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FISH CHARACTERISTICS AND DISTRIBUTION OF POTENTIAL FISHING ZONES IN THE MALACCA STRAIT USING HYDROACOUSTIC ASSESSMENT DURING THE SOUTHWEST MONSOON SEASON

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ABSTRACT

The Malacca Strait is a productive region in marine fisheries but limited information on fish characteristics and its potential fishing zones. This research aimed to determine fish characteristics and the distribution of potential fishing zones through the analyses of fish length and density. The hydroacoustic and trawling surveys were conducted during the Southwest Monsoon season in June 2008 along the Malacca Strait. The pelagic fishes detected in the eastern part of the Malacca Straits tended to be smaller than in the western part of the Malacca Strait, while the demersal fishes tended to be not significantly different in the eastern part and the western part of the Malacca Strait. Meanwhile, the density of pelagic fishes was relatively higher in the eastern part compared to the western part of the Malacca Strait, even though in general the density of pelagic fishes was relatively high (> 5 fishes m^{-3}) along the Malacca Strait. High potential fishing zones of pelagic fishes were only found in three of fourteen locations in the middle region of the Malacca Strait. Meanwhile, for demersal fishes, high potential fishing zones were only found in two of fourteen locations *i.e.,* one in the coastal region of Belawan waters in the western part of the Malacca Strait and one in the eastern part of Bengkalis waters of the eastern part of the Malacca Strait. Meanwhile, moderate to low potential fishing zones for both pelagic and demersal fishes were generally found along the Malacca Strait. The result can be used as an indicator that fisheries resources along the Malacca Strait are heading toward a declination. Therefore, for sustainable fisheries resources management in the region, some good efforts are needed to be taken from the three countries of Indonesia, Singapore, and Malaysia such as to enforce fishermen to only use friendly fishing gears and not to use trawls to avoid juvenile and small fishes to be captured.

Key words: Potential fishing zones, pelagic, demersal, acoustic, Malacca Strait

INTRODUCTION

The Malacca Strait is one of the busiest shipping lanes in the world and rich in marine resources. It serves as a primary channel for the cargo movement and human traffic between the Indo-European regions and the rest of Asia and Australia (Evers and Darit, 2011). The water mass in the Malacca Strait is a mixture of water masses from the Java Sea, the South China Sea, and Indian Ocean (Wyrtki, 1961). Surface current circulation along the Malacca Strait is generally affected by tides, heat flux, and monsoonal wind and shows the same pattern during the Southwest and Northeast Monsoon along the middle and the southern part of the strait (Rizal *et al*., 2012). During the Southwest Monsoon season (Jun-Sep), the southwesterly wind pushes high salinity water from the Indian Ocean and the Andaman Sea to the Strait. While, during the Northeast Monsoon (Dec-Feb), a significant low salinity from west coast Peninsular Malaysia enter the Strait (Amiruddin *et al*., 2011). In the northern section of the Strait, the water with the more stratified and warmer condition is found, while in the southern section a more homogenous indicating better mixing is found in every season (Amiruddin *et al*., 2011). The Malacca Strait water is also affected by freshwater discharge from several rivers

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of Sumatra and Malaysian islands. Therefore, the Malacca Strait water tends to have high nutrient and abundant in fish resources (Zen *et al*., 2006).

The Malacca Strait is a productive region for marine capture fishery with valuable demersal and pelagic resources of finfish and shellfish. This region yields one of the highest marine landings in Malaysian capture fishery with a contribution of about 48% of the marine total landing of Malaysia in 2013 (Jagerroos, 2016). However, the distribution of potential fishing zone along the Malacca Strait is still not well understood. A recent data from field survey also indicated that the fish stocks are declining considerably, especially the demersal fishery resources (Jagerroos, 2016).

The determination of a regional potential fishing ground by some Indonesian fishermen, including along the Malacca Strait is generally based on information obtained from other fishermen or fishing habits of fishermen by observing the signs of nature (conventional method or traditional) (Bawole *et al*., 2014). With this method, the efficiency level of fishing operation is relatively low because it takes a longer fishing trip to find a schooling fish and consume more gasoline (Simbolon *et al*., 2015).

The problem on the conventional method can be solved through the availability of information on a more accurate of potential fishing zones (PFZ) through the hydroacoustic method. This method has advantages compared with conventional methods such as direct estimation of fish availability, quick determination of fish stock assessment in real-time data, and relatively high accuracy of estimation (Simbolon and Manurung, 1997; Clay, 1990). PFZ category in this study was not only determined by fish abundance but was also considered by fish length composition. Simbolon *et al*. (2017) mentioned that the waters which are dominated by fish from the illegal (immature) size categories cannot be classified as PFZ although the fish is abundant. This is due to the dominance of unsuitable fish to be caught biologically and will have a negative impact on fish resource sustainability.

This research aimed to determine a fish characteristic (size and density) and the distribution area of potential fishing zones through the analyses of the fish length composition and the distribution of fish abundance in the Malacca Straits during the Southwest Monsoon (June 2008). PFZ distribution information generated from this research was expected to help the fishermen in increasing the effectiveness and efficiency of fishing operation and useful for determination management policies in order to achieve sustainable capture fisheries management.

MATERIALS AND METHODS

Bottom trawling

This study used bottom trawling and acoustic survey data conducted in June 2008 in the Malacca Strait (Figure 1). The survey along the Malacca Strait was started from Karimun island waters and end up near the Belawan coastal region following the "acoustic transect 1" trajectory and went back to Karimun island waters using the "acoustic transect 2" trajectory (Figure 1). Processing and analyses of acoustic data were conducted at the Fisheries Acoustic Laboratory, Marine Fisheries Research Institute, Jakarta.

Fish catch data collected from 20 stations using bottom trawling with the end mesh size of 3 cm were used to verify the certainty of the type and size of fishes detected by hydroacoustic equipment and used as a supporting factor in determining the area of fishing zone potential in the Malacca Strait. The fish catches were removed from the trawl bag on the deck, then grouped (sorted) based on the family and type (species) of fishes. Later, we measured the fish size, length, and weight for samples of each species that were dominantly caught. Fish samples in each sampling station were taken randomly, at least 10% of the sorted fish sub-population.

Determination of Trawling stations along the acoustic transects was determined by considering the depth contours of the waters in accordance with the bottom trawling dimensions. Furthermore, bottom trawl catches were used to verify the estimated demersal fish length by using the Foote (1987) formula.

Acoustic survey

The research used the *Bawal Putih* research vessel which equipped with hydroacoustic equipment (echosounder split beam), omni-directional sonar SIMRAD SP-70 with frequency 26 kHz, a global positioning system (GPS) which was integrated into SIMRAD EK 60 scientific echosounder system, and bottom trawl.

The survey track used in this study was a systematic triangular transect (zig-zag) based on procedures in designing acoustic survey plans as suggested by MacLennan and Simmonds (1992). Acoustic data were collected continuously 24 hours along the "acoustic transect 1" and "acoustic tract 2" using SIMRAD EK 60 scientific echosounder system. Integration echo process was done vertically on water column with 10 meter interval (adjusted with trawl mouth opening) and later to be averaged. Integration values were grouped regularly in an elementary sampling distance unit (ESDU) 0.5 nautical mile which intended for estimating the average fish density (individual of fish m^{-3}) for each depth layer.

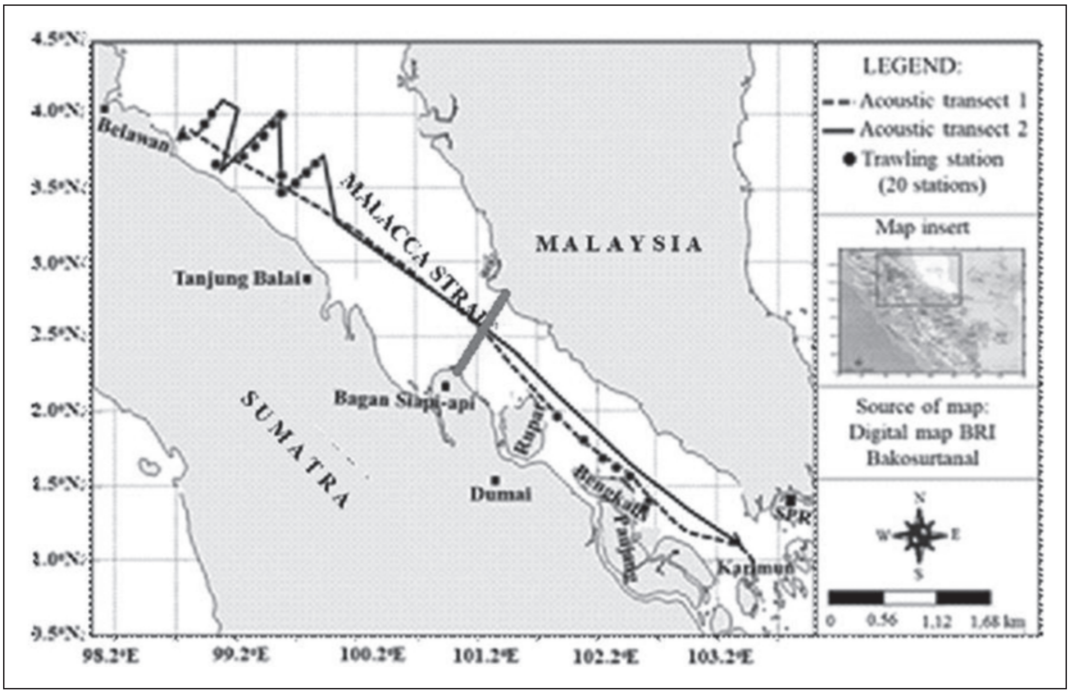

Fig. 1. Map of study sites. Dash and solid lines were survey tracks where acoustic data were collected. Solid dots were the locations for deploying bottom trawl to catch fish and to determine fish target strength. Red line was a borderline for the western part and eastern part regions of the Malacca Strait.

Data analysis

Acoustic data were processed and analysed using SIMRAD ER 60, SIMRAD BI 60, Sonar Data V4 Echoview (Siwabessy, 2001; MacLennan dan Simonds, 2005), Surfer 8.0, Microsoft Office Excel, and a Dongle as a data transfer tool and to find out the value of target strength (TS) and fish density. The flowchart for processing and analyses of acoustic data is presented in Figure 2.

To determine PFZ in each fishing spot using target strength and fish density indicators (Table 1), the following steps put into account:

1. Determined the criteria for each indicator (target strength and fish density).
2. Determined the reference point for each of the criteria on each indicator. The determination of the reference point on each criterion was based on a statistical calculation of the distribution of the target strength and fish density along the transect (Pasaribu, 1997).
3. Determined the category of each criterion.
4. Determined the scores for each category by using the Likert score (based on ordinal 1, 2, 3) in accordance with the performance of each criterion. A value of 2 is the lowest score indicating a bad condition, and a value of 4 is the highest score indicating a good condition.
5. The highest combination scores ($\geq$7) of the target strength and the density of fish indicates a high potential fishing zone, the medium combination scores (5-6) of the target strength and the density of fish indicates a moderate potential fishing zone, and the lowest combination scores (<5) of the target strength and the density of fish indicates a low potential fishing zone.

To calculate the fish length and fish density, we used the following equations:

(1) The target strength (TS) value was obtained employing the equation developed by Simmonds and MacLennan (2005):

$$TS = 10 \text{ Log } (Ts)$$
$$Ts = Sv/\tilde{n}$$

(2) The value of Sv and ρ were obtained from the equation developed by Simmonds and MacLennan (2005):

$$SV = 10 \log Sv, \text{ and } \rho = n/v$$

(3) The TS value was used to estimate the fish length detected by acoustic equipment with the formula presented by Foote (1987):

$$TS = 20 \text{ Log } (L) + A$$

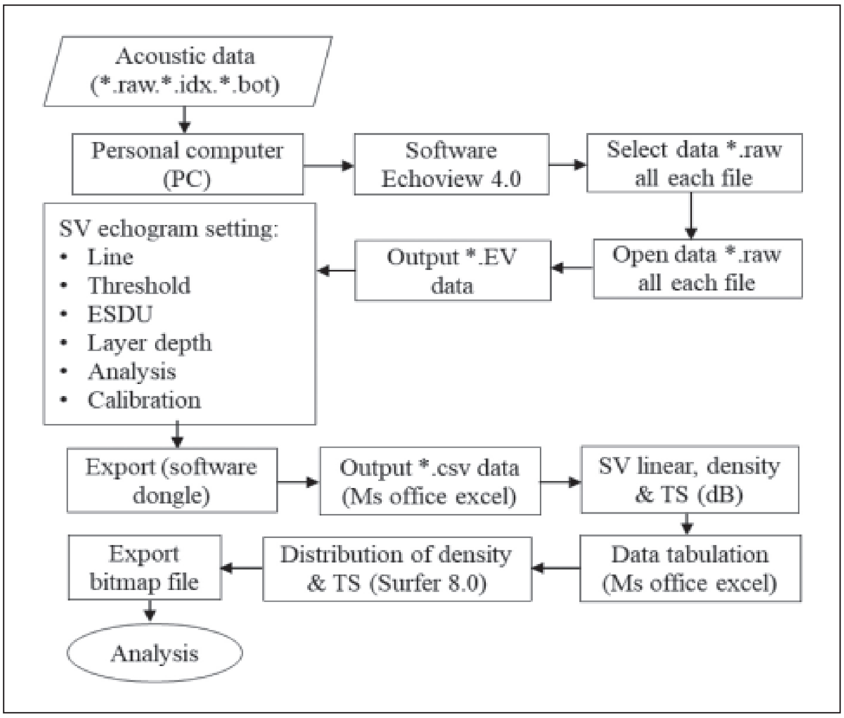

Fig. 2. Flowchart of processing and analysis of acoustic data.

Table 1. Indicators and criteria of the potential fishing zone in the Strait of Malacca

No.	DPI Indicator	Criteria	Category	Score
1	Target strength	< -60 dB	Small	2
		-60 -57 dB	Moderate	3
		> -57 dB	Large	4
2	The density of fish	< 3 fishes m^{-3}	Low	2
		3-5 fishes m^{-3}	Moderate	3
		> 5 fishes m^{-3}	High	4
3	Target strength + the density of fish	[< -60 dB + < 3 fishes m^{-3}]	Low	<5
		[< -60 db + 3-5 fishes m^{-3}; < -60 dB + > 5 fishes m^{-3}; -60 - -57 dB + 3-5 fishes m^{-3}]	Moderate	5-6
		[-60 - -57 dB + > 5 fishes m^{-3}; > -57 dB + > 5 fishes m^{-3}]	High	≥7

This approach indicated that a larger target strength value indicated a longer fish length.

(4) Fish density average was determined by echo integration detected in the vertical direction of each water layer and horizontal direction along the acoustic transect based on the following equation (Simmonds and MacLennan 2005):

$$\rho v = 10^{0.1(SV - TSv)}$$

where, TS=target strength (dB), Ts=target strength (linear), SV=volume backscattering strength (dB), Sv=volume backscattering (linear), ρ=fish density (individual fish m^{-3}), n=number of samples (individual fish), v=beam volume sum (m^3), L=fish length (cm), A=value of normalized TS (-67,5 dB), ρv=average fish density (individual fish m^{-3}), TSv= average target strength (dB).

RESULTS AND DISCUSSION

Target strength and fish length

The range of fish target strength (TS) during the daytime was -86 dB (at 14-24 m deep) to -59 dB (at 64-74 m deep), while during the nighttime the fish target strength (TS) was -73 dB (at 4-14 m deep) to -61 dB (at 54-64 m deep) (Figure 3). In general,

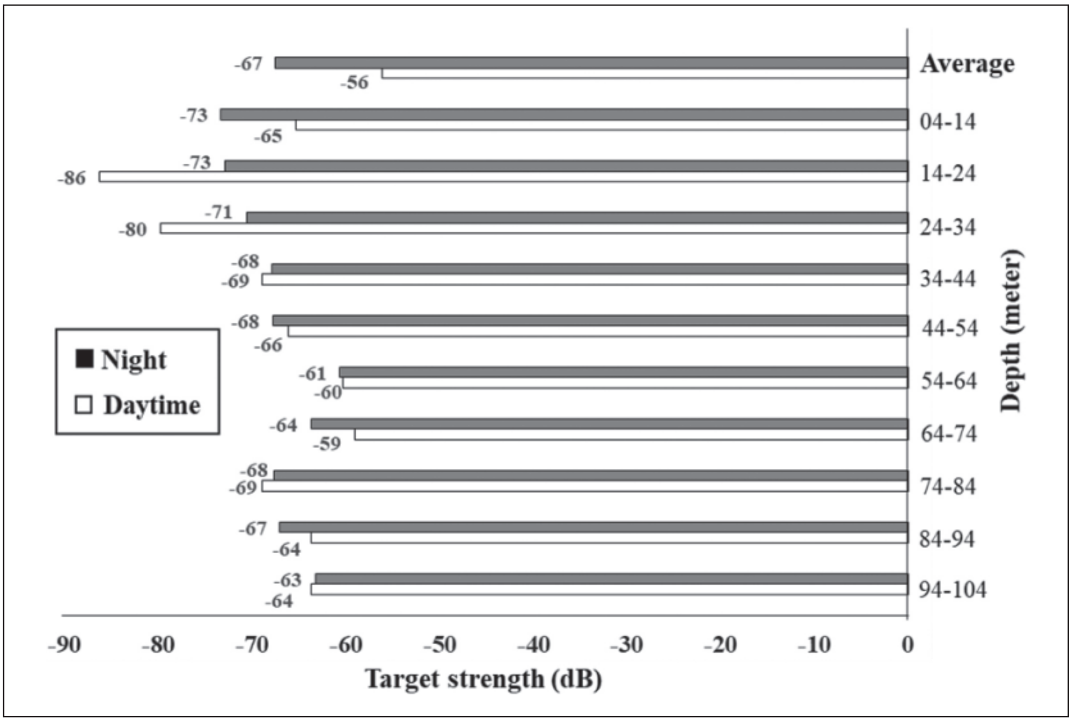

Fig. 3. Daytime (06:00-18:00 local standard time) and nighttime (18:00-06:00 local standard time) of fish TS value of pelagic fish at various depth in the Malacca Strait, June 2008.

the average of fish TS during the daytime (-56 dB) was greater than that of the nighttime (-67 dB). The TS variability was influenced by fish behavior differences during the period of light and darkness (Laevastu and Hayes, 1981). During the daytime, pelagic fishes tend to be more active foraging by clustering on the surface layer, while nighttime pelagic fishes spread more evenly from the surface to a deeper water column (Gunarso, 1985; Simbolon *et al*., 2015). As a result, pelagic fishes have a higher chance of being detected with acoustic on the surface during the daytime than at nighttime resulting in higher target strength during the daytime compared to the nighttime. Fish TS value which was relatively larger in the depth of 94-104 m depth at night, was presumably due to the target strength value of demersal fish. Demersal fish eating behavior at night spread evenly in the midwater layer, while during the daytime generally gathered at the bottom layer (Burczynski *et al*., 1987; Tsagarakis *et al*., 2015).

The target strength values of pelagic fishes during the daytime and nighttime tended to increase with increasing depth. This tendency linearly increased with the length of the fish (Foote, 1987). This indicated that smaller fish spread in the surface layer, while larger fish spread in the deeper layer of water. The existence of pelagic fishes was related to feeding behavior (Nelson & Dark, 1986), that smaller fish generally prey on plankton in the surface layer, while larger fish foraging is not limited to the surface layer, but also look for other prey in deeper layers of water.

Based on the regions, the fish TS values in the western part (Tanjung Balai and Belawan regions) and in the eastern part (Northen regions of Dumai) of the Malacca Strait at various depth are shown in Figure 4. The fish TS values in the western part of the Malacca Strait (average of -67 dB) tended to be larger than that of the eastern part (average of -69 dB) of the Malacca Strait. However, in the upper layer of 14-24 m deep, the average of fish TS values in the western part of the Malacca Strait (-83 dB) was lower compared to the eastern part of the Malacca Strait (-75 dB) (Figure 4). This indicated that the size of pelagic fishes in the upper layer of 14-24 m deep in the western part of the Malacca Strait was relatively lower compared to the eastern part of the Malacca Strait. A lower target strength value indicated a lower fish length (Foote, 1987). If we assume that pelagic fishes can be found from the surface up to 54 m deep, therefore, the size of pelagic fishes, in general, was lower in the eastern part compared to the western part of the Malacca Strait (Figure 4).

The bigger size of pelagic fish found in the eastern part of the Malacca Strait in the upper layer of 14-24 m deep may due to more favourable environmental factors such as temperature, salinity, current, and fertility of water in the eastern part compared to the western part of the Malacca Strait (Simbolon & Limbong, 2012). Gunarso (1985) also

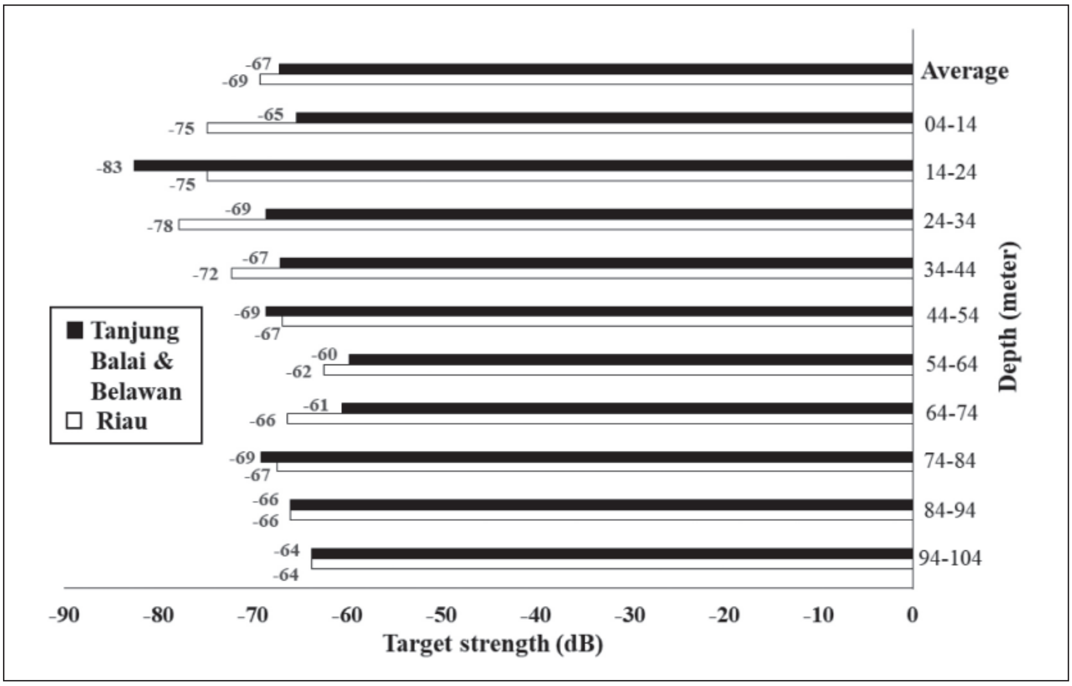

Fig. 4. Fish TS values at various depth in Western Part (Tanjung Balai & Belawan) and Eastern Part (Riau) of the Malacca Strait, in June 2008.

reported that fish can sense a temperature change of 0.03°C, and if the fish is not able to adapt to the change, the fish will migrate. In addition, variability in fish species may contribute to the variability of fish length (Love, 1977; Maclennan & Simmond, 1992). A relatively shallower and narrower of the eastern part of the Strait, relatively more river runoff, and more homogenous (mixing) water masses in the entire season in this region (Zikra *et al*., 2015; Siswanto & Tanaka, 2014; Amiruddin *et al*., 2011) provided a more favorable conditions for development and abundance of pelagic fishes along the upper layer of the eastern part of the Malacca Strait.

Vertical distribution of fish in the western and eastern part of the Malacca Strait showed a similar distribution pattern i.e., larger fishes tended to be found in a deeper layer (Figure 4). This was in line with the finding of Nelson and Dark (1986), that small fishes were generally preying on plankton in the surface layer, whereas larger fish feed not only limited to surface layers but also in a deeper layer.

For demersal fishes, the fish TS values in the bottom layers (84-94 m and 94-104 m) did not show a significant difference value (Figure 4). This result was confirmed based on fish catch employing bottom trawl that the average size of demersal fishes was not significantly different between the two regions (Table 2). The average size of demersal fishes in the eastern part of the Malacca Strait was slightly higher (23.09 cm) compared to the western part of the Malacca Strait (22.93 cm) (Table 2). The difference in the target strength value was due to differences in fish species and the length of the fish found between the two regions. Based on the demersal fish catch, the fish species found in the two regions were also not similar (Table 2).

The size of demersal fish caught with the bottom trawl was smaller than the prediction of fish size according to formula Foote (1987). The average length of demersal fish caught with bottom trawl in Eastern Part and Western Part of the Malacca Strait was 22.72 cm and 24.82 cm, respectively. On the other hand, the average length of a demersal fish that estimated by acoustic using Foote (1987) formula was 25.15 cm and 25.59 cm for Eastern Part and Western Part of the Malacca Strait, respectively. The difference was probably caused by the fishes detected during the TS sampling were not all caught by the trawl (Simbolon & Manurung, 1997).

Density and distribution of fish

Daytime fish density from the surface to about 100 m deep of water column ranged from one fish m^{-3} to 31 fishes m^{-3}, with an average of four fishes m^{-3}. While at nighttime, the density ranged from one fish m^{-3} to 15 fishes m^{-3}, with an average of three fishes m^{-3}. The density of the pelagic fish detected during the daytime of 4-14 m deep was significantly higher than that of nighttime (Figure 5). The larger density of pelagic fish in the daytime along 4-14 m deep was due to the fact that fish tend to form a denser schooling at the surface during the daytime, while at night the fish tend to spread evenly over the water column (Laevastu & Hayes, 1981; Syahdan *et al*., 2007).

Table 2. The average length composition of fish caught with bottom trawl in Western Part (Tanjung Balai Asahan and Belawan) and Eastern Part (Riau Islands) waters of the Malacca Strait in June 2008

No	Fish species caught with trawl	Western Part			Eastern Part		
		N	Average length (cm)	STD	N	Average length (cm)	STD
1	Baronang (*Siganus canaliculatus*)	125	25.14	±5.51	–	–	–
2	Beloso (*Saurida undosquamis*)	132	32.16	±4.23	–	–	–
3	Buntal (*Lagocephalus inermis*)	104	16.18	±3.67	173	21.36	±4.45
4	Gerot-gerot (*Pomadasys hasta*)	–	–	–	190	32.14	±3.12
5	Gulama (*Johnius grypotus*)	–	–	–	176	30.93	±3.86
6	Kuniran (*Upeneus sundaicus*)	184	19.36	±5.03	–	–	–
7	Kurisi (*Nemipterus peroni*)	237	24.19	±3.68	–	–	–
8	Nomei (*Harpadon nehereus*)	–	–	–	319	18.50	±7.65
9	Pari (*Dasyatis kuhli*)	115	20.57	±4.69	35	17.39	±3.94
10	Tigawaja (*Nibea mitsukurii*)	–	–	–	285	18.20	±6.48
	Average		22.93[a]			23.09[a]	

N = number of fishes, STD = standard deviation, the average length in the Western part and Eastern part is not significantly different (p=0.966).

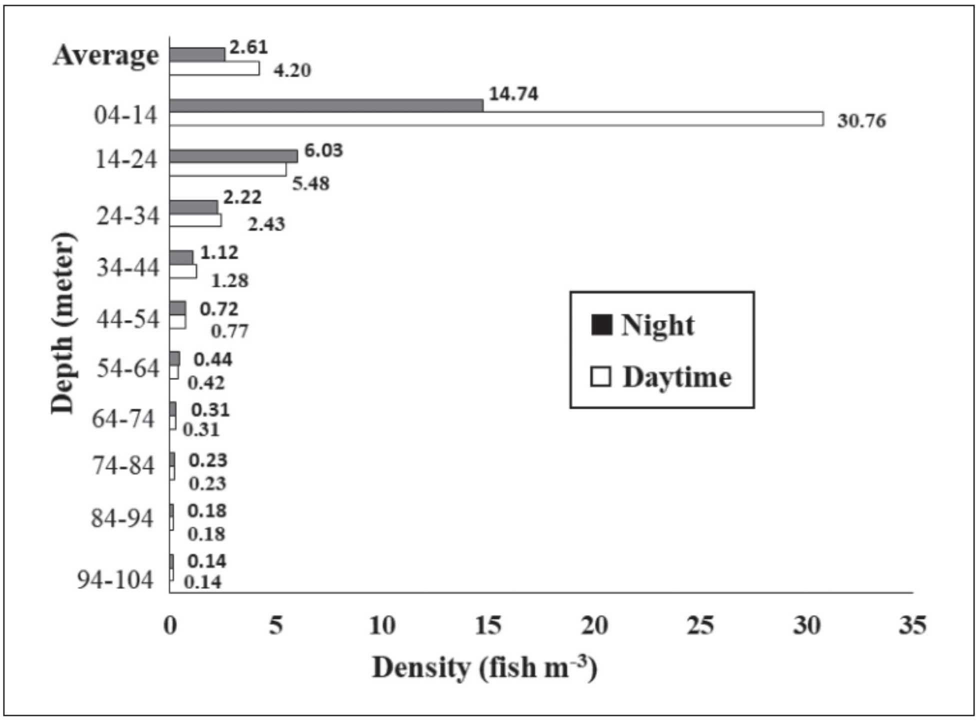

Fig. 5. Daytime and nighttime distribution of fish density at various depth in the Malacca Strait, June 2008.

The fish density in the eastern part of the Malacca Strait in average was denser compared to the western part of the Malacca Strait, except at the depths of 4 to 14 m (Figure 6). The fish density in all depth categories in the eastern part of the Malacca Strait ranged from 2-33 fishes m^{-3} with an average of 13 fishes m^{-3}, and the highest density was found at 44-54 meters depth. Fish density in the western part of the Malacca Strait ranged from 1-31 fishes m^{-3}, with an average of 4 fishes m^{-3}, and the highest density was found at 4-14 m depth. Fish density in the eastern part of the Malacca Strait was still high from the surface to a depth of 64 m (12-33 fishes m^{-3}). Meanwhile, in the western part of the Malacca Strait, high density (above average) was only found in the depth of 4-24 m (6-31 fishes m^{-3}).

Based on the vertical distribution of fish density, it also showed that pelagic fishes tended to concentrate in the upper layer of water column (4-14 m) in the eastern part of the Malacca Strait compared to the deeper layer of water column (44-54 m) in the eastern part of the Malacca Strait

(Figure 6). The highest density of pelagic fishes (33 fishes m^{-3}) found in the water column of 44-54 m in the eastern part of the Malacca Strait indicated that a more suitable habitat for pelagic fishes (more nutrient, enough sunlight input, suitable water temperature, and less saline of water) were found in this water column in this region.

In general, pelagic fishes with high density (>5 fishes m^{-3}) were found along the Malacca Strait, except some locations in the western and middle part of the Malacca Strait with medium density (3-5 fishes m^{-3}) (Figure 7). In average and spatially distributed density of pelagic fishes, more pelagic fishes were found in the eastern part of the Malacca Strait (waters of Karimun Besar, Bengkalis, Rupat, and Bagan Siapi-api) compared to the western part of the Malacca Strait (Tanjung Balai and Belawan waters) (Figure 7). The most suitable habitat for pelagic fish, especially in the eastern part of the Malacca Strait was also found from the surface layer to a depth of 64 meters because the fish density in this layer was higher compared with other layers (Figure 6). This was due to the fact that the surface layer had relatively high nutrient content, enough sunlight (euphotic) input to support the productivity of the waters, a suitable water temperature (29.24–29.76°C), and less saline water (29.69–33.06 psu).

The relatively lower density of pelagic fish was found along the western part of the Malacca Strait during the Southwest Monsoon season. During the Southwest Monsoon season (dry season, June-September), a high saline water entered from the Andaman Sea to the Strait from the Northern sector and the warmer water condition may possibly strengthen the stratification on the surface region in the region (Amiruddin *et al*., 2011; Wyrtki, 1961) caused less favorable condition for pelagic fishes. Meanwhile, in a relatively shallower and narrower of the eastern part of the Strait was found a more homogenous water mass in the entire season signifying a fine mixing and receive relatively higher nutrient input from river inflows (Zikra *et al*., 2015; Amiruddin *et al*., 2011). Siswanto and Tanaka (2014) also reported that relatively higher chlorophyll-a concentration found along the eastern part of the Malacca Strait during the Southwest Monsoon season was associated with river runoff. These conditions caused a more favorable environment for development and abundance of pelagic fishes along the eastern part of the Malacca Strait.

For demersal fish, oceanographic factors such as currents, temperature, and salinity are not only a limiting factor in determining the distribution pattern and fish abundance, but also influenced by substrate, food sources such as phytoplankton and zooplankton, water contaminant, bottom layer suspended matter (Febrianto *et al*., 2015; Simbolon *et al*., 2010; Simbolon, 1996).

Distribution of potential fishing zone (PFZ)

Based on the analyses of target strength (fish length) and fish density indicators, we determined the spatial distribution of potential fishing zone

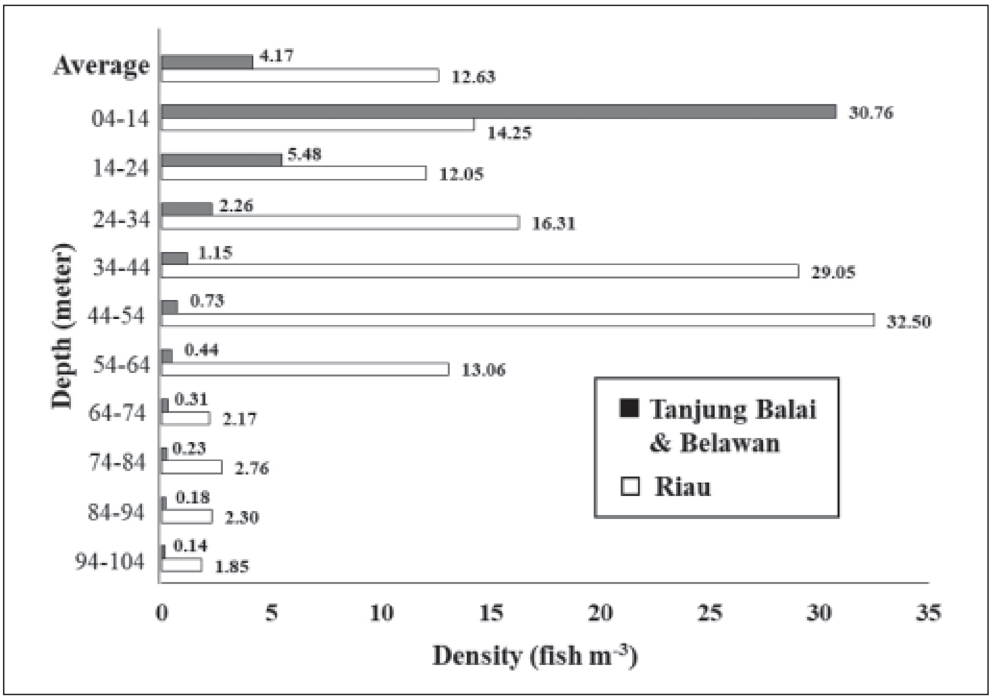

Fig. 6. Vertical distribution of fish density in the western part (Tanjung Balai & Belawan) and eastern part (Riau) of the Malacca Strait at various depths.

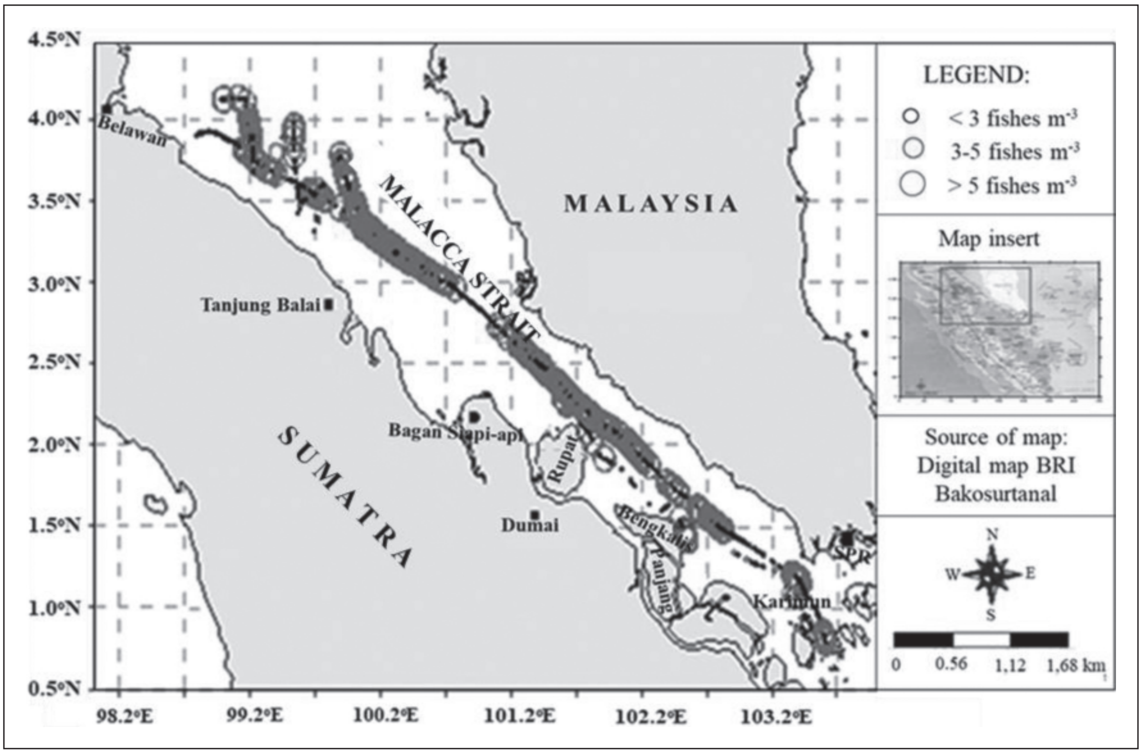

Fig. 7. Horizontal distribution of pelagic fish density in the waters along the Malacca Strait, June 2008.

along the Malacca Strait. The total scores for target strength, fish density, and the combination for pelagic fishes and demersal fishes along the Malacca Strait during the Southwest Monsoon season are listed in Tables 3 and 4. Code of areas in these Tables is associated with the location in the distribution map of the potential fishing zone along the Malacca Strait in Figures 8 and 9.

Based on the results of hydroacoustic detection and trawl capture at the Malacca Strait in June 2008, three categories of pelagic fishing grounds were identified in the Malacca Straits: (1) high potential fishing zones were found in the middle region of the Malacca Strait (northern of Tanjung Balai, Bagan Siapi-api, and northeastern Rupat waters); (2) moderate potential fishing zones were almost all found in western part of the Malacca Strait (northeastern and southeastern Belawan, eastern Tanjung Balai, and eastern Bagan Siapi-api waters); and (3) low potential fishing zones were found almost all in the eastern part of the Malacca Strait and some in the western part of the Malacca Strait (north of Bagan Siapi-api waters or east of Tanjung Balai waters, east of Belawan waters) (Figure 8).

For demersal fish, high potential fishing zones were found in the western part of the Malacca Strait specifically in the coastal region of Belawan waters and in the eastern part of the Malacca Strait specifically in the eastern part of Bengkalis waters (Figure 9). The regions of moderate potential fishing zones almost in the entire of the Malacca Strait except in the northern part of Tanjung Balai waters and eastern part of the Rupat and Karimun waters with low potential fishing zones (Figure 9).

The density of fish in the Eastern part of the Malacca Strait (Riau Islands waters) tended to be denser than that in the western part of the Malacca Strait waters (Tanjung Balai and Belawan) (see Figure 7). However, the fish length found in the eastern part of the Malacca Strait (Riau Islands waters) was dominated by smaller fishes classified as not biologically appropriate size to be caught. As a result, the waters of the eastern part of the Malacca Strait, especially in Karimun and Bengkalis waters were classified as low potential fishing zones (see Figure 8). This showed that the determination of potential fishing zones was not only based on fish density, but also based on the composition of fish length (biologically or not biologically appropriate to be caught). Fishing activities at the abundant fish resources that dominated by small fish size (not biologically appropriate size to be caught) will endangered fisheries sustainability at the particular área (Simbolon *et al.*, 2017). Therefore information about the distribution of potential fishing zones is very useful to prevent domination of illegal size fish catches. Illegal fishing from inappropriate size fishes must be prevented so that overfishing that caused fish stock decrease can be avoided. In addition to this, the degradation of fishing grounds

Table 3. Evaluation of potential fishing zone for pelagic fishes based on the analysis of target strength and fish density at the Malacca Strait in June 2008

Code of area*	Indicator				Total score	Category of the potential fishing zone
	Target strength (dB)	Score	Density (fish/m^3)	Score		
1	< -60	2	< 3	2	4	Low potential
2	< -60	2	< 3	2	4	Low potential
3	< -60	2	< 3	2	4	Low potential
4	< -60	2	< 3	2	4	Low potential
5	-60 ~ -57	3	>5	4	7	High potential
6	< -60	2	3–5	3	5	Moderate potential
7	-60 ~ -57	3	> 5	4	7	High potential
8	< -60	2	< 3	2	4	Low potential
9	< -60	2	3–5	3	5	Moderate potential
10	-60 ~ -57	3	> 5	4	7	High potential
11	< -60	2	< 3	2	4	Low potential
12	-60 ~ -57	3	3–5	3	6	Moderate potential
13	< -60	2	< 3	2	4	Low potential
14	-60 ~ -57	3	3–5	3	6	Moderate potential

*refers to the locations on the map of Figure 8.

Table 4. Evaluation of potential fishing zone for demersal fishes based on the analysis of target strength and fish density at the Malacca Strait in June 2008

Code of area*	Indicators				Total score	Category of the potential fishing zone
	Target strength (dB)	Score	Density (fish/m^3)	Score		
1	< -60	2	< 3	2	4	Low potential
2	< -60	2	> 5	4	6	Moderate potential
3	> -57	4	3-5	3	7	High potential
4	-60 ~ -57	3	3-5	3	6	Moderate potential
5	< -60	2	< 3	2	4	Low potential
6	-60 ~ -57	3	3-5	3	6	Moderate potential
7	-60 ~ -57	3	3-5	3	6	Moderate potential
8	-60 ~ -57	3	3-5	3	6	Moderate potential
9	< -60	2	< 3	2	4	Low potential
10	< -60	2	< 3	2	4	Low potential
11	-60 ~ -57	3	3-5	3	6	Moderate potential
12	-60 ~ -57	3	3-5	3	6	Moderate potential
13	> -57	4	>5	4	8	High potential
14	> -57	4	< 3	2	6	Moderate potential

in the Eastern part of Malacca Strait was also influenced by environmental pollution coming from industrial waste, traffic of commercial vessels, and river flows.

Based on the distribution potential fishing zones along the Malacca Strait that dominated by moderate to low fishing zones, this can be used as warning signal on the fisheries management along this region because this region is specifically utilized by three countries such as Indonesia, Singapore, and Malaysia. In order to have a sustainable fisheries resources in this region, some good efforts by the three countries are needed immediately such as to have agreeable and sustainable fish capture management, reducing pollutants entering the to region form each continent, and improve the fertility and quality of the water in the region by Indonesia, Singapore, and Malaysia.

For sustainable fish capture management, all the three countries may need to enforce fishermen to only use friendly fishing gears and to ban using trawls to avoid juvenile and small fishes to be captured.

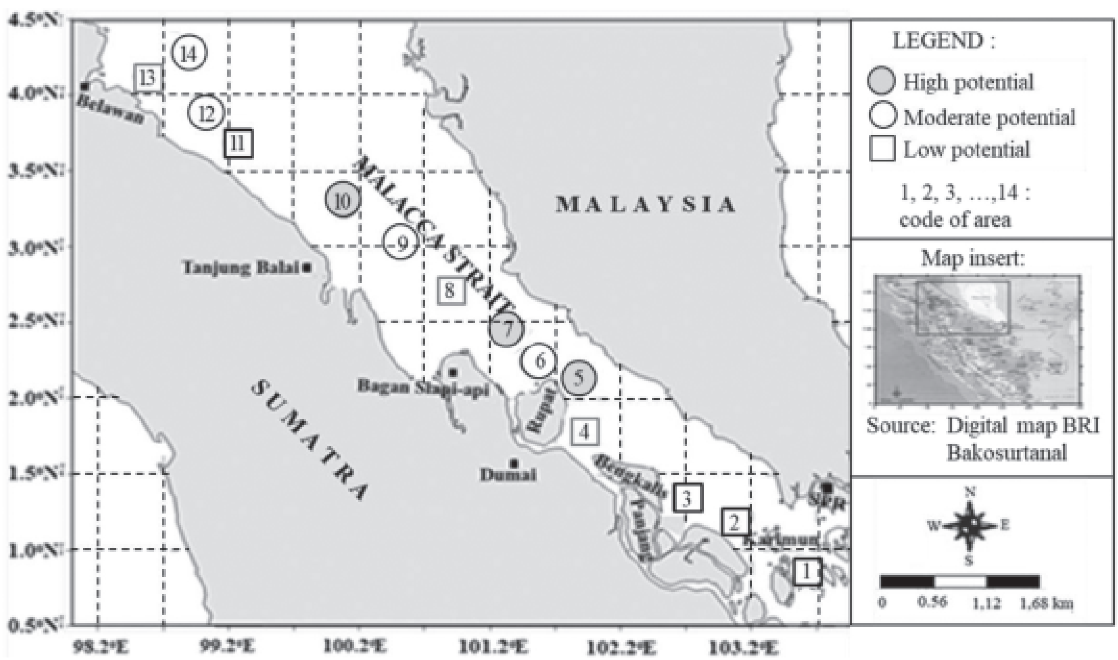

Fig. 8. Distribution of potential fishing zones for pelagic fishes in the Malacca Strait, June 2008.

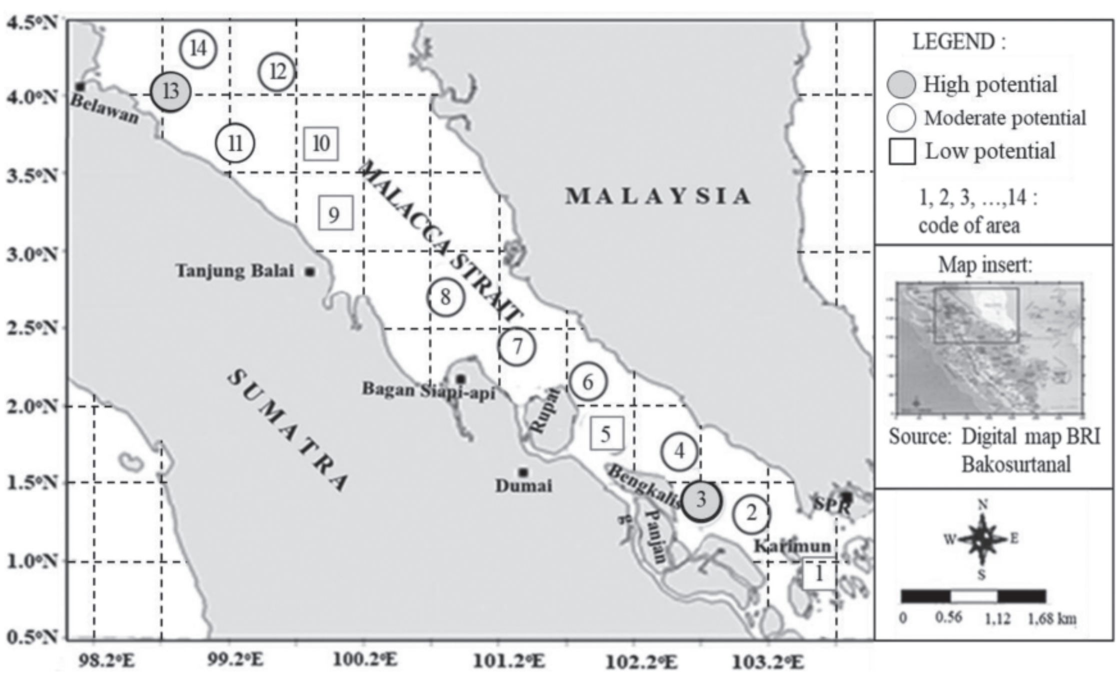

Fig. 9. Distribution of potential fish fishing zones for demersal fishes in the Malacca Strait, June 2008.

CONCLUSION

The size of pelagic fishes detected in the eastern part of the Malacca Straits tended to be smaller than in the western part of the Malacca Strait, while the size of demersal fishes tended to be similar in the eastern part and the western part of the Malacca Strait. Meanwhile, the density of pelagic fishes was relatively higher in the eastern part compared to the western part of the Malacca Strait, even though in general, the density of pelagic fishes was relatively high (> 5 fishes m^{-3}) along the Malacca Strait.

High potential fishing zones of pelagic fishes were only found in three of fourteen locations in the middle region of the Malacca Strait. Meanwhile, for demersal fishes, high potential fishing zones were only found in two of fourteen locations i.e., one in the coastal region of Belawan waters in the western part of the Malacca Strait and one in the eastern part of Bengkalis waters of the eastern part of the Malacca Strait. Meanwhile, moderate to low potential fishing zones for both pelagic and demersal fishes were generally found along the Malacca Strait.

The result can be used as an indicator that fisheries resources along the Malacca Strait are heading toward a declination. Therefore, for future and sustainable fisheries resources in the region, some good efforts are needed to take from the three countries of Indonesia, Singapore, and Malaysia.

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