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By J. Latumeten, F S Pello & V D V Latumeten

Pattimura University

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Composition, Density and Spatial Distribution of Zooplankton in Inner Ambon Bay, Indonesia

J. Latumeten [α], F S Pello [σ] & V D V Latumeten [ρ]

Abstract- Inner Ambon Bay is part of Ambon Bay; it is semi-closed area and a small pelagic fish fishing ground, especially anchovy. The anchovy is a zooplankton predator; therefore the existence of anchovy is affected by the abundance of zooplankton. The aims of the research are to obtain information on the composition, density, and spatial distribution of the zooplankton in these waters. Data of zooplankton composition were obtained from sampling by using plankton net at ten observation stations. Meanwhile, data of densities were collected using a scientific hydroacoustic system, BioSonic DTX supported with split-beam technology, 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 pattern were plot in the graphs. The result shows that the zooplankton community is dominated by Copepod and meroplankton. The highest average density was found in August (9393 ind./m^2), while the lowest density was in June (903 ind./m^2). Vertical distribution of zooplankton generally shows that the highest density was found near-surface and decrease to the deeper water column, except in June and July, where the highest density of zooplankton was found at a depth of 37m and 17m, respectively. On the horizontal distribution, lower densities (<500 ind./m^2) are distributed in a wide space; on the contrary, higher densities (>5000 ind./m^2) occupy smaller space.

I. Introduction

Ambon Bay is located in Maluku Province, Indonesia. It 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 to support skipjack tuna fishery from 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.) (Syahailatua, 1999).Ambon Bay is divided into two parts, namely Outer Ambon Bay and Inner Ambon Bay. The area of Inner Ambon Bay is approximately 11.04 km^2. This bay is considered a semi-enclosed area with a shallow basin. Based on depth detection using a hydroacoustic device in 2010, it was known that the maximum depth of this area amount to 45m (Latumeten and Pello, 2019). This area is small pelagic fishing ground, in particular the anchovy. The anchovy fish commonly caught are *Stelophorus-heterolobus, S. indicus, and S. bucannieri* (Wouthuyzen *et al*, 1984). These species are predators of zooplankton and best live baits used in skipjack pole and line fishery in Ambon City. *Stolephorus* spp. is major omnivore group towards phytoplankton and zooplankton (Morintoh, 2001).The young *S. heterolobus* fish size 40 mm length eat tiny phytoplankton and zooplankton. In contrast, the adult one eat Calanoid, Leptochela, polychaete larvae, Lucifer, Brachyuran, and other large zooplankton includes their eggs (Huliselan *et al*, 2015).

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 Evadne, Calanus, Parucalonus. Psedocalarus, Centropages, Acartia, Oithona, Lucifer, Oikopleura, Sagitta, and fish egg. The copepod is the dominant zooplankton in Inner Ambon Bay (Tahapary, 2013). 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, highvariety, high cost, and enormous bias also inconvenient (Liao*et al*, 1999). With the invention of the hydroacoustic appliance, the in situ estimation of plankton abundance, distribution, plankton and nekton behavior, pelagic fish can be conducted (Aoki and Inagaki, 1992; Castillo et al, 1996; Fischer and Visbeck, 1993; Petitgas and Levenez, 1996, Simard et al, 1992). Hydroacoustic instrument in zooplankton research has been used by several authors (Kidwai and Amjad, 2001; Marchin *et al*, 1996; De Robertis et al, 2003 Liao*et al,* 1999; Chu and Wiebe, 2005; Forman and Warren, 2010).

II. Materials and Method

a) Materials

The research had been done in Inner Ambon Bay waters from December 2011 to August 2012. The research location, zooplankton sampling sites, and transect design for raw acoustic data showed 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 DTX with frequency operational of 206 kHz, and a beam angle of six degrees; 4. One 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

Author α: Faculty of Fisheries and Marine Science, Pattimura University. e-mail: latumetenjacobs1@gmail.com
Author σ: Institut Agama Kristen Negeri Ambon.

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to the acoustic system during acoustic data collection (BioSonic, 2003); 6. Visual Analyzer software to estimate zooplankton abundance from echo integration result (BioSonic, 2004); 7. One unit of Panasonic Tough Book laptop to run the two software, saving acoustic data, and result fromanalysis.

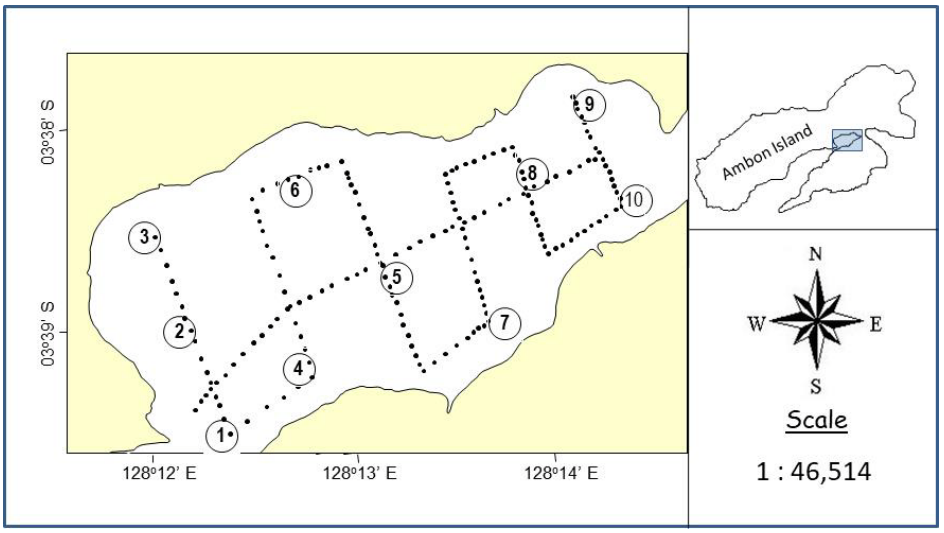


Figure 1: Map of survey location (Inner Ambon Bay). Black dots showing recording positions of zooplankton densities where the distance between the two black dots are the elementary sampling distance unit (ESDU) of echo integration. Numbers 1 to 10 in the circle are the sampling stations of zooplankton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

b) Data collection

The zooplankton sample was collected vertically using plankton net from the depth with 1% light intensity to the seawater surface. The sampling had been done at all ten stations (Figure 1) on the same day. 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. Before acoustic data collection, the hydroacoustic device was calibrated using a 31mm tungsten carbide sphere. The acoustic data collection using split-beam technique applied at six parallel transects and one transect which crossed 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 pulled with approximately 5 knots along the transect line. The acoustic system parameter for zooplankton data collection set as follows; data threshold is -130 dB, transmitting rate is three pings per second, collection range is 50m from transducer face, and pulse width is 0.1millisecond. The length of the echo integration period was set to one minute with an elementary sampling distance unit (ESDU) at a speed boat speed of 5 knots at approximately 125 m length.

Positioning adjustment and speed boat course with the position and line transect direction assigned controlled using standard marine survey GPS JRC. Position and time of data collection at each ESDU were simultaneously and automatically recorded. All data is automatically saved on the computer hard disk. Zooplankton sampling and acoustic data collection were done concomitantly started from 08.00 am to 12.00pm at local time.

c) Data analysis

The zooplankton sampled was then identified according to (Newell and Newell, 1977; Yamaji,1984). Zooplankton density from vertical hydroacoustic sampling within each ESDU was estimated following BioSonic (2004) as follows:

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

Where ZPCM is a zooplankton density per m^3,Sv is the volume of back-scattering strength, and σ_{BS} is the mean back-scattering cross-section (cross-section of zooplankton size assessed acoustically) from detected zooplankton. The Sv value is calculated using the following formula:

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

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

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

Where π = 3.14159, PW = pulse width (second), c = sound speed (m/second), SL = source level (dB/µPa), RS = receiver sensitivity of transducer (dB), and E[b^2] beam pattern factor. Zooplankton density analysis was conducted at each one-meter water thickness from

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transducer surface to bottom according to BioSonic (2004) with the following formula:

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

Where ZPUA is the zooplankton density per m^2 (unit area) which is the sum of absolute vertical density, AD, and zooplankton per cubic meter (ZPCM). AD values are obtained by the formula (BioSonic, 1990):

$$AD = RD * C$$

Where RD is relative density and C is echo integrator scaling factor. In the processing acoustic raw data for zooplankton the filtered of echo srength is from -90 dB to -78 dB. The vertical zooplankton distribution data was plotted to observe a vertical distribution pattern using Microsoft Excel 2007 software. The horizontal distribution data were analyzed using the gridding method through 2-D (two dimensional) ordinary krigging (Deutsch and Journel, 1992) with the following formula:

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

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

$$\beta = 1,\ \alpha = 1, \cdots n,\ \sum \lambda_\alpha = 1$$

where : x= site position estimated in two dimensional system
x_α = the position of a sample in two dimensional system
λ = kriging weight
n = number of nearest samples that used in kriging
γ = variogram of zooplankton density
μ = lag distance parameter

The variogramis obtained according to MacLennan and Simmonds (2005) with the following formula:

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

h = distance between the sample locations
F, F' = group of pair of samples for a particular distance

III. Result and Discussion

a) Composition

The result shows that in general zooplankton community is obtained at ten sampling stations during the research is dominated by a group of copepod (42.85% in February to 85.15% in August), followed by the meroplankton (10.15% in August to 51.17% in February) and a group of others zooplankton in a small percentage (4.80 % in August to 14.77% in July). The copepod was dominated by Oithona, Acrocalanus, Eucalanus Macrosetella. Meroplankton consists of the larvae of Peneidae, Cirripedia, Stomatopoda, Brachyura, Echinodermata, Gastropoda, Bivalvia, Annelida, and fish egg. Group of other zooplankton in small percentage consists of Medusa, Siphonophora, Urochrodata, Chaethognata, Amphipoda, Sergestidae, Ostrachoda, Cladocera. Copepod and meroplankton found in each sampling period. Other groups of zooplankton were found in each sampling period were Siphonophora, Urochrodata, Chaethognata, and Sergestidae, meanwhile Amphipoda was found in January, April, and June, but Ostrachoda and Cladocera were not found in April. The percentage of zooplankton group in Inner Ambon Bay shown in Figure 2.

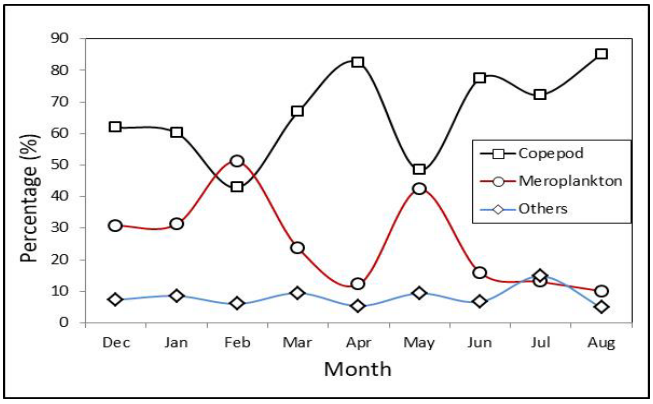


Figure 2: Variation of zooplankton percentage in Inner Ambon Bay

The high percentage of copepod is allegedly due to its ability to adapt to high dynamic of oceanographic conditions in coastal waters such as temperature and salinity compared with another group of zooplankton (Mulyadi and Wahab, 2015). This situation is, of course, also supported by the availability of phytoplankton as zooplankton's food (Huliselan *et al*. 2015; Pello *et al*. 2021; Latumeten *et al*. 2021). The presence of meroplankton (larval of various biota and fish egg) with a significant percentage such as a result of the research hint that the Inner Ambon Bay is a spawning ground, nursery ground, and feeding ground of finfish, crustacean, mollusk, shellfish, etc.

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Variation of zooplankton percentage in Figure 2 is seen there is a relationship between meroplankton and copepod where the more meroplankton followed by a fewer copepod, the curve fit in Figure 3 explain it more clearly. In the marine food chain system, meroplanktonis in the first and second level consumers while copepods are in the first level consumers (Lalli and Parson, 1993). Meroplankton in the second level consumers will use copepods as one kind of food. Thus the presence of copepods in Inner Ambon Bay is controlled by meroplankton.

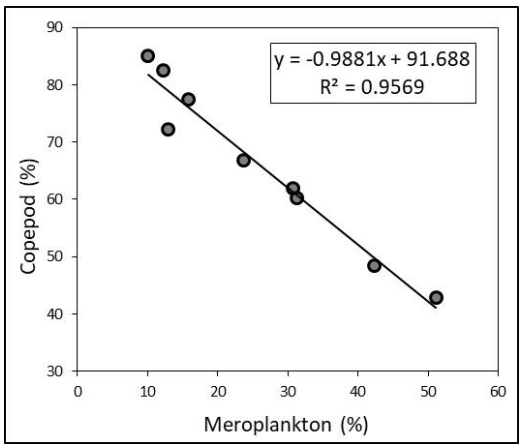


Figure 3: Relationship between meroplankton and copepod in Inner Ambon Bay

The equation in Figure 3 above explains that if there is an increase of one percent of meroplankton, it will reduce the copepod by 0.99 percent. From the value of the coefficient of determination (R^2), it is explain that the effect of the contribution of meroplankton to copepods is very high, which is equal to 95.69%.

b) Density of Zooplankton

Statistics of zooplankton density from hydroacoustic data during the research in Inner Ambon Bay are presented in Table 1.

Table 1: Statistical of zooplankton densities in Inner Ambon Bay

Month	No. ESDU	Density (ind./m²)			
		Minimum	Maximum	Average	Std. Deviation
December	100	64	75,134	921	6,591
January	98	66	5,240	367	537
February	99	78	578,000	1,495	9,073
March	101	111	43,400	936	4,433
April	102	72	4,180	208	157
May	100	157	6,860	600	813
June	104	119	4,969	903	1,112
July	103	139	142,581	2,880	16,144
August	99	120	357,822	9,393	43,627

Table 1 shows that the zooplankton average density values vary from month to month during the research time. The lowest zooplankton density was found in April (208 ind./m^2), while the highest density was found in August (9,393 ind./m^2). The standard deviation value shows that the higher variation of zooplankton density between Elementary Sampling Distance Units (ESDU) occurred in August (43,627 ind./m^2), in July (16,144ind./m^2), and in February (9,073ind./m^2), while the lower variation was found in April (157ind./m^2), in January (537 ind./m^2) and in May (813 ind./m^2). The occurrence of high zooplankton density variations at different times in Inner Ambon Bay is due to the high variation in phytoplankton density(Huliselan *et al*. 2015).

c) Vertical distribution

The vertical distribution of zooplankton densities in Inner Ambon Bay is presented in Figure 4.It is showed that the depth of the swimming layer of zooplankton varied from month to month. The deepest swimming layer of zooplankton was found in June (44m), and the shallowest was in May (18m).

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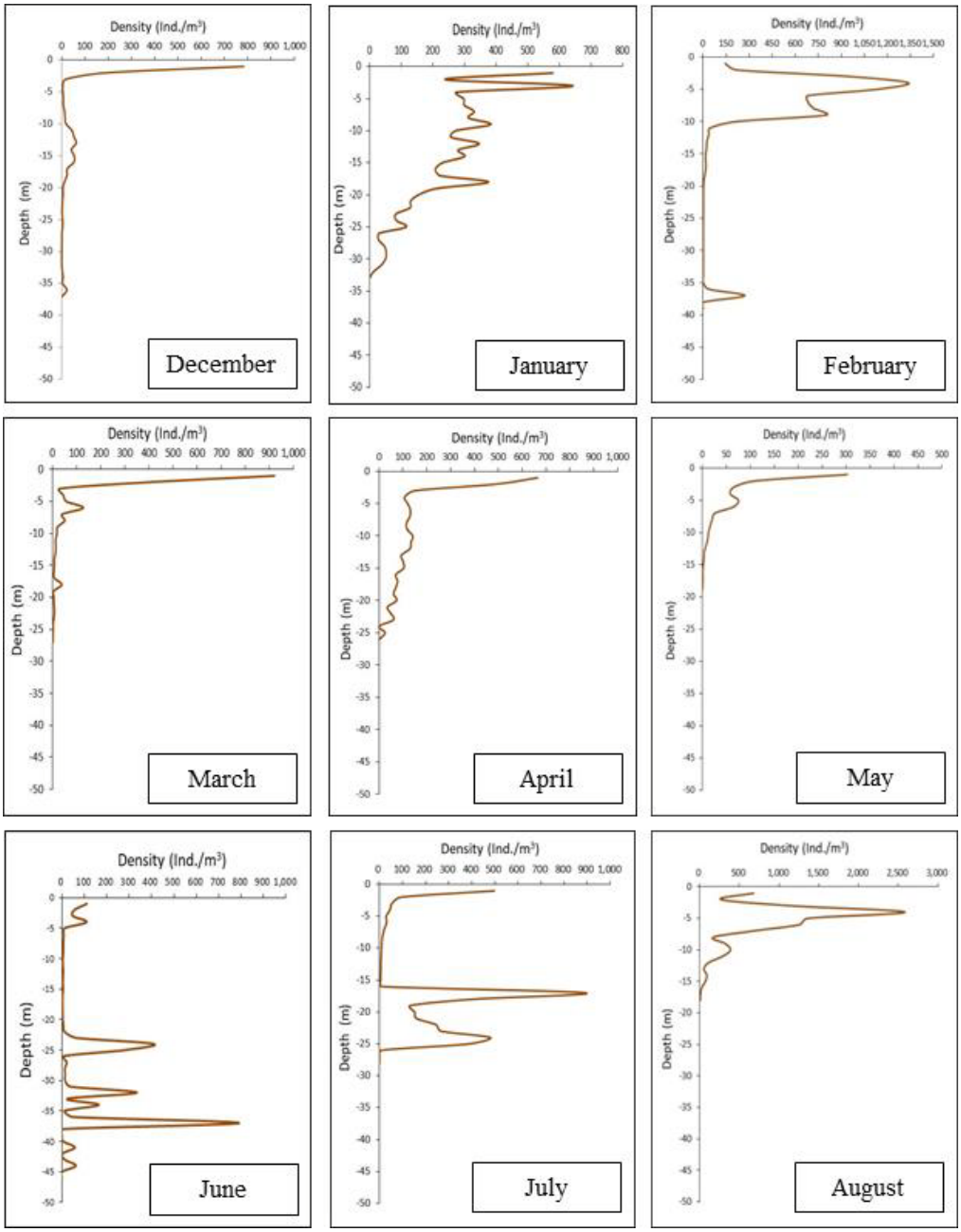


Figure 4: Vertical distribution of zooplankton densities in Inner Ambon Bay

Generally, a higher density of zooplankton was found near-surface layer and decreased down to deeper layers as appeared in December, January, February, May, and August. The situation is different in June, and July where higher density zooplankton was found far from the surface layer, i.e. at a depth of 37m and 17m, respectively. It is indicates there was a large migration of zooplankton from the surface to the deeper layers in both that months. This migration is the avoidance reaction of low salinity on the surface layer to a deeper water layer which is higher and stable salinity. The low salinity of the surface layer in June and July because in these months, the rainfall is usually higher than that of the other months. During this time, the input of freshwater from several rivers with large volumes into Inner Ambon Bay due to lower salinity in the surface layer (Table 3). In addition, especially in July, besides higher density of zooplankton distributed at a depth of 17m but there are a group of zooplankton with a fair density that have a tolerance to lower salinity near the surface. According to Pranoto (2005), the crustacean class, in general, is euryhaline or can withstand at extreme changes of salinity.

The vertical distribution pattern of zooplankton density in August was almost the same as the vertical distribution pattern of zooplankton density in the other monthsi.e higher zooplankton density was in the surface layer and decreased to the deeper water layers. The

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high density of zooplankton near the surface layer in August is allegedly due to the lower rainfall that occurs it month, which causes the salinity of the surface layer to be higher than the salinity in June and July (Table 2).

Tabel 2: The range and average salinity (psu) in the surface layer of Inner Ambon Bay during the Wet and Dry Season (Pello, 2014)

Value	Wet Season			Dry Season		
	June	July	August	December	January	February
Minimum	32.85	32.99	33.61	32.76	33.34	33.53
Maximum	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

Besides the salinity effect, 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 research result from Huliselan *et al.* (2015) in Ambon Bay indicated a high abundance of phytoplankton is followed by a high abundance of zooplankton, where Copepods always dominate the zooplankton community.

d) Horizontal distribution

The horizontal distribution of zooplankton density in Inner Ambon Bay is presented in Figure 5. It is shown that the horizontal distribution of zooplankton density in Inner Ambon Bay varies from month to month, thus making it difficult to predict. Low densities (<500 ind./m^2) are spread over a wider area of water. In contrast, high densities (>5000 ind./m^2) are spread over narrow water spaces, except in August, where high zooplankton densities are spread over a wider waters space compared to the high density found in other months.

High zooplankton densities are more often found near the inner-outer bay transition area except in January, April, and May, where high zooplankton densities are found in the south and east of these waters. Apart from near the transition areas of the inner-outer bay, high zooplankton densities were also found in the waters near the mangrove community, namely in the north in December, in the northeast and southeast in February and June, while in the east in July and August. The high density of zooplankton near the transition area of the inner-outer bay is thought related to the dynamics of mixing water masses from the Inner Ambon Bay and the water masses from the Ambon Outer Bay caused by tidal currents. These two water masses transport zooplankton which is a mixing near the transition area, which causes high-density zooplankton in this location. The mixing of two different water masses from inner bay and outter bay transport the zooplanktons. This mixing of water masses not only causes high density of zooplankt on but also high density of anchovies there(Latumeten and Latumeten, 2021[a]).Besides near the inner-outer bay transition area, a high density of zooplankton also found around the mangrove community; this is because mangroves are a nutrient supplier which causes the abundance of phytoplankton there, followed by zooplankton to eat the phytoplankton. From the horizontal distribution pattern of zooplankton density between locations and time in Ambon Bay, as shown in Figure 5, shows that the distribution pattern of zooplankton density in these waters is not random but clustered.

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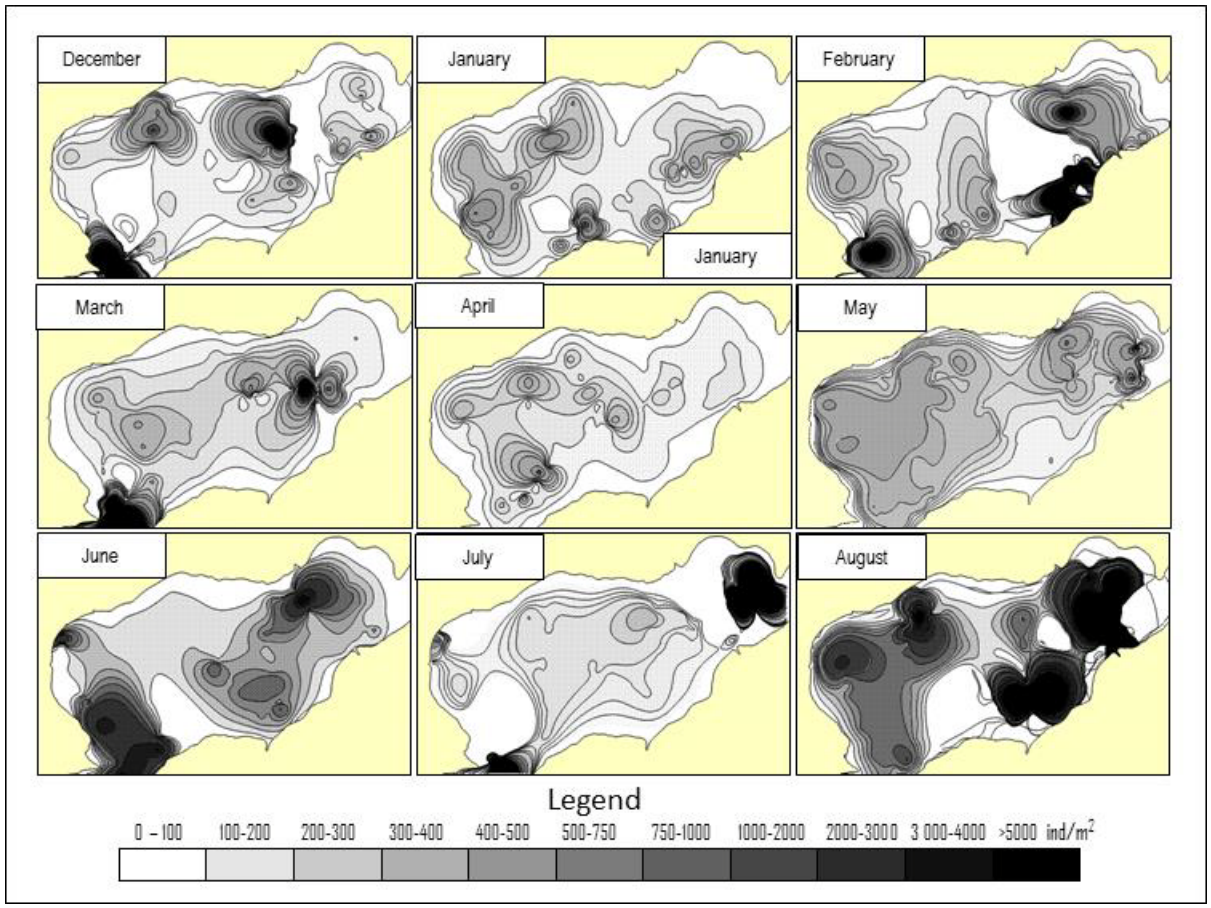


Figure 5: Horizontal distribution of zooplankton density in Inner Ambon Bay

According to Simard *et al.* (1992) that the distribution of animals in waters is not random but is well-organized by the physical, chemical, and biological factors that control their activities. These activities include: search for food, avoidance of predators, migration, reproduction, and habitat selection. However, in this study, no observations were made of these environmental factors. So, their contribution to the spatial distribution of zooplankton density in the waters of Inner Ambon Bay is uncertain.

IV. Conclucion

Based on the results of this researchcan be concluded as follows:

(1) The composition of zooplankton in Inner Ambon Bay wasa group of copepod (42.85% in February to 85.15% in August), followed by the meroplankton (10.15% in August to 51.17% in February) and a group of others zooplankton in small percentage (4.80 % in August to 14.77% in July). The copepod was dominated by Oithona, Acrocalanus, Eucalanus Macrosetella. Meroplankton consists of the larvae of Peneidae, Cirripedia, Stomatopoda, Brachyura, Echinodermata, Gastropoda, Bivalvia, Annelida, and fish egg. Group of other zooplankton in small percentage consists of Medusa, Siphonophora, Urochrodata, Chaethognata, Amphipoda, Sergestidae, Ostracoda, Cladocera. Copepod and meroplankton were found in each sampling period. Other groups of zooplankton that were founded in each sampling period were Siphonophora, Urochrodata, Chaethognata, and Sergestidae, meanwhile Amphipoda was found in January, April, and June, but Ostrachoda and Cladocera were not found in April. The presence of meroplankton (larval of various biota and fish egg) with a significant percentage hints that the Inner Ambon Bay is a spawning ground, nursery ground, and feeding ground of finfish, crustacean, mollusk, shellfish, etc.

(2) The highest average density with highest variation of zooplankton was found in August, while the lowest density with lowest variation was in April.

(3) In the vertical distribution, the deepest swimming layer of zooplankton was 44m in June, and the shallowest was 18m in May. Generally, a higher density of zooplankton was found near-surface layer and decreased down to deeper layers, except in June and July, where a higher densities of zooplankton was found at both depths of 37m and 17m, respectively. This zooplankton behavior is a reaction to avoid low salinity on the surface layer

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and then migrating to a deeper water layer which is higher and stable salinity.

(4) Low zooplankton density (<500 ind./m^2) spread over a wider area of water. In contrast, high density (>5000 ind./m^2) spread over a narrow water space, except in August where zooplankton density which are spread over a widerange of waters. High zooplankton densities are more often found near the inner-outer bay transition area and near mangrove communities. The distribution of zooplankton in Inner Ambon Bay is not random but clustered.

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