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Trawling ban impact on the stock density of shrimps in the Java Sea, Indonesia

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Abstract. *Tirtadanu, Suprapto. 2017. Trawling ban impact on the stock density of shrimps in the Java Sea, Indonesia. Ocean Life 1: 49-54.* The level of over-exploitation of shrimps and the use of destructive fishing gear in the Java Sea caused the goverment of Indonesia to ban the trawl operation since 2015. Information on the stock density of shrimps in the Java Sea is needed for evaluation of the management regime. The aims of this research was to study the impact of the trawling ban on the density of shrimps in the Java Sea. The research was conducted in October-November 2015 and October-November 2017 using a swept area trawl method. The results showed that the biomass of demersal fish and rays has increased but the biomass of shrimps in the Java Sea has decreased that might be due to the predator-prey relationship.The biomass of some smaller-size shrimps such as *Metapenaeopsis palmensis*, *Trachypenaeus malaiana* and *Metapenaeopsis stridulans* decreased, while the biomass of larger shrimps such as *Metapenaeus ensis*, *Penaeus merguiensis* and *Penaeus monodon* increased. This condition caused the changes of dominant shrimps in Java Sea where the dominant shrimps before the trawling ban were *M. palmensis*, while the dominant shrimps after two years trawling ban were *M. ensis*. From the results, there is an assumption that the ecosystem is more stable after two years of the trawling ban. Most of the density of larger-sized shrimp increased only in the middle of Java Sea, while the density in the coastal zone still decreased. We suggest regulations to control the quota of fishing vessels in the coastal waters to ensure the sustainability of shrimp resources.

Keywords: Java Sea, shrimp, ecosystem, stock density, trawling ban

INTRODUCTION

The Java Sea is one of the fishing ground for shrimps in Indonesia. It has shallow depths and muddy substrate so that it is compatible for the operation of shrimps trawl. The shrimp fishing in the Java Sea has been conducted for a few dacadesand the information of the trawling exploration has been reported since 1976 (Losse and Dwiponggo 1977). The shrimp fishery stocks in the Java Sea were reported as overfishined in 2013 (Suman and Prisantoso 2017). The decline of shrimps stock by non-selective fishing gear and high fishing pressure caused the government to ban trawl fishing operations since 2015 to maintain the sustainability of shrimp resources (Ministerial decree No. 2/PERMEN-KP/2015).

This study evaluating the effectiveness of the trawling ban on the density of shrimps was conducted to evaluate its policy and to determine the future management for shrimp fisheries. Previous studies from the other areas (La Paz Bay, Bombay Waters, Tyrrhenian Sea) reported that the high fishing pressure by trawling could decrease the stability of the ecosystem and cause the extinction of stock, and the trawling closure could increase the recruitment rate of fish (Salcido-Guevara et al. 2012; Deshmukh 2001; Sinopoli et al. 2012). Also, Badrudin et al. (2011) reported that the trawling ban could increase the catch rate of demersal fishes in the Java Sea.

Previous research reported that the density of shrimps in the Java Sea before the trawling ban in 2015 was 21.34 kg/km^2 and the biomass was 9,938 tons (Tirtadanu et al. 2016). The research related on the stock density of shrimps after two years trawling ban was important information to find out the sustainability of shrimp resources in the Java Sea. This study compared the stock density of shrimp between 2015 (before the trawling ban) and 2017 (after two years of trawling ban), in order to evaluate the impact of the trawling ban on the stock density of shrimps in the Java Sea.

MATERIALS AND METHODS

Study area

The location of the research was on the Java Sea, from 106°E to 114.5°E and from 3°S to 6.5°S (Figure 1). The depths of the area were between 10 and 80 m.

Procedure

The research was conducted by swept area method using Madidihang 02 research vessel on October to November 2015 and using Bawal Putih 03 research vessel on October to November 2017. The trawl gear used for surveys in 2015 and 2017 consisted of a 4 inch meshsize net, 36 m of headrope and 41 m of groundrope. The operation of trawl used 15 buoys and 150 kg of ballast. The study area was in the northern Java Sea and sampling was conducted at 39 stations in 2015 and 30 stations in 2017 (Table 1). The trawl was operated by 0.5-1 hour for each

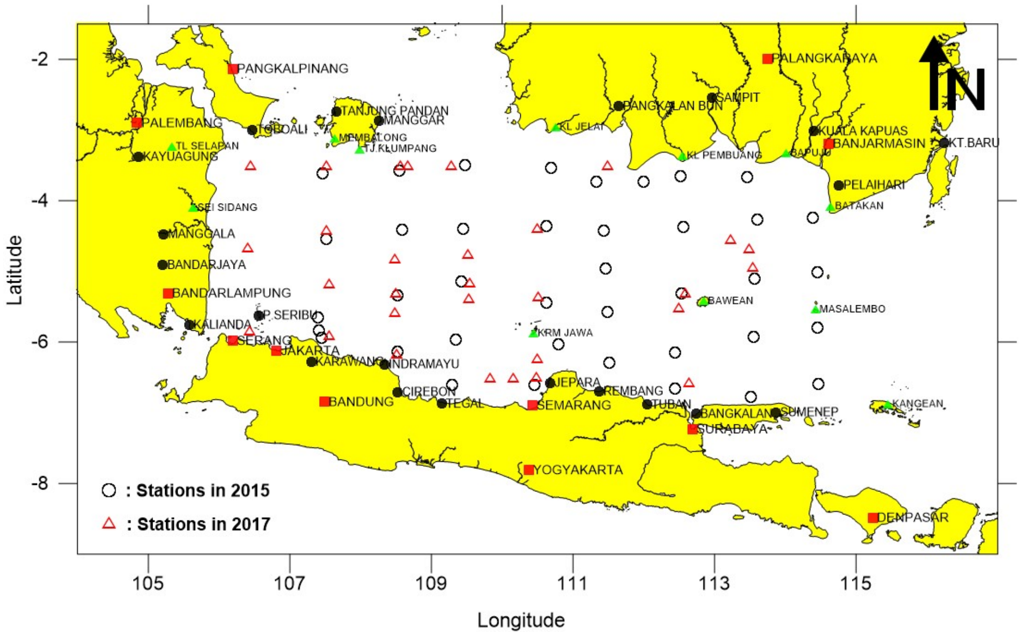

Figure 1. The stations of shrimp trawl exploration in the Java Sea, 2015 and 2017.

Table 1. The stations and depths of trawl exploration in the Java Sea, 2015 and 2017

Stations	2015				2017			
	Latitude	Longitude	Depth (m)	Time	Latitude	Longitude	Depth (m)	Time
1	-5.9433	107.4557	13	10:00:00 PM	-5.8363	106.4339	39	10:42:00 AM
2	-5.8309	107.4058	31	2:30:00 AM	-4.6638	106.4005	20	2:10:00 AM
3	-5.6553	107.4028	47	8:00:00 AM	-3.5017	106.4381	15	14:31:00 PM
4	-4.5472	107.5191	29	1:45:00 AM	-3.4981	107.5103	25	4:14:00 AM
5	-3.6098	107.4624	24	4:00:00 PM	-4.4168	107.5103	27	15:26:00 PM
6	-3.5738	108.5496	39	8:30:00 AM	-5.1667	107.5501	42	3:42:00 AM
7	-4.4102	108.5822	46	7:00:00 PM	-5.9001	107.5501	30	9:56:00 AM
8	-5.3407	108.5164	49	6:10:00 AM	-6.1596	108.5130	33	6:42:00 PM
9	-6.1433	108.5154	40	5:30:00 PM	-5.5731	108.4867	45	6:04:00 AM
10	-6.6134	109.2929	37	9:30:00 AM	-5.3055	108.4991	45	10:13:00 AM
11	-5.9700	109.3424	52	7:45:00 PM	-4.8221	108.4868	41	3:35:00 PM
12	-5.1505	109.4272	54	3:00:00 PM	-3.4974	108.5606	19	5:52:00 AM
13	-4.3972	109.4434	46	3:00:00 AM	-3.4940	108.6683	30	9:15:00 AM
14	-3.4920	109.4744	36	6:00:00 PM	-3.4956	109.2796	44	3:51:00 PM
15	-3.5340	110.6953	19	10:30:00 AM	-4.7495	109.5184	50	5:59:00 AM
16	-3.7273	111.3290	39	7:00:00 PM	-5.1552	109.5359	52	1:31:00 PM
17	-3.7297	111.9935	27	6:00:00 AM	-5.3847	109.5261	53	4:56:00 PM
18	-3.6511	112.5272	18	4:00:00 PM	-6.5057	109.8254	45	6:10:00 AM
19	-4.3757	112.5589	43	3:30:00 AM	-6.5027	110.1537	44	10:45:00 AM
20	-5.3107	112.5378	70	5:30:00 PM	-6.4966	110.4868	45	1:52:00 PM
21	-6.1461	112.4436	67	5:30:00 AM	-6.2312	110.4999	50	4:39:00 PM
22	-6.6647	112.4402	52	1:30:00 PM	-5.3567	110.5111	65	6:00:00 AM
23	-6.2966	111.5119	48	2:35:00 AM	-4.3914	110.4917	42	3:42:00 PM
24	-5.5780	111.4924	74	12:35:00 PM	-3.4940	111.4917	25	9:53:00 AM
25	-4.9663	111.4592	63	9:55:00 PM	-6.5674	112.6325	55	2:15:00 PM
26	-4.4195	111.4335	58	5:50:00 AM	-5.5108	112.4959	69	11:35:00 AM
27	-4.3558	110.6320	48	10:10:00 AM	-5.3034	112.5838	66	4:23:00 PM
28	-5.4432	110.6284	67	6:00:00 AM	-4.5427	113.2327	47	7:06:00 AM
29	-6.0314	110.7927	55	5:00:00 PM	-4.6717	113.4855	38	11:52:00 AM
30	-6.6142	110.4517	36	7:00:00 AM	-4.9339	113.5465	46	3:34:00 PM
31	-6.7819	113.5105	43	8:05:00 PM				
32	-5.9273	113.5545	68	7:30:00 AM				
33	-5.1000	113.5703	56	6:30:00 PM				
34	-4.2694	113.6074	28	5:35:00 AM				
35	-3.6719	113.4581	17	3:00:00 PM				
36	-4.2390	114.3942	27	3:30:00 PM				
37	-5.0123	114.4487	31	4:20:00 AM				
38	-5.8023	114.4488	58	8:40:00 PM				
39	-6.5923	114.4690	83	7:00:00 AM				

station, during the day time and night time. The catch was sorted by species before weighing and the shrimps were identified using Carpenter and Niem (1998). Also, the demersal fish and rays were weighted and sorted by each family groups.

Data analysis

The stock density of shrimps, demersal fishes and rays were calculated using the formula (Sparre and Venema, 1992):

$$a = V \; x \; t \; x \; hr \; x \; X2 \; x \; 1{,}852 \; x \; 0{,}001 \quad \ldots\ldots\ldots\ldots (1)$$

$$D = \left(\frac{1}{a}\right) x \left(\frac{c}{f}\right) \ldots\ldots\ldots\ldots (2)$$

Where: α = the swept area (km^2); V = the velocity of the trawl when trawling (knot); t = the time spent trawling (hour); hr = the length of *headrope* (m); X2 = the fraction of head rope length that was 0.5 based on Pauly (1980); 1,852 = The conversion from mile to km; D = The stock density (kg/km^2); c = catch rate (kg/hour); f = *escapement factor* as the proportion of shrimps that was caught by trawl based on Saeger et al. 1976.

The stock density of shrimps, demersal fishes and rays in the Java Sea was obtained from the mean density from 39 stations in 2015 and 30 stations in 2017. The catch rate was obtained from the catch in weight per hour. The biomass was calculated from the formula (Sparre and Venema, 1992):

$$B = \frac{\left(\frac{Cw}{a}\right) * A}{X1} \ldots\ldots\ldots\ldots (3)$$

or

$$B = D*A \ldots\ldots\ldots\ldots (4)$$

Where: B = Biomass, Cw/a = the mean catch per unit area of all hauls, A = the total area in Java Sea that was 465,680 km^2 based on Losse (1981), X1 = 0,5 based on Saeger et al. 1976, D = the stock density.

The stock density of shrimps was also calculated based on the region of the area in the Java Sea such as North Coast of Java, Middle of Java Sea and South Kalimantan. The composition of shrimps was calculated based on the total biomass of shrimps in the Java Sea.

RESULTS AND DISCUSSION

Stock Density

The stock density of demersal fishes and rays in the Java Sea increased between 2015 and 2017, while the stock density of total shrimps decreased. The stock density of demersal fishes has increased from 1,362 kg/km^2 to 3,031 kg/km^2 and the stock density of rays has increased from 121 kg/km^2 to 150 kg/km^2, otherwise the stock density of shrimps has decreased from 25.4 kg/km^2 to 8 kg/km^2 (Table 2).

The species of *Penaeid* shrimps that were caught in the Java Sea were banana shrimps (*Penaeus merguiensis*), green tiger prawn (*Penaeus semisulcatus*), giant tiger prawn (*Penaeus monodon*), red-spot king prawn (*Penaeus longistylus*), greasyback shrimp (*Metapenaeus ensis*), velvet shrimp (*Metapenaeopsis palmensis*), fiddler shrimp (*Metapenaeopsis stridulans*) and Malayan rough shrimp (*Trachypenaeus malaiana*) (Figure 2). The density of larger-size shrimps such as *P. merguiensis*, *P. semisulcatus*, *P. monodon* and *M. ensis* has increased in the Middle of Java Sea, while the density of small-size shrimps such as *M. palmensis*, *M. stridulans* and *T. malaiana* has decreased in North Coast of Java and in Middle of Java Sea (Table 3).

Table 2. The stock density and biomass of demersal fishes, rays and shrimps in the Java Sea, 2015 and 2017

Groups	2015		2017	
	Stock density (kg/km^2)	Biomass (tons)	Stock density (kg/km^2)	Biomass (tons)
Demersal Fishes	1,362	634,446	3,031	1,411,339
Rays	121	56,257	150	69,666
Shrimps	25.14	11,707	8	3,866

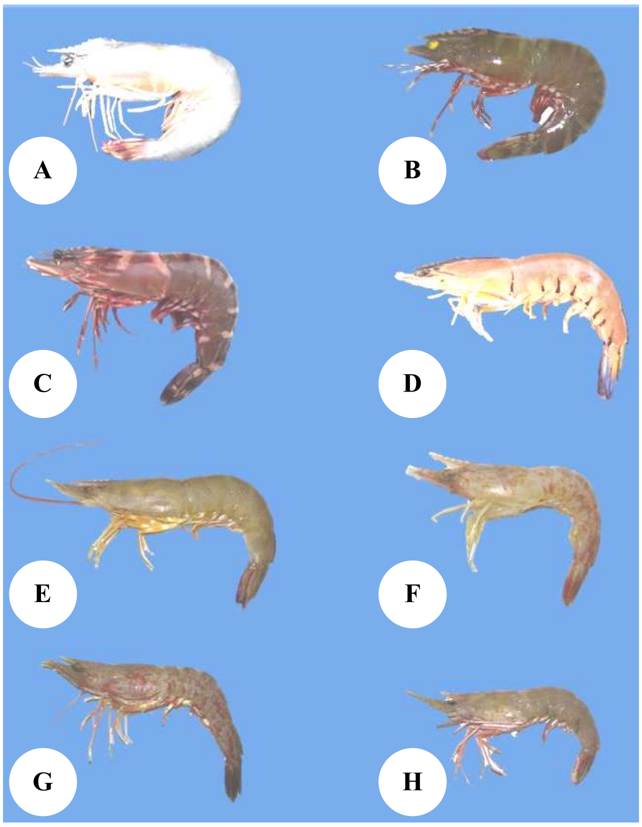

Figure 2. Some species of shrimps caught by trawl in the Java Sea (A) *Penaeus merguiensis* (mean size = 35 mmCL), (B) *P. semisulcatus* (mean size = 37 mmCL), (C) *P. monodon* (mean size = 71 mmCL), (D) *P. longistylus* (mean size = 30 mmCL), (E) *M. ensis* (mean size = 30 mmCL), (F) *M. palmensis* (mean size = 15 mmCL), (G) *M. stridulans* (mean size = 15 mmCL), (H) *T. malaiana* (mean size = 16 mmCL).

Composition

Based on the total biomass of shrimps in the Java Sea, The proportion of the species of shrimps in the Java Sea has changed after two years of the trawling ban. The dominant shrimp species in 2015 was *M. palmensis* with the proportion of 55%, while the dominant shrimps in 2017 was *M. ensis* with the proportion of 50.4%. The proportion of *M. palmensis* after two years of trawling ban or in 2017 was 11.4% and the proportion of *M. ensis* in 2017 was 50.4% (Figure 3).

The highest stock density of shrimps in 2015 was *M. palmensis* (12.83 kg/km^2), different with the highest stock density after two years trawling ban that the dominant species was greasyback shrimp (*M. ensis*) (4.19 kg/km2). The stock density of some species that are economically important such as *P. merguiensis*, *P. monodon*, *P. longistylus* and *M. ensis* has increased but the others have decreased (Table 4).

Biomass

The biomass of shrimps in the Java Sea has decreased in 2017 for *M. palmensis*, *T. malaiana*, *M. stridulans* and *P. semisulcatus*, while the biomass of *M. palmensis*, *M. stridulans* and *T. malaiana* in 2017 has decreased by more than 50% from the biomass in 2015. The biomass of economically important species of shrimps such as *M. ensis*, *P. merguiensis*, *P. monodon* and *P. longistylus* has slightly increased after two years of the trawling ban (Figure 4).

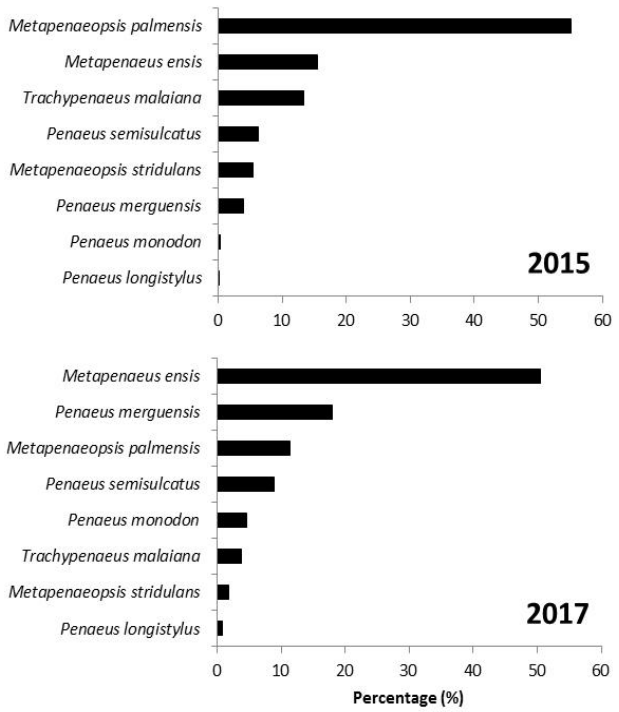

Figure 3. The proportion of eight species of shrimps in the Java Sea based on the total biomass, 2015 and 2017

Table 3. Stock Density of shrimp species in the North Coast of Java (NJ), Middle of Java Sea (MJ) and South Kalimantan (SK), 2015 and 2017

Species	NJ		MJ		SK	
	2015	2017	2015	2017	2015	2017
Penaeus merguiensis	1.86	3.49		0.38	0.80	
Penaeus semisulcatus	3.62	1.32	0.12	0.44	0.96	
Penaeus monodon				0.62	0.32	
Penaeus longistylus			0.02			0.47
Metapenaeus ensis	5.10	3.20	0.08	4.78	6.93	0.53
Metapenaeopsis palmensis	11.42	2.05	12.14	0.47	19.24	0.82
Metapenaeopsis stridulans	1.22	0.17	1.01	0.16	2.10	
Trachypenaeus malaiana	1.95	0.59	5.86	0.17	1.02	

Note: *NJ: North Coast of Java; MJ: Middle of Java Sea; SK: South Kalimantan

Table 4. The stock density of some species of shrimps in the Java Sea, 2015 and 2017

Species	Common Name	Density (kg/km^2)	
		2015	2017
Penaeus merguensis	Banana prawn	0.93	1.49
Penaeus semisulcatus	Green tiger prawn	1.48	0.75
Penaeus monodon	Giant tiger prawn	0.09	0.39
Penaeus longistylus	Red-spot king Prawn	0.01	0.07
Metapenaeus ensis	Greasyback shrimp	3.60	4.19
Metapenaeopsis palmensis	Velvet shrimp	12.83	0.95
Metapenaeopsis stridulans	Fiddler shrimp	1.25	0.15
Trachypenaeus malaiana	Malayan rough shrimp	3.10	0.32

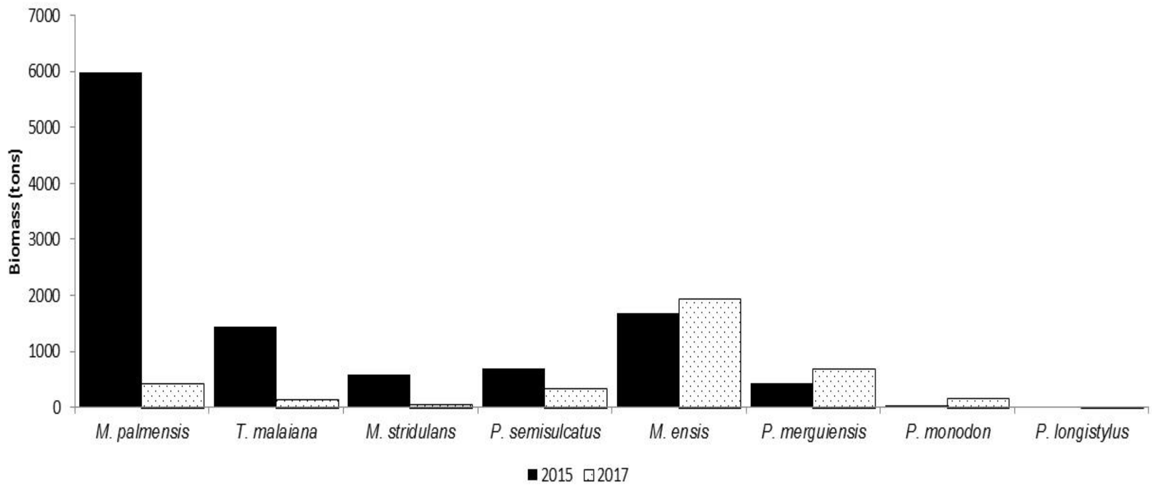

Figure 4. The biomass of eight species of shrimps in the Java Sea, 2015 and 2017.

Discussion

The most dominant species of shrimps based on the stock density by each region in the Java Sea (north coast of Java, middle of Java Sea and south Kalimantan) before the trawling ban was *M. palmensis*. The most dominant species of shrimps after the trawling ban was *P. merguiensis* in the north coast of Java region and *M. ensis* in the middle of Java Sea. This condition showed that there are shifting dominance in the north coast of Java Sea and in the middle of Java Sea region. The previous study noted that there was the correlation between depths and the density of *P. merguiensis* in Semarang Waters where the highest density was found in the shallow depths (Pramonowibowo et al. 2007). Tirtadanu et al. (2018) noted that *P. merguiensis* in Makassar Strait was more abundant in the depth of less than 40 m and *M. ensis* found in the depths of more than 60 m but more abundant in the depths of less than 40 m. The decreasing of fishing pressure of trawlers in the Java Sea caused the population of *P. merguiensis* as the bigger-size shrimp which lived in the shallow waters in the north Coast of Java could compete *M. palmensis* as the smaller-size shrimp and the population of *M. ensis* could compete *M. palmensis* in the middle of the Java Sea.

The stock density of some fisheries resources has changed after two years of the trawling ban in the Java Sea where the stock density of demersal fishes and rays has increased and the stock density of shrimps has decreased. Rastgoo et al. (2015) reported that shrimps were the main preys of whitespotted whipray (*Himantura gerrardi*). Some of the demersal fishes such as *Nemipterus* sp. and *Priacanthus* sp. were the main predators of shrimps (Manojkumar et al. 2015; Saker et al. 2013). The same condition was reported by Worm et al. (2003) in Atlantic ocean where the increasing biomass of cod as predator caused the decreasing of shrimps biomass.

The dominant shrimps in the Java Sea after two years of trawling ban or in 2017 were *Metapenaeus ensis* while the dominant shrimps in 2015 was the smaller shrimps such as *Metapenaeopsis palmensis*. The high fishing pressure of trawl has caused the decreasing biomass of top trophic level species so there are shifting dominance by the lower trophic level species (Manickchand-Heileman et al. 2004). The trawl ban after two years caused the decrease of fishing pressure by trawl in the Java Sea so some species have recovered in the Java Sea where the dominant species after the trawling ban was the higher trophic level such as *M. ensis.* When the fishing pressure was low, it was suggested that the larger shrimp have out-competed the smaller shrimp from getting the food and survive from predators so the big-size shrimp could shift the dominance of the smaller shrimps.

Most of the density for the big size shrimps such as *P. merguiensis, P. semisulcatus, P. monodon* and *M. ensis* has increased only in the Middle of the Java Sea. The density of some species of the big size shrimp in the North Coast of Java Sea still decreased after two years of trawling ban. This condition could be caused by the big trawllers in the Java Sea was only operated in the Middle of Java Sea where in the coastal zone was dominated by the traditional fishers. It concluded that the trawling ban has more affected the density of shrimps in the Middle of the Java Sea rather than in the coastal waters. When the trawl was banned, the traditional fishing vessel was increased that caused the high fishing pressure in the coastal zone so it could decrease the density of shrimps in the coastal waters.

The total biomass of *M. ensis*, *P. merguiensis* and *P. monodon* has increased after two years of trawling ban while the biomass of *M. palmensis*, *T. malaiana* and *M. stridulans* has decreased. Salcido-Guevara et al. (2012) reported that the high fishing pressure of trawl could decrease the stability of the ecosystem. The trawling ban has decreased the fishing pressure of trawl so the ecosystem was estimated to be more stable where the high dominance of small-size shrimps (*M. palmensis*) was shifted by the upper trophic level (*M. ensis*). The trawling ban in the Java Sea has caused the shifting dominance of shrimps by the bigger size and the increasing density of some species most in the Middle waters of the Java Sea. Most of the species of shrimps density in the coastal zone still decreasing so it was suggested to control the quota of the fishing vessel in the coastal waters to prevent the decreasing stock of shrimps in the Java Sea.

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