Survey Report on Fisheries Resources Abundance around Sulu and Sulawesi Seas by Using Hydroacoustic Equipment

- Hydro-Acoustic Survey during Pre and Post Monsoon in Sulu Sulawesi Seas
- Distribution of Pelagic Fish Aggregations in around Fish Aggregating Devices (FADs) by Acoustic Surveys in Sulawesi Sea

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Joint Research Program on Tuna Resources in Sulu and Sulawesi Seas

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Survey Report

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Southeast Asian Fisheries Development Center

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Hydro-Acoustic Survey during Pre and Post Monsoon in Sulu Sulawesi Seas

Hydro-Acoustic Survey during Pre and Post Monsoon in Sulu Sulawesi Seas

Raja Bidin bin Raja Hassan[1], Jamil bin Musel[2], Abdul Wahab bin Abdullah[3], Mohammad Faisal bin Md Saleh[1], Mohd Zamani@Zamani bin Nayan@Sukardi[4], Osman bin Muda[1], Rosdi bin Mohd Nor[1] and Ali Suman[5]

ABSTRACT

An acoustic survey was carried out from 25 October 2014 until 27 November 2014 for pre-monsoon season and 28 March 2015 until 1 May 2015 for post-monsoon season which covered all Sulu-Sulawesi Sea areas. The objective of the survey is to evaluate the small pelagic resources in Sulu Sulawesi Sea waters. The survey was conducted by using research vessel M.V.SEAFDEC2 that equipped with a scientific echo sounder FURUNO FQ80-M system. The survey was carried out covering a total area of approximately 327,420 km^2. Raw data of back scattering strength from 130 transects were recorded by FQ80 Data Analyzer and then was analysed by FQ80 and MS Excel. Calculation for pelagic fish density was based on the dominant pelagic species for each leg. While, quantitative assessment to estimate for pelagic fish biomass was carried out by using the average density of pelagic fish at each transect. The dominant pelagic species observed during samplings were *Rastrelliger kanagurta*. The average density of pelagic fish in Sulu Sulawesi Sea in 2014 and 2015 were estimated at 2.80 MT/km^2 and 2.88 MT/km^2 respectively. The total pelagic fish biomass for Sulu Sulawesi Sea in 2014 and 2015 were estimated at 889,924 MT and 932,761 MT respectively. Estimated potential yield of pelagic fish for these two years were based on the natural mortality (M) of *Rastrelliger kanagurta* (1.23 year^{-1}). Their estimated values were 279,129 MT in 2014 and 294,932 MT in 2015. There are significant different observed between density and temperature in 2015 and density with chlorophyll in 2014 ($p>0.05$).

Keywords: pelagic fish resources, pelagic fish density, biomass, potential yield, oceanographic parameters

1 Southeast Asian Fisheries Development Center, Marine Fishery Resources Development and Management Department (SEAFDEC/MFRDMD), Taman Perikanan, Chendering, 21080 Kuala Terengganu, Malaysia

2 Fisheries Research Institute Sarawak, Jalan Perbadanan, Bintawa, Peti Surat 2243, 93744 Kuching, Sarawak, Malaysia

3 Bahagian Penyelidikan Perikanan Tangkapan, Fisheries Research Institute Kg. Acheh (FRIKA), Kompleks Perikanan Kg. Acheh, 32000 Setiawan, Perak, Malaysia

4 Pusat Penyelidikan Perikanan Likas, 89400 Likas, Sabah, Malaysia

5 Research Institute for Marine Fisheries (RIMF), Ministry of Marine Affairs and Fisheries, JLN Muara Baru Ujung, Jakarta, 14440, Indonesia

ABSTRAK

Satu kajian akustik telah dijalankan dari 25 Oktober 2014 hingga 27 November 2014 untuk musim pra-monsun dan 28 Mac 2015 hingga 1 Mei 2015 untuk musim selepas musim monsun yang meliputi semua kawasan Sulu-Sulawesi Sea. Objektif kajian ini adalah untuk menilai sumber pelagik kecil di perairan Sulu Sulawesi Sea. Kajian itu dijalankan dengan menggunakan kapal penyelidikan M.V.SEAFDEC2 yang dilengkapi dengan echo sounder FURUNO FQ80-M sistem saintifik. Kajian itu dijalankan meliputi kawasan seluas kira-kira 327.420 km2. Data mentah kekuatan berselerak kembali dari 130 transek direkodkan oleh FQ80 Data Analyzer dan kemudian data dianalisis dengan menggunakan FQ80 dan MS Excel. Pengiraan kepadatan ikan pelagik adalah berdasarkan kepada spesies pelagik dominan bagi setiap leg. Walaupun, penilaian kuantitatif untuk menganggar biomas ikan pelagik telah dijalankan dengan menggunakan ketumpatan purata ikan pelagik di setiap transek. Spesies pelagik dominan diperhatikan semasa sampel adalah Rastrelliger kanagurta. Ketumpatan purata ikan pelagik di Sulu Sulawesi Sea pada 2014 dan 2015 adalah dianggarkan sebanyak 2.80 tan metrik/ km2 dan 2.88 tan metrik/ km2 masing-masingnya. Jumlah biomas ikan pelagik untuk Sulu Sulawesi Sea pada tahun 2014 dan 2015 adalah dianggarkan sebanyak 889.924 tan metric dan 932.761 tan metrik. Anggaran hasil potensi ikan pelagik untuk dua tahun ini adalah berdasarkan kepada kematian semula jadi (M) Rastrelliger kanagurta (1.23 tahun-1). Nilai yang dianggarkan mereka ialah 279.129 tan metrik pada tahun 2014 dan 294.932 tan metrik pada tahun 2015. Terdapat perbezaan yang ketara diperhatikan untuk ketumpatan dan suhu pada tahun 2015 berbanding kandungan klorofil pada tahun 2014 (p> 0.05).

***Kata kunci**: sumber pelagik ikan, perairan Sarawak, biojisim, hasil potensi, densiti ikan pelagik, parameter oseanografi*

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INTRODUCTION

The Sulu-Sulawesi Sea (SSS) is located in the Indo-west Pacific region which surrounded by three countries, namely Indonesia, Malaysia and Philippines. The SSS was covering an area of about 900,000 km^2. The SSS is physically subdivided into the Sulu Sea and the Sulawesi Sea. The SSS marine eco-region (SSME) is a highly bio-diverse globally significant bio-geographic unit in the heart of the Coral Triangle - the center of the world highest concentration of marine biodiversity.

The SSS also providing livelihoods and food for coastal communities in the entire region due to its higher fishing grounds for pelagic and coral reef fishes. As located in the Coral Triangle Region, it is evident by previous studies have reported that the SSS is an important spawning and nursery ground, and migratory routes for the bigeye, yellowfin, skipjack, and neritic tunas.

The Coral Triangle also supports large population of commercially important tuna, fueling a multi-billion dollar global tuna industry. However, tuna resources have been declining and overexploited over the years due to several factors such as the increasing demand, competition, by-catch of juveniles, particularly of oceanic and neritic tunas, and lack of regional collaborative research program for sustainable management and development of marine and coastal resources in the SSS. In addition, the impacts of thousands of Fish Aggregating Devices (FADs) deployed (particularly in the Sulawesi Sea) in the area where tuna–resources have not been assessed and thus, still the status of the resources remain unknown (SEAFDEC, 2013).

There are numerous ways to estimate the status of pelagic fish resources. In this study, the pelagic fish biomass and stock status were estimated using fisheries acoustic approach. Acoustic techniques for fish resources assessment had already been widely used for a long time in European and American waters. However, this technique was only introduced in Malaysia in the early 1980s (Jamil *et al*, 2014). Meanwhile, in Philippines, previous acoustic study was done in the western part using M.V.SEAFDEC in 1998 with FQ70 system installed on board (Raja Bidin *et al*., 1998).

This survey was conducted by using research vessel M.V.SEAFDEC2 equipped with a scientific echo sounder FURUNO FQ80-M system. In this study, the area of interest is off Indonesia, Malaysia and The Philippines waters. The status of current landing pelagic fishes of Sulu Sulawesi Sea is 301,039 tonnes in 2014 and 327,364 tonnes in 2015 (JPLS, 2014, DJPT, 2015). The survey area of Sulu Sulawesi Sea waters are 327,420 km^2.

Apart from estimating fish density, biomass estimation, and correlation of the oceanographic parameters to fish distribution, acoustic survey can also estimate total biomass, potential yield, and distribution of pelagic and semi-pelagic fishes. Even though the information from the previous studies is quite thorough, a new acoustic survey needed to be done to update and validate the current status of fish resources, especially the pelagic fish density, biomass and potential yield. These will enable the fisheries management and policy formulation.

Realizing the above issues and data requirement, a research project entitled "**Hydro-Acoustic Survey during Pre and Post Monsoon in Sulu Sulawesi Seas**" was conducted in 2014 and 2015 through collaboration of three countries to evaluate the current status of pelagic fish resources in Sulu Sulawesi Sea. The financial costs were borne by each countries involved according to the Cost Sharing Policy for the Operation of the M.V.SEAFDEC2. This research project was carried out from 25 October 2014 until 27 November 2014 for pre-monsoon season and 28 March 2015 until 1 May 2015 for post-monsoon season which covered all Sulu-Sulawesi Sea areas.

OBJECTIVES

The objectives of this study are;

1. To determine the density and distribution of pelagic fishes in the Sulu Sulawesi Sea.
2. To estimate the Biomass and Maximum Sustainable Yield (MSY) for pelagic fishes by area.
3. To determine the potential fishing grounds for pelagic fishes in the Sulu Sulawesi Sea.
4. To study the correlation between fish density and oceanographic parameters.

MATERIALS AND METHODS

3.1. Survey Area and Period

The survey was conducted from 25 October 2014 until 27 November 2014 for pre-monsoon season and 28 March 2015 until 1 May 2015 for post-monsoon season covering all the Sulu-Sulawesi Sea areas as shown in **Figure 1** (2014 and 2015). The area of survey was estimated about 327,420 km^2. Survey was carried out for all proposed area of Sulu Sulawesi Sea. However the buffer zones of about 10nm were uncovered due to security reasons as advised by the National Security Council.

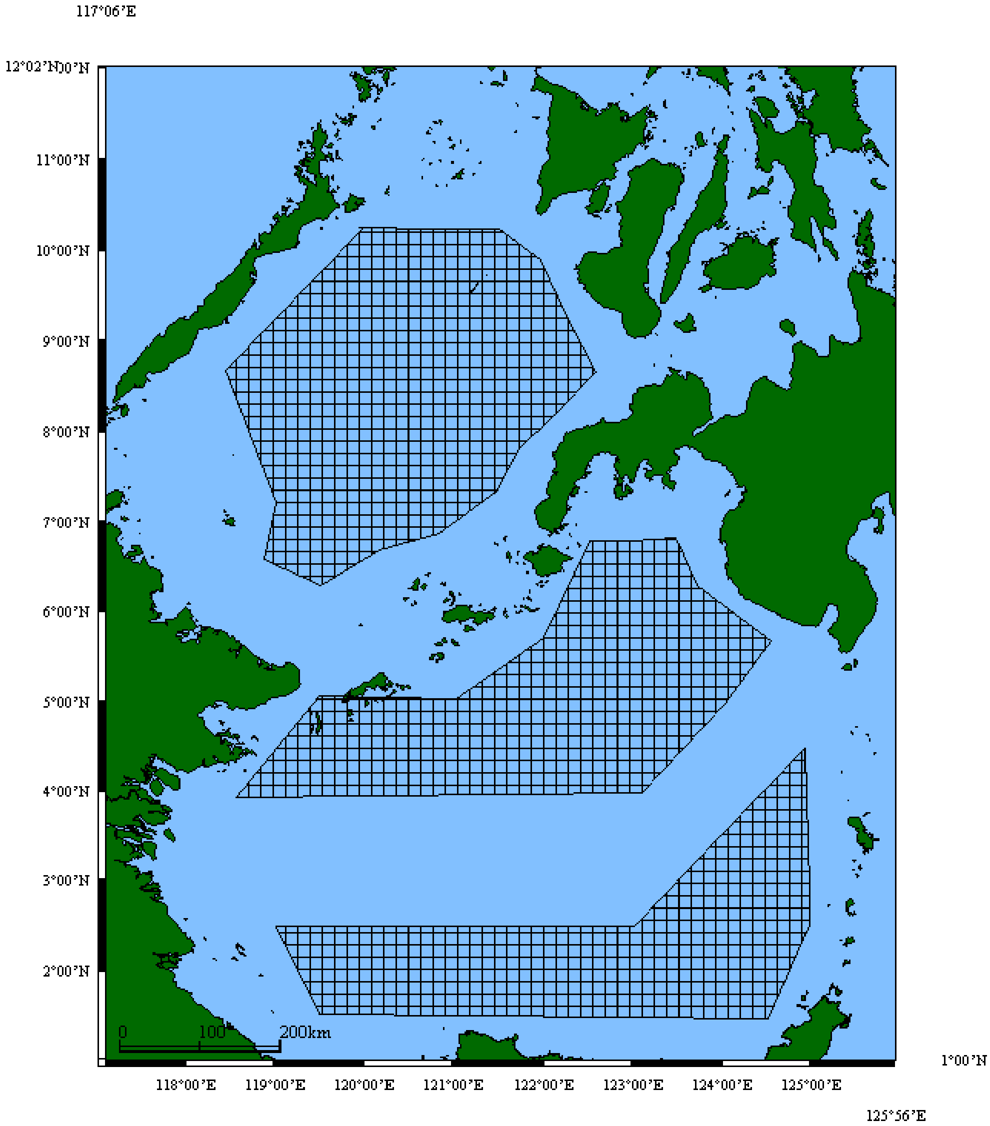

Figure 1: Acoustic survey areas of Sulu Sulawesi Sea in 2014 and 2015

3.2. Research Vessel and Equipment

3.2.1. Research Vessel

The survey was carried out by using the research vessel M.V.SEAFDEC2 (see **Figure 2**) belongs to the Southeast Asian Fisheries Development Center (SEAFDEC)/Training Department based at Samut Prakan, Thailand. The vessel is steel hull of 33.24 m overall length and 7.2 m breadth with gross tonnage of 211 GRT.

Figure 2 : Side view of M.V.SEAFDEC2 used for acoustic survey in 2014 and 2015

3.2.2. Scientific Echo Sounder

The scientific echo sounder FURUNO FQ80-M system (**Figure 3**) is the main scientific equipment installed on board of M.V.SEAFDEC2 used for collecting raw back scattering strength by volume (sv, SV) and raw back scattering by area (sa, SA) for acoustic survey. These values were automatically stored into FQ80-M Data Analyzer.

Figure 3: Monitor is one of the major components using in Scientific Echo Sounder FQ80-M System

The FQ80-M used in this study has been equipped with dual frequency transducers of 38 kHz (low frequency) and 120 kHz (high frequency). The system also comes with Data Analyzer Unit, FQ808 and link with a GPS (Global Positioning system). It has capability to separate maximum of 20 layers depth settable for higher resolution and better integration process. This system is capable to collect the sv and sa data for both frequency which then are stored automatically into system hard disk. However only sv and sa from the high frequency are used for data analysis, whilst the sv and sa values from the low frequency are only used for echogram verification. The technical operational of FQ-80M was summarized in **Figure 4.**

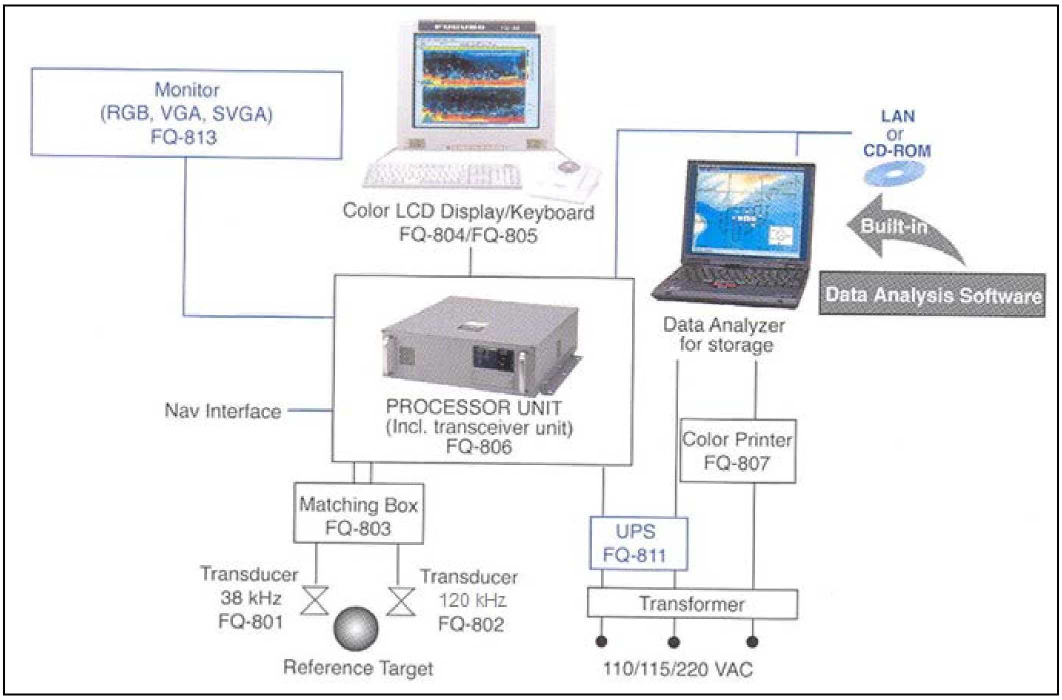

Figure 4 : Diagram of FQ-80 system configuration

3.3. Survey Personnel

This survey was conducted by team of researchers from 3 participating member countries (The Philippines, Malaysia and Indonesia). The list of researchers and supporting staff are described in the appendix B.

3.4. Calibration of FQ80-M

Calibration process is very important for the scientific echo sounder FQ80-M to ensure minimum bias/error during data collection. Calibration could be performed by using a "calibration sphere" of 38.1 mm diameter, made of tungsten carbide steel which has predetermined TS value of – 38.3dB (120kHz) or -42.4dB (38kHz).

3.5. Survey Design

The current survey has a total of 63 transects. The distance of each transect is ranged between 26.9nm and 138.3nm. The longest distance recorded in Station 38 (Leg 2) and the shortest distance recorded in station 16 (Leg 1) in 2014. The different of transect distance was depending on the survey area. The line transect of acoustic survey was shown in **Figure 5** (2014) and **Figure 6** (2015).

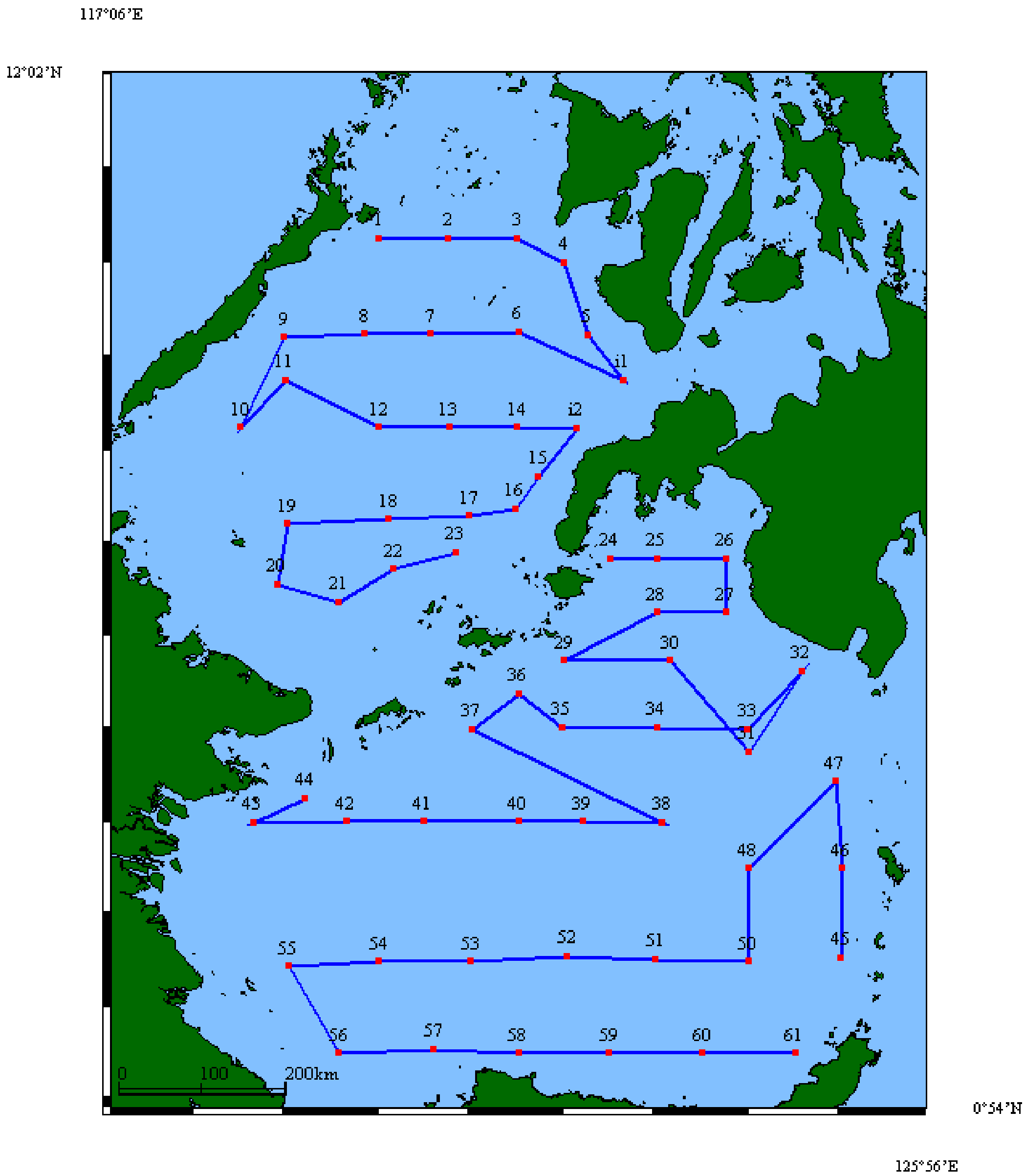

Figure 5: Line transects for the acoustic survey off Sulu Sulawesi Sea in 2014.

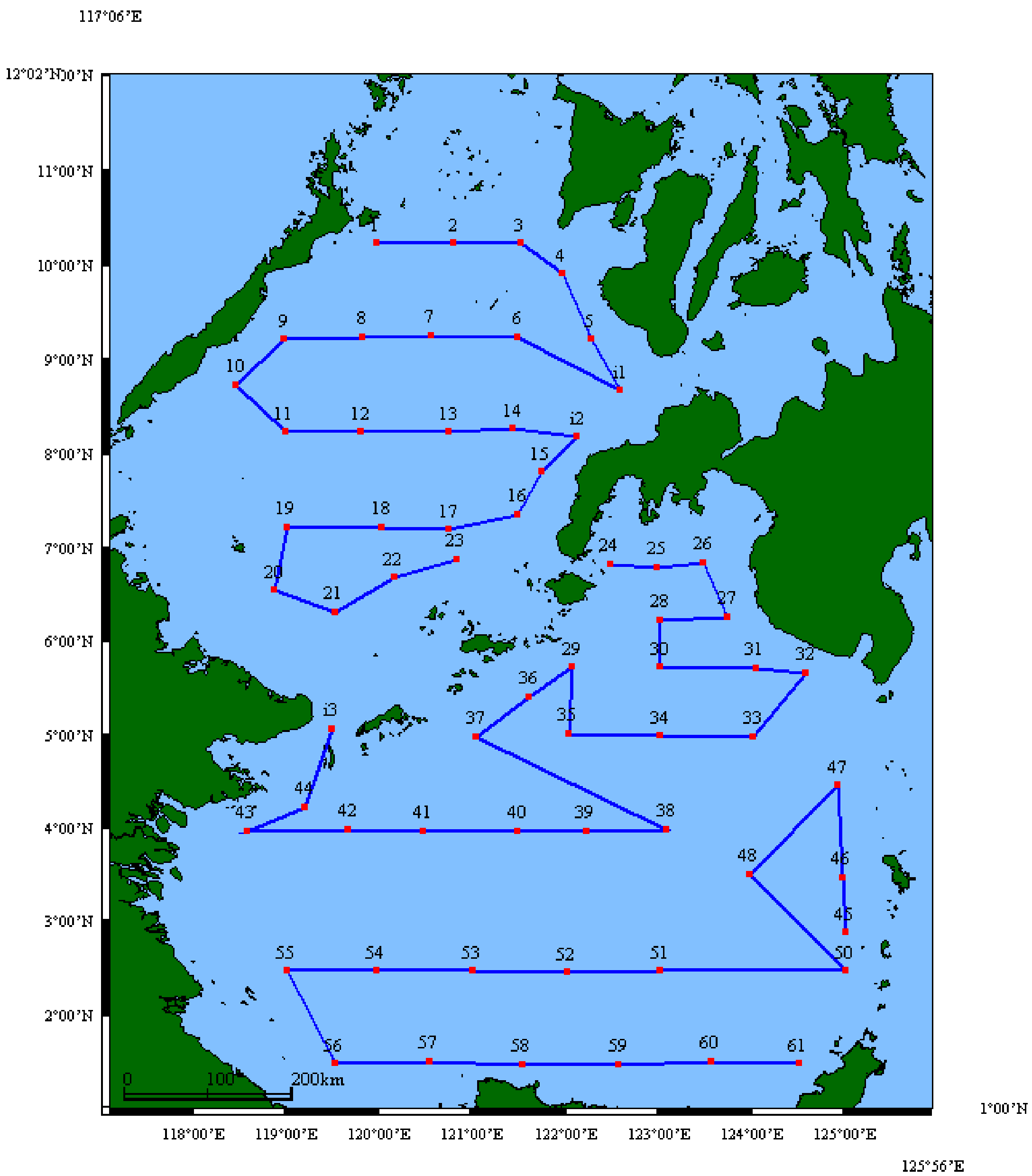

Figure 6: Line transects for the acoustic survey off Sulu Sulawesi Sea in 2015.

3.6. Sampling Procedures

3.6.1. Back Scattering Strength Values (SA and SV) Data Collection

The recording system of FQ80-M was set for 20 depth layers as shown in **Table 1**. The vessel was cruising along the survey transects at a normal speed of about 9 -10 knot. The survey cruise took about 2 hours and 15 minutes to complete one transect. The raw data of each transect were saved by individual file name which automatically stored in the FQ80-M Data Analyzer.

Table 1: Depth layers setting of FQ80-M system during the survey

Layer	Depth Range (m)	Layer	Depth Range (m)
1	0-15	11	150-165
2	15-30	12	165-180
3	30-45	13	180-195
4	45-60	14	195-210
5	60-75	15	210-225
6	75-90	16	225-240
7	90-105	17	240-255
8	105-120	18	255-270
9	120-135	19	270-285
10	135-150	20	285-300

3.6.2. Oceanographic Data Collection

The sea surface (< 3m depth) physical oceanographic parameters comprising of sea surface temperature (SST) and chlorophyll were collected by using CTD at each odd number of sampling station **(Figure 7)**. A total of 63 stations were successfully sampled. The CTD was soaked in water at each station for about 5 minutes.

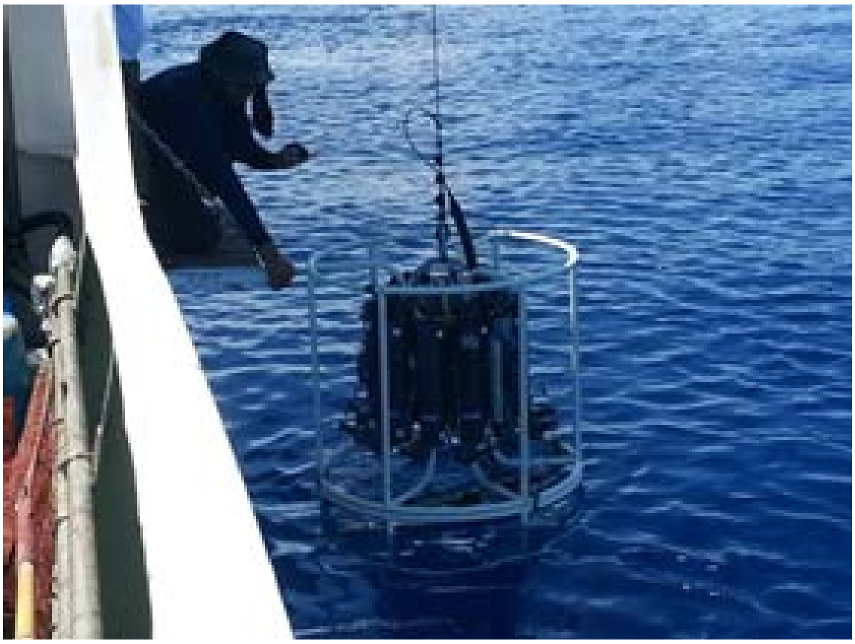

Figure 7: Utilization of CTD to gather data for oceanographic parameters.

3.6.3. Echo Verification and Partitioning

Echogram verification was carried out by chartering the local purse seine fishing vessel and land base survey program. Four fishing sampling were successfully carried out at Tanjung Sirik to Mukah, and from Bintulu to Miri. For fishing operations, about 50kg of catches were sampled and sorted by species to determine the dominant one. The individual total length, standard length and body weight of the dominant species were measured and recorded.

During land base sampling activities, sub-sample of catches were taken from selected purse seine vessel. The amount of samples taken is commensurate to the total landing by each sampling vessel. Normally one full basket of samples were taken and treated as according to the former procedure (Appendix C).

3.7. Data Processing and Analysis

3.7.1. SA Data Correction

The raw data were processed by FQ80-M Data Analyzer for each file name respectively to tabulate integrated sv and sa values. These values were checked and corrected thoroughly to remove interferences such as due to traffic noise, dynamic scattering layers and bottom lock errors. The corrected sa values were transferred to MS Excel file to calculate average sa for that particular transect.

3.7.2. Determination of Target Strength (TS) value

Target strength values for each sampling sector were determined based on the species composition data obtained from the fishing and land base sampling activities. Dominant species were determined and TS values were calculated using empirical formula derived by Furusawa (1990) as follow:

TS = 20 log L – 66

Where;

TS = Target strength (dB)

L = Fish standard length (cm)

TS values were also obtained from TS database that was estimated from previous studies in Redang Island conducted by SEAFDEC/MFRDMD. The TS database was given priority to determine TS values, however Furusawa estimation will be used whenever information from TS database is not available.

3.7.3. Calculation for Pelagic Fish Density

The pelagic fish density of each transect were calculated based on the following formula:

$$\mathbf{D_i = sa_i/ts_i * w_i}$$

Where;

D_i = Average fish density of each transect
sa_i = processed average sa value of each transect
ts_i = ts value of reference species
w_i = average body weight of reference species to represent for each transect

The density distributions of pelagic fish were mapped using GIS software (Marine Explorer) by symbol and contour. The values of density estimation for pelagic fish in Sulu Sulawesi Sea waters are shown in Appendix A.

3.7.4. Mapping by GIS Software

The current studies used Marine Explorer to map:

i. SA distribution
ii. Density of pelagic fish
iii. Potential fishing grounds
iv. Sea Surface Temperature (SST) and chlorophyll distribution
v. Correlation of pelagic fish density with physical oceanographic parameters. The density distributions of pelagic fish were overlay to physical oceanographic parameters using Marine Explorer by symbol and contour respectively. Correlations among the oceanographic parameters with fish density were also presented using line graphs.

3.7.5. Estimation of the Pelagic Fish Biomass

The total pelagic fish biomass was calculated based on the following formula:

$$\sum_{i}^{n} Q_i = \sum_{i}^{n} (D_i \times A_i)$$

Where;

Q_i = Fish Biomass of each grid area (tonne)

D_i = Average fish density of each transect (t/km^2)

A_i = A survey grid area of each transect (km^2)

$\sum_i^n Q =$ Total of fish biomass in the study area (tonne)

3.7.6. Calculation of the Maximum Sustainable Yield (MSY) or Potential Yield

Calculation for the MSY (Maximum Sustainable Yield) or Potential Yield is based on the formula given below:

Exploited Area

Cadima's formula for exploited area:

MSY = 0.2* (MBc + Y)

Where;

Bc = current biomass determined

Y = current yield **

M = natural mortality

* = constant value 0.2 is used based on precautionary approach

** = South China Sea is experiencing IUU problem and it was estimated that 9% of "missing catch" occurred in this region (FAO, 2015). This percentage will be considered in the actual total landing.

Gulland Model:

$$\mathbf{MSY = x.M.B_0}$$

Where;

- **x** **=** Constant that may be related to the growth and mortality characteristics of the stock
- **M** = natural mortality
- $\mathbf{B_0}$ = Virgin biomass

Schaeffer and Fox model (Garcia):

Schaeffer Model

$$\mathbf{MSY = (F_{MSY}B_c)^2 / (2F_{MSY}B_c - Y_c)}$$

Where;

$\mathbf{F_{MSY}}$ **=** Fishing mortality at MSY

$\mathbf{B_c}$ **=** Current biomass

$\mathbf{Y_c}$ = Current yield

Fox Model

$$\mathbf{MSY = F_{MSY}\, B_c\, exp\, ((Y_c / F_{MSY}\, B_c) - 1))}$$

Where;

$\mathbf{F_{MSY}}$ **=** Fishing mortality at MSY

$\mathbf{B_c}$ **=** Current biomass

exp = Exponential

$\mathbf{Y_c}$ = Current yield

3.7.7. Estimation of fishing effort and fish landing

The estimation of fishing capacity was based on current purse seine performance operated in fishing zones that was estimated about 250 MT /boat/year. In Malaysia, the fishing vessel has to achieve the landing limit (250 mt) in order to allow this vessel concerned to renew their licenses in the next fiscal year. However for economical reason and precautionary approach, the vessel fishing capacity was set at 400 MT.

The current landing for pelagic fish was based on annual fisheries statistical bulletin in 2015 that was published by the Department of Fisheries Malaysia (DOF) and Statistics of Marine Capture Fisheries by Fisheries Management Area (FMA), 2005-2014 by the Ministry of Maritime Affairs and Fisheries Catch, Indonesia. The number of vessel that could be licensed by areas was estimated based on the gear performance and any surplus or deficit of production recorded.

RESULTS

4.1. Distribution of SA Values

The SA values of all transect in Sulu Sulawesi Sea in 2014 were ranged from -57.36 dB/m^2 to -53.92 dB/m^2 as shown in **Figure 8**. The highest and lowest values were observed along station 26 to station 27 and along station 3 to 4 respectively. Meanwhile in 2015, The SA values of all transect in Sulu Sulawesi Sea in 2015 was ranged from -57.97 dB/m^2 to -53.18 dB/m^2 as shown in **Figure 9**. The highest and lowest values were observed along station 8 to station 9 and along station 59 to 60 respectively.

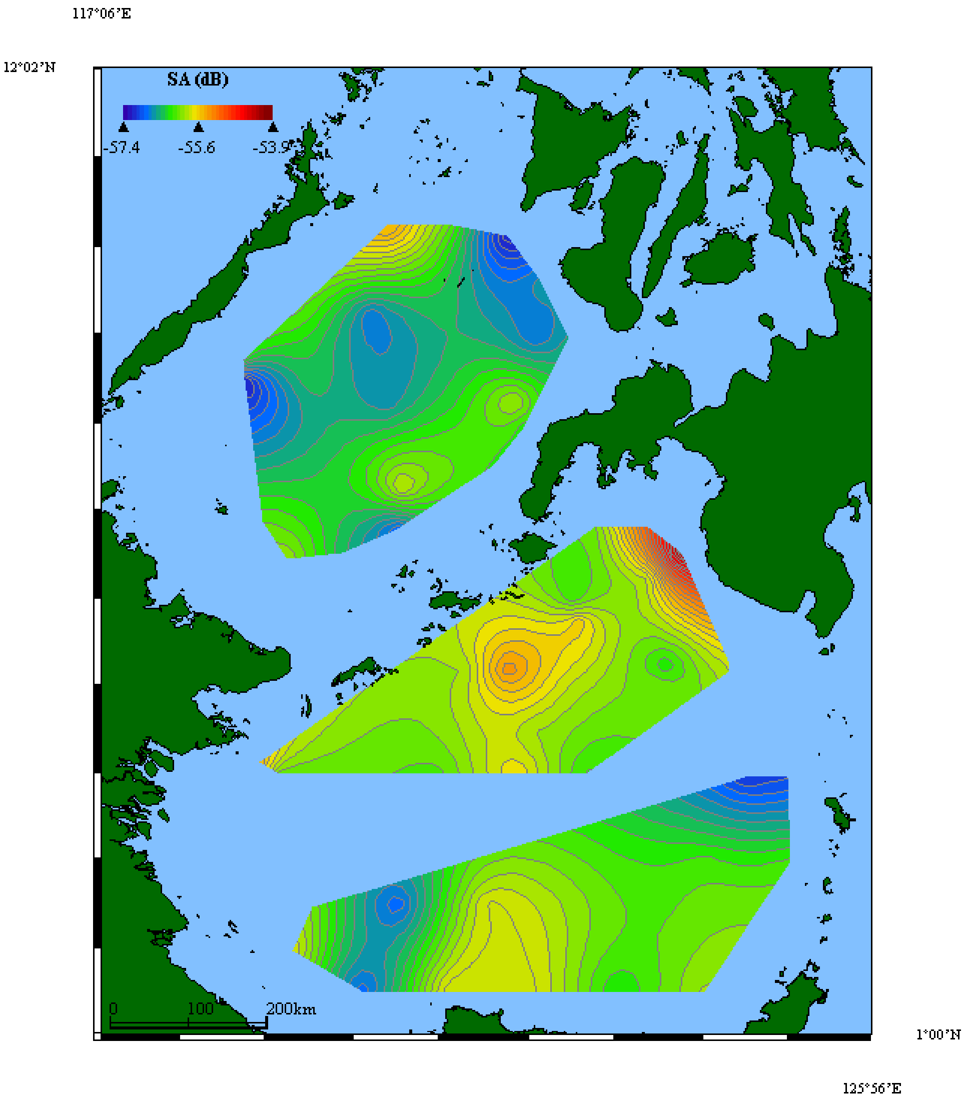

Figure 8: Distribution of SA values in Sulu Sulawesi Sea in 2014

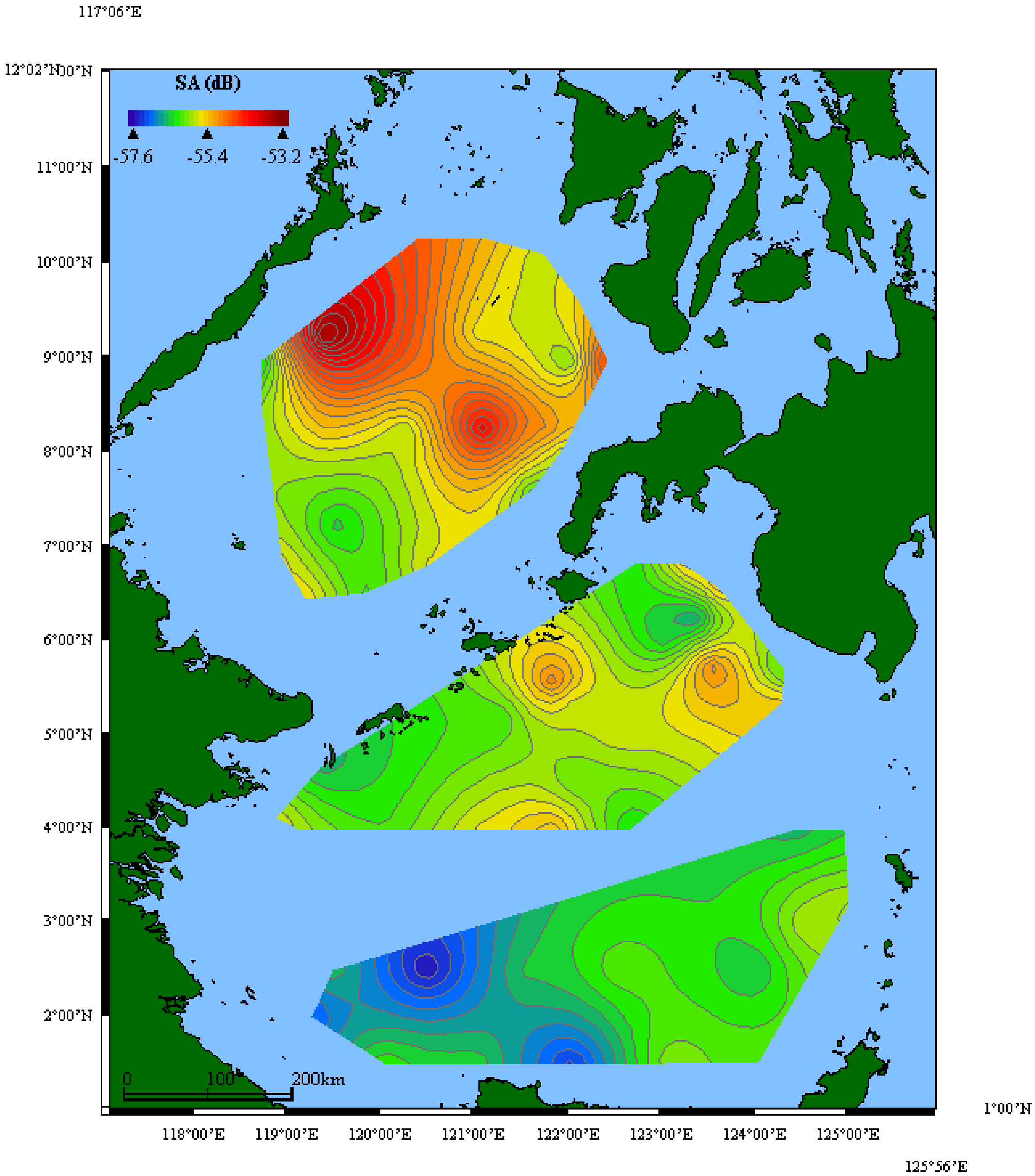

Figure 9: Distribution of SA values in Sulu Sulawesi Sea in 2015

4.2. Estimation of Target Strength Value (TS)

The values of TS for Sulu Sulawesi Sea waters in 2014 and 2015 are listed in **Table 2**. Based on the table, Scads and mackerels are found more common in Sulu Sulawesi Sea waters.

Table 2: TS values for each area in Sulu Sulawesi sea waters (2014 and 2015)

Year	Area	St	Dominant Species	FL (mm)	BW (g)	TS (dB)	Mortality ($Year^{-1}$)
2014	Puerto Princesa	St. 1-23	*Decapterus macrosoma*	169.0	61.6	-41.44*	1.51***
	Zamboanga	St. 24-44	*Selar crumenopthal mus*	183.0	100.5	-40.75*	1.44**
	Bitung	St. 45-61	*Rastrelliger kanagurta*	203.0	141.1	-39.85*	1.23
2015	Puerto Princesa	St. 1-26	*Decapterus macrosoma*	169.0	61.6	-41.44*	1.51***
	Zamboanga	St. 24-44	*Selar crumenopthal mus*	183.0	100.5	-40.75*	1.44**
	Bitung	St. 45-i3	*Rastrelliger kanagurta*	203.0	141.1	-39.85*	1.23

* Target strength (TS) was estimated using the formula derived by Furusawa (1990)
** Secondary data from data management for offshore pelagic fish stock (beyond 30 nm) through acoustic approach in Sarawak waters (2013)
*** Secondary data from information collection for sustainable pelagic fisheries in the SCS, SEAFDEC (2007)

4.3. Distribution of Pelagic Fish Density

The distributions of pelagic fish density along each transect in Sulu Sulawesi Sea is shown in **Figure 10** (2014) and **Figure 11** (2015)**,** in which it ranges from 1.58 tonnes/km^2 to 4.84 tonnes/km^2. The highest value of fish density was observed along station 26 to station 27 in 2014 and the lowest density was observed along station 3 to 4 also in 2014.

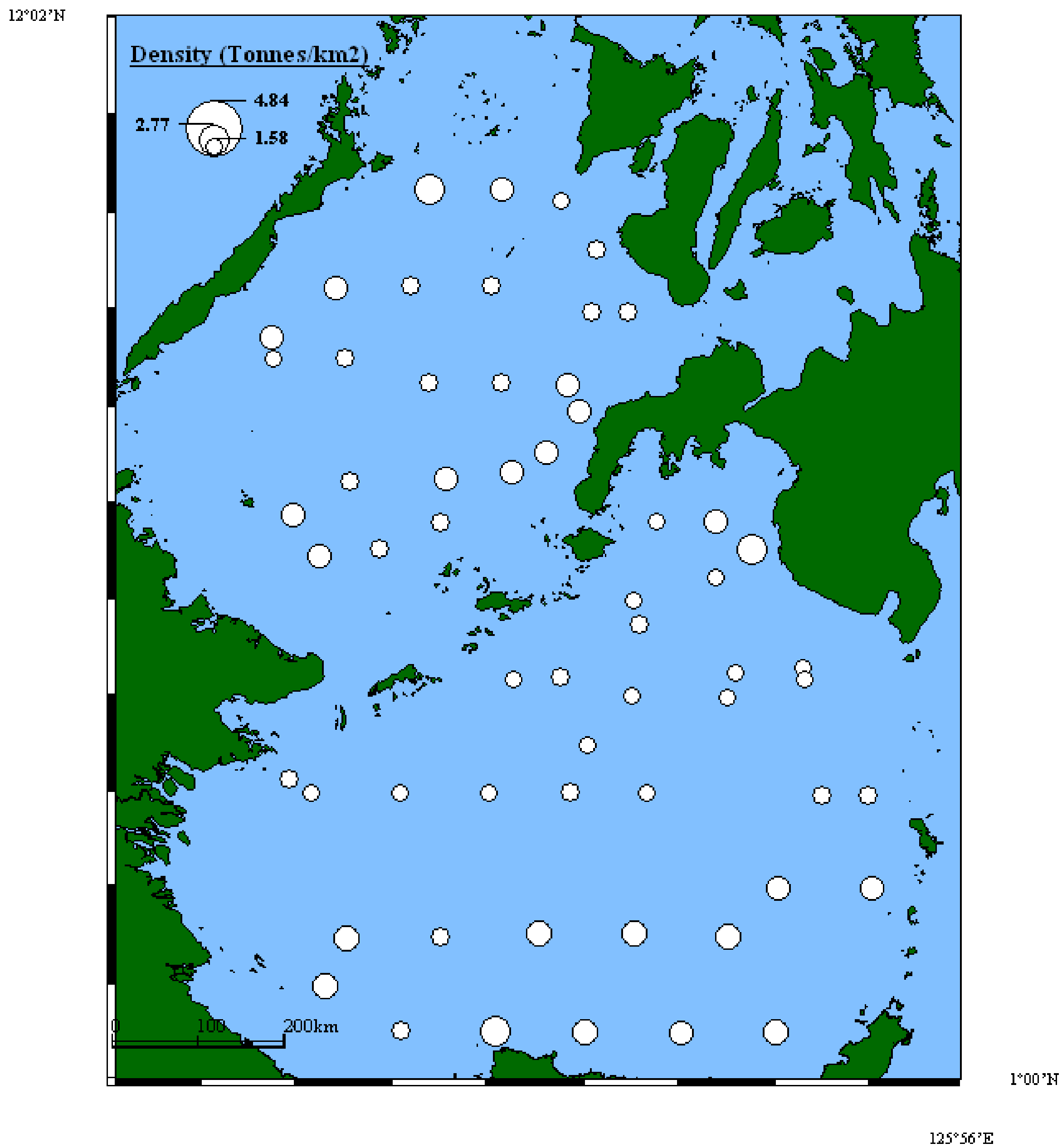

Figure 10: Pelagic fish density off Sulu Sulawesi Sea waters in 2014

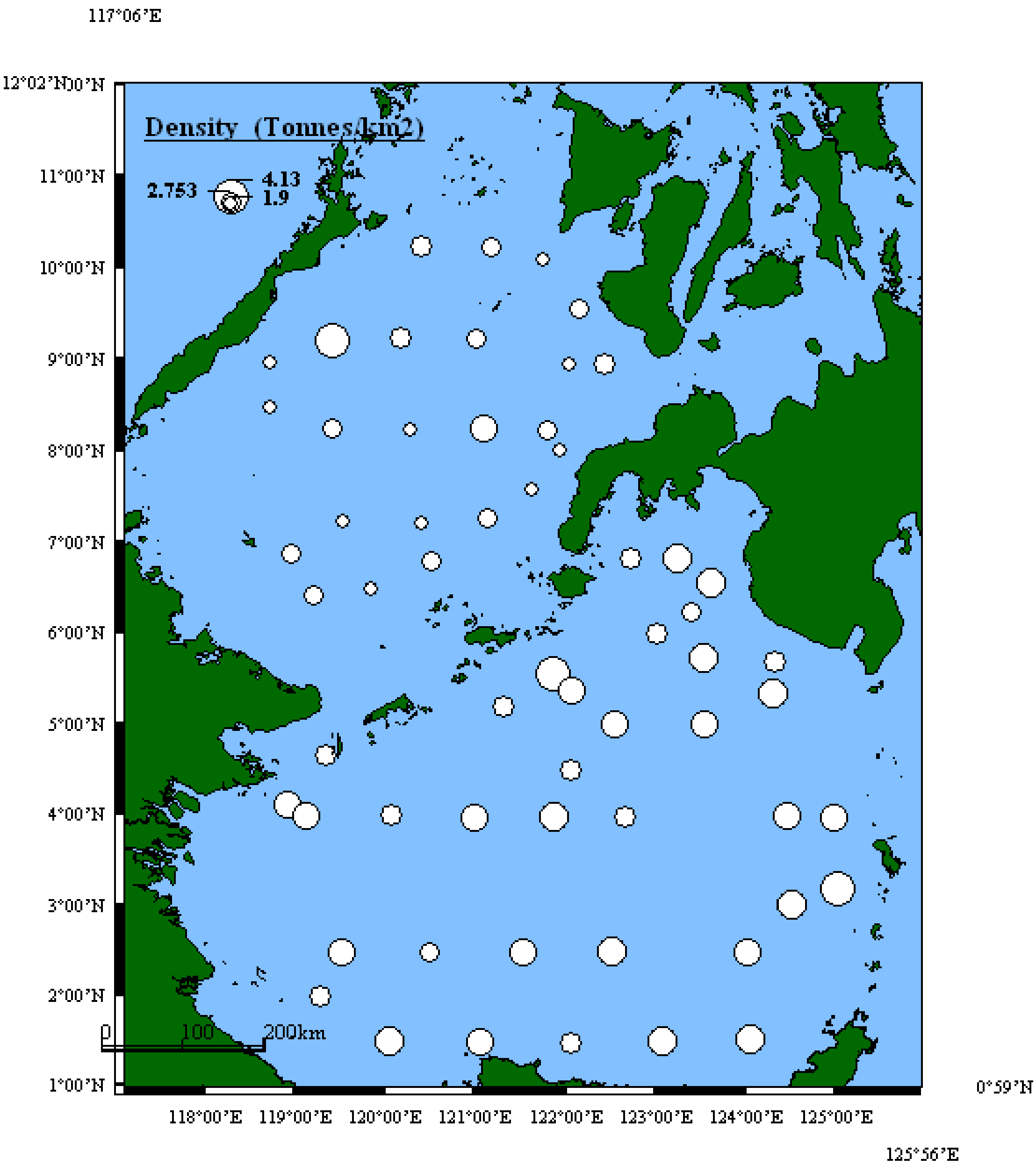

Figure 11: Pelagic fish density off Sulu Sulawesi Sea waters in 2015

4.4. Potential fishing grounds for pelagic fish species

In 2014, seven potential fishing grounds were identified in Sulu Sulawesi Sea. Four of them are located in Philippines (off Puerto Princesa and Zamboanga). Three locations were identified on the north west of Bitung, Indonesia and only one fishing ground in East Sabah, Malaysia was recorded as good fishing grounds for pelagic fish. The potential fishing grounds are shown in **Figure 12** (2014)**.**

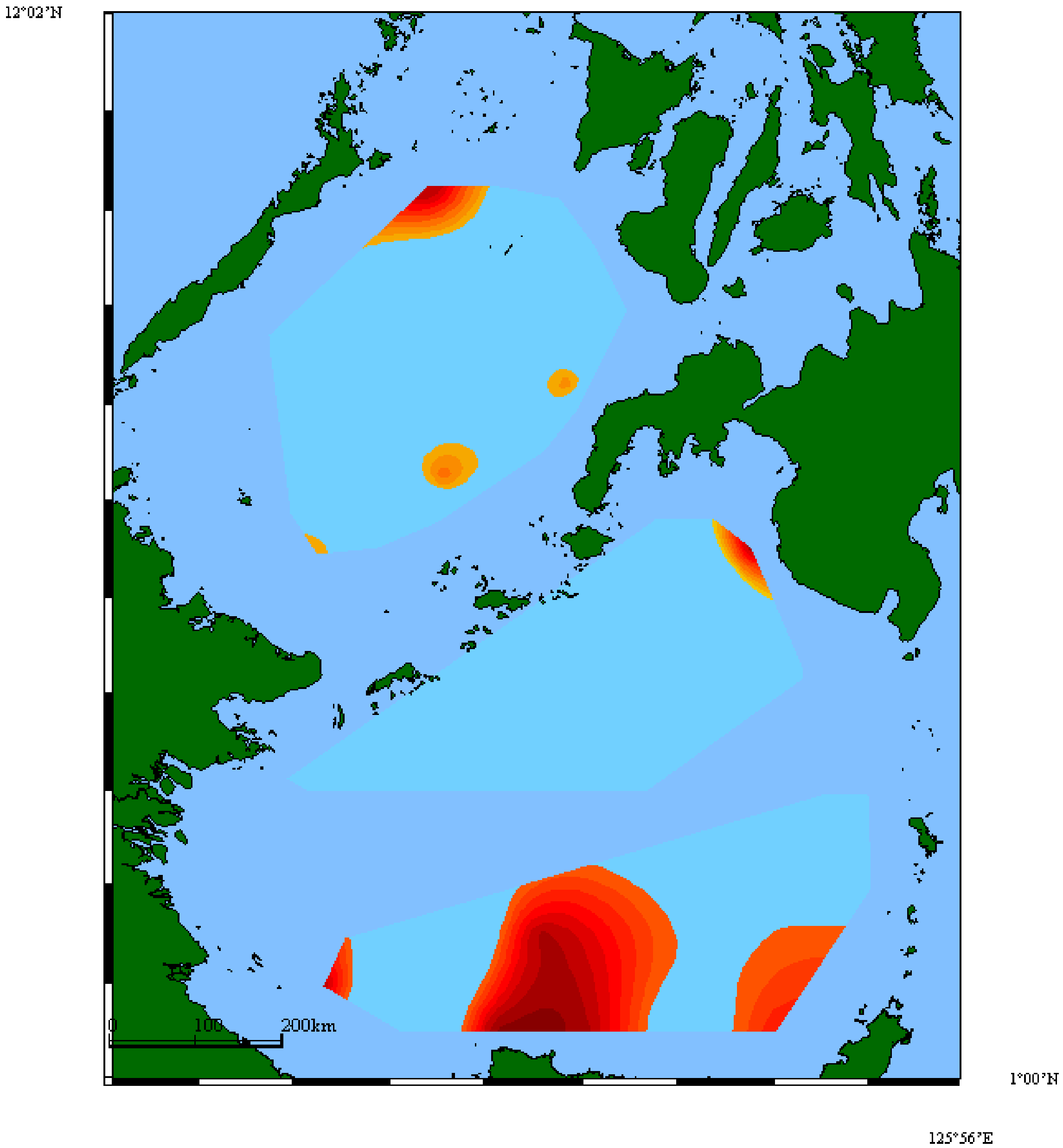

Figure 12: Potential fishing grounds for Pelagic Fish Species in Sulu Sulawesi Sea waters in 2014.

Meanwhile, eight potential fishing grounds were recorded in 2015. Five potential fishing grounds were identified in Philippines, off Puerto Princesa and Zamboanga and three fishing grounds were identified on the north coast of Bitung, Indonesia (**Figure 13).**

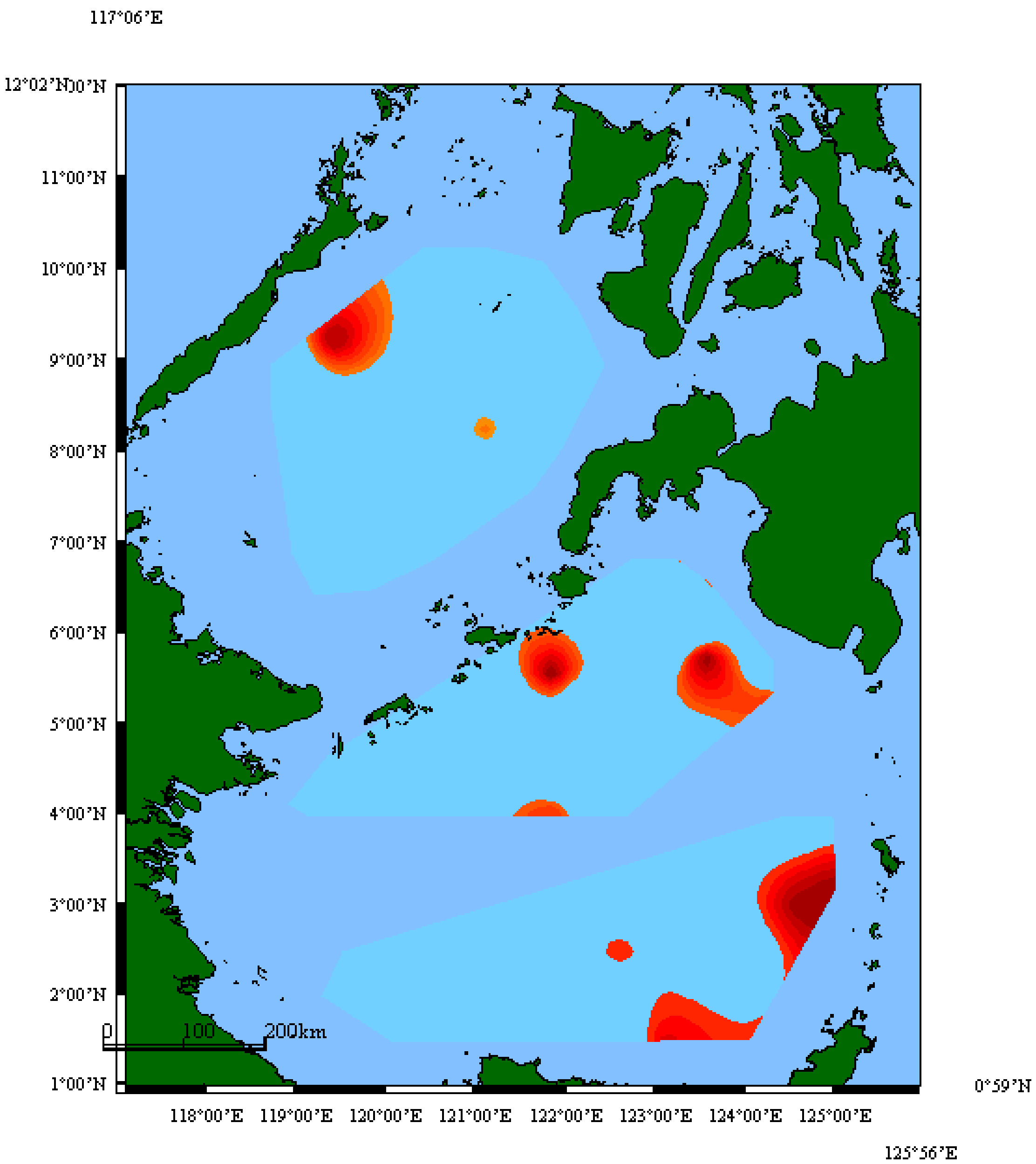

Figure 13: Potential fishing grounds for Pelagic Fish Species in Sulu Sulawesi sea waters in 2015.

4.5. Estimated Biomass and Potential Yield

The value of annual natural mortality (M) of dominant species in Sulu Sulawesi Sea waters was used in the estimation of potential yield. The dominant species in Sulu Sulawesi Sea waters are *Decapterus macrosoma, Selar crumenopthalmus* and *Rastrelliger kanagurta* respectively. The M value used for different areas are shown in Table 3.

Table 3: Mortality value (M) for dominant species sampled in Sulu Sulawesi Sea waters (2014 and 2015)

Year	Fish Sampling Area	St	Mortality (M)***	Dominant sp.
2014	Puerto Princesa	St. 1-23	1.51	*Decapterus macrosoma*
	Zamboanga	St. 24-44	1.44	*Selar crumenopthalmus*
	Bitung	St. 45-61	1.23	*Rastrelliger kanagurta*
2015	Puerto Princesa	St. 1-23	1.51	*Decapterus macrosoma*
	Zamboanga	St. 24-44	1.44	*Selar crumenopthalmus*
	Bitung	St. 45-i3	1.23	*Rastrelliger kanagurta*

*** Secondary data from data management for offshore pelagic fish stock (beyond 30 nm) through acoustic approach in Sarawak waters (2013) and information collection for sustainable pelagic fisheries in the SCS, SEAFDEC (2007)

The total biomass by year is shown in Table **4**. The total biomass (Q) estimated in Sulu Sulawesi Sea in 2014 and 2015 are 889,924 tonnes and 932,761 tonnes respectively, whilst the potential yields for the same year are estimated at 279,129 tonnes and 294,932 tonnes.

Table 4 : Results of acoustic survey in Sulu Sulawesi Sea in 2014 and 2015

Item(s)	Unit	2014	2015
Area	km^2	301,039	327,420
Average Density (D)	$tonnes/km^2$	2.80	2.88
Total biomass (Q)	tonnes	889,924	932,761
Natural mortality (M)	$year^{-1}$	1.23	1.23
Current yield (Y)	tonnes	301,039*	327,364*
Potential yield (MSY)	tonnes	279,129	294,932
Surplus	tonnes	21,910	32,624
Dominant species	-	*Rastrelliger kanagurta*	*Rastrelliger kanagurta*
Body weight (BW)	g	141.1	141.1

* Y + 9%

4.6. Oceanographic Data

Distribution of Sea Surface Temperature (SST) is shown in **Figure 14** (2014) and **Figure 15** (2015). The average temperature value in Sulu Sulawesi sea waters are 28.24 °C to 30.40 °C respectively. The highest value of SST was observed at station 55 in 2014 and the lowest temperature recorded was at station 56 in 2014 with values of 30.40 °C and 28.69 °C respectively.

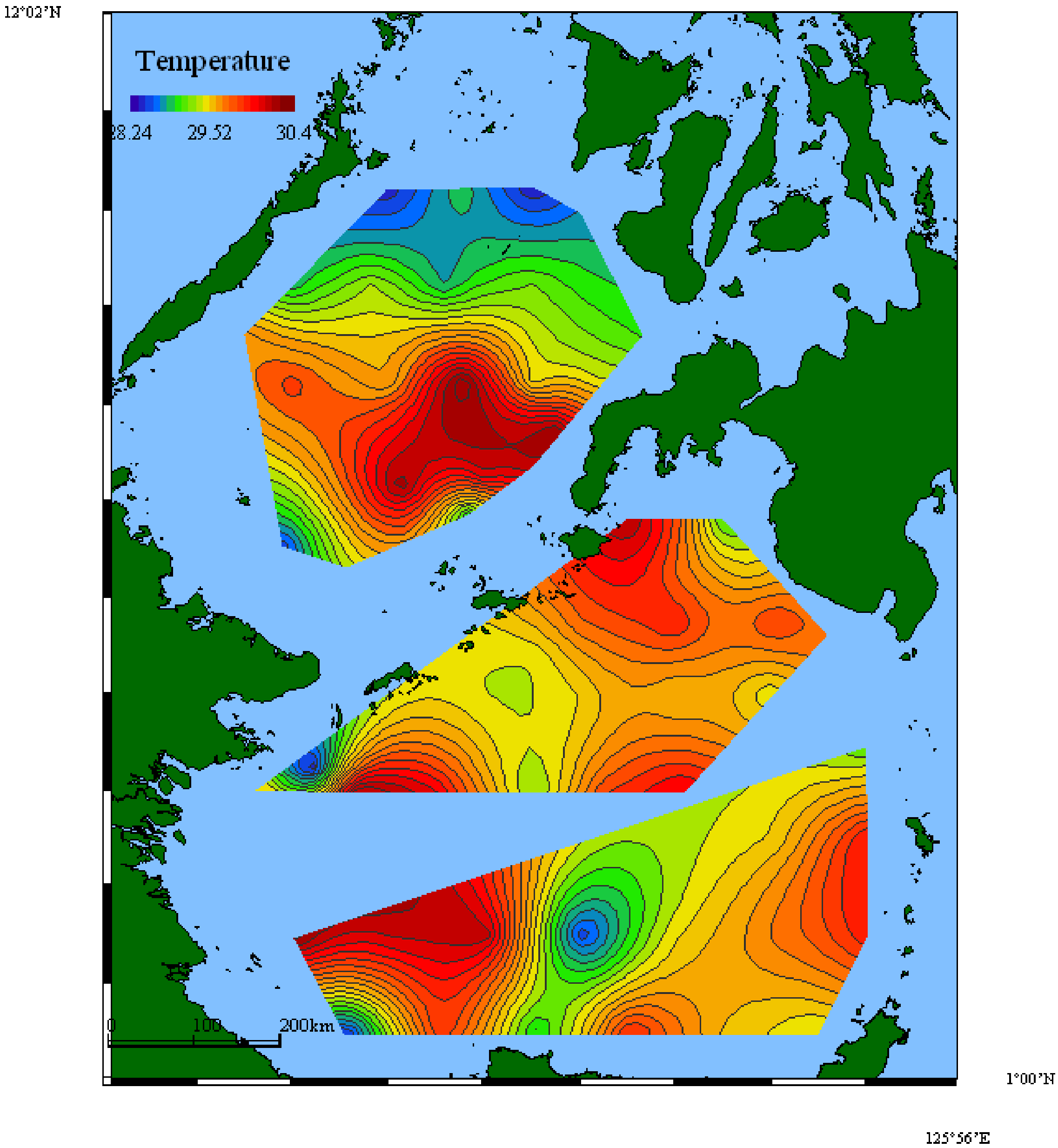

Figure 14: Distribution pattern of SST along the survey transects in Sulu Sulawesi Sea waters in 2014

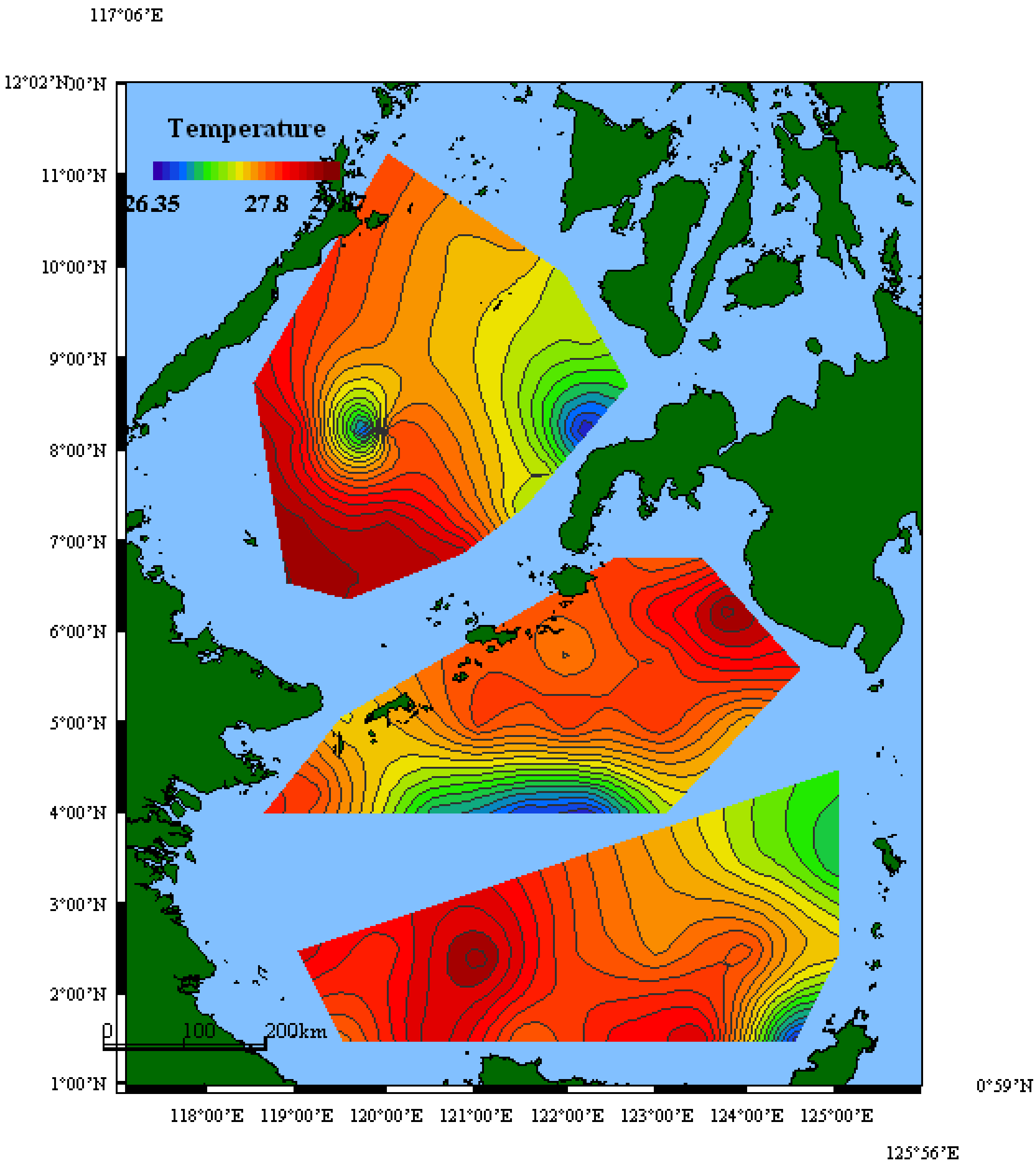

Figure 15: Distribution pattern of SST along the survey transects in Sulu Sulawesi Sea waters in 2015

The distribution patterns of chlorophyll densities are shown in **Figure 16** (2014) and **Figure 17** (2015). The average chlorophyll value in Sulu Sulawesi Sea is ranged between 1.85 µg/l to 2.33 µg/l respectively. The highest value of chlorophyll was observed at station 1 in 2014 which is 2.33 µg/l and the lowest value of 1.85 µg/l was observed at station 32 in 2015.

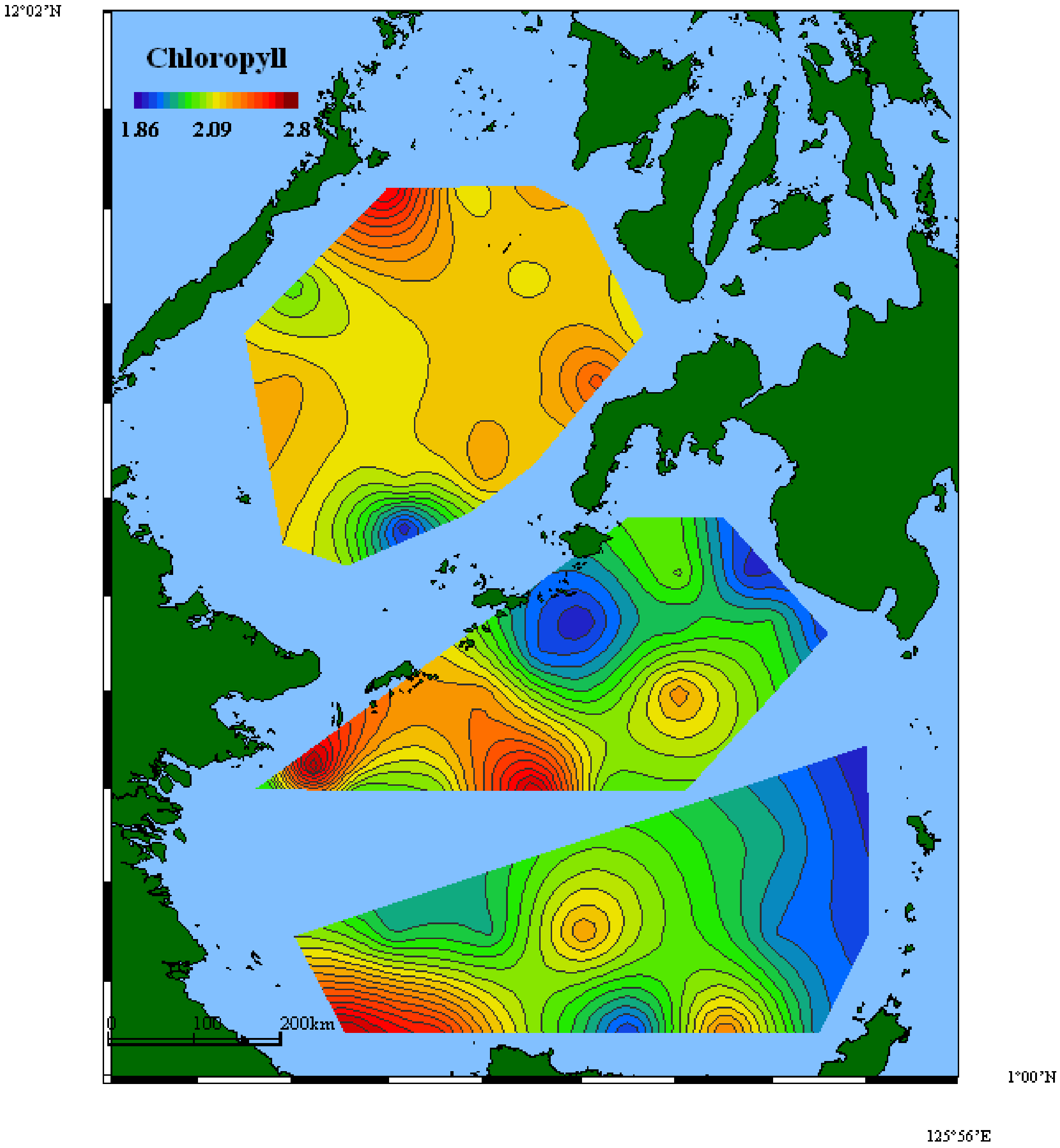

Figure 16: Distribution pattern of chlorophyll along the survey transects in Sulu Sulawesi Sea waters in 2014

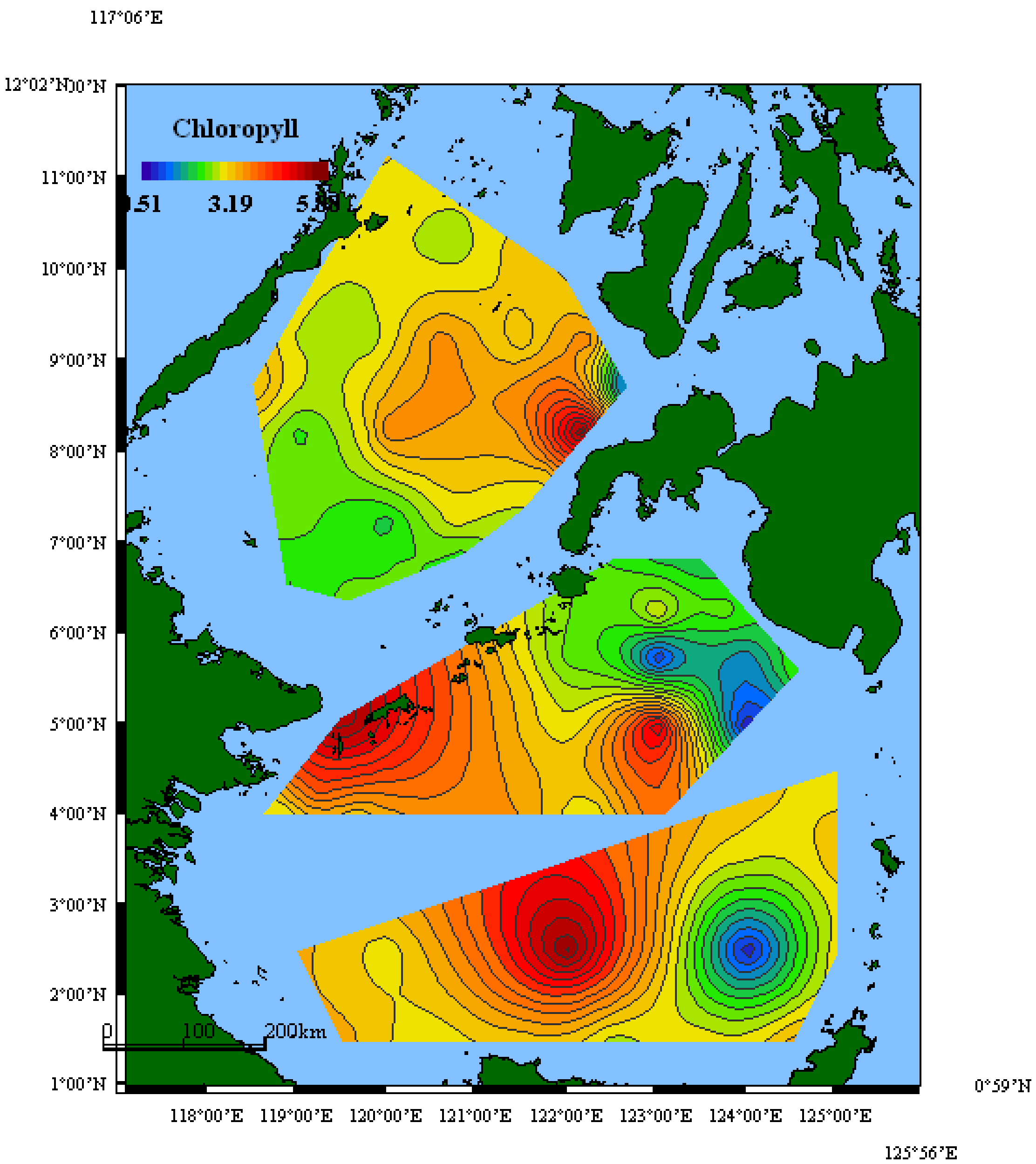

Figure 17: Distribution pattern of chlorophyll along the survey transects in Sulu Sulawesi Sea waters in 2015

4.7. The correlation of pelagic fish density to SST

The distribution of pelagic fish density with response to SST is shown in **Figure 18** (2014) and **Figure 19** (2015). Further statistical analysis has shown that no positive correlation was observed between pelagic fish density and SST in 2014. Meanwhile in 2015, there was small positive correlation recorded between SST and fish density with ($r^2 = 0.14$).

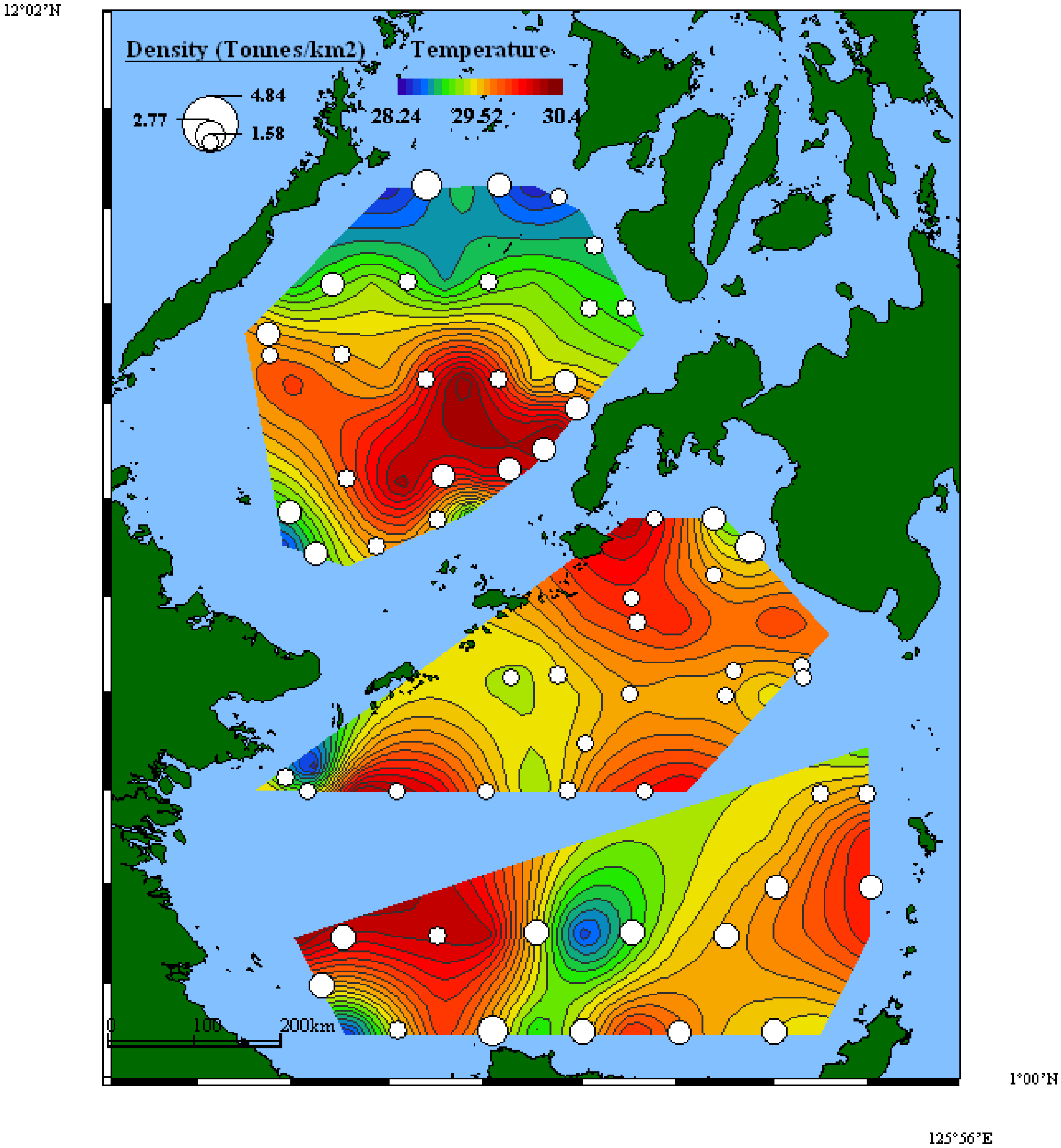

Figure 18: Map of distribution of fish density versus SST in Sulu Sulawesi Sea waters in 2014

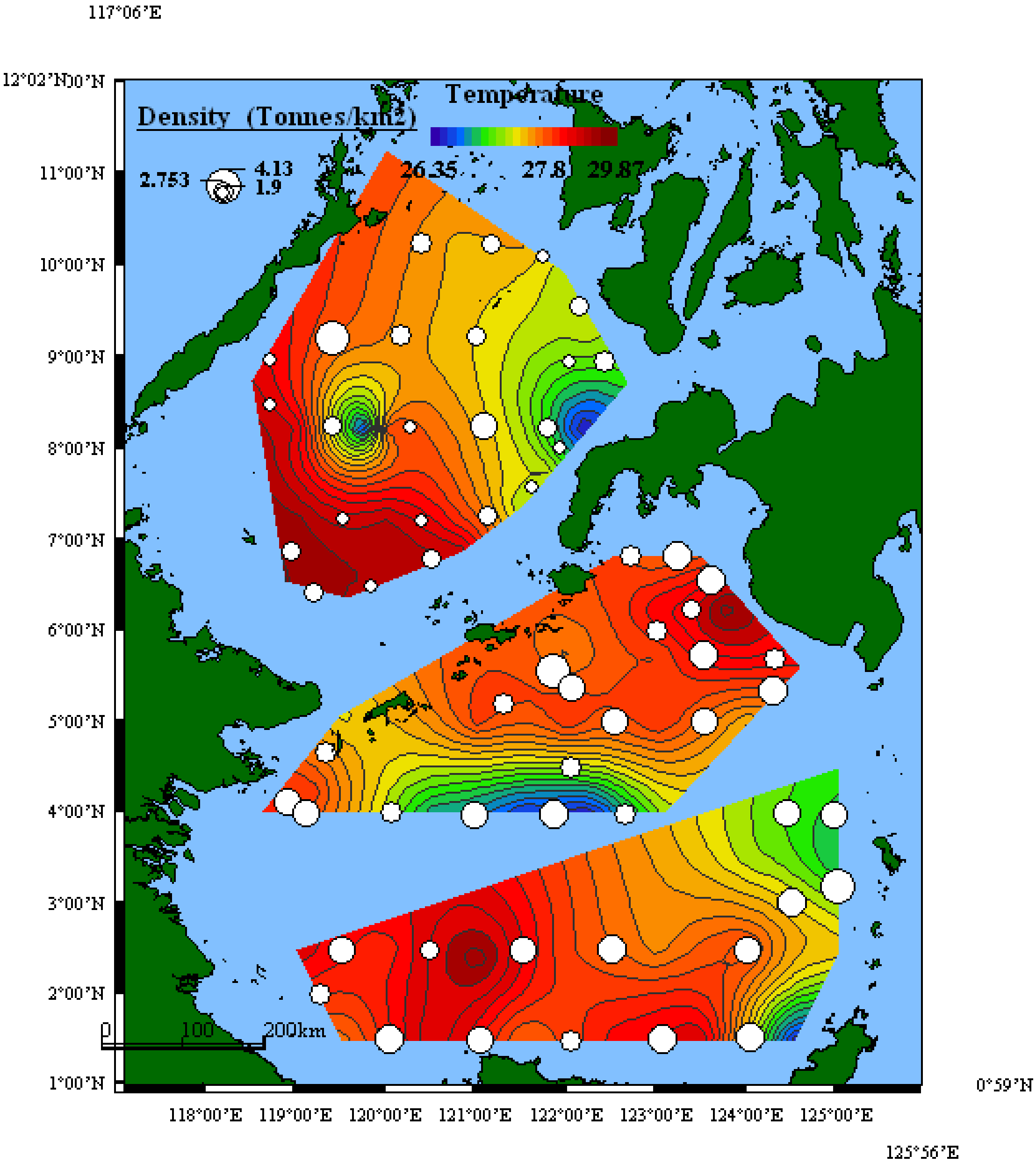

Figure 19: Map of distribution of fish density versus SST in Sulu Sulawesi Sea waters in 2015

4.8. The correlation of pelagic fish density to chlorophyll

The distribution of pelagic fish density with chlorophyll is shown in **Figure 20** (2014) and **Figure 21** (2015). Positive correlation between pelagic fish density and chlorophyll concentration was observed in 2014 ($r^2 = 0.14$) as in 2015 shown no positive correlation.

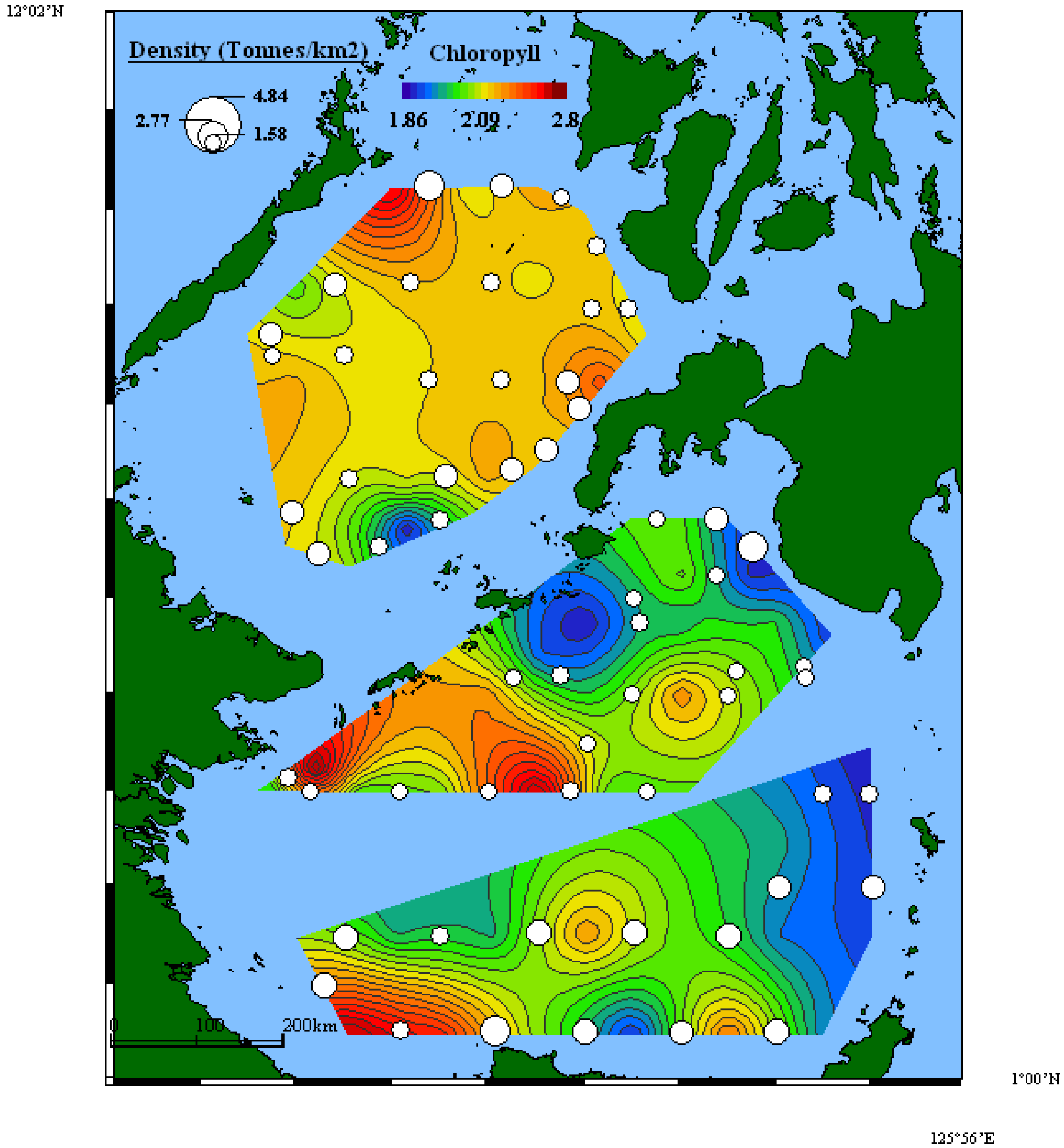

Figure 20: Map of distribution of fish density versus chlorophyll in Sulu Sulawesi Sea waters in 2014

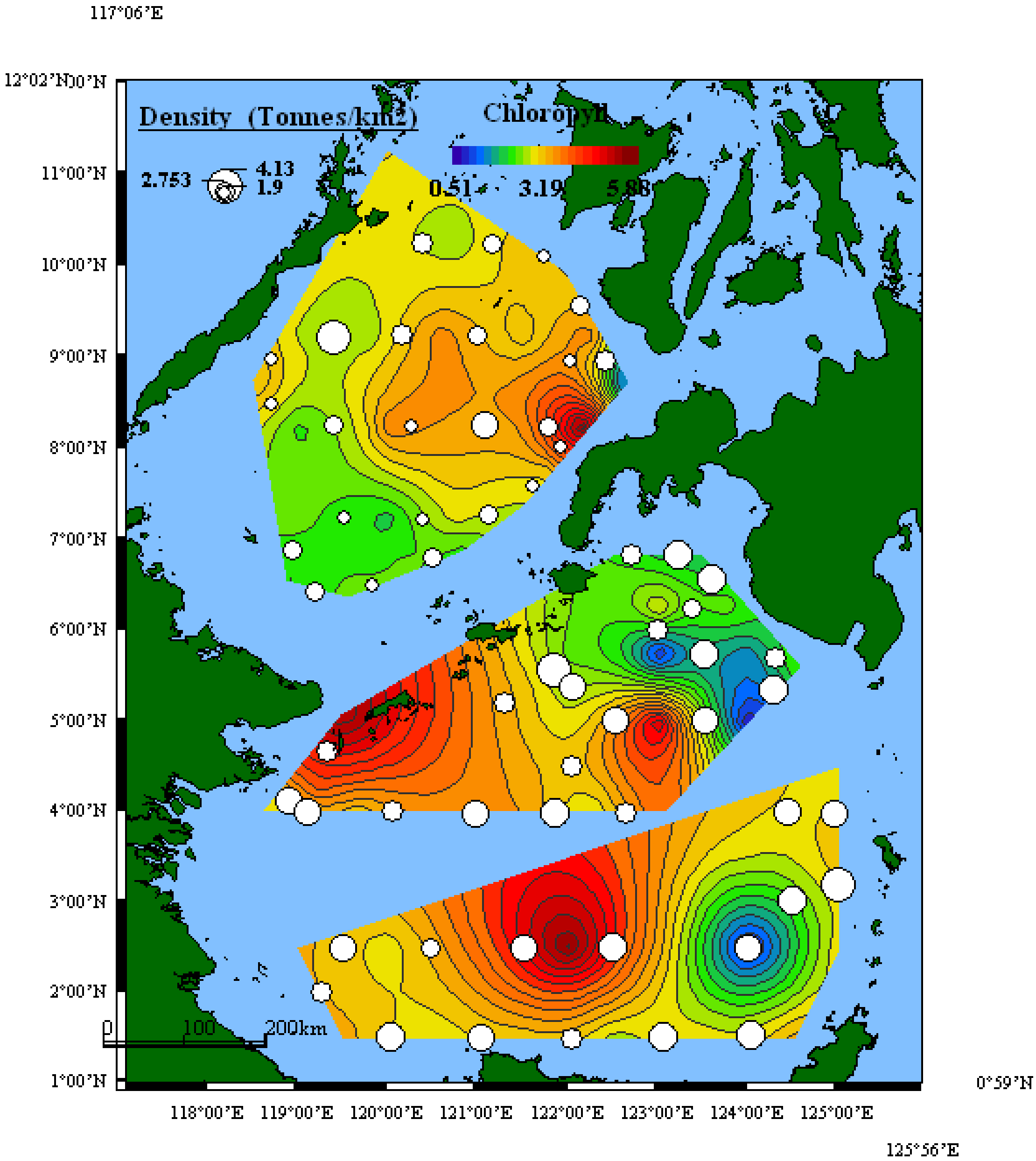

Figure 21: Map of distribution of fish density versus chlorophyll in Sulu Sulawesi Sea waters in 2015

DISCUSSION

This paper presents updated information on pelagic fish stock in Sulu Sulawesi sea waters. This is the first acoustic survey that was conducted by SEAFDEC in the Sulu Sulawesi Sea. Previous study was conducted by Raja Bidin *et al* (1998) in the western part of Philippines using M.V.SEAFDEC, installed with scientific echo sounder FQ-70 on board. However, the report was only covered off western Philippines not the whole Sulu Sulawesi Sea. On another story, the latest acoustic survey for East Coast of Sabah (part of SSS) was carried out in May 2015. (DOFM, 2015).

The current survey indicated that pelagic fish density in Sulu Sulawesi Sea waters faced 2.8% increase from the previous survey in 2014. A similar trend was observed for the potential yield or MSY, which increased about 5.6% within one year duration. The pelagic fish resources surplus in Sulu Sulawesi Sea from current survey has increased from 21,909 tonnes in 2014 to 32,431 tonnes. This surplus is estimated could support an additional 81 units of commercial purse seine vessels.

Rastrelliger kanagurta is the major pelagic fishes found in survey areas. The same species of pelagic fish was observed during the survey in 1997 (Hadil, et al., 1998). The highest potential fishing ground was identified in Philippines on 2014 and 2015. The fish density in this area was found higher compared to Indonesia and Malaysia. The current result has shown that high densities of pelagic fish in Philippines are found within the depth contour of 50m to 100m.

In this study, an attempt was made to correlate the fish density distributions with the sea surface temperature and chlorophyll. Although their relationship shows positive trend, their correlation coefficient (r^2) were 0.14, which were statistically insignificant ($p>0.05$). Overall, this study had indicated that no significant correlation between pelagic fish density with SST and chlorophyll concentration. This different observation may due to low sampling intensity which might mask any significant changes in the values of SST and chlorophyll concentration. According to Bambang and Ratih (2009), the SST and Chlorophyll distribution have close relationship with the distribution of potential fishing grounds. Therefore, for further study, the method adopted by Bambang and Ratih (2009), which used the satellite imaging and commercial fishing, need to be considered.

CONCLUSION AND RECOMMENDATIONS

Acoustic approach is a potential method for estimation of pelagic fish stock in the Sulu Sulawesi Sea waters. The method is fast, reliable and efficient to examine the status of pelagic fish stock. The estimated average density in Sulu Sulawesi Sea waters in 2014 and 2015 are 2.80 and 2.88 tonnes/km^2 respectively. The total biomasses of the same year are 889,924 tonnes in 2014 and 932,761 tonnes in 2015 respectively.

Based on our findings, the estimated potential yield of the pelagic fish resources of Sulu Sulawesi Sea waters are 279,129 tonnes in 2014 and 294,932 tonnes in 2015 respectively. The surplus of pelagic fish resources were observed in Sulu Sulawesi Sea waters. Thus, in Sulu Sulawesi Sea, the expansion of pelagic fishery is possible. However, repetition of such survey with higher sampling intensity during pre and post monsoons is recommended to confirm our earlier findings.

From this survey, the highest potential fishing ground was identified in Philippines on 2014 and 2015, off Puerto Princesa and Zamboanga.

In future acoustic survey, fish sampling strategy should be more emphasized in order to produce comprehensive and meaningful results. In addition, satellite imageries and Geographical Information System (GIS) are other useful methods needed for comparison with ground truthing data observed during oceanographic sampling activities.

ACKNOWLEDGEMENTS

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APPENDICES

9.1. APPENDIX A

The values of density estimation for pelagic fish in Sulu Sulawesi Sea waters in 2014

Year	Area	Transect	SA (db)	D (tan/km^2)	Q (M.tan)	Species
2014	Puerto Princesa Port, Philippines	St. 1-2	-55.27	2.55	7,756.77	*Decapterus macrosoma*
2014	Puerto Princesa Port, Philippines	St. 2-3	-56.20	2.06	6,261.54	*Decapterus macrosoma*
2014	Puerto Princesa Port, Philippines	St. 3-4	-57.36	1.58	3,626.90	*Decapterus macrosoma*
2014	Puerto Princesa Port, Philippines	St. 4-5	-56.71	1.83	5,970.70	*Decapterus macrosoma*
2014	Puerto Princesa Port, Philippines	St. 5-i1	-56.64	1.86	4,988.18	*Decapterus macrosoma*
2014	Puerto Princesa Port, Philippines	St. i1-6	-56.88	1.76	5,354.03	*Decapterus macrosoma*
2014	Puerto Princesa Port, Philippines	St. 6-7	-56.52	1.91	7,117.87	*Decapterus macrosoma*
2014	Puerto Princesa Port, Philippines	St. 7-8	-56.85	1.77	5,391.14	*Decapterus macrosoma*
2014	Puerto Princesa Port, Philippines	St. 8-9	-56.19	2.06	6,977.89	*Decapterus macrosoma*
2014	Puerto Princesa Port, Philippines	St. 9-10	-56.30	2.01	5,837.21	*Decapterus macrosoma*
2014	Puerto Princesa Port, Philippines	St. 10-11	-57.34	1.58	4,594.15	*Decapterus macrosoma*
2014	Puerto Princesa Port, Philippines	St. 11-12	-56.47	1.94	7,897.10	*Decapterus macrosoma*
2014	Puerto Princesa Port, Philippines	St. 12-13	-56.74	1.82	5,565.81	*Decapterus macrosoma*
2014	Puerto Princesa Port, Philippines	St. 13-14	-56.38	1.98	6,046.84	*Decapterus macrosoma*
2014	Puerto Princesa Port, Philippines	St. 14-i2	-55.91	2.20	5,857.18	*Decapterus macrosoma*
2014	Puerto Princesa Port, Philippines	St. i2-15	-56.32	2.00	4,608.24	*Decapterus macrosoma*
2014	Puerto Princesa Port, Philippines	St. 15-16	-56.28	2.02	3,720.70	*Decapterus macrosoma*
2014	Puerto Princesa Port, Philippines	St. 16-17	-56.20	2.06	6,385.12	*Decapterus macrosoma*
2014	Puerto Princesa Port, Philippines	St. 17-18	-55.82	2.25	6,879.05	*Decapterus macrosoma*
2014	Puerto Princesa Port, Philippines	St. 18-19	-56.42	1.96	7,988.54	*Decapterus macrosoma*
2014	Puerto Princesa Port, Philippines	St. 19-20	-56.16	2.08	5,986.87	*Decapterus macrosoma*
2014	Puerto Princesa Port, Philippines	St. 20-21	-55.97	2.17	6,254.60	*Decapterus macrosoma*
2014	Puerto Princesa Port, Philippines	St. 21-22	-56.53	1.91	5,307.04	*Decapterus macrosoma*

2014	Puerto Princesa Port, Philippines	St. 22-23	-56.95	1.73	5,095.12	*Decapterus macrosoma*
				1.96	**5,894.53**	
2014	Zamboanga, Philippines	St. 24-25	-56.10	2.93	6,041.31	*Selar crumenopthalmus*
2014	Zamboanga, Philippines	St. 25-26	-54.93	3.84	7,909.17	*Selar crumenopthalmus*
2014	Zamboanga, Philippines	St. 26-27	-53.92	4.84	12,596.13	*Selar crumenopthalmus*
2014	Zamboanga, Philippines	St. 27-28	-55.84	3.11	9,527.64	*Selar crumenopthalmus*
2014	Zamboanga, Philippines	St. 28-29	-56.24	2.84	13,005.57	*Selar crumenopthalmus*
2014	Zamboanga, Philippines	St. 29-30	-55.59	3.30	13,522.21	*Selar crumenopthalmus*
2014	Zamboanga, Philippines	St. 30-31	-56.35	2.77	6,810.81	*Selar crumenopthalmus*
2014	Zamboanga, Philippines	St. 31-32	-55.86	3.10	10,785.57	*Selar crumenopthalmus*
2014	Zamboanga, Philippines	St. 32-33	-55.81	3.14	12,854.28	*Selar crumenopthalmus*
2014	Zamboanga, Philippines	St. 33-34	-56.05	2.97	12,163.20	*Selar crumenopthalmus*
2014	Zamboanga, Philippines	St. 34-35	-55.89	3.08	7,756.48	*Selar crumenopthalmus*
2014	Zamboanga, Philippines	St. 35-36	-55.27	3.55	9,940.81	*Selar crumenopthalmus*
2014	Zamboanga, Philippines	St. 36-37	-55.95	3.04	28,778.77	*Selar crumenopthalmus*
2014	Zamboanga, Philippines	St. 37-38	-55.96	3.03	10,358.34	*Selar crumenopthalmus*
2014	Zamboanga, Philippines	St. 38-39	-56.28	2.81	8,665.92	*Selar crumenopthalmus*
2014	Zamboanga, Philippines	St. 39-40	-55.65	3.25	10,018.77	*Selar crumenopthalmus*
2014	Zamboanga, Philippines	St. 40-41	-56.19	2.87	11,777.35	*Selar crumenopthalmus*
2014	Zamboanga, Philippines	St. 41-42	-56.13	2.91	9,960.70	*Selar crumenopthalmus*
2014	Zamboanga, Philippines	St. 42-43	-56.13	2.91	12,640.19	*Selar crumenopthalmus*
2014	Zamboanga, Philippines	St. 43-44	-55.43	3.42	9,102.18	*Selar crumenopthalmus*
				3.19	**11,210.77**	
2014	Bitung, Indonesia	St. 45-46	-56.23	3.25	13,379.26	*Rastrelliger kanagurta*
2014	Bitung, Indonesia	St. 46-47	-57.07	2.68	11,026.36	*Rastrelliger kanagurta*
2014	Bitung, Indonesia	St. 47-48	-57.16	2.62	15,413.89	*Rastrelliger kanagurta*
2014	Bitung, Indonesia	St. 48-50	-56.21	3.26	19,182.81	*Rastrelliger kanagurta*

2014	Bitung, Indonesia	St. 50-51	-56.19	3.28	13,503.06	*Rastrelliger kanagurta*
2014	Bitung, Indonesia	St. 51-52	-56.01	3.42	14,074.47	*Rastrelliger kanagurta*
2014	Bitung, Indonesia	St. 52-53	-55.74	3.64	14,977.25	*Rastrelliger kanagurta*
2014	Bitung, Indonesia	St. 53-54	-56.94	2.76	11,361.41	*Rastrelliger kanagurta*
2014	Bitung, Indonesia	St. 54-55	-56.07	3.37	13,881.36	*Rastrelliger kanagurta*
2014	Bitung, Indonesia	St. 55-56	-55.75	3.63	16,683.72	*Rastrelliger kanagurta*
2014	Bitung, Indonesia	St. 56-57	-56.94	2.76	11,361.41	*Rastrelliger kanagurta*
2014	Bitung, Indonesia	St. 57-58	-55.69	3.68	15,150.68	*Rastrelliger kanagurta*
2014	Bitung, Indonesia	St. 58-59	-55.72	3.65	15,046.38	*Rastrelliger kanagurta*
2014	Bitung, Indonesia	St. 59-60	-56.37	3.14	12,954.84	*Rastrelliger kanagurta*
2014	Bitung, Indonesia	St. 60-61	-55.94	3.47	14,303.17	*Rastrelliger kanagurta*
			3.24	**4,386.67**	**14,153.34**	

The values of density estimation for pelagic fish in Sulu Sulawesi Sea waters in 2015

Year	Area	Transect	SA (db)	D (tan/km^2)	Q (M.tan)	Species
2015	Puerto Princesa Port, Philippines	St. 1-2	-54.65	2.94	8,947.07	*Decapterus macrosoma*
2015	Puerto Princesa Port, Philippines	St. 2-3	-55.29	2.54	7,721.13	*Decapterus macrosoma*
2015	Puerto Princesa Port, Philippines	St. 3-4	-55.79	2.26	5,206.37	*Decapterus macrosoma*
2015	Puerto Princesa Port, Philippines	St. 4-5	-55.46	2.44	7,962.05	*Decapterus macrosoma*
2015	Puerto Princesa Port, Philippines	St. 5-i1	-54.33	3.17	8,490.67	*Decapterus macrosoma*
2015	Puerto Princesa Port, Philippines	St. i1-6	-56.02	2.15	6,526.51	*Decapterus macrosoma*
2015	Puerto Princesa Port, Philippines	St. 6-7	-55.57	2.38	8,858.30	*Decapterus macrosoma*
2015	Puerto Princesa Port, Philippines	St. 7-8	-54.40	3.12	9,477.22	*Decapterus macrosoma*
2015	Puerto Princesa Port, Philippines	St. 8-9	-53.18	4.13	13,954.81	*Decapterus macrosoma*
2015	Puerto Princesa Port, Philippines	St. 9-10	-56.54	1.90	5,523.38	*Decapterus macrosoma*
2015	Puerto Princesa Port, Philippines	St. 10-11	-55.97	2.17	6,298.04	*Decapterus macrosoma*
2015	Puerto Princesa Port, Philippines	St. 11-12	-55.38	2.49	10,150.03	*Decapterus macrosoma*
2015	Puerto Princesa Port, Philippines	St. 12-13	-55.84	2.24	6,847.45	*Decapterus macrosoma*
2015	Puerto Princesa Port, Philippines	St. 13-14	-54.05	3.38	10,340.20	*Decapterus macrosoma*
2015	Puerto Princesa Port, Philippines	St. 14-i2	-55.09	2.66	7,074.39	*Decapterus macrosoma*
2015	Puerto Princesa Port, Philippines	St. i2-15	-55.75	2.28	5,254.55	*Decapterus macrosoma*
2015	Puerto Princesa Port, Philippines	St. 15-16	-56.18	2.07	3,807.37	*Decapterus macrosoma*
2015	Puerto Princesa Port, Philippines	St. 16-17	-55.58	2.38	7,364.94	*Decapterus macrosoma*
2015	Puerto Princesa Port, Philippines	St. 17-18	-55.84	2.24	6,847.45	*Decapterus macrosoma*
2015	Puerto Princesa Port, Philippines	St. 18-19	-56.49	1.93	7,860.81	*Decapterus macrosoma*
2015	Puerto Princesa Port, Philippines	St. 19-20	-55.66	2.33	6,717.38	*Decapterus macrosoma*
2015	Puerto Princesa Port, Philippines	St. 20-21	-55.52	2.41	6,937.45	*Decapterus macrosoma*
2015	Puerto Princesa Port, Philippines	St. 21-22	-56.32	2.00	5,569.96	*Decapterus macrosoma*
2015	Puerto Princesa Port, Philippines	St. 22-23	-55.65	2.34	6,873.13	*Decapterus macrosoma*
				2.50	**7,525.44**	
2015	Zamboanga, Philippines	St. 24-25	-56.38	2.75	5,664.10	*Selar crumenopthalmus*

2015	Zamboanga, Philippines	St. 25-26	-55.47	3.39	6,984.43	*Selar crumenopthalmus*
2015	Zamboanga, Philippines	St. 26-27	-55.42	3.43	8,917.38	*Selar crumenopthalmus*
2015	Zamboanga, Philippines	St. 27-28	-56.78	2.51	7,673.36	*Selar crumenopthalmus*
2015	Zamboanga, Philippines	St. 28-29	-56.52	2.66	12,193.53	*Selar crumenopthalmus*
2015	Zamboanga, Philippines	St. 29-30	-54.99	3.79	15,525.58	*Selar crumenopthalmus*
2015	Zamboanga, Philippines	St. 30-31	-56.35	2.77	6,810.81	*Selar crumenopthalmus*
2015	Zamboanga, Philippines	St. 31-32	-55.41	3.44	11,963.08	*Selar crumenopthalmus*
2015	Zamboanga, Philippines	St. 32-33	-55.62	3.28	13,429.13	*Selar crumenopthalmus*
2015	Zamboanga, Philippines	St. 33-34	-55.70	3.22	13,184.02	*Selar crumenopthalmus*
2015	Zamboanga, Philippines	St. 34-35	-55.70	3.22	8,103.35	*Selar crumenopthalmus*
2015	Zamboanga, Philippines	St. 35-36	-54.96	3.81	10,676.33	*Selar crumenopthalmus*
2015	Zamboanga, Philippines	St. 36-37	-56.25	2.83	26,857.91	*Selar crumenopthalmus*
2015	Zamboanga, Philippines	St. 37-38	-56.12	2.92	9,983.66	*Selar crumenopthalmus*
2015	Zamboanga, Philippines	St. 38-39	-56.46	2.70	8,314.09	*Selar crumenopthalmus*
2015	Zamboanga, Philippines	St. 39-40	-55.25	3.57	10,985.37	*Selar crumenopthalmus*
2015	Zamboanga, Philippines	St. 40-41	-55.68	3.23	13,244.87	*Selar crumenopthalmus*
2015	Zamboanga, Philippines	St. 41-42	-56.27	2.82	9,644.73	*Selar crumenopthalmus*
2015	Zamboanga, Philippines	St. 42-43	-55.86	3.10	13,450.97	*Selar crumenopthalmus*
2015	Zamboanga, Philippines	St. 43-44	-55.71	3.21	8,533.86	*Selar crumenopthalmus*
2015	Zamboanga, Philippines	St. 44-i3	-56.65	2.58	6,872.99	*Selar crumenopthalmus*
				3.11	**10,905.41**	
2015	Bitung, Indonesia	St. 45-46	-55.82	3.57	14,703.89	*Rastrelliger kanagurta*
2015	Bitung, Indonesia	St. 46-47	-56.46	3.08	12,689.14	*Rastrelliger kanagurta*
2015	Bitung, Indonesia	St. 47-48	-56.67	2.93	17,254.89	*Rastrelliger kanagurta*
2015	Bitung, Indonesia	St. 48-50	-55.86	3.54	20,792.77	*Rastrelliger kanagurta*
2015	Bitung, Indonesia	St. 50-51	-56.60	2.98	12,286.61	*Rastrelliger kanagurta*
2015	Bitung, Indonesia	St. 51-52	-56.18	3.28	13,534.19	*Rastrelliger kanagurta*

2015	Bitung, Indonesia	St. 52-53	-56.56	3.01	12,400.30	*Rastrelliger kanagurta*
2015	Bitung, Indonesia	St. 53-54	-57.63	2.35	9,692.42	*Rastrelliger kanagurta*
2015	Bitung, Indonesia	St. 54-55	-56.61	2.98	12,258.35	*Rastrelliger kanagurta*
2015	Bitung, Indonesia	St. 55-56	-57.23	2.58	11,865.68	*Rastrelliger kanagurta*
2015	Bitung, Indonesia	St. 56-57	-56.31	3.19	13,135.06	*Rastrelliger kanagurta*
2015	Bitung, Indonesia	St. 57-58	-56.49	3.06	12,601.79	*Rastrelliger kanagurta*
2015	Bitung, Indonesia	St. 58-59	-57.41	2.47	10,196.05	*Rastrelliger kanagurta*
2015	Bitung, Indonesia	St. 59-60	-56.03	3.40	14,009.81	*Rastrelliger kanagurta*
2015	Bitung, Indonesia	St. 60-61	-56.19	3.28	13,503.06	*Rastrelliger kanagurta*
				3.05	**13,394.93**	

9.2. APPENDIX B

List of Personnel on Board Cruise M.V.SEAFDEC2 NO 47-3/2014 (17 October – 8 December 2014, 52 days) in Sulu-Sulawesi Sea Waters

I. Ship Personnel (M.V.SEAFDEC2)

No	Position	Name
1	Captain	Mr. Vudhirat Vudthipanyo
2	Chief Engineer	Mr. Nanthawat Phungsuk
3	Chief Officer	Mr. Aussawin Buachuay
4	Second Officer	Mr. Suren Pruksarat
5	Second Engineer	Mr. Padung Ngowlimhuat
6	Third Engineer	Mr. Kitinai Sukdit
7	Third Engineer	Mr. Boontarin Wora-in
8	Boatswain	Mr. Thana Rungjoy
9	Steersman	Mr. Pradit Kui-prasert
10	Able Seaman	Mr. Anan Khanseta
11	Fishing Assistant	Mr. Somyos Pomprasert
12	Oiler	Mr. Plew Shodok
13	Oiler	Mr. Chanchai Chid U dom
14	Cook	Mr. Veeraphon Vorakun
15	Ship's Boy	Mr. Tongchai Poyoo

II. Researcher from SEAFDEC/TD

No	Position	Name	Remarks (Date and Duration)
1	Researcher	Mr. Isara Chanrachkij	22/10 – 4/11/ 2014, 14 days
2	Researcher	Mr. Sayan Promjinda	22/10 – 1/12 2014, 41 days
3	Researcher	Mr. Nakaret Yasook	22/10 – 1/12 2014, 41 days
4	Researcher	Mr. Sukchai Arnupapboon	22/10 – 1/12 2014, 41 days
5	Assistant Researcher	Mr. Pontipa Luadnakrob	22/10 – 1/12 2014, 41 days
6	Assistant Researcher	Mr. Komson Pohfar	22/10 – 1/12 2014, 41 days

III. Researcher from Indonesia, Malaysia and Philippines

No	Cruise No & Position	Name	Remarks (Date and Duration)
Trip 1/1st Leg Puerto Princesa – Zamboaga, 23/10 – 3/11 2014, 42 days			
1	Researcher	Mr. Mohammad Faisal Md Salleh	Cruise Leader: Mr. Mohammad Faisal Md Salleh
2	Researcher	Mr. Zamani Nayan	
3	Researcher	Mr. Osman Muda	
4	Researcher	Mr. Binjamin Martin	
Trip 2/2nd Leg Zamboaga - Sandakan, 3/11 – 16/11 2014, 14 days			
1	Researcher	Mr. Abdul Wahab Abdullah	Cruise Leader: Mr. Abdul Wahab Abdullah
2	Researcher	Mr. Mohd Tamimi Ali Ahmad	
3	Researcher	Mr. Rosdi Mohd Nor	
4	Researcher	Mr. Muhammad Yusof Nor Jasman	
5	Researcher	Mr. Azizul Ros	
6	Researcher	Mr. Mohd Sukri Muda	

Trip 3/3rd Leg Sandakan – Bitung, 16/11 – 30/11 2014, 15 days			
1	Researcher	Mr. Jamel Musel	Cruise Leader: Mr. Jamel Musel
2	Researcher	Ms. Masazurah Rahim	
3	Researcher	Mr. Saiful Hak Yahya	
4	Researcher	Mr. Ruzelan Jusoh	

List of Personnel on Board Cruise M.V.SEAFDEC2 NO 48-1/2015 (20 March – 13 May 2015, 54 days) in Sulu-Sulawesi Sea Waters

I. Ship Personnel (M.V.SEAFDEC2)

No	Position	Name
1	Captain	Mr. Vudhirat Vudthipanyo
2	Act. Chief Engineer	Mr. Theerawat Paiwal
3	Chief Officer	Mr. Aussawin Buachuay
4	Second Officer	Mr. Suren Pruksarat
5	Second Engineer	Mr. Padung Ngowlimhuat
6	Third Engineer	Mr. Kitinai Sukdit
7	Third Engineer	Mr. Boontarin Wora-in
8	Petty Officer	Mr. Anuphap Lorpai
9	Boatswain	Mr. Thana Rungjoy
10	Steersman	Mr. Pradit Kui-prasert
11	Steersman	Mr. Yuttachai How-harn
12	Fitter	Mr. Prew Shodok
13	Oiler	Mr. Chanchai Chid U dom
14	Cook	Mr. Ditthaphol Sangkhae
15	Ship's Boy	Mr. Tongchai Poyoo

II. Researcher from SEAFDEC/TD

No	Position	Name	Remarks (Date and Duration)
1	Researcher	Mr. Isara Chanrachkij	6/4 – 5/5 2015, 30 days
2	Researcher	Mr. Sayan Promjinda	25/3 – 8/4 2015, 15 days
3	Researcher	Mr. Nakaret Yasook	25/3 – 5/5 2015, 42 days
4	Researcher	Mr. Sukchai Arnupapboon	25/3 – 8/4 2015, 15 days
5	Assistant Researcher	Mr. Rakkiet Punsri	25/3 – 5/5 2015, 42 days
6	Assistant Researcher	Mr. Komsan Pofa	

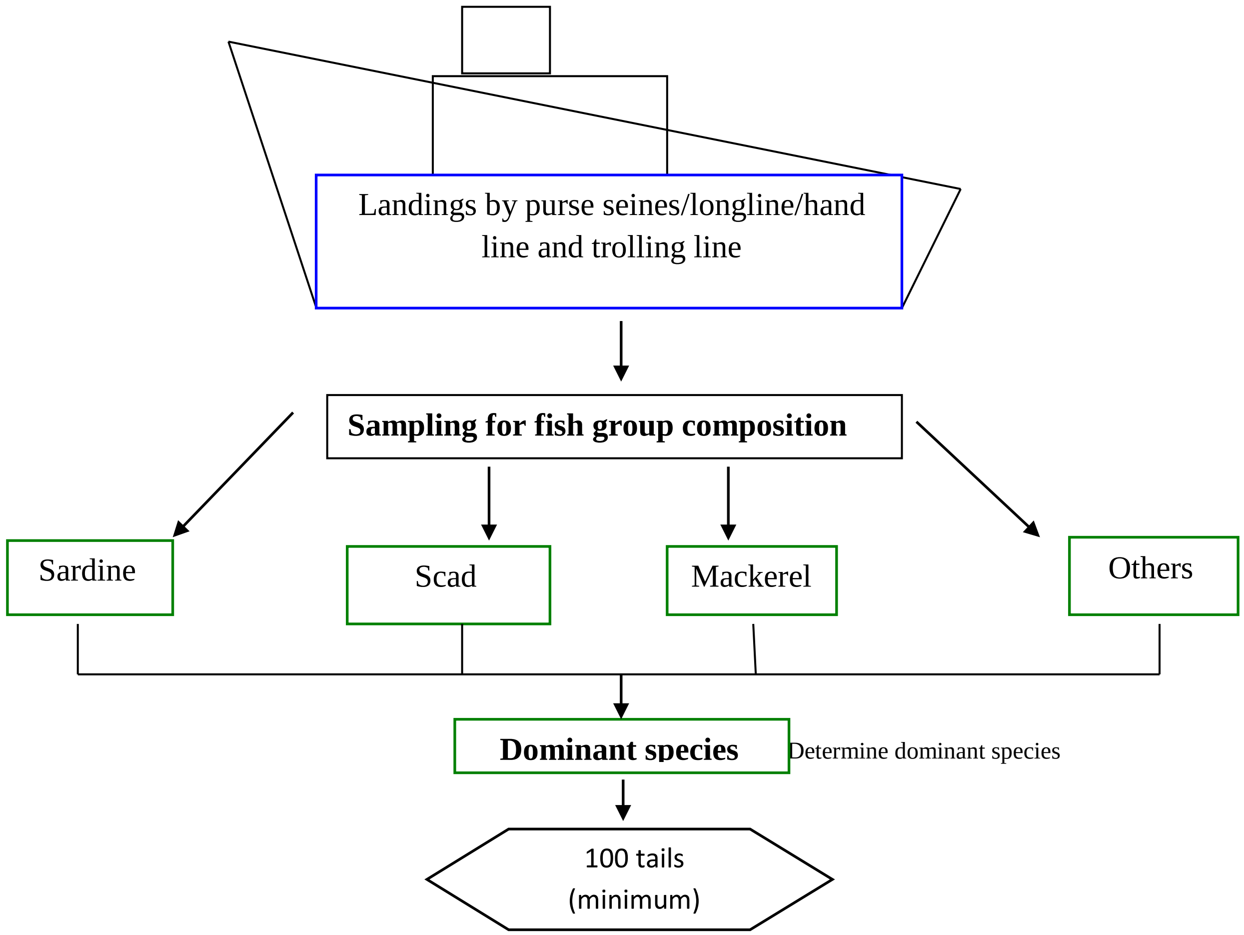
9.3. APPENDIX C

Flow Chart Diagram for Land Base Sampling Activities

Est. weight of total catch

Fish group composition and weighed sample taken and sorted to species and weighed

Length weight frequency data



♦ Distribution of Pelagic Fish Aggregations around Fish Aggregating Devices (FADs) by Acoustic Surveys in Sulawesi Sea

Distribution of Pelagic Fish Aggregations in around Fish Aggregating Devices (FADs) by Acoustic Surveys in Sulawesi Sea

Ali Suman *), Asep Priatna *) and Nakaret Yasook **)

ABSTRACT

The aim of this study is to define the vertical structures of pelagic fish aggregations around FADs as well as fish length and densities, in order to identify aggregation patterns. Acoustic surveys were conducted on November 2014 and April 2015 within the framework of the M.V.SEAFDEC2 Cruise. Acoustic data collection were carried out around FADs anchored in Sulawesi Seas, each two FADs was observed on November 2014 and April 2015. Data collected using echosounder SIMRAD EK60-120 kHz, together with the fishing trail by trolling line. The small pelagic <20 cm were dominated fish size composition around FADs with the 90% of the length distribution of them in November (west monsoon) were 14-20 cm. Large pelagic was dominated on April and 75%-90% of fish composition was <60 cm. Size distribution of large pelagic when transitional season was greater than west monsoon. Small pelagic were distributed between 10-60 m, but large pelagic dominant in November at the depth of 40-50 m and April at the depth of surface to 80 m. The low abundance found occuring around four FADs observed due to fishing activity. Fish density around FADs at oceanic zone was lower than FADs at neritic zone.

Keywords: pelagic fish, fish density, fish aggregating devices, acoustic survey, Sulawesi Sea.

*). Research Institute for Marine Fisheries, Jakarta, Ministry of Marine Affairs and Fisheries

**). Southeast Asian Fisheries Development Center, Training Department (SEAFDEC/TD), Samut Prakarn, 10290, Thailand

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Distribution of Pelagic Fish Aggregations in around Fish Aggregating Devices (FADs) by Acoustic Surveys in Sulawesi Sea

INTRODUCTION

Many types of tropical pelagic fisheries take advantage of the fact that pelagic fish aggregate around floating objects. For the last two decades, anchored man-made floating objects, known as fish aggregating devices (FADs), have greatly helped to develop and maintain artisanal pelagic fisheries, especially in tropical islands of the Pacific and Indian Oceans (Josse et al. 2000). At the same time, purse seine fisheries extend the use of FADs to increase catches.

However, better knowledge of aggregative behavior around floating objects is now required to allow for better stock assessment (Hallier, 1994) and management (Doray et al. 2006). FADs make convenient oceanic observatories where *in situ* studies on aggregative behavior can be conducted (Dagorn et al. 2007). Therefore, several approaches have already been used to study tuna aggregations.

The use of direct observational methodologies, namely active acoustics allowed to produce fisheries independent assessment of fish aggregations around FADs. Active acoustics methods are non-intrusive and provide the most exhaustive description of pelagic fish aggregations (Doray et al. 2006).

Acoustic signals appear to offer a great advantage over optics because sound absorption is much lower in the aquatic environment (at least at the frequencies used in fish sonar). Because the auditory perception of tuna is below approximately 2 kHz, sound should not disturb the fish. Acoustics appear to be an appropriate tool to observe and characterise fish density and biomass associated with FADs (Josse et al., 1999). However, experimental fishing (Simmonds and MacLennan 2005) or underwater video surveys (Hideyuki et al. 2005) must be conducted simultaneously to assess the composition of acoustic targets (Josse et al. 2000).

In this study we present acoustic observations of pelagic fish aggregations with a discrimination between the echoes of small pelagic fish and large pelagic fish such as tuna, tuna-like species. The objective is to define the vertical structures of pelagic fish aggregations around FADs as well as their fish length and densities, in order to identify aggregation patterns.

MATERIALS AND METHODS

Data acquisition

The acoustic surveys were conducted in Sulawesi Seas on November 2014 and April 2015 within the framework of the M.V.SEAFDEC2 Cruise No.47-3/2014, a Joint Research Program on Tuna Resources Survey in the Sulu and Sulawesi Seas within the EEZ of Indonesia, Malaysia and Philippines.

Acoustic data collection were carried out around FADs anchored some nautical miles off the main islands North of Sulawesi (Figure 1).

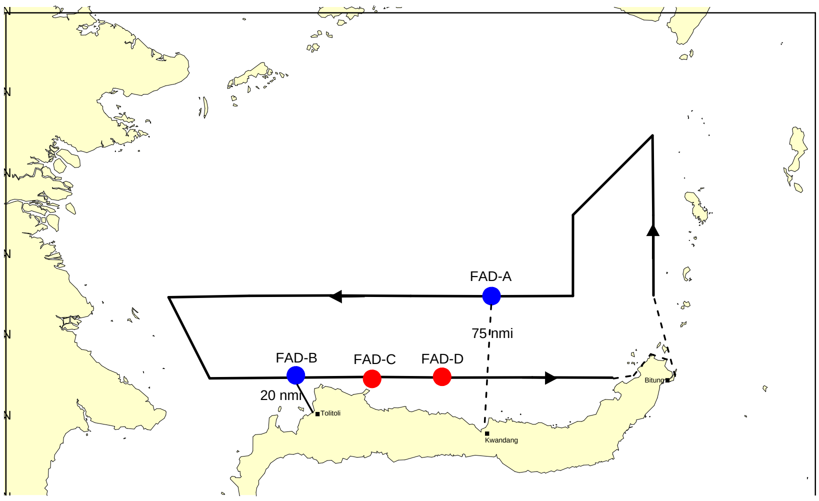

Figure 1. Geographical localization of FADs where echo surveys were conducted. FADs position in Sulawesi Sea.

Data were collected using small boat (service boat of M.V.SEAFDEC2) and equipped with a portable scientific echosounder SIMRAD EK60, together with the fishing trail by trolling line. The sounder was connected to a SIMRAD ES120-7C hull-mounted, split-beam transducer producing pulse duration of 0.5 ms at 120 kHz. The beam angle was 7.0°. Table 1 gives the results of the main settings used during acoustic surveys.

Table 1. Main settings of the SIMRAD EK60 echo sounder used during acoustic surveys around fish aggregating devices (FADs).

Menu	Parameter	value
Operation menu	Pulse Duration	512 ms
	Transmit power	50 watt
	Sound speed	1547 m/s
Transceiver menu	transducer depth	1 m
	Absorption Coef.	41.5 dB/km
	2-way beam angle	–21.00 dB
	Sv transducer gain	27.00 dB
	Ts transducer gain	27.00 dB
	angle sensitivity	23.00
	3 dB beamwidth	7.00 deg
	alongship offset	0.00 deg
	athw.ship offset	0.00 deg
TS detection menu	min. value	–60 dB
	min. echo length	0.8
	max. echo length	1.8
	max. gain comp.	6.0 dB
	max. phase dev.	8.0

The survey patterns were defined based upon a maximum survey time fixed a prior to 1 hour. Transect star survey pattern with eight branches (Josse et al., 1999), each 500 meters long and repeated twice (Figure 2), with mean speed of 4-5 knots. Additional target strength data were recorded during fishing operations at the same speed (trolling).

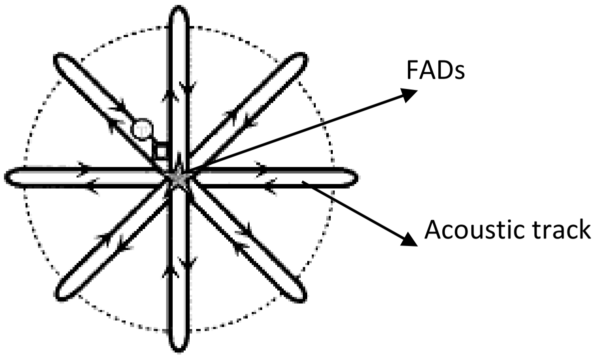

Figure 2. Survey patterns (Josse et al., 1999) used during acoustic surveys around FADs in Sulawesi Sea.

The transect pattern (figure 2), already used during previous acoustic surveys around FADs in French Polynesia (Depoutot, 1987; Josse, 1992; Bach et al., 1998;

Josse, 1999; Josse, 2000), allows an increase in the number of runs close to the FADs and exploration of an area a priori wide enough to take into account the whole aggregation. In fact, it was relatively difficult formed an ideal survey pattern as Figure 2, due to sea currents and waves, as well as using small boat. Figure 3 gives the results of real pattern of acoustic tracking surveys.

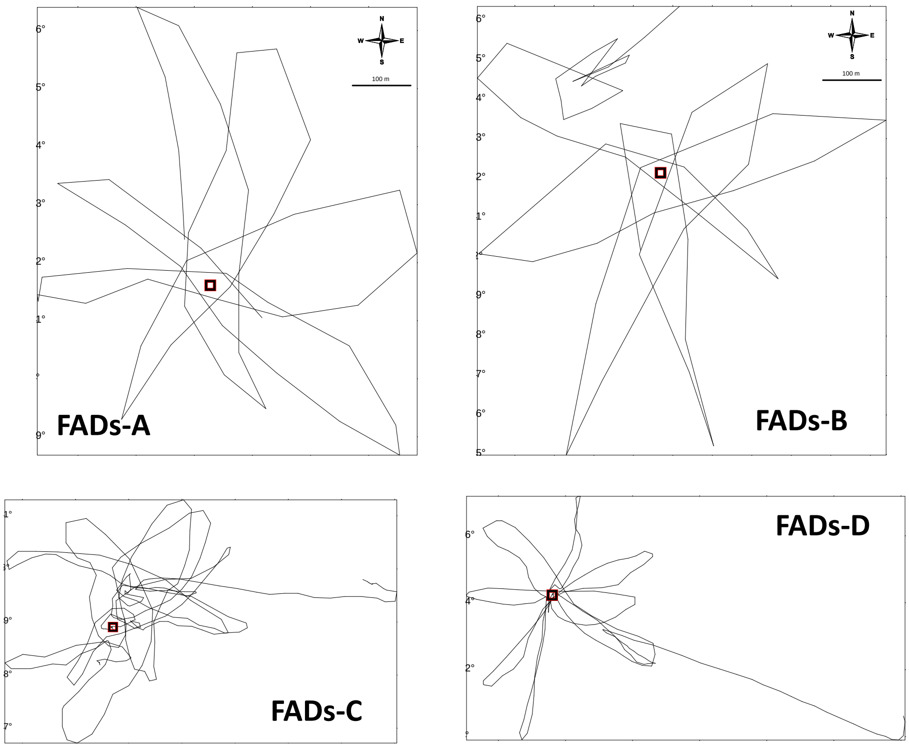

Figure 3. The real acoustic tracking during surveys around FADs in Sulawesi Sea.

SIMRAD ER60 software (Simrad, 2012) was used to record, via ethernet on a personal computer, acoustic and navigation data from the EK60 echo sounder. Acoustic measurements were extended down to 100 m in depth. Due to power transmitter of transducer (120 kHz) was limited, though tuna are known to inhabit 500 m vertical range within the tropical region (Bahtiar *et al*., 2013).

Data processing

In order to estimate pelagic fish densities associated with a FADs, surveyed areas were partitioned into 30 or 45° angular sectors based upon the survey pattern used (Figure 3). Each angular sector was then subdivided into volumes, using the distance of the sector from the FADs, (200 ping increments) and an arbitrary depth category. Depth categories included one 8-m layer for depths between 2 and 10 m, and seven 10-m layers for depths between 10 and 80 m. For each elementary sampling volume, densities, expressed as a number of fish per volume unit. SONAR version 4.0 software (Balk and Lindem, 2011) was used to process acoustic data. The output from post processing were TS distribution (decibel, dB) representing fish sizes, and distribution of s_A (m^2/nm^2) represented by fish density which were detected by transducer.

The estimation of fish length (L) from TS can be determined from using TS = 20 log L + A (Foote, 1987), where A was TS from 1 cm of fish length (normalized TS). For small pelagic fish used the equation TS = 20 log L – 73,97 (Hannachi, *et, al*. 2004), while large pelagic fish TS = 25,26 log FL – 80,62 (Bertrand & Josse, 2000). The fish density can be determined from using ρA = sA/σbs (MacLennan & Simmonds, 1992), where ρA was area density (number of fish//area), σbs=back-scattering cross (10TS/10, and volume density ρA = ρA x r (r = depth layer).

In order to compute fish density, length distribution calculated on fish dominant caught around FADs in Sulawesi Sea on November and April. Indian mackerel (*Decapterus macarellus*) as small pelagic were distributed at 14 - 31.5 cm or TS -51 to -44 dB, and large pelagic at 28 - 174 cm or TS -44 to -24 dB.

RESULT

Vertical Distribution of Fish Number around FADs

Acoustic survey around FADs-A indicated that small pelagic fish were detected from surface to 80 m. Above the depth of 30 m, small pelagic fish occupied smaller size (14-20 cm). While below the depth of 30 m , small pelagic fish were detected for all length composition (14-32 cm) and dominated by <20 cm fork length (Figure 4).

Large pelagic fish around FADs-A were detected at strata 40-70 m with the length composition about 30-50 cm (Figure 4) and the species of neritic tuna such as tuna fish, skipjack, and baby tuna. According of fishermen catch found out that neritic tuna were dominant around FADs-A. Last week before accoustic survey in FADs-A, the local fishermen of purse seine caught skipjack tuna about 5 tons in this area. Around FADs-B, that small pelagic found from the depth 10 m to 80 m. The all length composition of small pelagic fish (14-32 cm) found in all layer and dominated by fish in length smaller than 20 cm (fork length) (Figure 4). It is different with abundance in FADs-A, the large pelagic around FADs-B found from the depth of 10 m to 80 m, and all strata dominated by fish smaller than 50 cm in fork length (Figure 4).

Base on length composition, the neritic tuna such as tuna fish, skipjack, and little tuna found bigger in around FADs-B but lower in stock density. In around FADs-B were detected fish length bigger than 70 cm at strata 40-70 m (Figure 4).

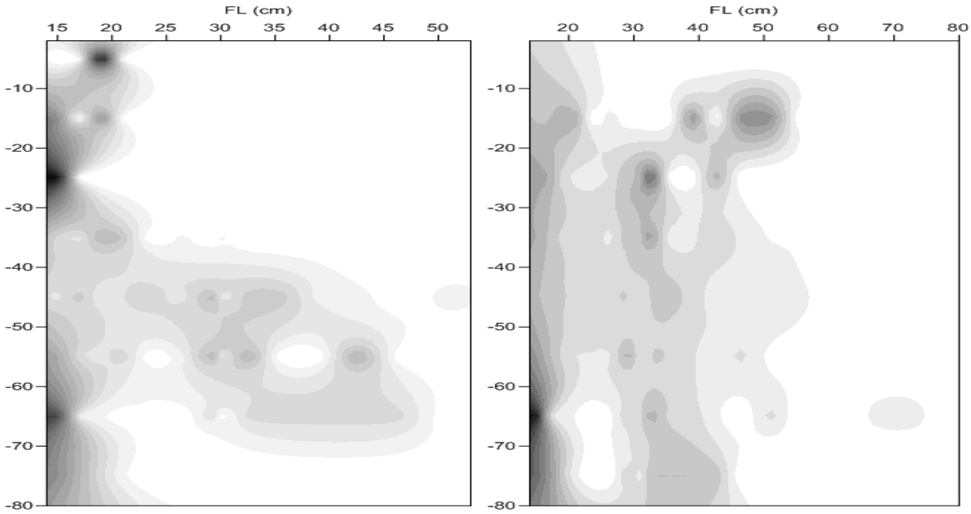

Figure 4. Percentage of composition numbers of pelagic fish (%) by depth around FADs-A (left) and FADs-B (right) in Sulawesi sea.

The TS between -51 to -44 dB not found during acoustic survey around FADs-C, indicates that no small pelagic fish were around this FADs. Large pelagic fish around FADs-C were detected at all layer from 2 m to 80 m. The length composition of neritic tuna such as tuna fish, skipjack, and baby tuna found at length 40 to 50 cm (Figure 4). The adult tuna with fork length bigger than 100 m found at strata between 60 m to 80 m of the depth (Figure 5).

Around FADs-D, the small pelagic were detected between the depth of 10 m to 80 m. The all length composition of small pelagic fish (14-32 cm) found in all the depth and dominated by fish length smaller than 20 cm in fork length. It is different with FADs-C, in that large pelagic in around FADs-D found from surface layer (10 m) to 40 m, and the dominated by fish length smaller than 60 cm in fork length (Figure 5). Base survey of catch composition of purse seine around FADs-D, the fishermen caught of large pelagic fish as skipjack, tuna fish, little yellowfin tuna (*Thunus albacares*) about 2 tons in this area. In catch composition found 3 adult tuna with 70 kg in mean weight.

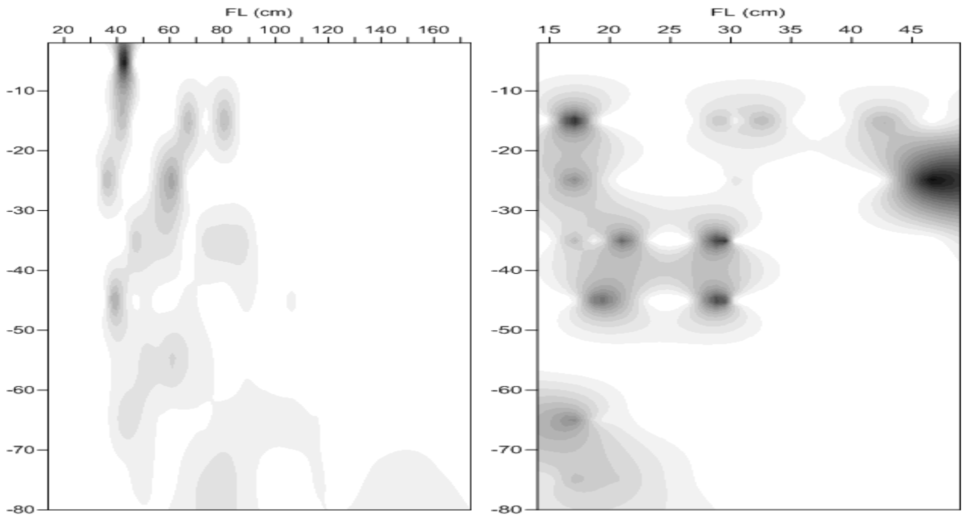

Figure 5. Percent composition numbers of pelagic fish (%) per depth around FADs-C (left) and FADs-D (right) in Sulawesi Sea.

Vertical Distribution of Fish Densities around FADs

The average of fish densities of small pelagic around FADs-A was about 0.008 fish/1000 m^3, it indicates the low densities category. The higher fish density found at the surface to 30 m in depth with length fish range about 14-20 cm. The large pelagic densities found 0.0005 fish/1000 m^3 and lower than small pelagic relatively with ratio 1:10 compare to small pelagic density. The length range of large pelagic was about 30-40 cm and this resources found at the depth of 40-50 m (Figure 6).

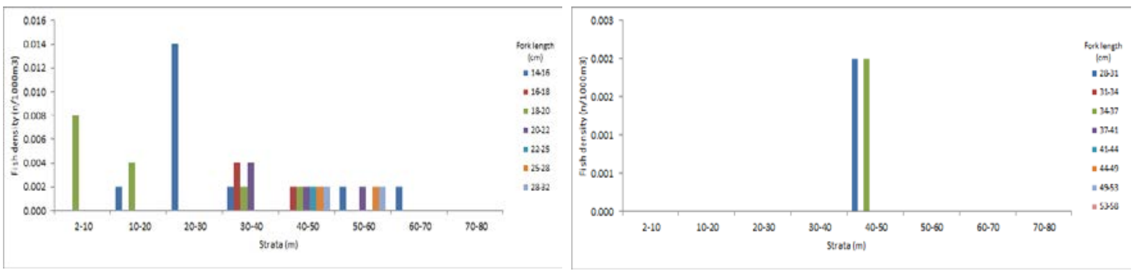

Figure 6. Fish densities by the depth (number of fish per 1000 m^3) around FADs-A of small pelagic (left) and large pelagic (right) in Sulawesi Sea.

The small pelagic fish densities around FADs-B were relatively low, was about 0.05 fish/1000 m^3. The length composition of small pelagic fishes was 14-20 cm and found at the depth between 20 m to 60 m. Large pelagic densities was lower than small pelagic, was about 0.01 fish/1000 m^3 and density ratio of large pelagic and small plagic was 1:5. The length range of large pelagic fish was about 30-40 cm and found at the depth 40-60 m (Figure 7).

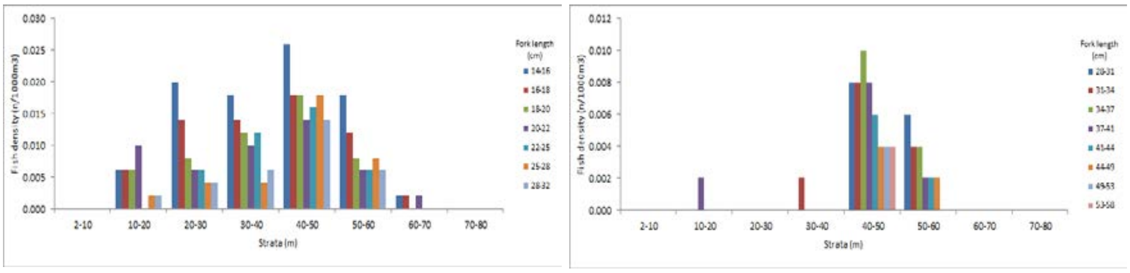

Figure 7. Fish densities by the depth (number of fish per 1000 m^3) around FADs-B of small pelagic (left) and large pelagic (right) in Sulawesi Sea.

The small pelagic fish were not found around FADs-C during acoustic survey. Large pelagic densities was about 0.028 fish/1000 m^3 with the length range between 70-80 cm found at the depth deeper than 40 m (Figure 8).

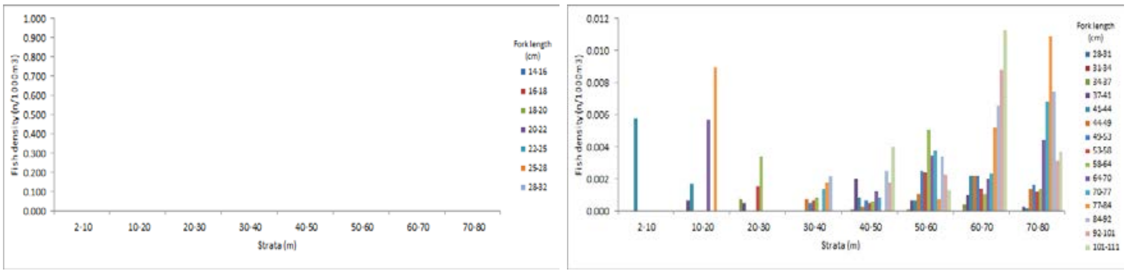

Figure 8. Fish densities (number of fish per 1000 m^3) by depth in around FADs-C of small pelagic (left) and large pelagic (right) in Sulawesi Sea.

The small pelagic fish densities around FADs-D were relatively low, was about 0.05 fish/1000 m^3. It mainly obtained by small pelagic fishes 14-20 cm which were distributed between 10 m to 30 m. Large pelagic densities was lower than small pelagic, was about 0.02 fish/1000 m^3. The length dominant of large pelagic was 40-50 cm and found at 10-20 m (Figure 9).

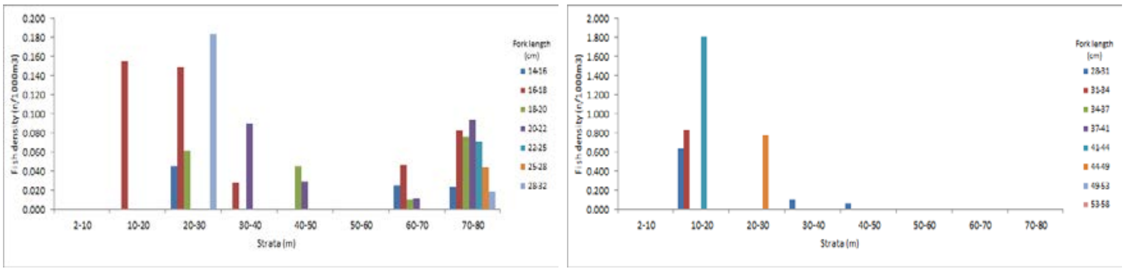

Figure 9. Fish densities (number of fish per 1000 m^3) by depth in around FADs-D of small pelagic (left) and large pelagic (right) in Sulawesi Sea.

According to the fish size composition during acoustic surveys that were conducted on November 2014, distribution of pelagic fish densities in both FADs (A and B) in around FADs dominated by small pelagic fishes smaller than 20 cm in fork length. The length of large pelagic around FADs-A were dominated by length class 28-31 cm and 34-37 cm, whereas around FADs-B dominated by fish 30-40 cm. In order to depth strata, that small pelagic tend to present between 20 m and 60 m, and large pelagic between 40 m and 50 m.

According to acoustic surveys on April 2015, that no small pelagic were detected around FADs-C. The length of small pelagic in FADs-D dominated by fish length smaller than 20 cm in fork length. The fish length of large pelagic around FADs-C were dominated by class 70-80 cm, and around FADs-D dominated by class 40-50 cm. In order to depth strata, that small pelagic around FADs-D tend to present between 20 m to 80 m, and large pelagic between 60 m and 80 m in FADs-C. In around FADs-D, the large pelagic fish was found on the depth between 10 m to 30 m.

DISCUSSION

The estimation of fish composition number in various length classes is the first step to calculate of fish stock. It could be quickly and real time obtained by acoustic surveys. Acoustically, fish length (L) was related to scattering crossection (σbs) according equation $\sigma bs = aL^2$, thus relationship between target strength (TS) and L becomes TS = 20 log (L) + A. One of the most influencing factors about TS was fish size. In general, in order to same species, the larger of size always have the greater of TS value.

In this paper, TS value (dB) were detected around FADs, was converted to fork length used equations Hannachi, *et al* (2004) and Bertrand & Josse (2000) to obtain length distribution (cm), assuming similarity of target species with them. In fact, the equation 20 log L was various, dependent species and equipment. The value of A was derived, that distinguish fish species roughly (MacLennan and Simmonds, 2005). In addition, survey experienced and data scrutinized to obtain species, that verification by fishing gear, underwater camera/video camera and so on were important.

Vertical Distribution of Fish % Composition around FADs

According to acoustic survey that were conducted on November (west monsoon), small pelagic <20 cm were dominated fish size composition around FADs in Sulawesi sea. It about 90% were 14-20 cm length distribution of small pelagic. Those indicates whether on November was period of developmental stage of small pelagic fish. According to the dominance of fish size was less than length of maturity (Lm). However, the hypothesis need to be clarified by studying the biological aspects of small pelagic fisheries.

Acoustic survey on April (transitional season) indicates that fish around FADs dominated by large pelagic. It about 75%-90% fish composition was <60 cm. Size distribution of large pelagic fish when transitional season was greater than west monsoon which <50 cm an average. The large pelagic group that dominated fish around FADs on April, were suspected to be predator of small pelagic. Therefore, no small pelagic fish were detected around FADs-C, which have been preyed by large pelagic fish, or migration from FADs as avoidance reaction by predator. When acoustic survey around FADs-C, some target which have >100 cm were detected between on the depth 60 m and 80 m. It was tuna size category with average weight of 3 tuna was 70 kg.

Vertical Distribution of Fish Densities around FADs

According to the acoustic survey in both season (November and April), small pelagic fish were distributed between on the depth 10 m to 60 m, and large pelagic between 40 m and 50 m in November and between surface to 80 m in April.

Acoustic survey were carried out around four FADs on two season (November and April), indicates that have low abundance occuring around four FADs observed.

Due to fishing activity in around FADs-A, local fishermen caught 5 tons of skipjack by purse seine. The exploitation of fishermen carried out one week before acoustic survey conducted in around FADs-A (personal communication). Therefore, the fish in this FADs-A still not recovered when the acoustic survey carried out. As well as density of large pelagic was lower than small pelagic fish. Similarly, occuring around FADs-B, some handline fleet were operated during acoustic survey.

In addition to predictions of predatory factors, which the large pelagic fish have strong dominance around FADs-C. Surveys were carried out coincides with feeding habit of large pelagic such as tuna and skipjack. In addition, purse seiners have operation around both FADs (C and D). Fishing activity has occurred about 3 days before acoustic survey around FADs-D. The fisherman caught about 70-100 kg of neritic tuna and three (3) tails of yellowfin tuna (*Thunus albacares*) with the average weight about 70-80 kg.

According to the first trip of acoustic survey in the west season, shows that fish density around FADs-A at oceanic zone was lower than around FADs-B at neritic zone.

CONCLUSION

Distribution by depth of large pelagic fish in around FADs in Sulawesi sea found at the depth of 0-80 m and small pelagic fish at the depth of 10-60 m. The average of fish densities of small pelagic around FADs was about 0.008 fish/1000 m^3, it indicates the low densities category. The higher fish density found at the surface to 30 m with length fish range about 14-20 cm. The large pelagic densities found 0.0005 fish/1000 m^3 and lower than small pelagic relatively with ratio 1:10 compare to small pelagic density. Fish abundance of large pelagic in around FADs in oceanic area was lower than neritic area and the large pelagic fish in around FADs was dominated at west monsoon. The condition of fish densities in around FADs due to several things, i.e. environmental such as food sources around FADs, sea current (flow and directon), attractors (good or damaged, age, type, and etc), as well as fishing activities around FADs.

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SEAFDEC Addresses

Secretariat

P.O. Box 1046
Kasetsart Post Office, Chatuchak
Bangkok 10903, Thailand
Tel: +66 2940 6326
Fax: +66 2940 6336
E-mail: secretariat@seafdec.org
http://www.seafdec.org

Training Department (TD)

P.O. Box 97 Phrasamutchedi,
Samut Prakan 10209, Thailand
Tel: +66 2425 6100
Fax: +66 2425 6110 to 11
E-mail: td@seafdec.org
http://www.seafdec.or.th

Marine Fisheries Research Department (MFRD)

2 Perahu Road,
Off Lim Chu Kang Road,
Singapore 718915
Tel: +65 6790 7973
Fax: +65 6861 3196
E-mail: ava_mfrd@ava.gov.sg
http://www.seafdec.org

Aquaculture Department (AQD)

Main Office: Tigbauan,
5021 Iloilo, Philippines
Tel: +63 33 511 9171
Fax: +63 33 511 8709, 511 9170
Manila Office: Rm 102 G/F
Philippines Social Science Center (PSSC)
Commonwealth Avenue, Diliman
Quezon City 1101, Philippines
Tel & Fax: +63 2 927 7825
E-mail: aqdchief@seafdec.org.ph
http://www.seafdec.org.ph

Marine Fishery Resources Development and Management Department (MFRDMD)

Taman Perikanan, Chendering,
21080 Kuala Terengganu, Malaysia
Tel: +609 616 3150
Fax: +609 617 5136
E-mail: mfrdmd@seafdec.org.my
http://www.seafdec.org.my

Inland Fishery Resources Development and Management Department (IFRDMD)

Jl. Gub. HA. Bastari No.08
RT.29 RW.07 Kel. Silaberanti
Kec. Seberang Ulu l, Jakabaring,
Palembang 30252,
Sumatra Selatan, Indonesia
Tel: +62 711 5649600
Fax: +62 711 5649601
http://www.seafdec.id

Joint Research Program on Tuna Resources
in Sulu and Sulawesi Seas