Stock Assessment by Hydro-Acoustic Method in the South China Sea Area II: Sabah, Sarawak, Brunei Darussalam

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ABSTRACT

Acoustic resource surveys were conducted by M/V SEAFDEC off Sarawak, Brunei and the east coast of Sabah from July 10 to August 2, 1996 for pre-NE monsoon season and from May 1 to May 24, 1997 for post-NE monsoon season, using the scientific echosounder FQ-70, developed by Furuno Electric Co. Japan. Collected raw values of backscattering strength (SV) from the 200 kHz transducer were carefully corrected and filtered to eliminate the influence of plankton. These corrected SV values were divided into pelagic and demersal fish, and were used to estimate the biomass of pelagic and demersal multi-species in the limited coastal waters off Sarawak. *Decapterus macrosoma* for pelagic fish and *Priacanthus macracanthus* for demersal fish were selected as representative species, based on the fisheries statistics, landing place survey, and research vessel survey in order to estimate biomass. The standard length (SL) and weight of these representative species were obtained from research vessel survey and supported by previous literatures. Target strength (TS) of these representative species were calculated using formula TS = 20 log(SL) - 66. The distribution of the SV values for pelagic fish showed distinct difference between pre and post Northeast (NE) monsoon seasons along the coastal waters. Greater concentrations of SVs were observed from depth 100 and 200m on the continental shelf along the survey area for both the seasons. The estimated biomass of multi-species fish off coastal Sarawak waters for the pre and post NE monsoon seasons was 120,000 tonnes (100,000 tonnes of pelagic fish and $2x10^5$ tonnes of demersal fish) and 470,000 tonnes (360,000 tonnes of pelagic fish and 110,000 tonnes of demersal fish), respectively. Estimated Maximum Sustainable Yield (MSY) was 83,000 tonnes for pelagic fish and 31,000 tonnes for demersal fish when using Cadima's model.

Key words: Acoustic survey, Multi-species biomass estimation, Sarawak, Brunei, and the east coast of Sabah waters, MSY

Introduction

Fish stock assessment is a growing necessity in many countries in Southeast Asian region bordering the South China Sea waters. In Sarawak, Brunei Darussalam and the east coast of Sabah waters are the same as other tropical regions, with complexity of biological characteristics, such as the multitude of fish species and spawning throughout the year, or the inherent characteristics of fisheries hinder the collection of reliable landing statistics throughout the area. Suitable fish stock assessment methods are not readily available in this region. SEAFDEC has been making efforts to develop appropriate stock assessment procedures, using hydro- acoustic method (Rosidi et al., 1998). Hydro-acoustic method seems to be a more appropriate among others to meet overall goal of the quick stock assessment, although the method does not give a complete answer for the tropical multi-species condition.

This report examines whether distributions of volume backscattering strength (SV) collected by the scientific echosounder FQ-70 off Sarawak, Brunei Darussalam and the east coast of Sabah waters are influenced by the Northeast monsoon, and presets one approach of stock assessment including biomass estimation off Sarawak.

Materials and Methods

Two hydro-acoustic surveys, using the scientific echosounder FQ-70 (Furuno Electric Co.), were carried out simultaneously with oceanographic studies by M/V SEAFDEC off Sarawak, Brunei Darussalam and the east coast of Sabah. The first survey was conducted from July 10 to August 2, 1996 designated as the pre Northeast (NE) monsoon season. The second survey was carried out from May 1 to May 24, 1997 designated as the post NE monsoon season. These timing of the surveys were primarily to examine whether the NE monsoon season (November to March) affects the distribution of fish in the survey area.

Calibration of FQ-70 was done prior to each survey near Oceanographic Station 1 (2∞19'N, 110∞00'E) off Kuching, Sarawak in July 9, 1996 for the first survey, and in April 30, 1997 for the second survey. The source level, receiving sensitivity, and the gain of amplifier were measured by means of a hydrophone. Parameter settings of the acoustic system, based on the Calibration results, were shown in Table 1.

Survey transect was set between oceanographic stations. Both surveys were conducted along the same transect as shown in Figure 1. The total number of transects was 78, and were assigned in ascending order from 1 to 78. The transects were cruised throughout day- and nighttime at a speed of approximately 10 knots.

Data Collection

The hydro-acoustic system was set up to process echo and output of the volume backscattering strength (SV in dB/m^3) in real time from depth of 10m to 200m at horizontal intervals of 0.1 nautical mile. The depths were set into 10 layers as shown in Table 2. Layers 1 to 8 were set between 10m to 200m from the surface, while layers 9 and 10 were set between 1 to 10m from the bottom.

The SV values from the low frequency (50kHz) and the high frequency (200kHz) transducers were both recorded. However, only the values from the high frequency transducer were used in data processing and subsequently in the fish biomass estimation. The data were recorded in the following forms:

1. Numeric data of integrated result of echo signals which were recorded in a floppy disk through data analyser FQ-770.
2. Print-out of the numeric data from the results of the integrated echoes (This output was also recorded simultaneously in a floppy disk).
3. Echo signals including echo of vertical distribution curve, which were traced on the recording paper through the recorder unit FQ-706.
4. Analog data for echo signals and log data which were recorded on a video tape.

Only the numeric data on a floppy disk and in printed form were used to process the SV values. The traced echo signals were only used as a reference. Analog data in the video tapes were not utilized due to the absence of the post data analyser.

SV Correction

Noise from other electric devices and unlocked echoes due to rough sea conditions may create errors to the collected raw SV values. Besides noise and bottom unlocked echoes, the raw SV values may also be affected by plankton and other dense micronecton. Therefore, these raw SV values need to be corrected prior to further analysis.

The graphical method was used to correct SV values obtained by chance from noise of other electric devices and bottom unlocked echoes. The SV values were plotted against integration number for each depth layer of 1 to 8 and average of layers 9 and 10. From the graphs, extremely high echo traces were carefully corrected by referring to the recording paper. These were termed as the Corrected SV values.

The corrected SV values were further filtered to select the values from fish, using five-point moving average. These filtered SV values will be called the Calculated SV values.

The calculated SV values for each transect were averaged vertically from depth layer 1 to 8 for each integration number, and horizontally from the first integration number to the end. The calculated SV were sorted out into pelagic and demersal fish. Average SV values of layers 9 and 10 were considered as demersal fish. The values remained from the subtraction of the SV values of layers 9 and 10, from the total SV values of layers 2 to 8, were considered as pelagic fish. The overall averaged calculated SV values throughout transects within the specified area for pelagic and demersal fish were used for fish biomass estimation.

Biomass estimation

The pelagic and demersal multi-species fish biomass off Sarawak waters within Malaysian EEZ was only estimated due to the availability of necessary information. Area of the biomass estimation is only limited coastal waters at the shallower than 100m in depth as shown in Figure 1. Table 3 shows transect number for biomass estimation. The area was calculated based on transects accorded with grids of 30' in latitude by 30' in longitude.

The following expression was used to estimate fish biomass:

$$Q = (sv/ts)\ w \bullet a \bullet d \qquad (1)$$

where Q : Biomass

$sv = 10^{(SV/10)}$:Backscattering strength

$ts = 10^{(TS/10)}$: Target strength

w : average fish weight(g)

a : survey area(m^2)

d : layer depth(m)

Target strength (TS) was estimated using the following equation from Furusawa (1990):

$$TS = 20 \log SL - 66 \qquad (2)$$

Where TS : Target strength(dB)

SL : Fish standard length(cm)

To determine single TS for biomass estimation, a representative species was used in this report. The representative species for pelagic and demersal fish were determined in two steps, using the same method by Rosidi *et al*.(1998). Selection of possible detected pelagic and demersal fish for FQ-70 was listed in Table 4. Representative pelagic and demersal fish groups were selected based on the catch statistics of the major fishing gears operating in the biomass estimation area off Sarawak waters within Malaysian EEZ. Then the representative species was determined in examining information from the previous landing statistics and literatures. After determining the representative species, necessary information on standard length and average weight were calculated from the landing survey data.

Maximum Sustainable Yield (MSY) Estimation

MSY is one of the important management goals. When catch and effort data from the fishery statistics are available, the surplus production models (Schaefer, 1954 and Fox, 1970) can be applied. In Sarawak, these historic statistics are not readily available to fit these models to estimate MSY. In spite of these models, Cadima's empirical equation (Troadec, 1977), modifying Gulland's model (1971), are applicable to estimate MSY using biomass estimated by the hydro-acoustic method:

$$MSY = X \bullet (Y + M \bullet B) \qquad (3)$$

where X : Constant
M: Annual natural mortality
B: Biomass for exploited fish stocks
Y: Average annual yield

Cadima's model is applied for exploited stock while Gulland's model is for unexploited stock. In Sarawak waters, both pelagic and demersal fish stock are rather exploited and, therefore, Cadima's model is employed. In this present study, constant X is set at 0.2 followed the results of the simulation study by Beddington and Cooke (1983).

For the model, average annual yield in 1996 and 1997 accorded with the survey periods was obtained from landing statistics of Sarawak Department of Fisheries (Anon., 1996 and 1997). Annual natural mortality, M, for both the models was estimated by a linear relationship between logarithms of maximum age and natural mortality rate applied by a method of Hoenig (1983):

$$ln(M) = a + b\ ln\ (A) \qquad (4)$$

where M: Annual natural mortality
A: Maximum age (years)
a and b: Model parameters

To estimate the parameters a and b of equation (4), three parameters of Von Bertalanffy growth curve (L•, K, and t_0) (von Bertalanffy, 1934) were used. Information on these parameters for various fish in South China Sea were obtained from Mohsin (1996). For each fish, the maximum age (A), and annual natural mortality (M) were obtained by the following methods. A is estimated from Von Bertalanffy Growth Curve parameters when L_t set at 98 % of L• in the following equation:

$$A = t_o - (1/K)\ ln\ (1 - L_t/L\bullet) \qquad (5)$$

where L• : maximum length
K : Growth coefficient
t_0 : age at length L=0
L_t : length at age t

M was estimated by the following empirical equation of Pauly (1980):

$$ln\ M = -0.0152 - 0.279\ ln\ L\bullet + 0.6543\ ln\ K + 0.463\ ln\ T \qquad (6)$$

where M : Annual natural mortality
L•: maximum length
K : Growth coefficient
T : Average annual temperature at the surface(∞C).

The surface water temperature in tropical waters are relatively constant at approximately 27-28

∞C (Chua and Charles, 1980). In this analysis, T was set at 27 ∞C.

Results

Figure 2 shows an example of echogram with SV vertical distribution curves for both high and low frequency. When fish school appeared, SV for high and low frequency showed the almost same level of SV values. However, from the low frequency between depth 40-80m, continuous SV (averaged 60dB) were recorded.As recorded by Termvidehakorn (1998) presented in the same seminar, there appeared to be abundance of surface fish, fish larvae and mesopelagic fish larvae especially during early morning, night time and during cloudy day. Beside fish larvae, Jivaluk (1998) reported in the same seminar, that copepoda dominated the zooplankton population followed by ostracoda and chaetognatha.Boonyapiwat (1998) reported during the same cruise that the quantity of phytoplankton in the chlorophyll maximum layer (18-70m in the coastal area) and 45-80m in offshore area was most abundant among 3 layers (surface, seasonal thermocline and chlorophyll maximum depth). Due to such continuous and dense echoes attributed to abundant fish larvae,zooplankton and phytoplankton, only SV values from high frequency were used for further analysis.

SV Distribution

The distributions of the calculated SV values of pelagic and demersal fish for pre and post NE monsoon seasons for each transect were shown in Figures 3 to 6. There are apparent differences in SVs between seasons and areas.

Figures 3 and 4 show the distribution of pelagic fish. These figures showed that higher SV appeared in post NE monsoon season. There were higher SV values in depth between 100 and 200m on the continental shelf along the Sarawak, Brunei and Sabah for both seasons.

Distributions of SV values in Figures 5 and 6 for demersal fish showed an apparent difference between seasons and areas which were similar to the those of the pelagic. In post NE monsoon, higher SV values were distributed off shore as well as coastal waters while higher SV values were distributed only offshore for pre NE monsoon. There were apparent larger SV values in depth between 100 and 200m on the continental shelf along the Sarawak, Brunei, and Sabah for both seasons.

Biomass Estimation

Fishing activities off the survey area is limited to the coastal waters up to 60 nm. It is difficult to obtain fishing information on further off shore waters in order to estimate biomass. In this report, the biomass estimation is just the coastal waters off Sarawak (Figure 1). Total area for biomass estimation is 61,378 km^2.

Decapterus macrosoma and *Priacanthus macracanthus* are the representative species for biomass estimation of pelagic and demersal fish respectively. These species were recorded as one of the dominant species caught during the demersal survey in the same area (Richard *et al*., 1998 and Vidthayanon 1998). The standard length, estimated TS and average weight are shown in Table 5.

Results of biomass estimation of pelagic and demersal fish off the coastal waters of Sarawak within Malaysia EEZ between the two seasons were shown in Table 5. The estimated density and biomass of pelagic fish for pre and post NE monsoon seasons were 1.61 tonnes/km^2 and 100,000 tonnes, and 5.87 tonnes/km^2 and 360,000 tonnes respectively. Using the same data, for waters <100m Yuttana estimated the biomass to be 105,949.99 tonnes for pre-monsoon season and 314,746.01 tonnes for post-monsoon which are quite similar to our estimates. Albert and Hadil (1998) reported that the average estimated density for pelagic was 1.74 tonnes/km2 and the average estimated biomass of 216,300 tonnes. The estimated density and biomass of demersal fish for pre and post NE monsoon were 0.30 tonnes/km^2 and 20,000 tonnes and 1.83 tonnes/km^2 and 110,000 tonnes, respectively. This estimated biomass is comparable to that of Albert and Hadil (1998) at 108,078 tonnes using swept area method. Total biomass of multi-species fish for the pre-and post-NE monsoon seasons were 120,000 tonnes and 470,000 tonnes, respectively. Differences of estimated biomass is very large

Table 1. Parameter settings derived from calibration work of the acoustic system FQ-70 prior to the survey off Sarawak, Brunei, and Sabah waters.

Parameters	July/Aug. 1996		May 1997	
Frequency (kHz)	50	200	50	200
Source Level(dB)	215.1	220.0	212.3	218.1
Pulse Duration(ms)	1.2	1.2	1.2	1.2
Beam Width(dB)	-14.5	-16.1	-14.5	-16.1
Absorption Coefficient(dB)	9.9	92.7	9.9	92.7
Receiving Sensitivity(dB)	-185.6	-194.9	-186.8	-197.7
Amplifier Gain(dB)	49.0	50.3	49.8	50.4

Table 2. Depth layers and ranges of SV integration off Sarawak, Brunei, and Sabah waters.

Depth Layer	Ranges(m)
1	10-20
2	20-40
3	40-60
4	60-80
5	80-100
6	100-130
7	130-160
8	160-200
9	10-5 (from Bottom)
10	5 -1 (from Bottom)

Table 3 Transect for biomass estimation off Sarawak waters within the Malaysian EEZ.

Transect number between the oceanographic Stations
St. 1-2, 2-3, 3-4, 4-5, 7-8, 8-9
St. 15-16, 16-17, 17-18, 28-29, 29-30
St. 32-33, 33-34, 44-45, 45-46, 47-47
Total number of transects 20

Table 4 List of pelagic and demersal fish based on the Annual Fisheries Statistics, Department of Fisheries, Ministry of Agriculture, Malaysia (1996).

Fish Group	
Pelagic	**Demersal**
Sphyraena jello/S. optusa	Callyodon spp./Thalassoma spp.
Rachycentrom canadus	Upeneus spp.
Alectis indica/Caranx spp.	Drepane punctata
Megalaspis cordyla	Caesio spp.
Carangoides spp.	Tachysurus spp./Arius spp./
Polynemus spp./Eleutheronema	Osteogenius spp.
teradactylum	
Selar spp.	Siganus spp.
Sardinela spp.	Sciaena spp./Otolithoides spp.
Decapterus spp.	Otolithus spp./Johnius spp.
Elagatis bipinnulatus	Pomadasys spp.
Scomberoides commersonianus	Lutjanus spp.
Stolephorus spp.	Plectrorhinchus picfus
Rastrelliger spp.	Nemipterus spp.
Scomberomorus spp.	Pristipomoides typus
Trichiurus lepturus	Leiognathus spp./Gazz spp./
Abalostes stellaris	Secutor spp.
Fomio niger/Pompus spp.	Saurida spp.
Liza spp./Valamugil spp.	Plotosus spp.
	Lactarius lactarius
	Sillago sihama/S. maculuta
	Scolopsis spp.

Table 5. Estimated biomass with additional information for demersal and pelagic fish off Sawarak waters within Malaysian EEZ in pre and post Northeast monsoon season, using FQ-70.

	Northeast Monsoon	
	Pre(Jul/Aug, 1996)	Post(May, 1997)
Area for biomass estimation (km^2)	61,378	
Pelagic Decapterus macrosoma		
Depth layer(m)	181	181
SV(dB)	-80.0	-73.8
SL (cm)	22 ^{*1}	16^{*2}
TS(dB)	- 40.8	- 41.6
Weight(g)	71^{*1}	52^{*2}
Density(tonnes/km^2)	1.61	5.58
Biomass(10,000 tonnes)	10	36
Demersal Priacanthus macracanthus		
Depth layer(m)	9	9
SV(dB)	-72.7	-64.8
SL (cm)	15.4^{*3}	15.4^{*3}
TS(dB)	- 42.3	- 42.3
Weight(g)	81.2^{*3}	81.2^{*3}
Density(tonnes/km^2)	0.30	1.83
Biomass(10,000 tonnes)	2	11

1) Data ontained from the Mukah landing place in July and August 1998.
2) Data ontained from the Mukah landing place in March 1998.
3) Data ontained from the Malaysian EEZ Survey off Sarawak in May-Sep., 1998.

between pre and post NE monsoon seasons.

MSY Estimation

A total of 151 cases of Von Bertalanffy growth parameters, L•, K and t_0 of more than 30 species were obtained from Mohsin (1996). The relationship between A and M were shown in Figure 7. Following the empirical formula a linear relationship between logarithms of A and M is:

$$Ln\ M = 1.656 + 0.780\ ln\ A \quad (r^2 = 0.88, n=151).$$

Maximum age for *Decapterus macrosoma* and *Priacanthus macracanthus* were estimated at 4.21 and 3.26 years respectively. However their parameters are as listed in Table 6 if using the Von Bertalanffy growth curve. Estimated natural mortality, M was 1.71 for *Decapterus macrosoma* and 2.08 for *Priacanthus macracanthus*.

Estimated MSY is shown in Table 7. Using the average catch in 1996 and 1997 for selected species as indicated in Table 4, MSY is estimated MSY at 83,000 tonnes for pelagic fish and 31,000 tonnes for demersal fish.The results were comparable to the 86,892 tonnes as estimated using Fox (exploited model) and 80,031 tonnes using Fox (unexploited model) for pelagic fish and 54,000 tonnes for demersal (Albert and Hadil 1998). Average catch of pelagic and demersal fish in 1996 and 1997 is 22 % and 51 % of MSY, respectively. Catch of pelagic fish has not been reached at MSY level.

Discussion

This paper presents one of the approaches for multi-species stock assessment using hydro-acoustic method to estimate fish biomass. This survey has collected only SV values without fish echoes identification. Future survey design need to include the fish echo identification with appropriate fishing methods, such as mid-water trawl or vertical longline.

Distribution of SV in Figures 3 and 4 for pelagic fish showed apparent difference between seasons and areas. There is higher SV values during post NE monsoon season than pre NE monsoon season. At the moment, it is difficult to find suitable causes for the changes of SV distributions. This change might be correlated in respond to the oceanographic condition in between Northeast monsoon and Southwest monsoon seasons especially in terms of distribution of water masses and currents (Liong, 1974). Appearance of the coastal waters and the occurrence of upwelling off Sarawak during Northeast monsoon season seems to have close relationship to the distributions of SV in pre and post NE monsoon seasons. Anomalously high biomass of phytoplankton were recorded by Snidvong (1998) in the vicinity of the area, specifically at stations 37 and 38, could be partially related to the upwelling nearby. There were no great variations of temperature, salinity and density values of the water mass due to pronounced mixing effect (Saadon *et al.* 1998). Geostrophic current pattern contributing to the divergence as well as convergence inferred from horizontal circulation matched quite well with the observed vertical migration of the pynocline of the area which is an indication of upwelling and downwelling (Snidvong 1998). Average trawl catch rates obtained by KK MANCHONG during the same periods; July/August, 1996(Pre NE monsoon) was 4.36 kg/hour and April/May 1997(Post NE monsoon) was 5.42 kg/hour (Richard *et al*. 1998) although diferrences were not large between seasons. The results between the acoustic method and the trawl survey also show the similar seasonal trend.

The acoustic survey by R/V Rastrelliger in the coastal waters of Sarawak during June and July in 1986 showed the density of pelagic fish at 2.41 tonnes/km^2 (Anon, 1987). The present survey estimated the average density of pelagic fish in these waters during July and August at 1.83 tonnes/km^2. The results obtained in this study seemed to be comparable to the previous one.

Recently, Total Allowable Catch (TAC) has been discussed and is compulsively set under the Law of the Sea of the United Nations. Under this TAC, one of the important management goals is the Maximum Sustainable Yield (MSY). However, recent interpretations have shown to secure more

Table 6 Estimated natural mortality with additional information for demersal and pelagic fish

Species	Von Bartalanffy Growth Parameters *1 K	L_∞	t_0	Maximum Age, A (year)	Estimated M
Decapterus macrosoma	0.93	33.0	0	4.21	1.71
Priacanthus macracanthus	1.20	23.7	0	3.26	2.08

*1 Parameters of Von Bertalanffy Growth for *Decapteru macrosoma and Priacanthus macracanthus* were obtained from Ingles and Pauly (1984) and Dwiponggo *et al*. (1986), respectively

Table 7 Estimated MSY for pelagic and demersal fish, using Cadima's equation based on the biomass from the acoustic survey off Sarawak between 1996 and 1997.

Fish Group	Average Catch *1 (tonnes)	Average Biomass (tonnes)	MSY (tonnes)	2/3MSY (tonnes)
Pelagic	18,000	231,000	83,000	55,000
Demersal	16,000	66,000	31,000	20,000

*1 Average catch between 1996 and 1997 for the selected fish of pelagic and demersal fish (Table 4), derived from landing statistics of Sarawak Department of Fisheries (Anon., 1996 and 1997).

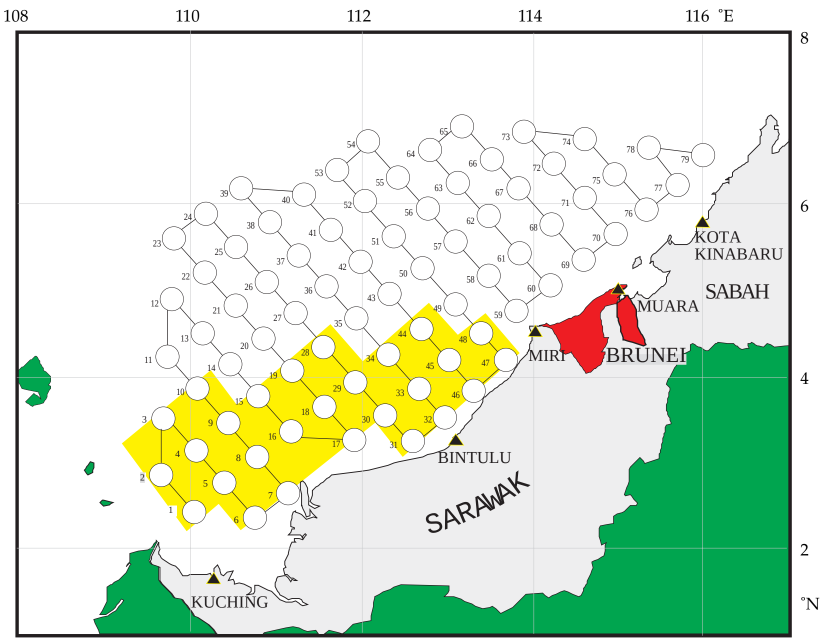

Fig. 1. Survey transects for the acoustic survey off Sarawak, Brunei and Sabah waters in July-August 1996 and May 1997. Number indicates the oceanographic station

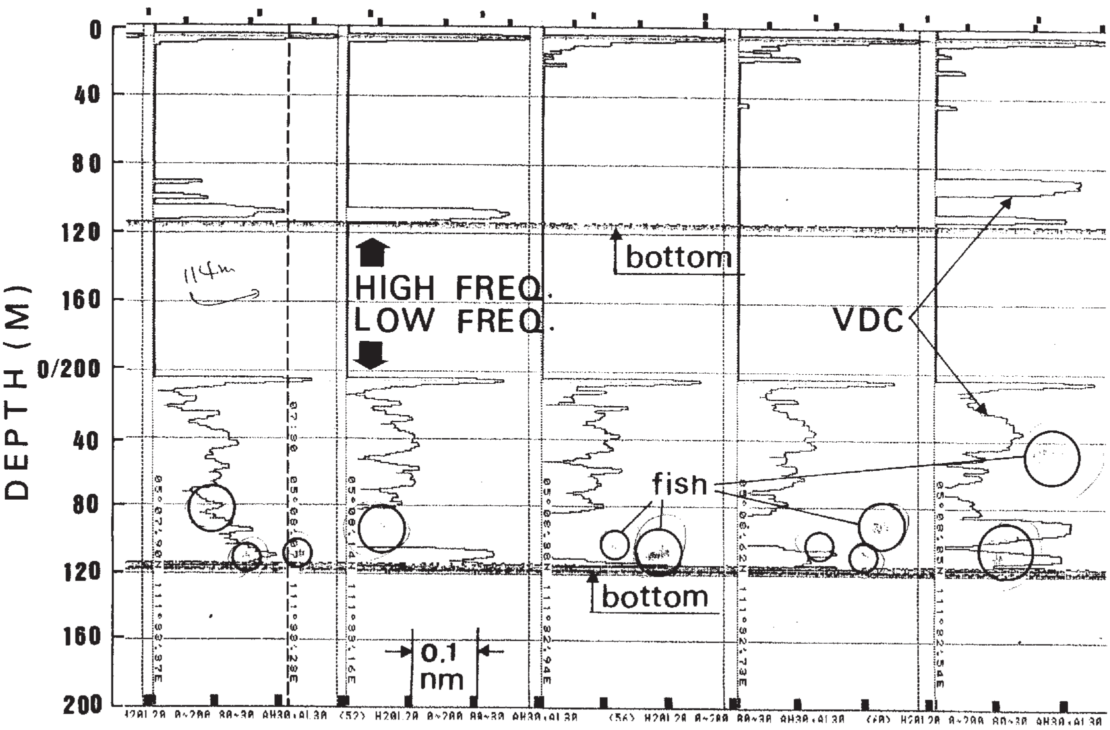

Fig. 2. An example of large fish school echograms with SV vertical distribution curve (VDC) between station no. 36 and 37 during day-time in May, 1997

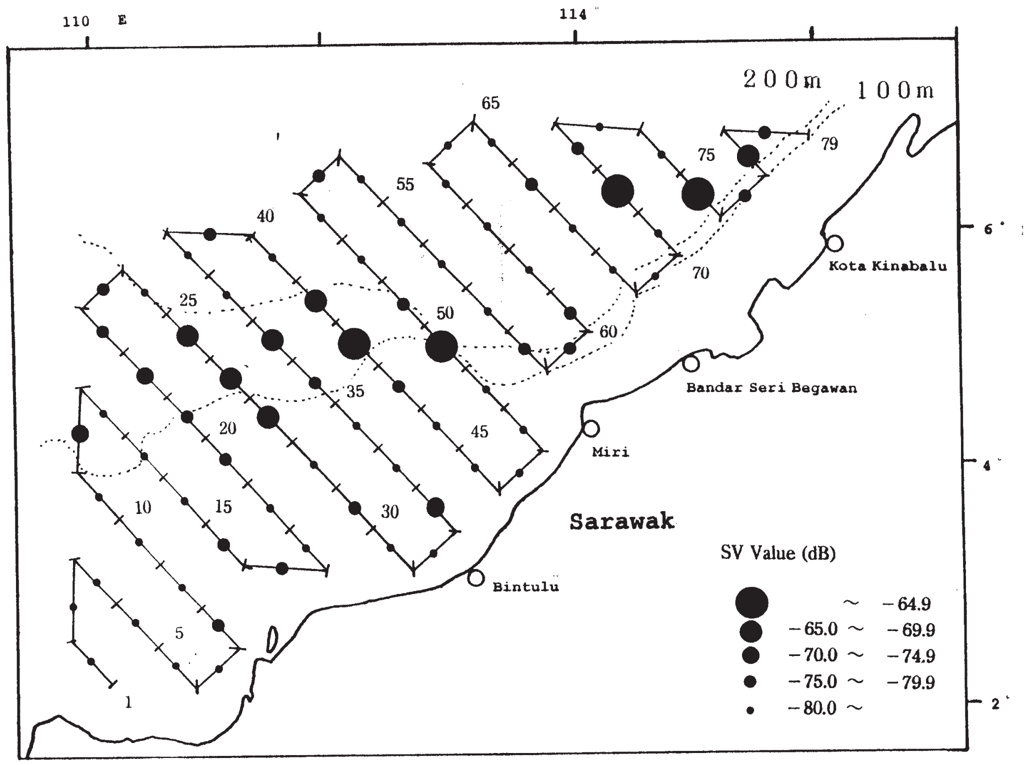

Fig. 3. SV value distribution for the pelagic fish along transects off Sarawak, Brunei and Sabah waters in July-August 1996 (Pre Northeast monsoon). Number indicates the oceanographic station

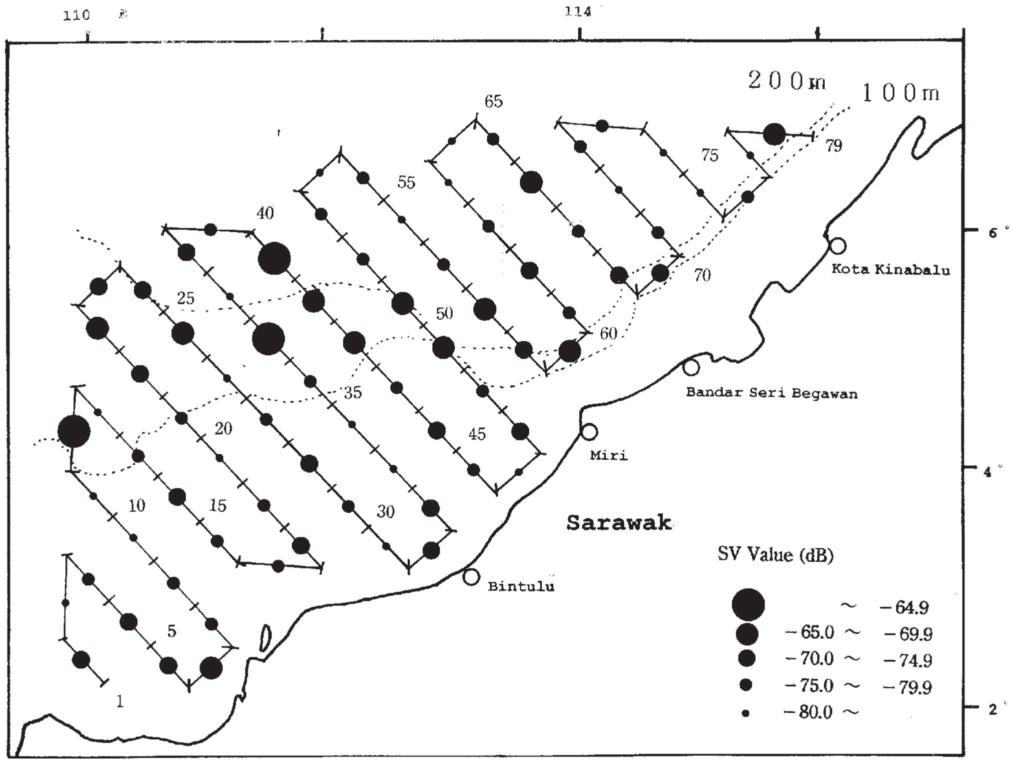

Fig. 4. SV value distribution for the pelagic fish along transects off Sarawak, Brunei and Sabah waters in May 1997 (Post Northeast monsoon). Number indicates the oceanographic station

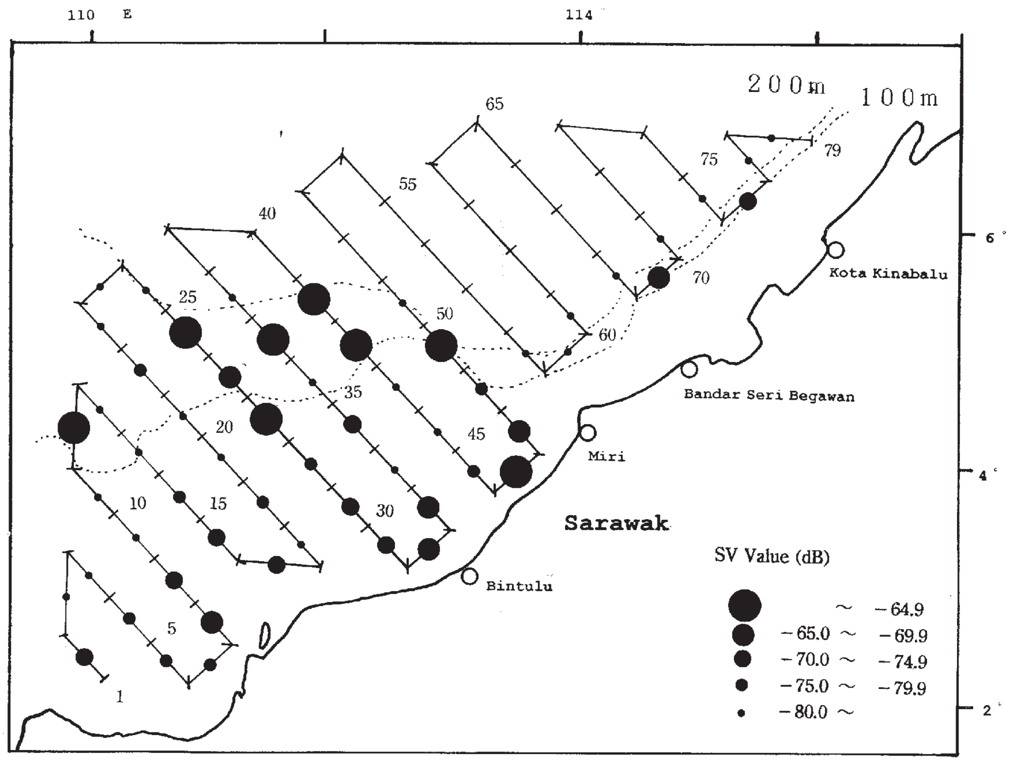

Fig. 5. SV value distribution for the demersal fish along transects off Sarawak, Brunei and Sabah waters in July-August 1996 (Pre Northeast monsoon). Number indicates the oceanographic station

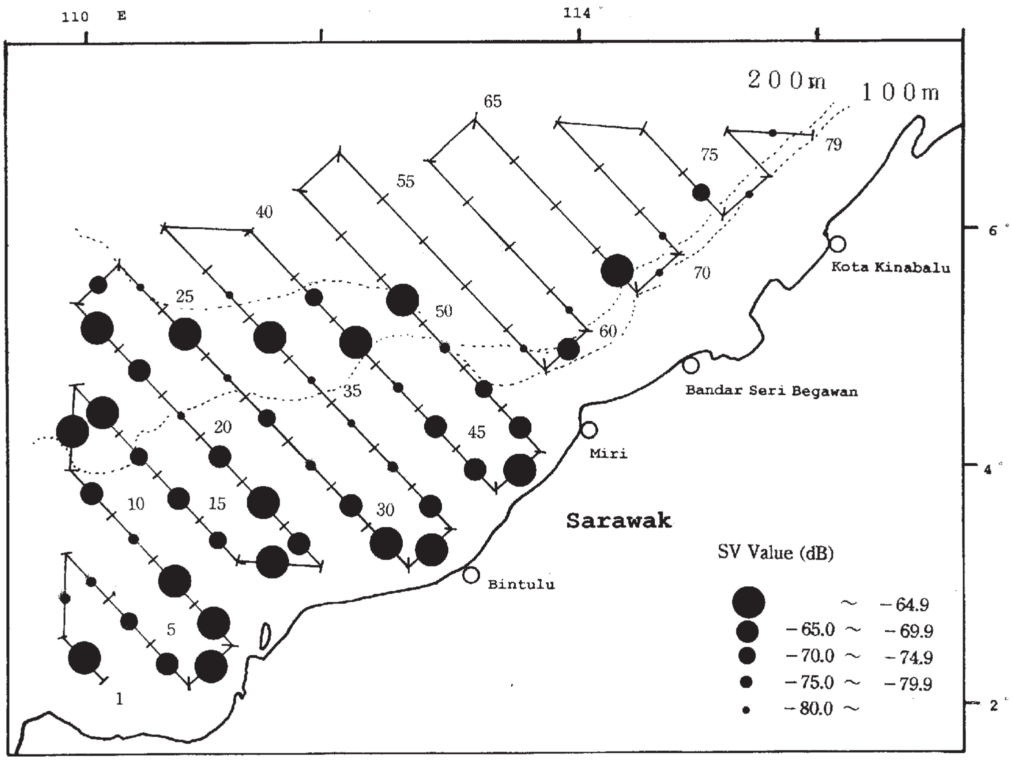

Fig. 6. SV value distribution for the demersal fish along transects off Sarawak, Brunei and Sabah waters in May 1997 (Post Northeast monsoon). Number indicates the oceanographic station

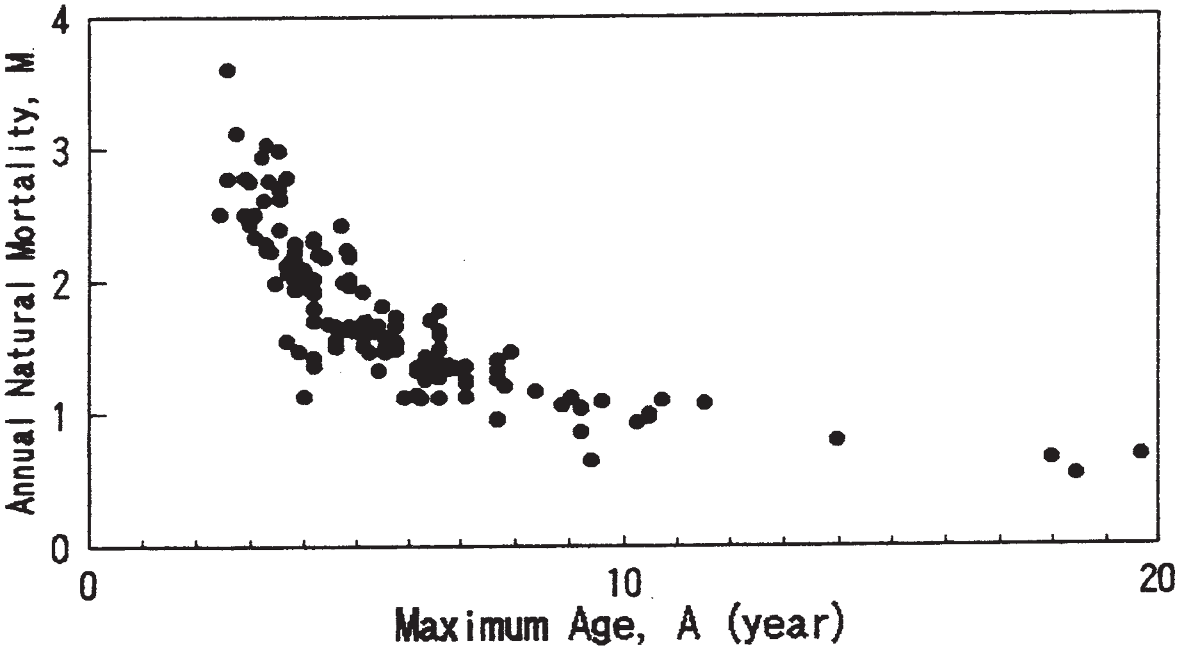

Fig. 7. The relationship between logarith of maximum age (A) and annual natural mortality rate (M), Information was obtain from Mohsin (1996).

conservative management goals, the biological reference point should be less than the MSY (FAO, 1993). In the fisheries management of New Zealand, 2/3 of the MSY is used as the biological reference point (Annala, 1993). When this measure is practiced to the present results, the biological reference points for pelagic and demersal fish were estimated at 55,000 tonnes and 21,000 tonnes, respectively (Table 7). Average catch of pelagic and demersal fish in 1996 and 1997 is 33 % and 77 % of 2/3 of the MSY, respectively. As the result of using this 2/3 of the MSY, both pelagic and demersal fish show potential increase in production from the present level of catch.

The MSY or 2/3 of the MSY mentioned above, are based on annual basis. Seem that the obtained SV values appeared to change seasonally, an appropriate management measures should be taken carefully to consider the effects of the season. Periodical surveys are needed to address these changes with a view of formulating suitable localized fisheries management strategies.

This report shows one of the approaches taken to get estimates of fish biomass. Even though the report is based on a number of assumptions, nevertheless it is a positive step towards introducing the hydro-acoustic method for stock assessment in the tropical region. More efforts are necessary to further improve the precision and accuracy of this multi-species biomass estimation. For example, the representative species need to be correctly identified, including the TS values and weight used in the estimation. Further analyses with Geostatistical method (Pititgas, 1993) can provide the confidence interval of fish biomass estimation. Also, since the Geographical Information System (GIS) is able to show the visualized images of relationships between SV values (or estimated biomass) and the environmental factors, which include distribution and abundance of plankton, the use of this technique is another useful tool for examining the existence of such relationships.

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References

Albert,C.G. and Hadil, R. 1998.Resources potential and Sustainability: the basis for biomass estimate and its exploitation pattern. In Proceedings of Fisheries Research Seminar 1998. Fisheries Research Institute, Penang. (in press)

Annala, J. H. 1993. Fishery assessment approaches in New Zealand's ITQ system. pp. 791-804. In Proceedings of the International Symposium on Management strategies for exploited fish populations. Alaska Sea Grant AK-SG-93-02, 824 pp.

Anon. 1987. Deep Sea Fisheries Resource Survey Within the Malaysian Exclusive Economic Zone. Vol. 2. Department of Fisheries, Ministry of Agriculture Malaysia, 101p.

Anon. 1996. Annual Fisheries Statistics. Department of Marine Fisheries, Sarawak.

Anon. 1997. Annual Fisheries Statistics. Department of Marine Fisheries,Sarawak.

von Bertalanffy, L. 1938. A quantitative theory of organic growth. Hum. Biol. 10:181-213.

Beddington, J. R. and J. G. Cooke. 1983. The potential yield of fish stocks. FAO Fish Tec. Pap. 242:47 p.

Boonyapiwat, S. 1998. Distribution, abundance and species composition of phytoplankton in the South China Sea. In Proceedings of the SEAFDEC Techinical Seminar on the Interdepartmental Collaborative Research Program in the South China Sea, Area II: Sarawak, Sabah, and Brunei Darussalam.Kuala Lumpur, Malaysia 14th15thDecember 1998.

Chua, T.E. and K. J. Charles. 1980. Coastal resources of east coast of Peninsular Malaysia-An Assessment in relation to potential oil spill. Penang: Universiti Sains Association.

Department of Fisheries Malaysia. 1996. Annual Fisheries Statistics 1995. Ministry of Agriculture, Malaysia.

Dwiponggo, A., T. Hariati, S. Banon, M. L. Palmores, and D. Pauly. 1986. Groth, mortality, and recuitment of commercially important fishes and penaeid shrimps in Indonesian waters. ICLARM Tech. Rep. 17.

FAO Fisheries Department. 1993. Reference points for fishery management:their potential application to straddling and highly migratory resources. FAO Fish. Cir. 864.52pp.

Fox, W. W. 1970. An exponential yield model for optimizing exploited fish populations. Trans. Am. Fish. Soc.99:80-88.

Furusawa, M. 1990. Study on Echo Sounder for Estimating Fisheries Resources. Bull. National Res. Institute of Fish. Engineering. 11: 173-249.

Gulland, J. A. 1971. The fish resources of the ocean. West by-fleet, Surrey, Fishing News (Books), Ltd., for FAO.255p.

Hoenig., J. M.. 1983. Empirical use of longevity data to estimate mortality rates. Fish. Bull. 81(4):898-903.

Ingles, J. and D. Pauly. 1984. An atlas of the growth, mortality and recuitment of Philippine fishes. ICLARM Tech. Pap. 13.

Jivaluk, J. 1998. Distribution, abundance and composition and zooplankton in the South China Sea. In Proceedings of the SEAFDEC Techinical Seminar on the Interdepartmental Collaborative Research Program in the South China Sea, Area II: Sarawak, Sabah, and Brunei Darussalam. Kuala Lumpur, Malaysia 14th15thDecember 1998.

Liong, P. C. 1974. Hydroacoustic conditions off the east coast of the Peninsular Malaysia during August 1972. Malay. Agri. J. 4(4):492-573.

Mohsin, A. K. M. 1996. Marine fishes and fisheries of Malaysia and neighbouring countries. Universiti Pertanian Malaysia Press, Malaysia. 744p.

Pauly, D. 1980. On the interrelationship between natural mortality, growth parameters, and mean environmental temperature in 175 fish stocks. J. Cons. CIEM.39(2):175-192

Pititgas, P. 1993. Geostatistics for fish stock assessments:a review and an acoustic application. ICES J. mar Sci.50:285-298.

Richard, R., A. Daud, M. Jamil, and R. Biusing. 1998. Distribution,abundance and biological studies of economically important fishes in the South China Sea, Area II: Sarawak, Sabah, and Brunei Darussalam. In Proceedings of the SEAFDEC Techinical Seminar on the Interdepartmental Collaborative Research Program in the South China Sea, Area II: Sarawak, Sabah, and Brunei Darussalam.Kuala Lumpur, Malaysia 14th15thDecember 1998.

Rosidi, A., A. C. Gambang, R. Hadil, R. H. Raja Bidin, B. Samsudin, K. Shiomi, and S. Fujiwara. 1998. Application of the acoustic method in biomass estimation of multi-species fish in the South China Sea. J. Korean Fish.Soc. Res. 1:157-167.

Saadon, M. N. 1998. Physical characteristics of watermass in the South China Sea. In Proceedings of the SEAFDEC Techinical Seminar on the Interdepartmental Collaborative Research Program in the South China Sea, Area II: Sarawak, Sabah, and Brunei Darussalam. Kuala Lumpur, Malaysia 14th15thDecember 1998.

Schaefer, M.. 1954. Some aspects of the dynamics of populations important to the management of thecommercial marine fisheries. Bull. Inte-Am. Trop. Tune Comm. 1(2):27-56.

Snidvong, A. Geostropic current, divergence and convergence in the South China Sea. In Proceedings of the SEAFDEC Techinical Seminar on the Interdepartmental Collaborative Research Program in the South China Sea, Area II: Sarawak, Sabah, and Brunei Darussalam.Kuala Lumpur, Malaysia 14th15thDecember 1998.

Termvidehakorn, A. 1998. Kind, abundance and distribution of fish larvae in the South China Sea. In Proceedings of the SEAFDEC Techinical Seminar on the Interdepartmental Collaborative Research Program in the South China Sea, Area II: Sarawak, Sabah, and Brunei

Darussalam.Kuala Lumpur, Malaysia 14th15thDecember 1998.
Troadec, J. P.. 1977. Méthod semi-quantitative d'évaluation. FAO Circ., Pêches. 701:131-141.
Vidthayanon, C. 1998. Species composition and diversity of trawled fishes in the South China Sea. In Proceedings of the SEAFDEC Techinical Seminar on the Interdepartmental Collaborative Research Program in the South China Sea, Area II: Sarawak, Sabah, and Brunei Darussalam.Kuala Lumpur, Malaysia 14th15thDecember 1998.
Theparoonrat, Y. Biomass estimation by hydro-acoustic method in the South China Sea. In Proceedings of the SEAFDEC Techinical Seminar on the Interdepartmental Collaborative Research Program in the South China Sea, Area II: Sarawak, Sabah, and Brunei Darussalam.Kuala Lumpur, Malaysia 14th15thDecember 1998.