Correlation of temperature, salinity, and water depth to the demersal fish density in Natuna Sea

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Abstract. A sustainable demersal resources management and utilization policy in Natuna Sea should be based on stock assessment results as its scientific evidence. The research aimed to analyse the demersal stock density, and its relationship with environmental aspects. The research result showed that the distribution of demersal fish found was between 40 and 60 m below surface water in Anambas Island, Tambelan Island, Subi Island and Midai Island. The stock density of demersal fish was estimated between 68.9 kg km^{-2} to 5,685.9 kg km^{-2} with an average estimated around 1.070,86 kg km^{-2} and the total biomass of demersal fish was estimated around 188,765.14 tons. The impact of environmental conditions such as temperature, salinity and water depth in Natuna Sea gives very low contribution to the distribution and density of demersal fish stocks, whereas the most influent component is salinity (r=0.114).

Key Words: biological aspect, demersal fish, density, distribution, Natuna Sea.

Introduction. Natuna Sea area which is included in the State Fisheries Management Area of the Republic of Indonesia (WPPNRI) 711 (Ministry of Marine Affairs and Fisheries Republic of Indonesia 2014) is a potential area for demersal and penaeid shrimp fishing. The utilization of demersal fish resources in the area has been going on for a long time and the exploitation status tends to be at a saturated level (Loose & Dwiponggo 1977; Wudianto & Sumiono 2008).

Sustainable management of demersal fish resources depends on a good understanding of how the variation and composition of the fishing results becomes a concern in the fishing business and its management. Therefore, this research was conducted to see the correlation between environmental conditions (temperature, salinity, and water depth), distribution and demersal fish stock density in Natuna Sea.

Total area of the Natuna Sea including Karimata Strait is estimated to be approximately 590,000 km² (Nurhakim et al 2007). This survey was conducted in an area of 176,284.22km², therefore, it is expected that the area study provides a good description of demersal fish resources condition in the northern equator with a survey area ratio of 1:3.35.

Material and Method. The survey was conducted in WPP 711 Natuna Sea area focused on the South Natuna Sea between latitudes 01º00.00 N - 04º30.00 N and 105º00.00 E - 109º00.00 E where depths range between 25 and 80 m. KM Madidihang 02 training and research vessel was equipped with a trawl which was used in this research from 9 May to 7 June 2016. Data was obtained from 27 trawling stations and 29 oceanographic stations. (Figure 1).

Station selection procedures are determined using echosounders and grids with different fish sampling station depths between 25 and 80 meters (Szalay & Somerton 2005). The method used in this study is called Cruise Track Design (Maclennan &

Simmonds 1992). Sampling was done using the layered random method (Steel & Torrie 1960) and performed a net pull at each trawl station using the swept area method (Bell et al 2008). Data was collected at noon and night with the speed of 2.5-3.5 knots when pulling the net for 1 hour (60 minutes). The stations were determined using stratified random sampling based on bathymetry feasibility for operating the trawl net.

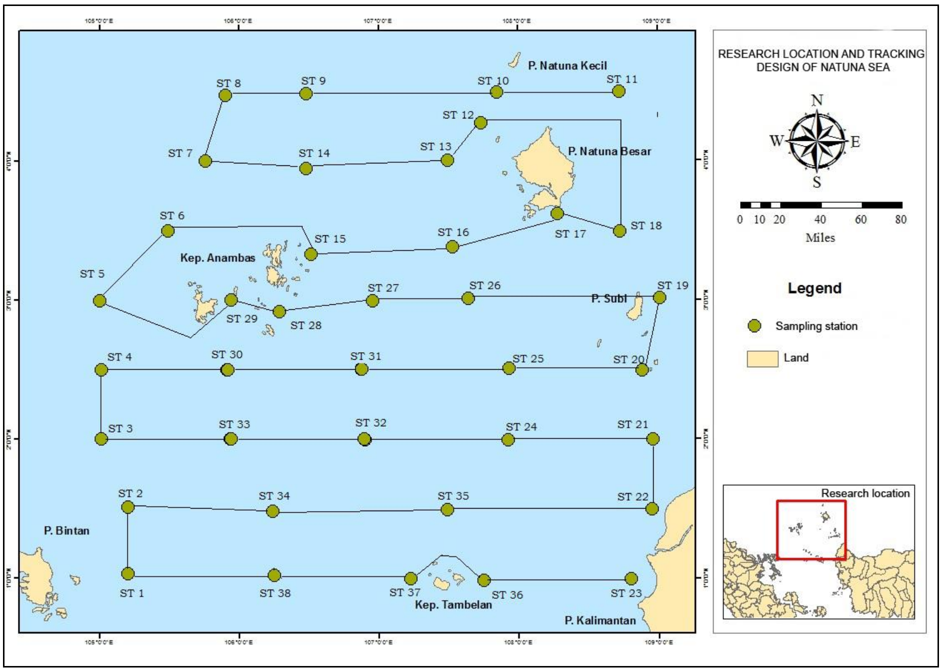

Figure 1. Research location and tracking design.

The detailed list of tools and materials used in this study are shown in Table 1 and Figure 2 below.

Table 1

Tools and materials used in this study

No	*Tools*	*Function*
1	MV Madidihang 02 training and research vessel	
2	Head rope = 36 m Ground rope = 40 m Mesh net bag size = 1.5 inch Outer board (iron) = 1.5 x 2.0 m Polyethylene material net	Standard fishing gear modified to shrimp and demersal fish. (Figure 2)
3	GPS (*Global Positioning System*), *scientific echosounder* SIMRAD EK 80.	Location recording
4	Fish species identification book Gloerfelt-Tarp and Kailola (1985) and Allen (1997).	Reference in fish species identification
5	Measuring instrument, Measuring board/measuring paper, scale, and dissecting set (surgical scissors, knives, tweezers, and magnifying glass)	Fish biology parameters instrument for caliper length measurement
6	CTD SBE 19plus and grab van veen type.	Measure the basic environmental conditions (temperature and salinity)
7	Camera, sampling form, bridge log, fishing log and stationery. Excel software for tabulating data and surfers for visualizing results using the swept area method	Documentation

FISHING GEAR			FISHING VESSEL	
Local Name	Pukat		Vessel Name	KM MADIDIHANG 02
National Name	Pukat Hela / Trawl		Fishing Master	Sakti P. Nababan
Fishing Method	Swept		GT	163 GT
Foot Rope	40 m		Fish Hold Cap.	136 m^3
Head Rope	36 m		LOA	30.8 m
			Breadth	6.3 m
			Depth	3 m
Drawing by	Agus Salim		Propulsion power	402 HP

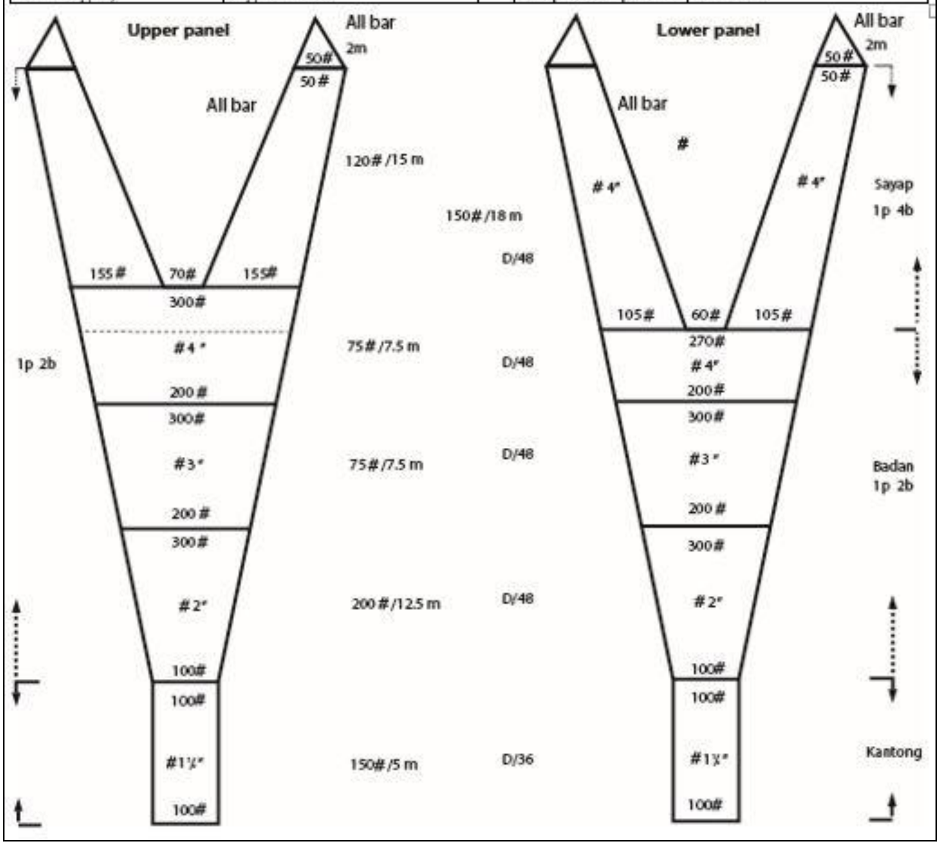

Figure 2. Trawling net with 36 meter-head rope.

The environmental conditions parameters included in this research are salinity, temperature, and water depth. The relationship between stock density with environmental conditions was analysed using Pearson product moment correlation within the formula below (Sugiyono 2004):

$$r_{XY} = \frac{n(\sum XY) - (\sum X)(\sum Y)}{\sqrt{\{n \sum X^2 - ((\sum X)^2)\}.\left\{n \sum Y^2) - (\sum Y)^2\right\}}}$$

Pearson product moment correlation (r) ranges from -1 to 1 (-1 ≤ r ≤ +1) which can be interpreted that the value of r = -1 means a perfect negative relationship; r = 0 means there is no relationship and r = 1 means a very strong relationship. X and Y are environmental condition parameters to be calculated and n is amount of data.

Results and Discussion

Water depth. In general, the Natuna Sea bottom profile has a variable contour, with several sea trenches found within a depth of >90 m, in several places. The depth contour changes slowly from shallow waters in south (<20 m) to deeper waters (>50 m) to the north (Figure 2). This kind of bottom contour affects the pattern of water mass flow from the southern part of the Java Sea and the northern part of the Pacific Ocean. During the east monsoon, warm water mass from Java Sea moves into Natuna Sea and dominates the upper water column, whereas deeper layers are dominated by cold water masses entering from the Pacific Ocean (Masrikat 2002).

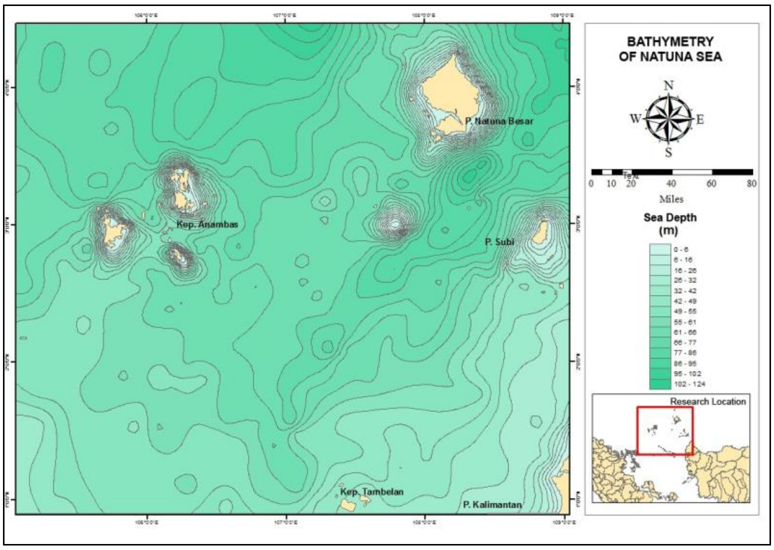

Figure 2. Bottom contour of the survey area in Natuna Sea (Source: data processing, 2017).

Salinity. Low salinity was found near the west coast of Kalimantan (stations 22 and 23 within values of 28.89 PSU (practical salinity unit) and 28.73 PSU at the surface and 33.2 PSU at the bottom. Meanwhile, other areas have a salinity >31.5 PSU at the surface and >33.4 PSU near the bottom. Lower salinity at stations 22 and 23 might be caused by the influence of freshwater mass from rivers that flow around the coast. Besides that, vertical variation in salinity is greater at 28.73 PSU on the surface up to 33.2 PSU near the bottom of the sea (Figure 3). Variations in salinity are often used to indicate changes in water mass. Fluctuations in salinity values in Natuna Sea show the same pattern, in which surface salinity value in the northern part of the waters is higher than in southern part. The result from this research did not differ much with the results of Ilahude research (1997) wherein a range of surface salinity is between 31.0 and 33.0 PSU during the west monsoon season and 32.0-33.0 PSU during the east monsoon season and according to Wyrtki (1961) average surface salinity in Natuna Sea amounted to 32.3‰. The salinity distribution is strongly influenced by the pattern of water circulation, evaporation, rainfall, and rivers flow. In shallow waters, homogeneous layers occurred until the bottom area within similar salinity and temperature (Nontji 2004).

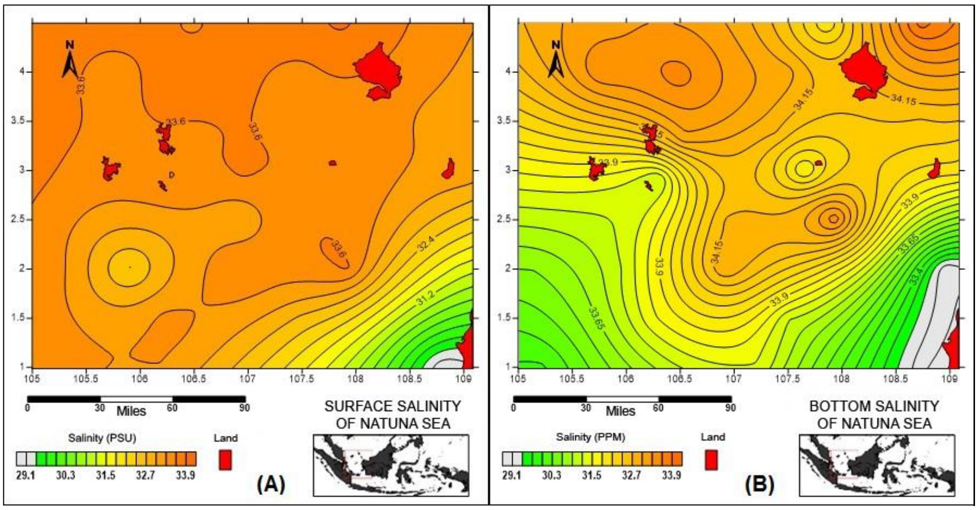

Figure 3. Salinity horizontal distribution on the surface (A) and bottom area (B) (Source: data processing, 2017).

Temperature. The temperature of the surface layer is not too varied, around 30.45–32.22°C (average of 31.07°C). Based on the horizontal distribution pattern, the lowest temperature occurred on the western part of Kalimantan and southern area which is shallower. On the other hand, northwestern area temperatures tend to be higher, especially in deeper waters (Figure 4.A). On the contrary, the horizontal distribution near bottom areas, showed that the lowest temperature is in deeper waters in the northern part of survey area, while higher temperatures occurred at the southern part of the survey area and the west coast of Kalimantan. The temperature in the bottom areas ranges between 21.53-30.38°C (average of 25.52°C) (Figure 4.B).

Surface and bottom temperatures in the Natuna Sea were found to be warmer in the southern part of the Natuna Sea. Higher temperatures dominate areas close to the mainland and shallow. Temperature differences between the north and south waters of the Natuna Sea, according to Ilahude (1997), occur due to the presence of water input from the north (Pacific Ocean) which is low in temperature and in general the Natuna Sea temperature increases from north to south waters. Furthermore, it also explained that during the west monsoon season (December-February) temperatures range between 26.5°C in the northern part up to 28.0°C in southern area. Whereas, during the east monsoon season (July-September) the temperature is relatively warm between 28.5 and 29.0°C.

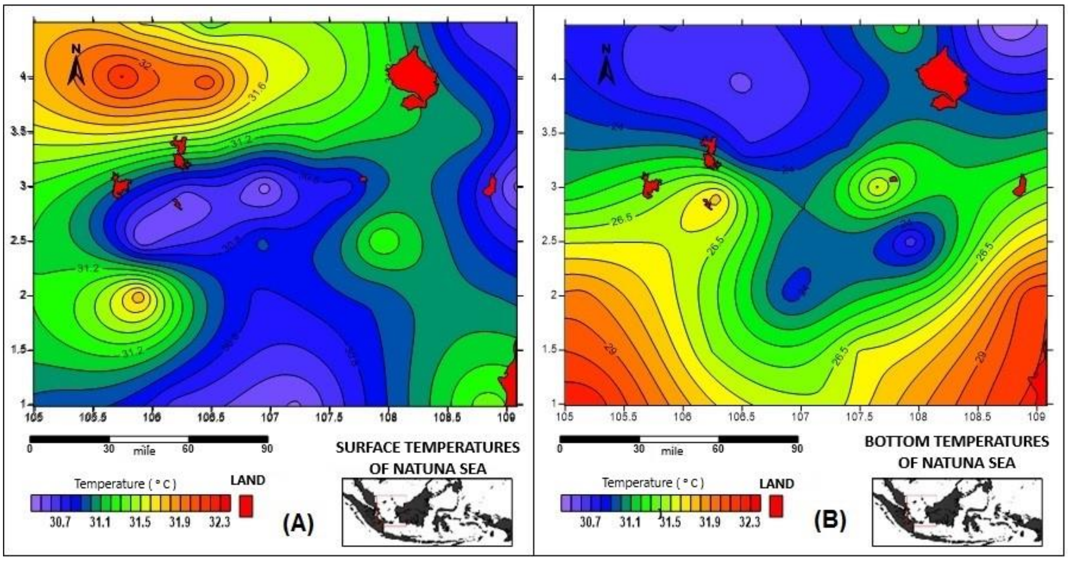

Figure 4. Temperatures horizontal distribution on the surface (A) and bottom area (B) (Source: data processing, 2017).

Demersal fish distribution. The highest number of species is in the depth range of 50–59 m. The highest number of fish species was recorded at station 16 in the southern part of Natuna Besar Island, with 47 species at 71.08 m depth, followed by station 23 at a depth of 28.29 m in the western part of Singkawang, with 45 species and stations at a depth of 59.9 m, in the western part of Midai Island and station 12 (53.8 m depth) in the Western part of Natuna Besar Island within a total of 42 species each. The station with the smallest number of species is station 2 in the northeast of the Bintan Island, at a depth of 47.56 m and station 24 in the southwest of the Cape Kemuning, at a depth of 67.42 m, with 14 species each (Figure 6).

The dominant species discovered along the surveyed area are *Leiognathus bindus* (1,248 individuals), *Pentaprion longimanus* (1,195 individuals), *Upeneus luzonius* (274 individuals), *Upeneus sulphureus* (220 individuals), *Leiognathus elongatus* (219 individuals), *Nemipterus thosaporni* (147 individuals), *Apogon poecilopterus* (135 individuals), *Priacanthus tayenus* (122 individuals), *Nemipterus furcosus* (121 individuals), *Arothron immaculatus* (111 individuals) and *Gymnocranius griseus* (108 individuals).

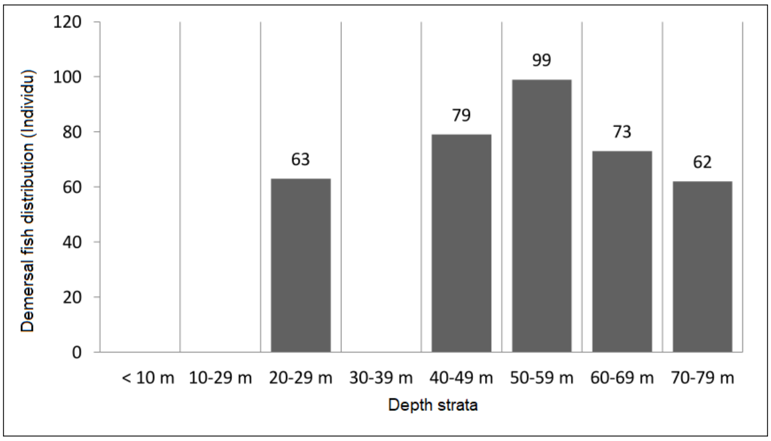

Figure 6. Histogram of demersal fish species distribution based on depth in the Natuna Sea (Source: data processing, 2017)

Sweep analysis conducted at the catch stations found that total catch rate varies between 3.8 kg hour^{-1} to 103.9 kg hour^{-1}. The highest catch rate is at station 38 (western part of Tambelan island) at 103.9 kg hour^{-1} in the depth range of 50-59 m, the second highest catch rate is at station 37 (western part of the Tambelan island) with a catch rate of 85.28 kg hour^{-1} at the same depth with station 38. The third highest catch rate is at station 20 at the southern part of Subi Besar island at 84.30 kg hour^{-1} at a depth of 40m-49m (Figure 7 and Figure 8).

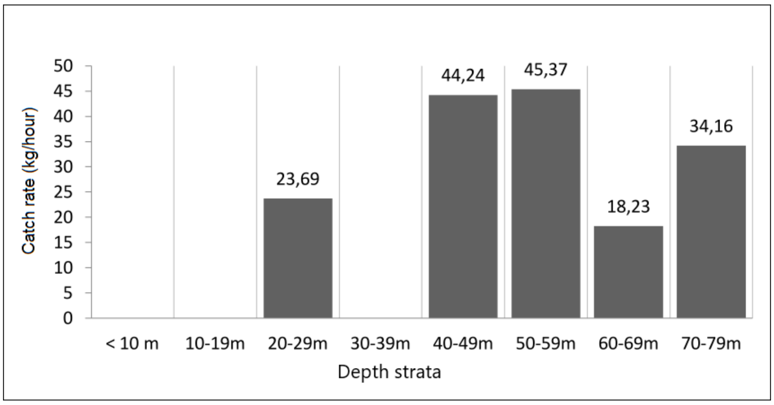

Figure 7. Histogram of demersal fish catch rate in Natuna Sea based on depth (Source: data processing, 2017).

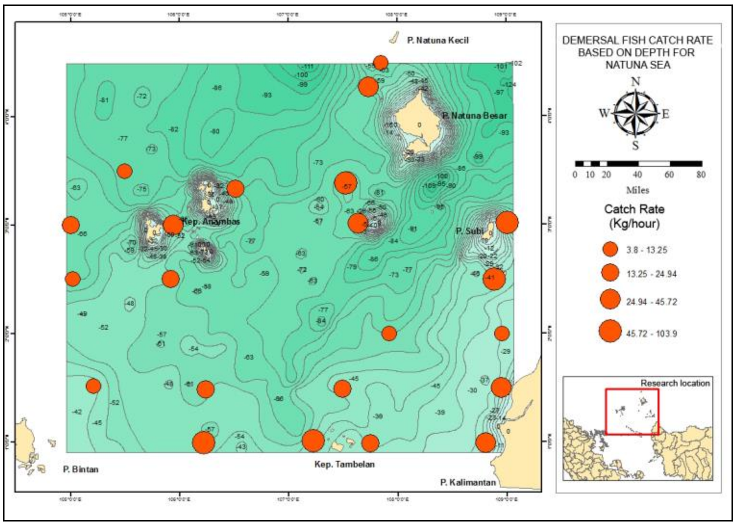

Figure 8. Distribution of demersal fish catch rates for Natuna Sea based on depth (Source: data processing, 2017).

Demersal fish stock density. Demersal fish stocks density from 22 stations ranges between 68.9 kg km^{-2} (station 2) to 5,685.9 kg km^{-2} (Station 29) (Figure 9 and Table 2).

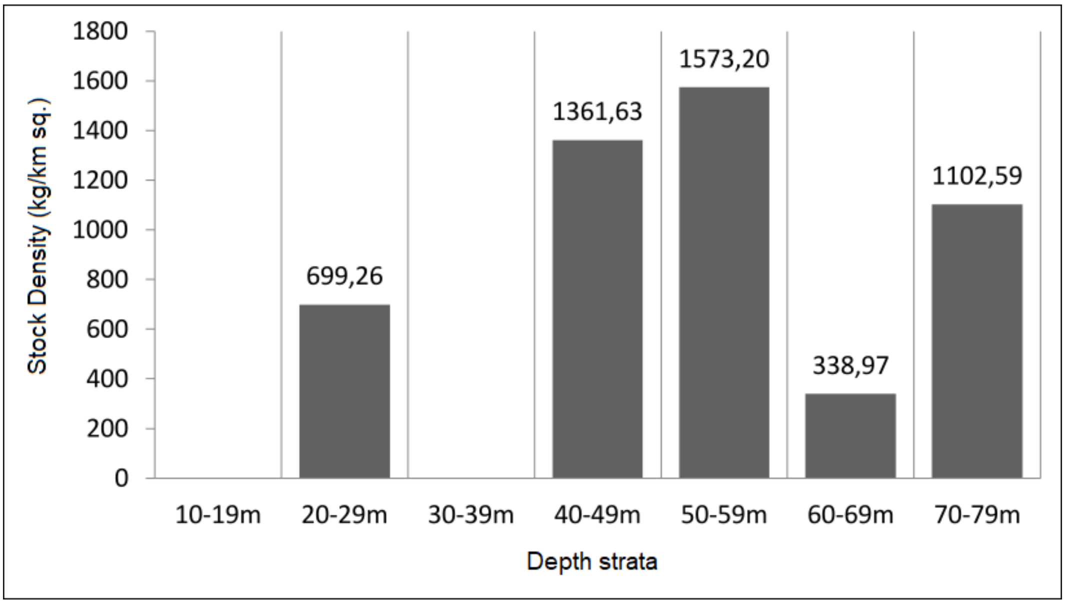

Figure 9. Histogram of demersal fish stock density based on depth (Source: data processing, 2017).

Table 2

Catch Rate and Demersal Fish Stocks Density

Depth interval	*Actual sea depth*	*Station*	*Catch (kg)*	*Stock density (kg km^{-2})*
20m-29m	29,50	21	1,90	190,00
	27,24	22	16,85	1.382,84
	26,71	23	32,85	524,93
40m-49m	48,24	19	36,47	1.673,09
	42,95	36	9,89	584,58
	42,18	20	40,76	3.119,98
	47,01	2	2,70	68,88
50m-59m	59,94	12	28,81	582,58
	58,50	10	7,55	365,92
	57,29	37	36,96	1.812,45
	59,81	30	10,26	494,65
	59,00	35	9,16	625,46
	59,11	38	51,95	1.445,43
	50,49	29	20,64	5.685,87
60m-69m	71,85	15	2,67	207,55
	67,42	24	3,96	90,26
	60,04	34	12,06	674,02
	63,06	26	26,49	393,88
	61,64	4	4,03	328,23
70m-79m	70,35	16	43,13	2.331,35
	73,88	6	7,46	690,72
	77,44	5	3,48	285,70
Average			34,56	1.070,86
Biomass				188.765,14 ton

The difference in stock density between sub-areas gives an evidence on the influence of environmental condition disparity which allows the formation of fish shoals and species diversity, different patterns density, height, and distance of schooling from the bottom (Wijopriono et al 2007). Demersal fish tends to be discovered in specific area based on east and west monsoon patterns (Sumiono et al 2011). This condition relates with the water mass pressure or high-speed currents during the Southeast wind, which occurs continuously (Gordon et al 2003). Therefore, south and west Kalimantan coastal area and the islands in the Natuna Sea are thought to be a shelter for demersal fish, thus a high stock density was found, as a result of this study.

Further demersal fish stock density analysis in Natuna Sea shows that stock density <500 kg km^{-2} (found in 8 sampling stations), stock density of 500-1000 kg km^{-2} (found at 7 sampling stations), fish stock density of 1000-2000 kg km^{-2} (found at 4 sampling stations), and fish stock density of >2000 kg km^{-2} (found at other 3 sampling stations). Highest stock density > 000 kg km^{-2} was found around the islands of Natuna Sea (Anambas, Subi, Midai and Tambelan Islands). Second highest stock density was found in the western part of Kalimantan coast with a range fish stock density of 1000-2000 kg km^{-2} (Figure 10). High stock density demersal fish in the area are in accordance with the results of a previous survey in the year 2005 and 2006 which successfully identified the abundance of demersal fish high on the west coast of Kalimantan from west Singkawang to the island Subi in the northwest of Kalimantan, in the west of Tambelan island and southwest of the island Natuna Besar (Wudianto & Sumiono 2008; Masrikat 2009). So as with the results of Sudrajat and Beck's research (1978) showing stock density levels in the eastern area of Natuna Sea on the west coast of Kalimantan spread from Bawal Island in the south to the southwest of Pemangkat and the western area of Natuna Sea in around Lingga Island, Singkep Island and Bintan Island.

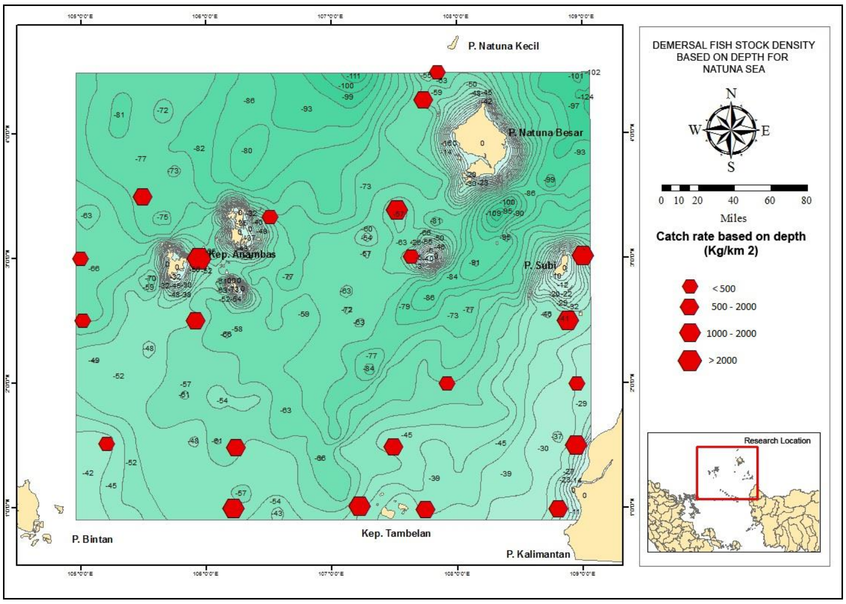

Figure 10. Distribution of demersal fish stock density in Natuna Sea (Source: data processing, 2017).

Generally, the average of demersal fish stock density in Natuna Sea is 1,070.84 kg km^{-2} from a 176,284.22 km^2 research area, with a catch rate of 34.56 kg hour^{-1} and biomass of 188,765.14 tons (Table 3). This stock density is higher than the survey conducted in 2005 which found the average stock density of 840 kg km^{-2} (Masrikat 2009), but lower if compared to Sudrajat and Beck's (1978) research that showed a stock density of 1,789 kg km^{-2}.

Table 3

Comparison of demersal fish catch rate, stock density and biomass in Natuna Sea

Survey conducted	*Identified area (km^2)*	*Catch rate (kg $hour^{-1}$)*	*Stock density (ton km^{-2})*	*Biomass (ton)*	*Reference*
1976	175.093	156,00	2,36	677.320,00	Saeger et al 1976
1978	287.093	119,00	1,79	516.600,00	Sudradjat & Beck 1978
2001	287.000	66,90	1,00	166.460,00	Masrikat 2009
2002	-	-	-	334.800,00	Masrikat 2009
2005	113.753,73	50,54	0,84	95.630,84	Masrikat 2009
		-	8,66	984.615,26[A]	
2006	76.754,52	-	6,32	485.287,69[A]	
2016	176.284,22	34,56	1,07	188.765,14	Present research

Correlation between stock and environmental condition. This research has considered several environmental parameters such as salinity, temperature, and water depth in the study of 22 trawl stations. The relationship between stock density and environmental conditions were analyzed using Pearson product moment correlation (r).

The result shows positive correlation between demersal fish stock density to salinity and temperature near the bottom, whereas negative correlation was found between demersal fish stock density and the water depth. The correlation coefficient of the density of demersal fish stocks with salinity and temperature show a stronger relationship (r = 0.114; 0.081) compared to water depth (r = -0.068). This negative correlation indicates that demersal fish density decreases with the increase in depth (Table 4). Thus, the effect of temperature, salinity, and depth on demersal fish stocks density in Natuna Sea is very low (smaller than 0,199), moreover the water depth has a very low effect on the demersal fish stocks density.

Overall, based on the significance test of all environmental condition factors, the probability values are greater than 0.025 (salinity 0.614, temperature 0.719, and water depth 0,763). Therefore, we can identify that the combination of environmental conditions had no significant effect on the demersal fish stocks density.

Table 4

Correlation between demersal fish stock density, salinity,
temperature and water depth at Natuna Sea (Pearson Correlation and Significance Test)

		Stock density	*Salinity*	*Temperature*	*Sea depth*
Stock density	Pearson Correlation	1	0,114	0,081	-0,068
	Sig. (2-tailed)		0,614	0,719	0,763
	N	22	22	22	22
Salinity	Pearson Correlation	0,114	1	-0,892**	0,828**
	Sig. (2-tailed)	0,614		0,000	0,000
	N	22	22	22	22
Temperature	Pearson Correlation	0,081	-0,892**	1	-0,812**
	Sig. (2-tailed)	0,719	0,000		0,000
	N	22	22	22	22
Depth	Pearson Correlation	-0,068	0,828**	-0,812**	1
	Sig. (2-tailed)	0,763	0,000	0,000	

N	22	22	22	22

**. Correlation is significant at the 0.01 level (2-tailed).

Based on research conducted by Masrikat (2009), oceanographic parameters have a small effect on the distribution of fish density. This condition is similar with Ridho (2004), which research found that temperature, salinity, and depth have small influence on demersal fish stocks in Natuna Sea.

The results from significance test analysis of environmental factors (salinity, temperature, and water depth) on the density of demersal fish show that environmental conditions gave small effect on demersal fish density and none of the environmental conditions had a significant correlation with the increase of demersal fish stocks density.

Observation's result showed that demersal fish stock density was almost evenly distributed, but there were some areas with high stock density the areas are between Natuna and Anambas island also Natuna and Subi islands, those areas have higher salinity and lower temperatures compared to others.

Conclusion. Based on the research results on biological aspects, distribution, and density of demersal fish stocks the following aspects can be concluded:

1. The spread of demersal fish is found to be spatially spreading at various depths with high densities found at the 40-60 m depth interval, around the Anambas, Tambelan, Subi, and Midai islands.
2. The density of demersal fish resource stock in Natuna Sea ranges from 68.9 kg km^{-2} to 5,685.9 kg km^{-2} with an average of 1,070.86 kg km^{-2} and a total biomass of 188,765.14 tons
3. The impact of environmental conditions such as temperature, salinity and water depth in Natuna Sea has a very low impact on the distribution and density of demersal fish stocks, and among them, salinity has the most influence (r=0.114).

In maintaining demersal fish resources in Natuna Sea, fisheries management must be carried out immediately, especially to control the net size and optimal efforts. Further research on population dynamics, peak spawning seasons and demersal spawning sites should be performed at Natuna Sea, so that comprehensive scientific evidence to support sustainable management that can be provided.

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