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Size, spatial distribution and potential of anchovy in Inner Ambon Bay

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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 aim of the research is to obtain information of population size, spatial distribution of densities and Maximum Sustainable Yield of anchovy. Densities data of fish were obtained using hydro acoustics device at six parallel transect lines and one cross parallel transect line in October 2015. Three fish species caught by beach seine, comprise *Encrasicholina heteroloba* (96.3%), *Sardinella* spp.(2.8%) and *Rastrelliger* spp.(0.9%). Mean value of total length of *E. heteroloba* was 5.30 cm shorter than the length of same fish noted in October 2005 was 5.48cm. Spatial distribution of anchovy densities shows that low density (0-2 fish/m²) occupy wider space, evenly distributed in north, east, and south of the bay. The fish density of 2-4 fish/m² were in small groups occupy smaller space distributed in the middle to west of the bay. The density 4–6 fish/m² to high density 28–30 fish/m² occupy only very small space in the west near bay mouth. Maximum sustainable yield of anchovy in inner Ambon Bay was estimated 6.9±4.3 tons.

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. 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 types (not selective) of anchovy. Fluctuation in fish catch in bait fish fishery in inner Ambon bay in 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 device 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 in management of this resources is rarely done. Information regarding size, density, and maximum sustainable yield of anchovy management resources, is not yet known in certainty.

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



The aim of this research is to obtain informations of : (1) population size of anchovy in different period of time, (2) densities of anchovy and its spatial distribution, and (3) maximum sustainable yield of anchovy. The result of this research hopefully useful as a basic information for management policy of anchovy resources in inner Ambon bay.

2. Materials and Method

2.1 Research tools

This research done in inner Ambon bay waters, Ambon city. Its located at coordinates 128°12.14' E - 128°14.65' E and 03°37.68' S - 3°39.38' S. Tools used in this research for data acquisition to data analysis in laboratorium are (1) speed boat size in length x width x height = 7x1.2x1m, (2) measuring ruler and digital balance, (3) BioSonics hydroacoustic device type DT-X with 200kHz operational frequency and beam degree (half power points) 6 degree, (4) Global Positioning System (GPS) receiver JRC (Japan Radio Corporation), (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.

2.2 Data collection

Data collected in this research are total length, wight, and density of anchovy. Length and weight of anchovy collected in two locations; waters of Waiheru village and waters of Hallong village. Fish samples obtained by catch of beach seine with fishing light. Length of beach seine is 100m, its width in middle is 7m, and its wings are 5m with mesh size in the middle of fishing net is 0.5mm and 25.5mm in its wings. Fishing net is made of knotless nylon (on bunt), meanwhile on its wings using fishing net made from polythylene. Fish sample acquisition done with simple randong sampling technique using scoop net. The fish samples also to measure its weight using digital balance. Acoustic raw data obtained using BioSonic hydroacoustic DT-X controlled by *Visual Acquisition* 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. The values of the hydroacoustic system parameters that were set on acoustic data collection are presented in Table 1. Acoustic 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 set in the *Visual Acquisition* program. To avoid systematic errors in collecting acoustic data, before collecting basic acoustic data, a hydroacoustic system calibration is performed using a standard sphere \varnothing 31 mm made of *tungsten carbid*.

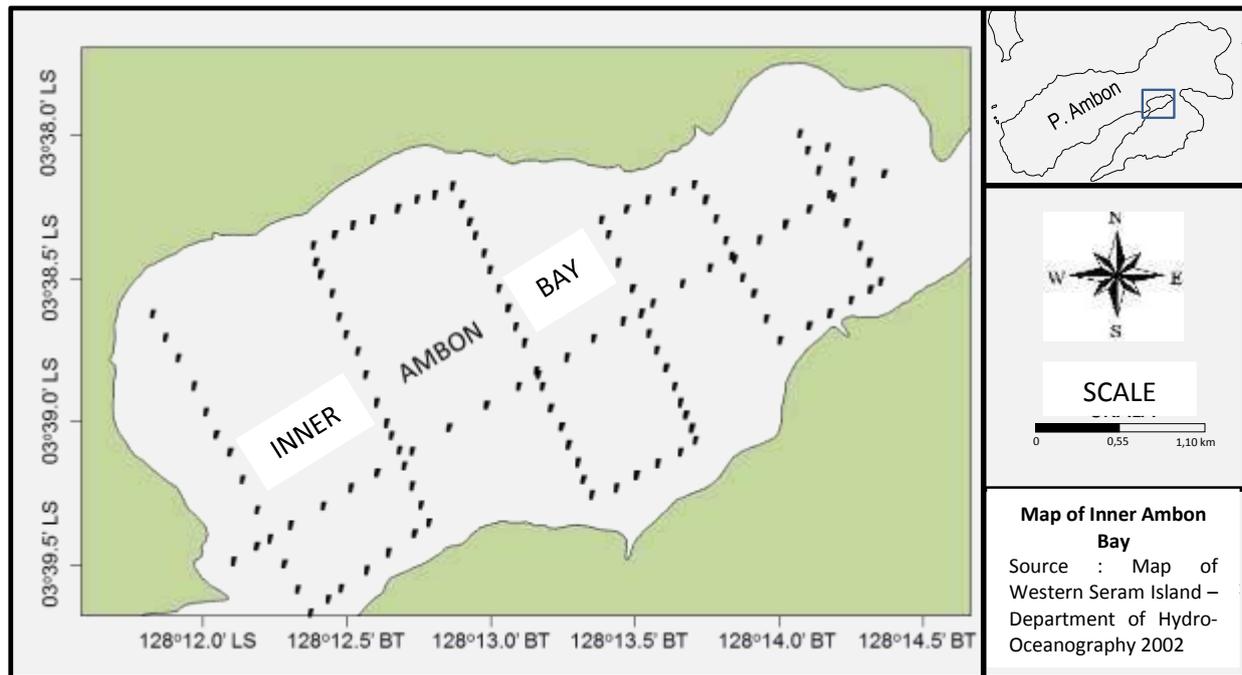


Figure 1. Map of research location in inner Ambon bay. Black dots following the shape of a parallel transect line of north-south direction and a transect line crosses the east-west direction showing recording positions of relative fish density data. The distance between these dots is a size of *Elementary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

Relative density values of fish were collected using *echointegration* technique which took place programmatically and automatically using the 20 log R time-variable gain (TVG) function, where R was the distance from the transducer to the target.

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

Hydroacoustic System Parameters	Value
Ping Range	1 – 1800
Sample Range	1 – 50 m
Bottom Threshold	-30 dB
Data Threshold	-60 dB
Number Strata	10
Number Reports	10

Size of *Elementary Sampling Distance Unit* (ESDU) for *echointegration* was set for a minute (± 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 haddisk. Acoustic data acquisition in this research started at 14.00 to 17.00 Eastern Indonesian Time.

2.3 Data analysis

Data of total length (TL) of anchovy was analyzed its frequency distribution with the distance between the class mean value of 0.5 cm. The mean value of the total length, variety and standard deviation of shorthead anchovy is calculated using formula [14]:

$$x = \sum \frac{x_i}{n} \quad (1)$$

where x is total length of shorthead anchovy and n is number of sample. Variety of sample length size of shorthead anchovy is obtained by the formula :

$$s^2 = n \sum x^2 - \left(\sum x \right)^2 / n(n-1) \quad (2)$$

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

deviation standard (Std) is obtained by formula :

$$Std = \sqrt{s^2} \quad (3)$$

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

Analyzes above solved with application of SPSS version 22.

Fish density in each ESDU estimated by formula of BioSonic Inc. (2004) in Visual Analyzer program as follows :

$$FPUA = \sum AD_i * IT_i * \frac{\%_i}{100} \quad (4)$$

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

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:

$$AD = RD * C \quad (5)$$

where RD is relative density and C is echointegrator scale factor. The hydroacoustic system parameter were set in acoustic data processing as presented in Table 2.

Table 2. The hydroacoustic system parameter values set in analysis of fish density.

Hydroacoustic System Parameters	Value
Data Threshold	-130 dB
Threshold Type	Squared
Ping Rate	3 pps
Collection Range	50 m
Pulse Width	0.1 μ s

The spatial distribution of fish density is obtained through a geostatistical approach, namely the two-dimensional *ordinary kriging* technique [15] as follows:

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

$$\sum_{\beta=1}^n \lambda_{\beta} \gamma(x_{\alpha}, x_{\beta}) + \mu = \gamma(x_{\alpha}, x) \quad (6)$$

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

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

where x is location position estimated in two dimension; x_{α} is position of an sample in two dimension system; λ = weight of kriging; n = number of adjacent samples used for kriging; γ = variogram of fish density and μ = parameter of distance *lag*.

The confidence interval of mean fish density is obtained by the formula :

$$d \pm \frac{t_{\alpha} \frac{s}{\sqrt{n}}}{\sqrt{n}} \quad (7)$$

$$d \pm t_{\alpha/2} s / \sqrt{n}$$

where d mean density of anchovy, s is deviation standard, n is number of densities.

The abundance (Q) of shorthead anchovy in inner Ambon bay is calculated by formula :

$$Q = d * A \quad (8)$$

where d is mean density of shorthead anchovy and A is area of inner Ambon bay. Biomass (Bo) of shorthead anchovy is obtained by the formula :

$$Bo = Q * w \quad (9)$$

where w is mean weight of shorthead anchovy. The shorthead anchovy potential is obtained by calculating value of Maximum Sustainable Yield (MSY). Cadima's empirical equation [16], which is modified from Gulland's model is applied to estimate MSY using biomass data from the hydroacoustic method as follows :

$$MSY = 0.5 * MBo \quad (10)$$

3. Result and Discussion

3.1. Variety and size of fish

Fish sampling data in waters of Waiheru village and waters of Hallong village, obtained three types of economic important fish, comprising shorthead anchovy (*Encrasicholina heteroloba*), indian oil sardine (*Sardinella longiceps*) and indian mackerel (*Rastrelliger kanagurta*), nevertheless, number of shorthead anchovy is dominating fish sample acquisition (Figure 2) at 96.3%, indian oil sardine 2.8%, and indian mackerel 0.9%. Thus, in this research shorthead anchovy is the priority species in the analysis, while indian oil sardine and indian mackerel were not included. The pelagic fish community in waters of inner Ambon bay consists of *resident* fish species, *occasional* species and *accidental* types [2]. Mean density of inter seasonal abundance of shorthead anchovy is increased in time of east season (April-August), and survive in the second transition season (September-October), this is due to the recruitment process, growth and / or elimination. Shorthead anchovy and indian oil sardine are local resident fish.

The total length size of sampled shorthead anchovy ranged from 3.4 to 6.9 cm with an average of 5.2 cm and an average weight of 0.9 grams. Length distribution of shorthead anchovy in inner Ambon bay during the research period is shown in Figure 2.

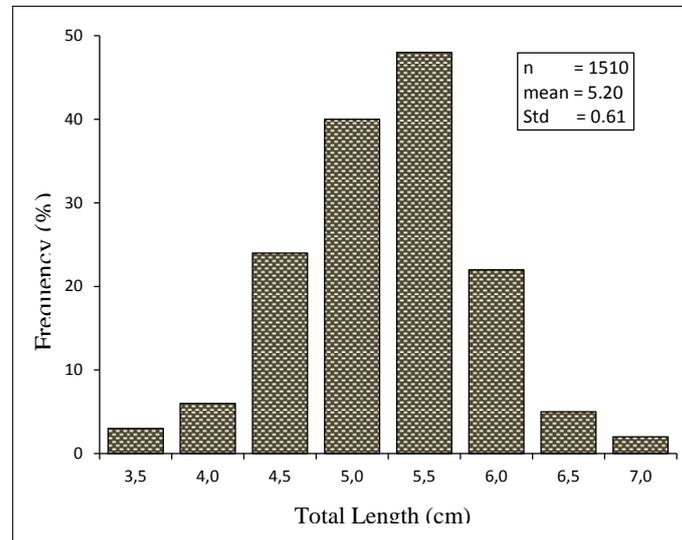


Figure 2. Frequency distribution of total length size of shorthead anchovy in inner Ambon bay in October 2015.

Histogram in Figure 2 above shows that the frequency of the total length of anchovy in 2015 is relatively have a normal distribution with the dominant mode or number of frequencies at a total length of 5.5 cm (32%) in total length, in this case it is not much differ from the size average total length of 5.20 cm with a standard deviation of 0.61 cm.

Meanwhile, in Figure 3 below shows sampled shorthead anchovy in October 2005 have dominant mode in length total of 6.0cm with mean length of 5.48cm. Thus, length of anchovy in 2015 is smaller than length of anchovy in 2005 in comparison.

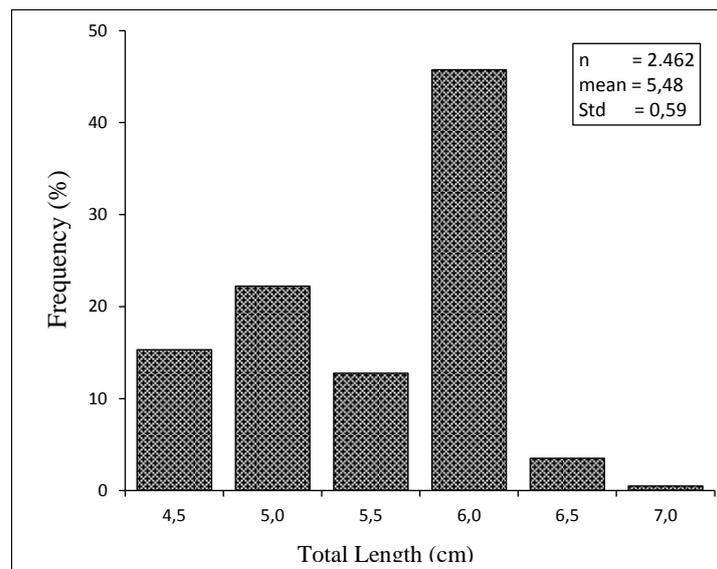


Figure 3. Frequency distribution of total length of shorthead anchovy in inner Ambon bay in October 2005.

The length of anchovy in two different of periods within 10 years shows its length getting smaller, the first could be due to the time of the recruitment period which is not constant where recruitment for fish populations in 2015 was slower than the recruitment period for anchovy population in 2005. This can be seen by smaller fish in the size class 3.5 and 4.0 cm in October 2015 while in October 2005 the two size classes were not found. The second reason is due to slower growth speed by availability of food and changes in water quality. Changes in water quality is in consequence of changes in the ecosystem around the bay through the demolition of land for residential development and the use of pesticides in horticultural farming activities nearby the gulf coast of the bay where in the rainy season, some of the land from demolition and residual pesticides are carried away by the flow of water into the bay which causes it to occur sedimentation and pollution. Ambon bay for several decades before was wellknown as the source of anchovy [17]. However, due to the development of the coastal areas of the bay, there was a degradation of the quality of the waters and this caused a tendency to decrease the abundance of phytoplankton and zooplankton. In connection with the degradation of water quality in Ambon Dalam Bay, [18] found three potential sources of heavy metal pollution in mangrove forests in inner Ambon Bay, namely agricultural activities, residential areas and motor boats / fishing boats.

3.2 Anchovy density and its spatial distribution

An example of the result of acoustic baseline data acquisition with the BioSonic DT-X hydroacoustic device in the form of an echogram is shown in Figure 4. The result of acoustic raw data analysis using the Visual Analyzer program obtained 121 ESDUs with density values ranging from 0.5 - 28.5 fish/m². The frequency distribution of anchovy density from each ESDU in inner Ambon bay is shown in Figure 5.

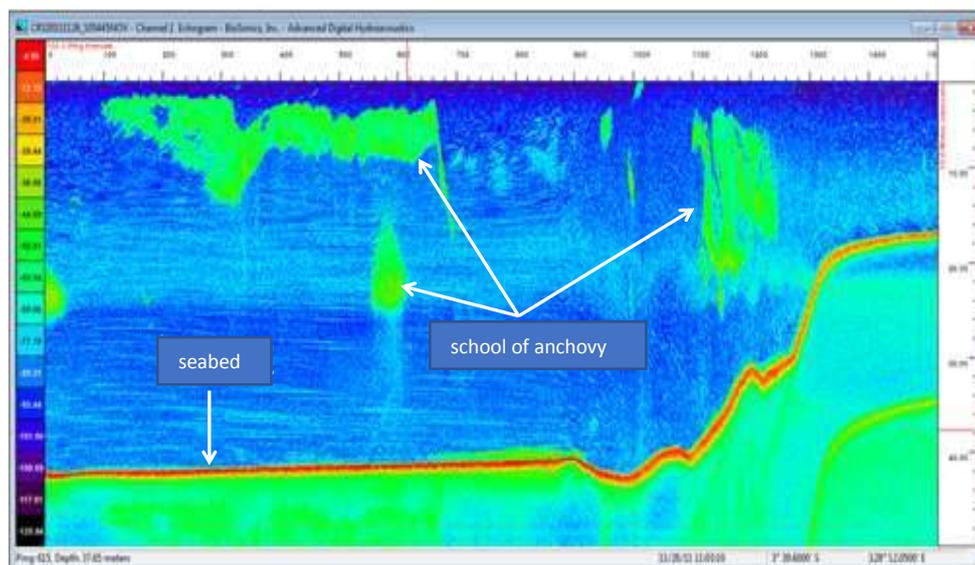


Figure 4. The recorded echogram of the school of shorthead anchovy with hydroacoustic device near the mouth of the inner Ambon bay on October 2015.

The histogram in Figure 5 below shows that the frequency of the density of anchovy in inner Ambon bay relatively have a log normal distribution with a dominant frequency (mode) is in the density value of 0.5 fish / m² (60.4%), with mean density 1.3 fish / m² and 2.95 fish / m² standard deviation. From this density mode value, it can be concluded that the density of anchovy in inner Ambon bay is dominated by low densities.

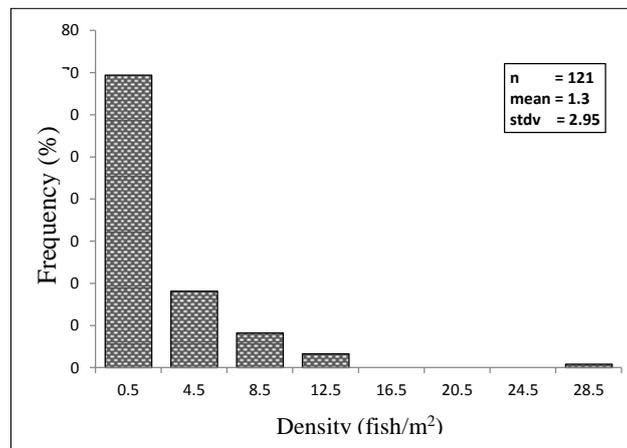


Figure 5. Frequency distribution of anchovy density in inner Ambon bay in the detection result of hydroacoustic device in 2015.

The spatial distribution pattern of shorthead anchovy density is presented in Figure 6. The contour in Figure 6 shows that fish with low density (0 - 2 individuals / m²) occupy a large space in inner Ambon bay, which is evenly distributed in the north, east and south. Fish with a density of 2 - 4 individuals / m² are in small fish school and occupy a small space and are scattered in the central to western part of inner Ambon bay. Fish with a density of 4-6 individuals / m² to fish with a high density of 28-30 individuals / m² only occupy a narrow space in the western part of inner Ambon bay, nearby the mouth of the bay. It is suspected that the high density of anchovy in this part of inner Ambon bay is related to their abundance of food, namely phytoplankton and zooplankton there.

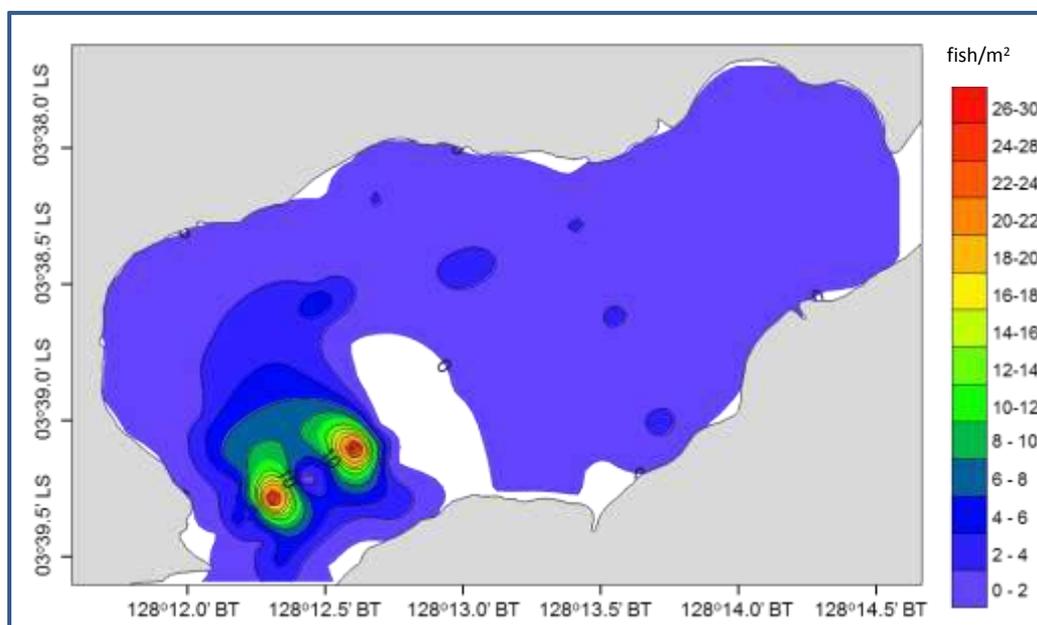


Figure 6. Pattern of Fish Spatial Distribution in Inner Ambon Bay.

The high abundance of fish at certain location and the low abundance of fish at other location in the waters indicate that the density distribution of small pelagic fish in the inner Ambon bay is not random but *clumping*. Distribution of fish in a 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 [19]. Particularly for fish in the waters, the fish that join the community are coherent according to different environmental factors such as: upwelling, seabed type, tropical system, water temperature and salinity and productivity [20]. However, this research did not observe environmental factors so that the contribution of their influence to the spatial distribution of fish density in the waters studied was unknown.

3.3 Potential of shorthead anchovy

The result of the analysis of the density, abundance, mean weight, biomass and maximum sustainable yield of shorthead anchovy in an area of inner Ambon bay 11.04 km² presented in Table 3 below.

Table 3. The results of the analysis of the maximum sustainable yield of anchovy in inner Ambon bay.

Biological Parameters	Value
Mean density (individual/m ²)	1.3±0.86
Abundance (individual)	14,339,000±10,467,671
Fish mean weight (gram/individual)	0.96
Biomass (ton)	13.77±8.6
Maximum Sustainable Yield MSY (ton)	6.90±4.3

The result of data analysis in Table 3 above shows that the maximum sustainable yield of shorthead anchovy in inner Ambon bay was 6.90 ± 4.3 tons in October 2015. If the need for live bait for one skipjack pole and liner is an average of 20 kg/trip, and the number of catch trips per boat is an average of 15 trips/month, then maximum sustainable yield of the shorthead anchovy may meet the needs of bait fish for 4-5 skipjack pole and liner per month.

4. Conclusion and Recommendation

4.1. Conclusion

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

- (1) The mean length of anchovy in 2015 in inner Ambon bay was 5.20 cm, smaller than the mean length of anchovy in 2005, was 5.48 cm, presumably due to differences in the recruitment season and water quality degradation.
- (2) The density of shorthead anchovy in inner Ambon bay is in the range of 0.5 - 28.5 ind./m², with an mean value of 1.3 ind./m². The spatial distribution shows that the low density (0 - 2 individuals/m²) occupies a wider space, which is evenly distributed in the north, east and south. Fish with a density of 2-4 individuals/m² are in small groups and occupy a small space scattered in the central to western part of inner Ambon bay, while fish with a density of 4-6 individuals/m² to 28-30 individuals/m² are only occupies a narrow space in the western part of inner Ambon bay which is near the boundaries of inner Ambon bay and outer Ambon bay.
- (3) The maximum sustainable yield of shorthead anchovy in inner Ambon bay in October 2015 was estimated at 6.90 ± 4.3 tonnes.

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.

Acknowledgement

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