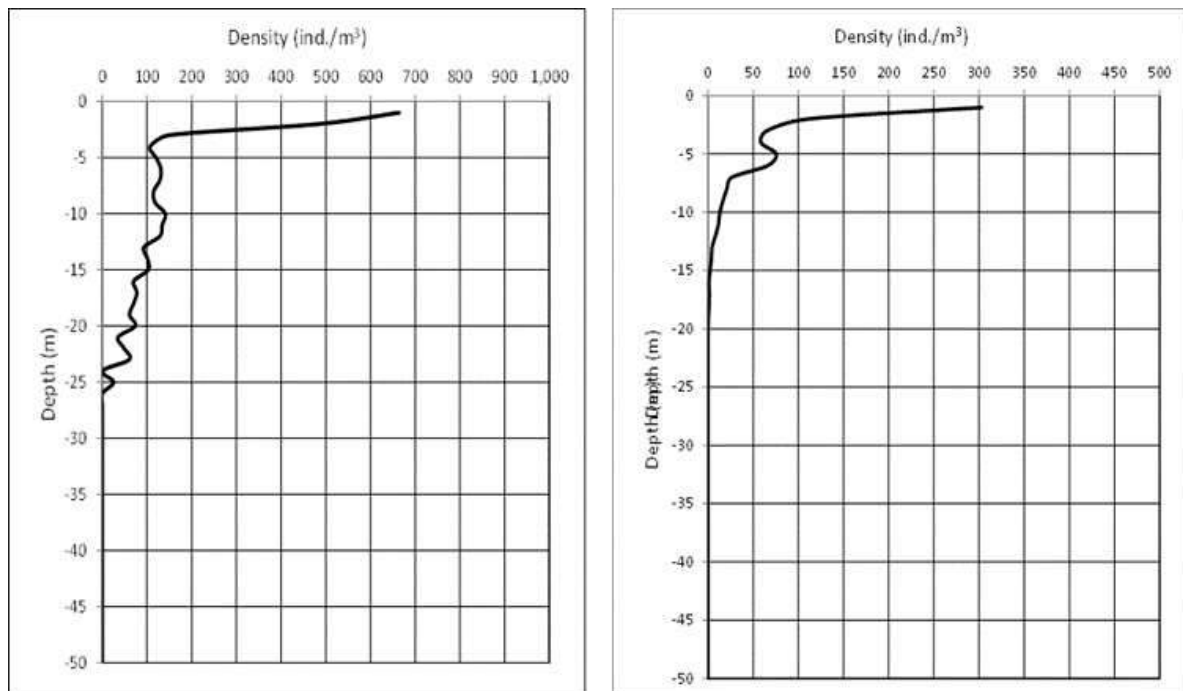


Figure 3. Vertical distribution of zooplankton densities in Inner Ambon Bay on April (A, left) and May (B, right)

The zooplankton density vertical distribution on March and April started from the surface layer down to 25 m. The zooplankton density vertical distribution on May also starts from the surface layer but only reaches the 15 m depth (Figure 3B). The high density, however, was found to be between 0–4 m for all three months of observation. The high zooplankton density on the near-surface layer is due to the high intensity of the sun that increases the phytoplankton density and abundance, which is the food source of zooplankton. The high abundance of phytoplankton in Ambon Bay was also followed by an abundance of zooplankton, where copepod was always the dominant one

3.4. Horizontal distribution

Zooplankton density vertical distribution in March shows that the lowest density (0 – 200 ind./m³) was found to distribute widely in the western, eastern, northern, and southern part of the bay. The highest density (3,000 – 4,000 ind./m³) was found to be at the southwest (water basin between Inner Ambon Bay and Outer Ambon Bay) and to the east (Figure 4).

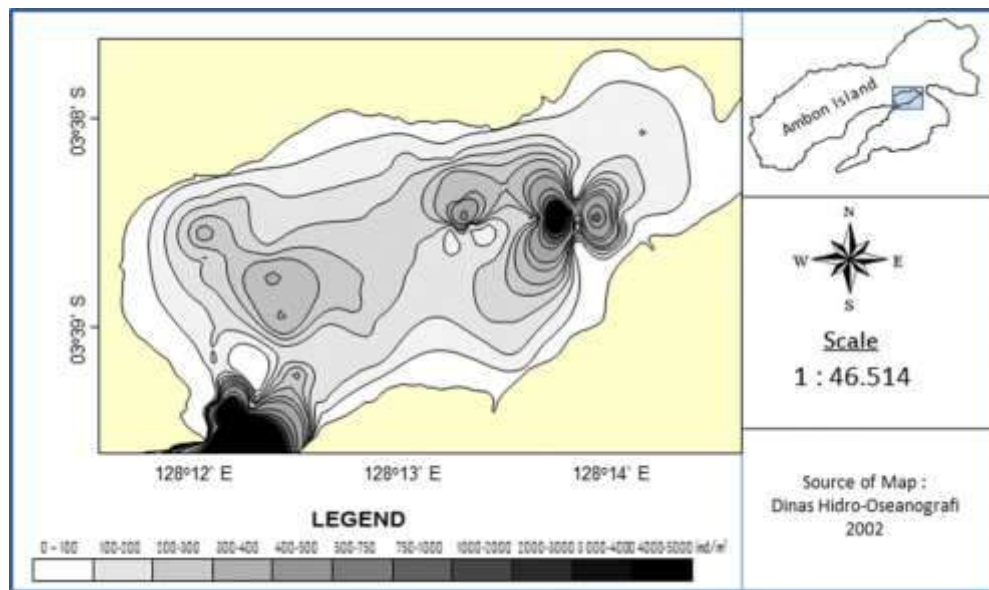


Figure 4. Horizontal distribution of zooplankton densities in Inner Ambon Bay on March

Horizontal distribution of zooplankton density in April shows that the lowest zooplankton density (0 – 200 ind./m³) was found to distribute widely at the western, southern, northern up to the northeast. The zooplankton density of 400 – 500 ind./m³ lies at the southwest, northwest up to the center of the bay. The highest zooplankton density (750-1000 ind./m³) lies at a narrow area of southwest of Inner Ambon Bay (Figure 5).

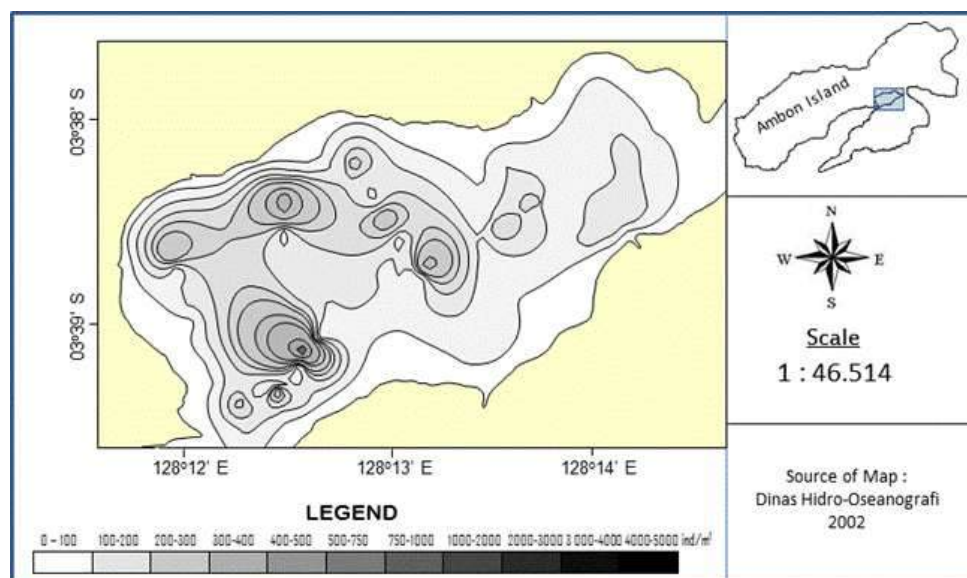


Figure 5. Horizontal distribution of zooplankton densities in Inner Ambon Bay on April

Horizontal distribution of zooplankton density in May shows that the lowest density (0-100 ind./m³) occupies an area of south, west, north, and up to the northeast. Horizontal distribution of zooplankton with a density between 300-500 ind./m³ occupies a wider area at the almost west part of the bay, and some occupy the northeast area, whilst zooplankton with high density with small distribution area was found at eastern part (Figure 6).

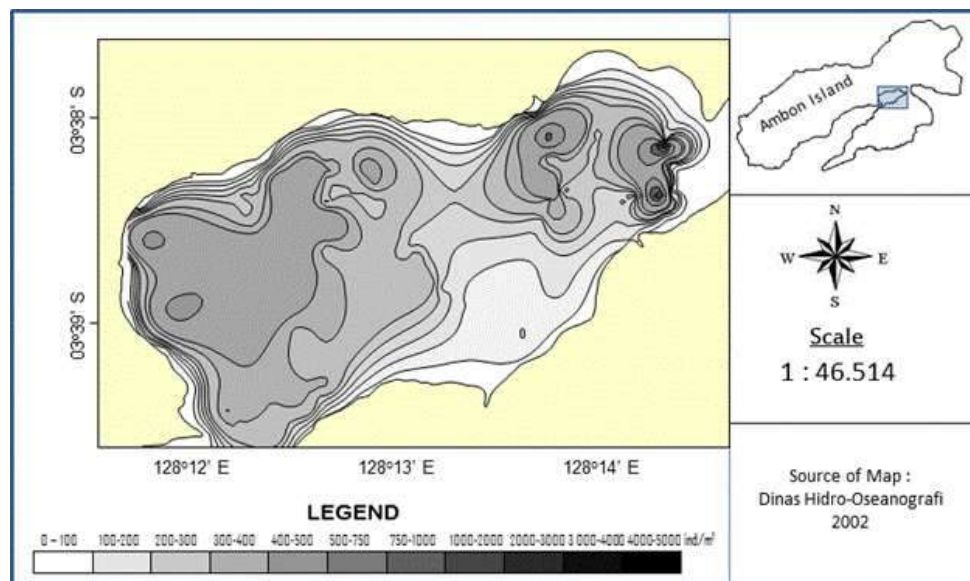


Figure 6. Horizontal distribution of zooplankton densities in Inner Ambon Bay on May

There are differences in zooplankton density distribution in Inner Ambon Bay between stations and time. The result reveals that spatial horizontal density distribution is not random but in an assemblage form. Organism distribution in the aquatic area is controlled by some factors and form a regular form. There are physical, chemical, and biological factors that control the organism activities [26]. Feeding activity, avoiding the predator, migration, reproduction, habitat selection are some of such activities that regulate the organism. These factors are not analyzed in this study, their contribution to the spatial distribution of zooplankton in Inner Ambon Bay henceforth is not understood.

4. Conclusion

The zooplankton composition in Inner Ambon Bay during the 1st transition monsoon is dominated by copepods and meroplankton. The mean highest zooplankton abundance was found in March, and the lowest abundance was found in April. The highest zooplankton density vertical distribution was found at the near-surface layer and decrease to a more depth water column. The lowest zooplankton abundance in horizontal distribution was found to occupies a wider area, whilst the highest abundance was found to occupy the small area of Inner Ambon Bay.

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