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Spatial and temporal distribution of anchovy density in Inner Ambon Bay on dry season (December-February)

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Abstract. Inner Ambon Bay is a small pelagic fish fishing ground, especially anchovy. Anchovy plays important role in the skipjack fishery as live bait in Ambon city. Nevertheless, research for its resource management is rarely done. The aims of the research are to obtain information of density, vertical distribution and horizontal distribution of anchovy on Dry Season. Densities data of anchovy were collected using hydro-acoustic device at six parallel transect lines and one cross- parallel transect line. Geo-statistical analysis technique was used to describe horizontal distribution of anchovy meanwhile, to observe vertical distribution pattern, vertical anchovy data was plotted on the graph. Result shows that lower average density of anchovy was found in January while higher density was in February. On vertical distribution, anchovy was distributed from near surface to 35m depth layer, but higher densities were found at 25m depth layer in December and February respectively and in January at 30m of depth layer. On horizontal distribution, lower density of anchovy occupies a large space, in contrast, higher density was in small fish schools occupy a small space and are scattered in given parts of Inner Ambon Bay but at differ locations between months.

1. Introduction

Ambon bay is divided in two parts of area; Outer Ambon Bay (OAB) and Inner Ambon Bay (IAB). Inner Ambon Bay is approximately 11.04 km², semi closed and a narrow basin. According to the result of depth detection with echosounder in 2010, known that inner Ambon bay has 45m maximum depth. This waters is a small pelagic fishing ground especially for anchovy (*Stolephorus* spp.) in Ambon island. Anchovy resources in Inner Ambon Bay waters comprises *Stolephorus heterolobus*, *S. indicus*, dan *S. buccannieri* [1]. These anchovy resources are best live bait used for skipjack pole and line fishery in Ambon island. Bait fish fishery in inner Ambon bay has been done years ago by fishermen who lived nearby the gulf coast to sustain the continuance of the skipjack pole and line fishery operational in Ambon city. Live bait fish fishery using beach seine with light is effective enough to catch fishes which are attracted to the light (positive phototaxis) to catch several species (not selective) of anchovy. Fluctuation in fish catch in live bait fish fishery in inner Ambon bay is consequence of 1) power change that supports biomass forming, 2) exploitation rate, and 3) fish in and out of the waters in outer Ambon bay. Since 2002 until 2007, either the production or fish catch per fishing gear unit/year experience decline and started to rise slightly in 2008 and 2009 [2]. Nevertheless, the importance of anchovy in inner Ambon bay is to support industry of skipjack pole and line fishery in Ambon city, meanwhile the research for management of the fish resources is rarely done. Information regarding density and its spatial and temporal distribution is not yet known in certainty.

Hydro-acoustic technique can be used in research of the pelagic fish density including anchovy. Application of this technique for pelagic fish have been done by [3, 4, 5, 6, 7, 8, 9, 10, 11]. Therefore, application of scientific hydro-acoustic technique in research of anchovy resource is important to solve the live bait problem in inner Ambon bay.



The aim of this research is to obtain information of densities of anchovy and its spatial and temporal distribution especially on dry season. The result of this research hopefully useful as a basic information for management policy of anchovy resources in Inner Ambon Bay.

2. Research Methodology

2.1. Research tools

This research was done in inner Ambon bay waters, Ambon city. Research located at coordinates 128°12.14' E - 128°14.65' E and 03°37.68' S - 3°39.38' S (Figure 1). Tools used in this research for data acquisition to data analysis in laboratory are (1) speed boat size in length x width x height = 7x1.2x1m, (2) BioSonic hydroacoustic device type DT-X with 200kHz operational frequency and beam angle (half power points) of 6 degree, (4) Global Positioning System (GPS) receiver JRC (Japan Radio Cooperation), (5) *Visual Acquisition Software 5.1* to control whole operational setting and functions of echosounder and transducer which are connected to its hydroacoustic system [12] in acquisition of acoustic data, (6) *Visual Analyzer software 4.2 pre-release* to estimate density of fish of *echo integration* result [13], and (7) Panasonic Tough Book Laptop to run both softwares, to both save and analyze acoustic data.

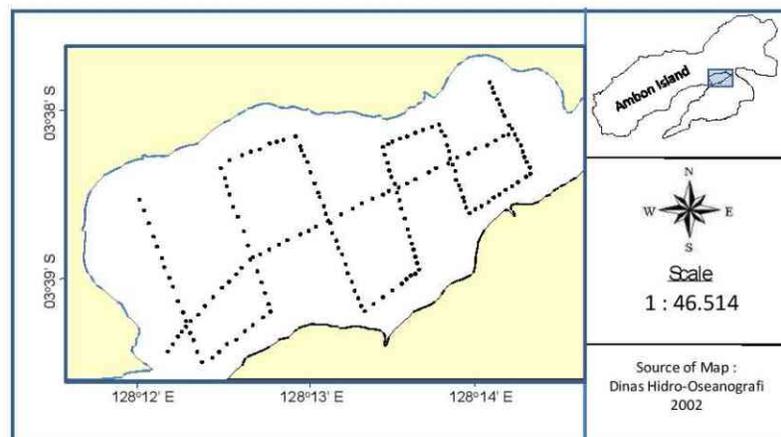


Figure 1. Map of research location in inner Ambon bay. Black dots following the shape of a parallel transect line of north-south direction and a transect line crosses the east-west direction showing recording positions of relative fish density data. The distance between these dots is a size of *Elementary Sampling Distance Unit* (ESDU).

2.2. Data collection

Data collected in the research are acoustic raw data. The acoustic raw data were obtained using BioSonic hydroacoustic DT-X controlled by *Visual Acquisition Software* on 6 (six) parallel transect lines designed in a north-south direction and one transect east-west direction (cross parallel line transect) (Figure 1). In obtaining acoustic data, the transducer is immersed at a depth of approximately 1.0 meter below the water surface on one side of the speed boat, then the speed boat moves to drag the transducer with an average speed of 5 knots following the transect lines that have been designed.

Acoustic raw data which collected are relative density value in V^2/ping ($V^2 \approx$ fish density), namely the voltage amplitude values that exceed the noise threshold value using *echo integration* technique which took place programmatically and automatically using the $20 \log R$ time-variable gain (TVG) function was set in the *Visual Acquisition* software, where R is the distance from the transducer to the target. To avoid systematic errors in collecting acoustic data, before collecting raw acoustic data, a hydroacoustic system calibration is performed using a *tungsten carbide* standard sphere \varnothing 31 mm. The

values of the hydroacoustic system parameters that were set on acoustic data collection are presented in Table 1

Table 1. Hydroacoustic system parameter values set on retrieval acoustic data in the field.

Hydroacoustic System Parameters	Value
Data Threshold	-130 dB
Ping Rate	3 pps
Collection Range	50 m
Pulse Width	0.1 μ s
Time Between Report (TBR)	10 minute

Size of *Elementary Sampling Distance Unit* (ESDU) for *echointegration* was set for a minute (\pm 125 meters for an average ship speed of 5 knots) with a transmission rate of 3 *ping/second*, meanwhile adjusting position and ship's voyage direction to the position and direction of transect lines which has been designed, was determined using a JRC (Japan Radio Cooperation) GPS receiver. Position and time of data acquisition in each ESDU recorded simultaneously and automatically, so that the output of *echointegrator* was equipped with data position and data acquisition time and saved automatically in computer harddisk. Acoustic data acquisition in this research started at 08.00 to 12.00 Eastern Indonesian Time.

2.3. Acoustic data processing method

Acoustic raw data processing for resulting anchovy densities data for both vertical and horizontal distribution directions were using Visual Analyzer Program. Anchovy density from vertical hydroacoustic sampling from each ESDU was estimated for each 5m water thickness from transducer surface down to the bottom according to [13] as follows:

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

where *FPCM* is an anchovy density per 10^3m^3 , S_v is volume of back-scattering strength, and $\bar{\sigma}_{BS}$ is mean backscattering cross section. The S_v value was calculated using the following formula:

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

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

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

where $\pi = 3.14159$, pw = pulse width (second), c = sound speed (m/second), SL = source level ($\text{dB}\mu\text{Pa}$), RS = receiver sensitivity of transducer (dB), and $E[b^2]$ = beam pattern factor.

Anchovy density from horizontal hydroacoustic sampling was estimated according to [13] as follows:

$$FPUA = \sum AD_i * IT_i * \frac{\%_i}{100}$$

where *FPUA* is anchovy density per 10^3m^2 (unit area) which is the sum of vertical absolute density, where *FPUA* is *Fish Per Unit Area*; *AD* is absolute density and *IT* is *Interval Thickness* of water layer

determined by the software operator during analysis, while i is the strata index. AD values are obtained by the formula [14]:

$$AD = RDxC$$

where RD is relative density and C is echointegrator scaling factor. Vertical distribution of anchovy data was plotted on the graph to observe vertical distribution pattern. The plot was done on Microsoft Excel 2007. In this research was not performed sampling fish data for verification, but using total length data of anchovy in research result of [2]. He noted that total length size of anchovy in Inner Ambon Bay were in the range of 3.5 – 7.0 cm. This fish length data then converted into target strength values for setting minimum and maximum amplitude threshold in receiving echo pulse of anchovy in acoustic raw data processing. Setting the threshold above is to ensure that echo signals received were only echo signals from anchovy, meanwhile, echo signals outside the setting values were rejected, so that, they were not included in the next analysis. Conversion total length sizes of anchovy to target strength values according to [15] as follows:

$$TS = 20 \text{Log} L - 71.9$$

where TS is target strength (dB) and L is anchovy length (cm). The target strength calculation results to anchovy length was obtained that for 3.5 cm total length was -61 dB and for 7.0 cm total length was -55 dB. These two target strength values were used as both data threshold and bottom threshold in processing anchovy density, respectively. The hydro-acoustic system parameters were set in acoustic data processing as presented in Table 2.

Table 2. The hydro-acoustic system parameter values were set in processing anchovy density

Hydroacoustic System Parameters	Value
Ping Range	1 – 1800
Sample Range	1 – 50 m
Bottom Threshold	-55 dB
Data Threshold	-61 dB
Number of Strata	10
Number of Reports	10

2.4. Data analysis method

The average density of anchovy is calculated using formulas of [16] as follows:

$$\bar{x} = \sum x_i / n$$

where x_i is density of anchovy and n is number of sample. Variance of anchovy densities is calculated by the formula:

$$s^2 = n \sum x_i^2 - (\sum x_i)^2 / n(n - 1)$$

deviation standard (Std) is obtained by formula :

$$Std = \sqrt{s^2}$$

Data of anchovy densities were also analyzed its frequency distribution with the range between the class mean values were 2000 individuals/10³m³. Analyzes above solved with application of SPSS version 22.

The horizontal distribution of anchovy density was analyzed using gridding method through two dimensional ordinary techniques [17] 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 weight
 n = number of nearest samples that used in kriging
 γ = variogram of fish density
 μ = lag distance parameter

The variogram was obtained according to [18] with the following formula:

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

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

3. Result and Discussion

3.1. Anchovy density

Statistical of anchovy densities in Inner Ambon Bay on Dry Season is presented in Table 3. The densities data in Table 3 shows that average density of anchovy varies between months on Dry Season. Lower average value of anchovy density was found in January (135 ind./10³m³), meanwhile higher average value of anchovy density was found in February (442 ind./10³m³). Based on standard deviation values in Table 3 showing variation of anchovy density intra *Elementary Sampling Distance Unit* (ESDU) were higher in February (861 ind./10³m³) meanwhile, lower variation was showed in December (394 ind./10³m³). These variations of anchovy from month to month in inner Ambon Bay on Dry Season allegedly caused by variation of fitoplankton and zooplankton abundance which play an important role as anchovy food. According to [19] anchovy is the main omnivore group of phytoplankton and zooplankton.

Table 3. Statistical of anchovy densities in Inner Ambon Bay on Dry Season

Month	Minimum	Maximum	Average	Std. Deviation
December	2	2,594	190	394
January	1	3,688	135	436
February	2	54,389	442	861

The frequency distribution of anchovy density from each time between report (TBR) in inner Ambon bay on Dry Season are shown in Figure 2.

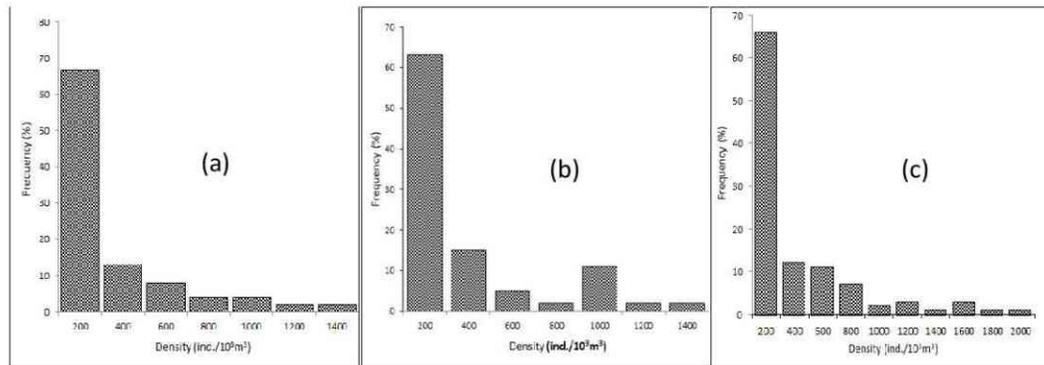


Figure 2. Frequency distribution of anchovy density in IAB on Dry Season.
(a) December, (b) January and (c) February.

The histogram in Figure 2 above shows that the frequency of the density of anchovy in inner Ambon bay relatively have a log normal distribution with a dominant frequency (mode) was in the density value of 200 fish / 10^3m^3 . Based on this density mode values, can be concluded that the density of anchovy in inner Ambon bay on Dry Season is dominated by low densities. Variation on average densities of anchovy in January was lower than average densities of anchovy in December and February might be affected of zooplankton variation as a food of anchovy. Research result of [20] shows same variation in zooplankton densities on Dry Season in Inner Ambon Bay where average density in January was lower than average densities in December and in February (Table 4). Comparing the average densities of anchovy in Table 3 and average densities of zooplankton in Table 4, it can be concluded that variation on anchovy densities in Inner Ambon Bay on Dry Season was effected of variation of zooplankton density in the season.

Table 4. Statistical of zooplankton densities in Inner Ambon Bay on Dry Season

Month	Minimum	Maximum	Average	Std. Deviation
December	64	75.134	921	6.591
January	66	5.240	367	537
February	78	578.000	1.495	9.073

Source: [20]

3.2. Vertical distribution

Vertical distribution of anchovy density in December shows that the anchovy distributed from near surface down to 35m depth layer with fluctuation pattern intra depth layers. At the near surface was found lower density of anchovy (20 ind. / 10^3m^3) meanwhile higher density was found at 25m depth layer (Figure 3). This vertical distribution pattern of anchovy densities was as same as vertical distribution pattern of anchovy densities on February (Figure 3).

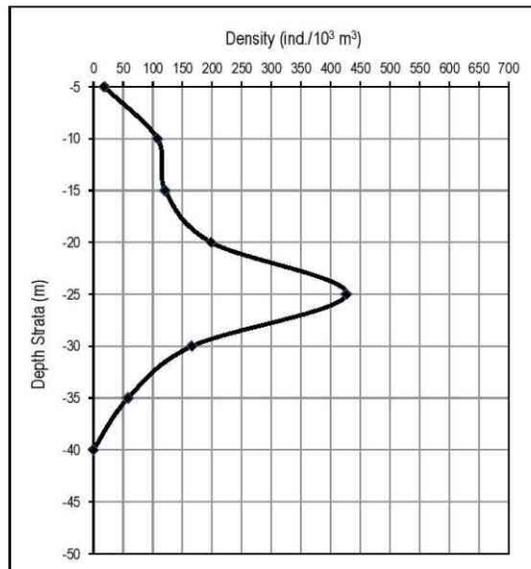


Figure 3. Vertical distribution of anchovy density in IAB on December

The range of vertical distribution of anchovy density on January was as same as the range vertical distribution of anchovy densities both on December and February i.e. from near surface to 35m depth layer, but higher density was found at 30m depth layer (Figure 4). The presence of high density of anchovy at differ depth layers might be an effort to adjust optimum temperature and sunlight intensity for their life.

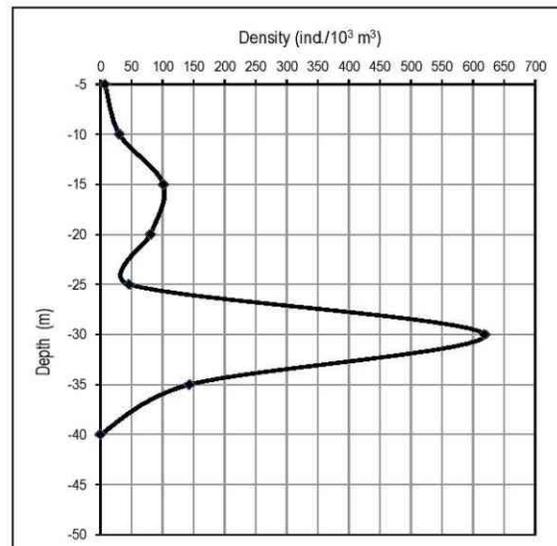


Figure 4. Vertical distribution of anchovy density in IAB on January

From the figures 3, 4 and 5, it can be seen that the high density of anchovy in December was lower than high densities of anchovy both in January and February.

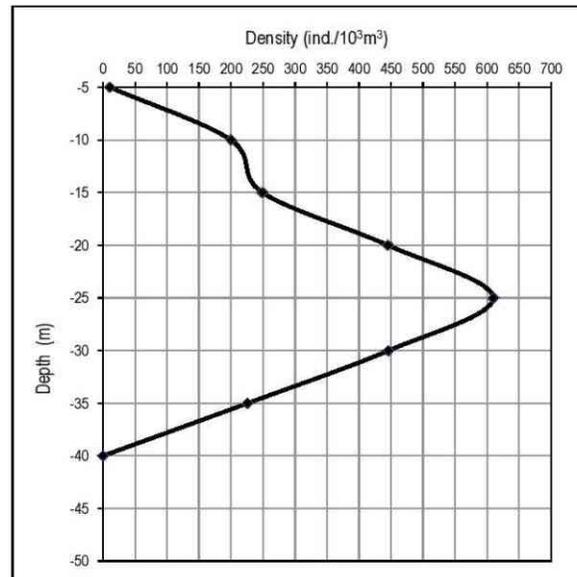


Figure 5. Vertical distribution of anchovy density in IAB on February

3.3. Horizontal distribution

The horizontal distribution pattern of anchovy density on December, January and February are presented in Figure 6, 7 and 8. The contour in Figure 8 shows that fish with low density (0 - 2000 individuals / 10³m²) occupy a large space in inner Ambon bay, which is evenly distributed in the west, north, east, central and south of the Inner Ambon Bay. Fish with a density of 2000 - 12000 individuals / 10³m² are in small fish school and occupy a small space and are scattered in the south-west, southern, northern and western part of Inner Ambon Bay (Figure 6).

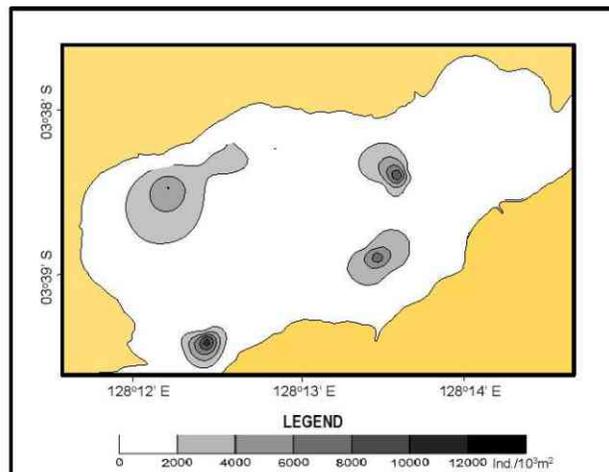


Figure 6. Horizontal distribution of anchovy density in IAB on December

Same with horizontal distribution of anchovy densities in December, Figure 7 shows that on January fish with low density (0 - 2000 individuals / 10^3m^2) occupy a large space in inner Ambon bay, which is evenly distributed in the northern, eastern, and south-west of the Inner Ambon Bay. But comparing with density of anchovy in December where fish with a density of 2000 - 36000 individuals / 10^3m^2 are in small fish school occupy a small space and are scattered only in the western, few in northern and southern part of Inner Ambon Bay.

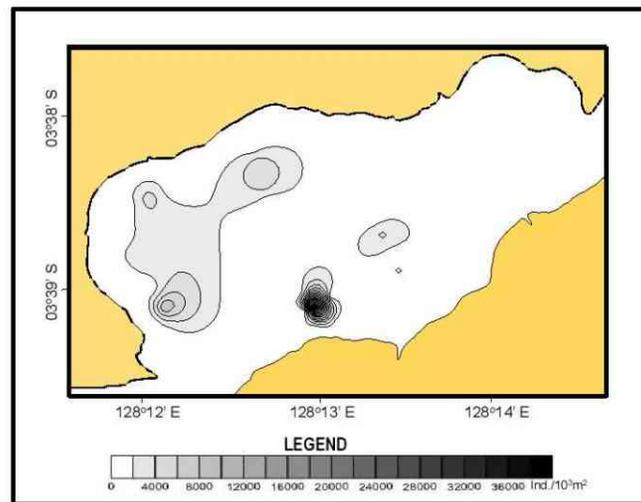


Figure 7. Horizontal distribution of anchovy density in IAB on January

The same as horizontal distribution of anchovy in December and January where in February anchovy with low density (0 - 2000 individuals / 10^3m^2) occupy a large space in inner Ambon bay, which is evenly distributed in the western, central and eastern part of the Inner Ambon Bay, comparing to anchovy density of 2000 - 36000 individuals / 10^3m^2 are in small schools and occupy a small space and are scattered only in the south-western, southern and eastern part of Inner Ambon Bay (Figure 8).

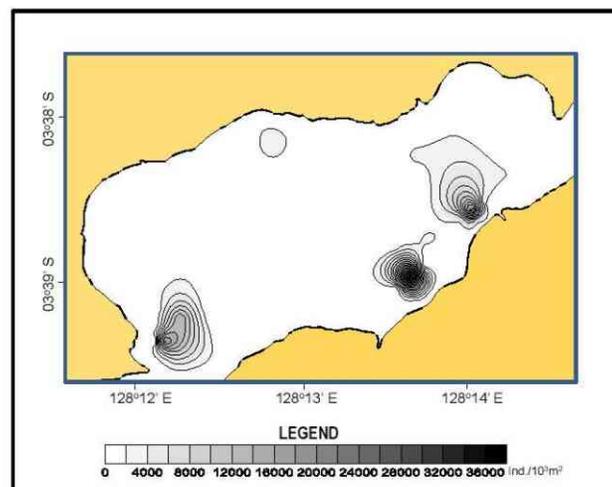


Figure 8. Horizontal distribution of anchovy density in IAB on February

The high density of anchovy at certain location and the low density at other location in the waters indicate that the density distribution of anchovy in the inner Ambon bay is not random but *clumping*. According to [21] the distribution of fish in waters is not random, but will be well organized by physical, chemical and biological factors that control the activity of these fish. These activities include: foraging for food, predator avoidance, testing, and habitat selection. Particularly for fish in the waters, [22] states that the fish that joint the community are coherent according to different environmental factors such as: up-welling, seabed type, tropical system, water temperature and salinity and productivity. However, this research did not observe environmental factors so that the contribution of their influence to the spatial and temporal distribution of anchovy density in the Inner Ambon Bay was unknown.

4. Conclusions and Recommendations

4.1. Conclusions

From the results of this research, can be concluded as follows :

- (1) The density of anchovy fluctuated in inner Ambon bay in Dry Season where average of 190 individuals/10³m³ in December, 135 individuals/10³m³ in January and 442 individuals/10³m³ in February and dominated by low density. Variation of anchovy densities are affected by variation of zooplankton densities in this season.
- (2) In vertical distribution, generally, anchovy were distributed from 5m to 35m depth layer, but high densities where found at 25m depth layer both in December and February, and at 30m depth layer in January.
- (3) horizontal distribution, generally, lower density of anchovy occupy a large space, in contrast, higher density are in small fish schools occupy a small space and are scattered in given parts of Inner Ambon Bay but at differ locations from month to month.

4.2. Recommendation

For the purposes of biomass management of anchovy in inner Ambon bay, a comprehensive research is needed on the type, size, spawning season, density, potential and level of exploitation as well as waters quality for several years.

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