Composition, Distribution, and Fisheries Biology of Penaeid Shrimp from the Strong Wavy Waters of Southern Java, Indonesia

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Abstract

Penaeidae is a family of shrimp that has a high economic value, leading to intensive exploitation in many areas. This research was conducted to ascertain the composition, distribution, and fisheries biology of Penaeid shrimps in the strong wavy water of southern Java Island, Indonesia. The research locations were the water of Eastern, Central, and Western Java. Shrimp samples were obtained using various ways. The carapace length (CL) of the shrimps were measured using plastic callipers and recorded to the nearest 1 mm. The results showed that eight species of shrimps were caught in the water of southern Java, with *Penaeus merguiensis, P. semisulcatus*, and *P. monodon* being the most common. The species *P. merguiensis* was found in each sampling location, while *P. latisulcatus* and *Metapenaeus palmensis* were only present at Drini Beach (Central Java). The results also showed that *P. japonicus* and *M. lysianassa* were only found at Ranca Buaya Beach (West Java). The species *P. merguiensis* and *P. monodon* were the two most commercially important species. The distributions of the shrimps were related to the water physical characteristics associated with the shrimp habitat namely SST, bathymetry, and tides. Fishery biology analysis found that the length at first impregnation of *P. merguiensis* at Damas and Sidem Water (East Java) was 25.9 cm CL. Furthermore, the LBSPR analyses revealed that the spawning capacity of *P. merguiensis* and *M. ensis* in the same waters were still very high under the current level of exploitation. Therefore, the magnitude of fishing has not endangered the sustainability of the two shrimps.

Keywords: crustacea, decapoda, malacostraca, intertidal, sea of Java

INTRODUCTION

Indonesia is a country with a big potential of fisheries sector, one of which is shrimp fishery. This sector is very important as it has high economic value and serves as a source of foreign exchange (Suman *et al*. 2014; Sari *et al*. 2017; Tirtadanu *et al*. 2016a; Pratiwi and Sukarjo 2020). Within shrimp group, family Penaeidae comprises the most economically important species. Shrimps of this family mosty inhabit Indo-Pacific Region (Hurzaid *et al*., 2020) including southern waters of Java Island, Indonesia. The species of the highest economic values are from genus Penaeus and Metapenaeus (Pratiwi, 2008; Wulandari *et al*., 2019).

Given its connection to Indian Ocean, the waters off southern Java generally have strong waves and currents, making it an exteme habitat for biota inhabiting the waters. A study by Damayanti and Ayuningtyas (2008) found that Gunungkidul water, i.e Sepanjang and Kukup Beach have very strong waves, with energy averaging to 1,871 Joules. According to Chou *et al*. (1999), oceanographic conditions have a strong influence on the composition of crustacean communities. Given these, the species composition of shrimps in southern Java waters, particularly Family Penaeidae may be unique and different from other waters. Therefore, study on the diversity of penaeid shrimp in these waters is important to conduct.

Extreme habitat condition may also affect the biological aspect of crustacean due to adaptation mechanism (Benvenuto *et al*., 2015). At the same time, the consistent high fishing pressure on these shrimps, driven by their high economic value, may endangered the populations (Nurulluddin *et al*. 2017; Sari *et al.* 2017; Suman *et al.* 2017a). Shrimp capture in coastal waters is usually a major problem to the sustainability of the resource (FAO, 2000). Therefore, other than biodiversity, the fishery biology (including population dynamics) of penaeid shrimp is also another important aspect to study.

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Despite great importance of these aspects, study on penaeid shrimps in southern Java is still very limited. So far, studies more focus in the waters of northern Java which have very different oceanograhic conditions from southern Java. A Few studies in southern Java were, for examples, Wagiyo *et al*. (2018) on population dynamic of *P. merguensis*, Kusbiyanto *et al*. (2020) on DNA barcoding of Crustacean larva, Pratiwi and Sukardjo (2020) on the ecology of *Penaeus monodon*, all located in Segara Anakan, Cilacap. Study that encompasses a long range of habitat such as whole southern Java waters has not been done. The current study tried to fill in this gap. With this study, it is expected that the species composition and distribution of penaeid shrimps as well as the fishery biology for few species along the southern Java waters with its strong wave and current can be known.

MATERIAL AND METHOD

This research was conducted in three different provinces along the southern coast of Java Island, i.e East Java (Trenggalek and Tulungagung) in May 2011, Central Java (Gunungkidul) in March 2012, as well as West Java (Garut) in May 2016. For each location, few sites were visited and surveyed, but shrimps were encountered only at six sites (Figure 1.)

The shrimp samples were obtained using various methods. In Damas Beach (Trenggalek) and Sidem Beach (Tulungagung), sampling was carried out by directly catching the shrimps using beach seine which were operated by some fishermen. Meanwhile, in Drini and Sepanjang Beach (Gunungkidul) as well as Rancabuaya 1 and Rancabuaya 2 Beach (Garut), shrimp samples were obtained from fishermen and shrimp collectors that were at the TPI or traditional markets around the research locations.

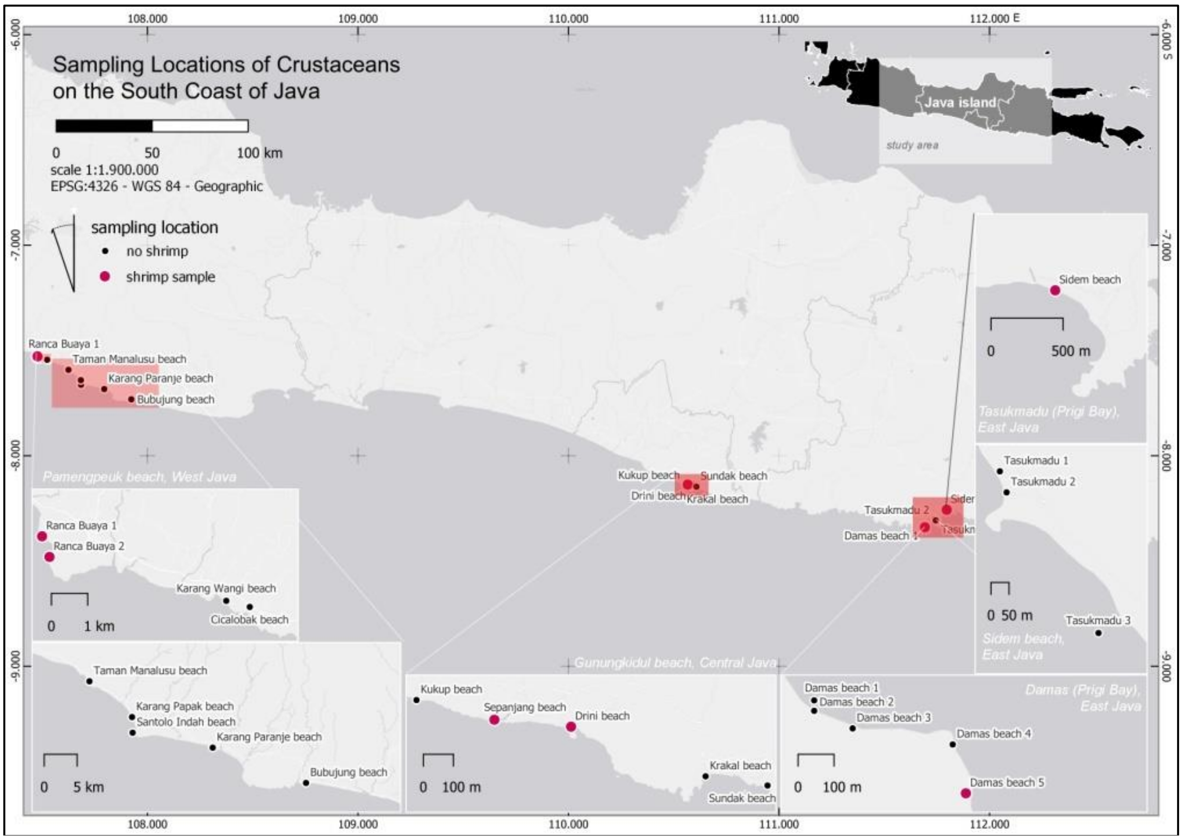

Figure 1. The sampling locations on the south coast of Java. Red dots represent the sites where shrimps were encountered, and black dots represents the sites where shrimps were not encountered.

The carapace length (CL) of the shrimp samples were measured using a caliper from the tip of the rostral spine to the apices of the sub median spines of the telson. The observed values were rounded to the nearest milimeter. Furthermore, specimens with broken telson and rostrum as well as soft or moulted animals were discarded.

The distribution of the shrimps was identified based on the physical characteristics of water that are associated with their habitat. However, only two physical parameters, namely sea surface temperature (SST) and water depth were used due to the absence of data for other parameters. According to (Chou 1999; Castro *et al*. 2005), water temperature affects the activity of shrimps in foraging and colonizing. Therefore, information about variations in the sea surface temperature (SST) that was obtained through ocean colour level 3 imagery (NASA, 1996) is expected to show the distribution patterns of certain shrimp species. Similarly, the water depth data obtained from the results of contour data modelling (BIG 2017), show the distribution of shrimp at certain depths. Therefore, information on the depth of the water was modelled to produce a beach profile at each sampling location.

Tidal data is also used as additional data on the distribution of shrimp around the coast (BIG 2014). According to (Pratiwi 2008), shrimp of certain species would rise to the surface of the water to find a colonizing location such as mangrove areas. Therefore, the height of tides would also affect the distribution of the shrimps.

Table 1. Spatial data sources for spatial distribution analysis of shrimp

Physical waters parameters	Sources	Related to shrimp habitat	Data type
Sea Surface Temperature (SST), day and night	Ocean Color Level 3 standard map image product https://oceancolor.gsfc.nasa.gov/l3/order/	Variation of SST related to the ideal conditions of shrimp species to grow and breed in surface, with the range temperate between (21^{0}C – 32^{0}C)	Raster
Bathymetry contour and beach profile	https://tanahair.indonesia.go.id/portal-web/inageoportal/#/	Related to the distribution of shrimp that mostly spread over shallow areas of ramps to an average depth of 40 meters	Line, vector
Tides	http://tides.big.go.id/pasut/	Related to the range of shrimp movement towards land which is a spawning area in mangrove	Line, vector

Two shrimp's species namely *P. merguiensis* and *M. ensis* from Damas waters (Trenggaek) and Sidem waters (Tulungagung) were analyzed in term of their fishery biology. To ascertain whether or not the two shrimps caught from these two locations came from the same populations, randomization tests were conducted on the carapace lengths (CL) of each shrimp. Firstly, the means of the CL for each location were computed using the original data along with the difference of the means. Then, the CL data were randomized as many as 5,000 times, from where the difference of the CL means were recomputed in each iteration. The distributions of the mean differences of as well as the 95% confidence interval (CI) were then generated. When the difference of the true CL means lie inside the CI, then it was concluded that there was no difference in size structure between the two locations. The above procedure and further analyses that followed were carried out in R (R Core Team 2020).

Further analysis tried to find the mean size at first impregnation (L_p) using the proportion of shrimps carrying eggs at each CL class. The procedure used the Lysack (1979) model in accordance with the following equation:

$$P_L = \frac{G}{1+e^{-\delta(CL-L_p)}}$$

where P_L is the proportion of shrimps with eggs at size CL: G, δ and Lp are parameters. Parameter G represents the highest P_L which, in this study, was predetermined from the data. Meanwhile, parameters δ and L_p were estimated using regression of equation (1) after it was transformed to the linear form.

To assess the population status of the two shrimps, length-based spawning potential ratio (LBSPR, Hordyk *et al*., 2015) analyses was applied. The LBSPR used was age-structured with logistic maturity as well as logistic selectivity, and was a function of size (CL). Besides, the fecundities of the shrimps were assumed to be proportional to their body weights. Biological parameters for the inputs on LBSPR were obtained from previous studies as well as the analyses on the current data. Some of these parameters were assumed to be random and form certain distributions, while some others were fixed (Table 2). The instantaneous natural mortality rate (M) of each shrimp was estimated indirectly through the method by Then *et al*. (2015), using the L_∞ and K values. The distribution of M which was assumed to be uniform was also determined using these values. Other parameters namely CVL_∞, steepness (h) in stock-recruit relationship, and b in fecundity function used the defaults.

To accommodate uncertainty in some input parameters, the LBSPR analyses applied Monte Carlo simulations by estimating SPR values 10,000 times. Subsequently, median and 95% CI of the SPR values were generated. Furthermore, using the ascertained median value as well as the mid value of the input random parameters, simulations were conducted to demonstrate the distribution of size (CL) frequency of the shrimps, with and without current exploitation, as well as the SPR value, spawning stock biomass (SSB), and relative yield to its maximum.

RESULTS AND DISCUSSION

Eight species of shrimps were found in the water of southern Java namely *Penaeus monodon*, *Penaeus merguiensis*, *Penaeus semisulcatus*, *Metapenaeus ensis*, *Penaeus latisulcatus*, *Metapenaeus palmensis, Penaeus japonicus, Metapenaeus lysianassa* (seel also Table 3). The species *P. merguiensis* could be found in every sampling location along the southern coast of Java. While *P. latisulcatus* and *M. palmensis* were only found on Drini Beach, Central Java. Finally, *P. japonica* and *M. lysianassa* were only found on Ranca Buaya Beach, West Java.

Table 2. Parameters as inputs in spawning potential ratio (SPR) analyses of *P. merguiensis* and *M. Ensis*

Parameter	*P. merguiensis*	*M. ensis*	Sources
a	Unif (0.0018, 0.0047)	Unif (0.002, 0.005)	Hufiadi *et al.* 2020; Putra *et al*. 2020; Suman *et al*. 2019
b	Unif (2.4211, 2.697)	Unif (2.387, 2.545)	Hufiadi *et al*. 2020; Putra *et al*. 2020; Suman *et al*. 2019
L_∞	Unif (55.0, 57.8)	Unif (51.45, 52.20)	Nurdin and Kembaren 2015; Suman, 1992; Suman *et al*. 2017a; Suman *et al*. 2017b; Suman *et al*. 2019
K	Unif (1.05, 1.45)	Unif (1.33, 1.63)	Nurdin and Kembaren 2015; Suman, 1992; Suman *et al.* 2017a; Suman *et al*. 2017b; Suman *et al*. 2019
L_{50}	29	33	Crocos and Kerr 1983; Lestari *et al*. 2018
L_{95}	36	44	Crocos and Kerr 1983; Lestari *et al*. 2018
M	Unif (1.14, 1.42)	Unif (1.38, 1.59)	Current study
Z	Unif (1.1, 2.1)	Unif (1.1, 2.1)	Current study
SL_{50}	22	20	Current study
SL_{95}	42	30	Current study

From many stations visited in this research, only 2 sites in each research location had shrimp samples (Figure 1 and Table 3). Through the analysis of SST image data that were recorded during the day (SST) and night (SST4), the SST at each sampling location was found to be close to 30°C which could be categorized as a warm temperatur (Kusuma *et al.* 2017). While at night, the SST4 at each sampling location decreased by 1°C. The results of the temperature analysis showed that the highest temperature was in the coast of West Java which is close to 31°C. While the lowest temperature is on the coast of East Java at 29.22°C. Based on the general SST identification, the temperature variations at all sampling locations was ideal as it ranged from 28-31°C (Table 4).

As shown in (Figure 2), the results of the contour data processing provide information about beach profiles. This information relates to the distribution of shrimps, where there are several species that live in shallow water and some that live at depths of 30 meters on average. Based on the results

Table 3. Distribution and abundance of shrimp based on location

Species	Distribution (D) and number of shrimp (n)	Damas	Sidem	Drini	Sepanjang	Ranca Buaya 1	Ranca Buaya 2
Penaeus	D	√	-	-	-	√	-
monodon	n	61				37	
Penaeus	D	√	√	√	√	√	-
merguiensis	n	215	171	31	43	4	
Penaeus	D	√	-	√	√	-	-
semisulcatus	n	51		46	29		
Metapenaeus	D	√	√	√	-	-	√
ensis	n	25	63	43			20
Penaeus	D	-	-	√	-	-	-
latisulcatus	n			14			
Metapenaeus	D	-	-	√	-	-	-
palmensis	n			40			
Penaeus	D	-	-	-	-	√	-
japonicus	n					34	
Metapenaeus	D	-	-	-	-	-	√
lysianassa	n						7

Table 4. Temperature variations and species distributions of shrimps at each sampling location

Location	Shrimp species	Year	SST4 (Monthly ^{0}C)	SST (Monthly ^{0}C)
Garut (Ranca Buaya 1&2)	*P. monodon* *P. merguiensis* *M. ensis* *P. japonicus* *M. lysianassa*	2016 9.5-2016 10.5.2016	29.6	30.79
Gunungkidul (Drini, Sepanjang)	*P. merguiensis* *P. semisulcatus* *M. ensis* *P. latisulcatus* *M. palmensis*	2012 25.3.2012 26. 3.2012	28.35	29.98
Trenggalek &Tulungagung (Damas beach, Sidem beach)	*P. monodon* *P. merguiensis* *P. semisulcatus* *M. ensis*	2011 15.5.2011 19.5.2011	28.34	29.22

of the coastal profile on water depth at the 3 sampling locations, the beach at the coast of Central Java is relatively steep while that in East Java is classified as 'ramps'. This variation in coastal profile further affected oceanographic characteristics such as currents, waves, and sediment accumulation associated with shrimp distribution (Chou 1999; Castro *et al*. 2005).

The data obtained through tide modelling were used as additional information because they relate to the distribution of shrimps that colonize the shallow areas around mangrove vegetation. However, the data was available only in the 2011 and 2012 sampling years (fig 3). While the 2016 data showed a pattern that did not make sense and thus could not be used. Detail of tide conditions per hour in two sampling locations could be seen in (Figure 3).

Based on composition analysis, the number of shrimp *P. monodon* amounted to 10.17%, *P. mergueiensis* was 53.21%, *P. semisulcatus* was 13.49%, *M. ensis* was 15.85%, *P. latisulcatus* was 4.60%, *M. palmensis* was 1.50%, *P. japonicus* was 0.43% and *M. lysianassa* was 0.75%. Data showed that *P. merguiensis* has the highest abundance compared to other species. The lowest abundance was found for the species *P. japonicus*.

The highest diversity of shrimp could be found at Drini beach, followed by Damas and Ranca Buaya 1 beach with the total number of species 5, 4, and 3, respectively. Variation in the distribution, abundance, and diversity of species is possibly caused by ecological parameters, such as water temperature, salinity, depth, current, and sediment type (Castro *et al*. 2005; Chou 1999). It could also be caused by biological parameters which are usually related to life cycle processes such as birth, death, and dispersal (Castilho *et al.* 2007; Costa *et al.* 2008).

Shrimp density was influenced by oceanographic conditions in the southern water of Java, especially high waves and strong currents as these caused a decrease in the amount of catch (Pratiwi and Widyastuti 2016). For Penaeid shrimps, sediment is a factor of importance in habitat preference given that many species display the behaviour of burying, which has an important function in their defence against predators or environmental changes (Freire *et al.* 2011).

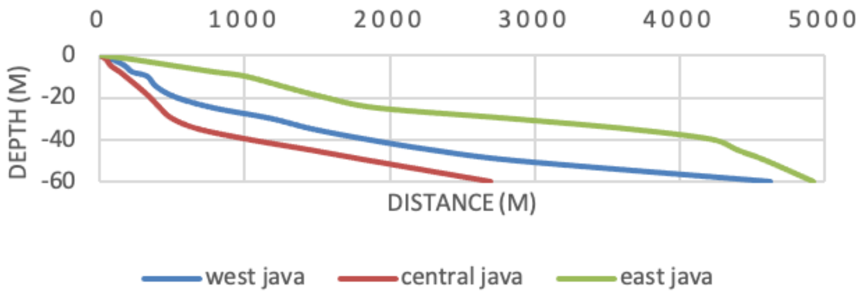

Figure 2. Beach profile in three sampling location.

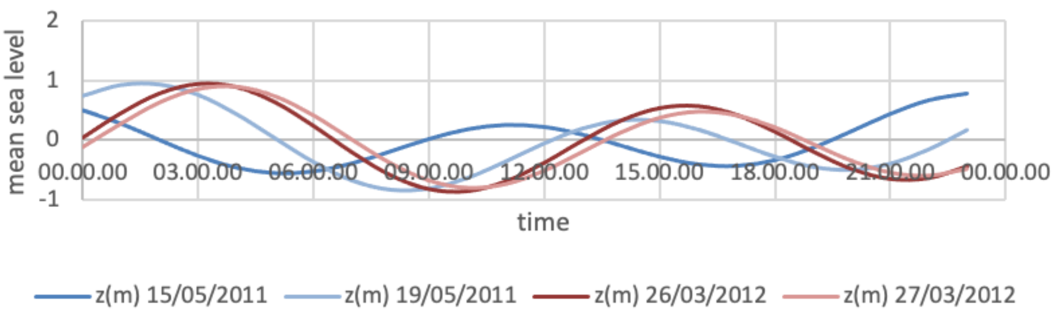

Figure 3. Tide condition in two sampling location, 2011 in East Java and 2012 in Central Java.

A previous study showed that shrimp resources in southern Java water are dominated by the Penaeidae family, with the dominant species including *M. ensis, P. semisulcatus,* and *P. monodon* (Pratiwi and Widyastuti 2016). The shrimp species observed in this research are important commercially, and according to Carpenter and Niem (1998), most of the commercial species belong to the Penaeus and Metapenaeus genera. Studies also show that the species *P. merguiensis, P. semisulcatus* and *P. monodon* is possibly found in the water of South Java in large quantities.

Based on Carpenter and Niem (1998), members of the Penaeidae family are generally of moderate to large size and are often present in shallow water along the continental shelf on trawl-able bottoms. Furthermore, they may be caught extensively by trawls, seines, set nets, traps, and artisanal gear. Members of this family could also be generally found in estuarine water (low salinity) and the sea area (high salinity) (Saputra 2008).

Based on data from this research, the abundance of the Metapenaeus species was smaller than Penaeus, with the species *P. merguiensis* being the most abundant. The same results also happened in the Banyuasin coastal water of South Sumatra where *P. merguiensis* was the most caught shrimp (Fauziyah *et al*., 2018). The abundance of commercial species found in this study is also due to the muddy substrate found in the sample location, which is a suitable habitat for the growth of some of the dominant shrimp species (Somers *et al*. 1987).

The size distribution of each shrimp species were analysed based on the characteristics of the species and their sex (males and females) (Figure 4). The results showed that the length of the carapace of the shrimps ranged from 7 to 70 mm. Furthermore, the CL of the male shrimps ranged from 7 to 70 mm, while that of the females ranged from 13 to 69 mm (Figure 5). Similar results were also found by Tirtadanu and Ernawati (2016) in the northern water of Central Java, with a shrimp length range of 14-68 mm. However, different finding were obtained in the Java Sea according to the research by Tirtadanu *et al*. (2016), where the maximum shrimp size was only 18 mm. This size difference could be caused by the difference in the distribution of juvenile and adult shrimp, the depth of the fishing ground, and the types of fishing gears used (Putri and Nastiti 2017; Tirtadanu *et al*. 2016).

Fishery biology aspect were studied for *P. merguiensis* and *M. ensis* in Damas and Sidem water. The randomization tests on the two shrimps showed that the CL samples from both waters were random data from the same population. This was indicated by the difference of the original CL mean (2.25 mm) which lies within the 95% CI (-2.94, 2.86) mm. The same thing applies to *M. ensis*, where the difference of the original CL mean (2.10 mm) lies within its 95% CI (-5.61, 5.73) mm (Figure 5). So, there is no evidence that the size structure of the samples are different between Damas and Sidem for the two shrimps. This is not a strong evidence, yet, this result gives an indication that *P. merguiensis* and *M. ensis* at Damas and Sidem water form unit stocks .

The same size (CL) structures indicate the same stock because size structure is determined by the parameters of the natural population, such as population growth rate and natural mortality rate as well as fisheries parameters such as fishing mortality rate and gear selectivity. These parameters are expected to be different for different populations. Meanwhile, for the same population, they would be the same. Even when the fishing are concentrated only on certain parts of population, the random mixing of individuals in the population makes the effects of fishing hold uniformly to the whole population.

Randomization test is more powerful compared to the conventional t-test, which tests the difference of mean size only in the original samples. This is because randomization is not subject to the assumptions of specific distribution from where the size sample is obtained. Meanwhile, the t-test requires the population to be normal, which rarely occurs in reality (Figure 8b).

The size at first maturity (L_{50}) for the two shrimps could not be described in this research because the maturity stage of the shrimps was not identified. The observation was carried out to determine whether female shrimps were carrying eggs or not. Therefore, the farthest this research could go is to describe the size at first impregnation (L_p), and it is only for *P. merguiensis* where sufficient data exists. While for *M. ensis*, this analysis cannot be conducted because of the insufficient sample size.

Figure 4. Shrimp size distribution analysis based on species and sex.

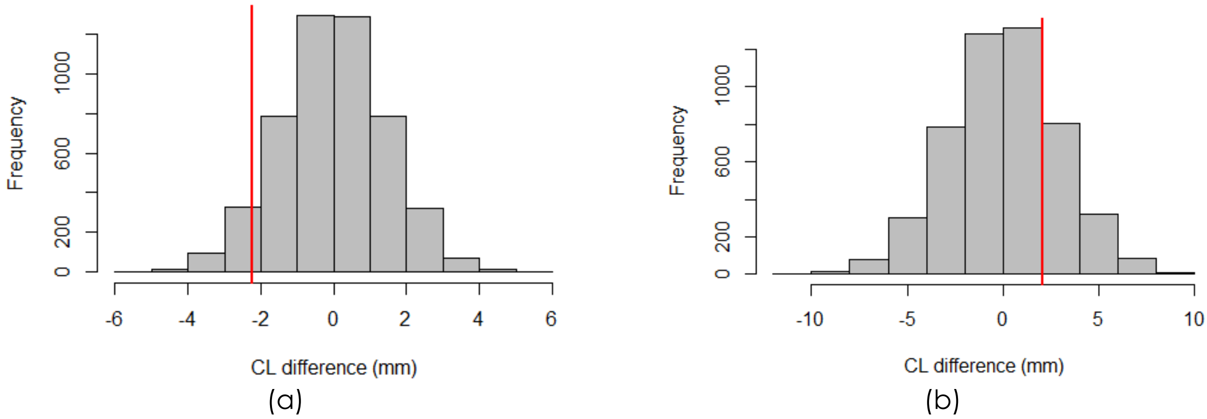

Figure 5. Distributions of the mean CL differences of shrimps at Damas and Sidem waters generated from randomization tests (histogram) as well as the CL differences of the original data (red vertical line) for (a) *P. merguiensis* and (b) *M. ensis*

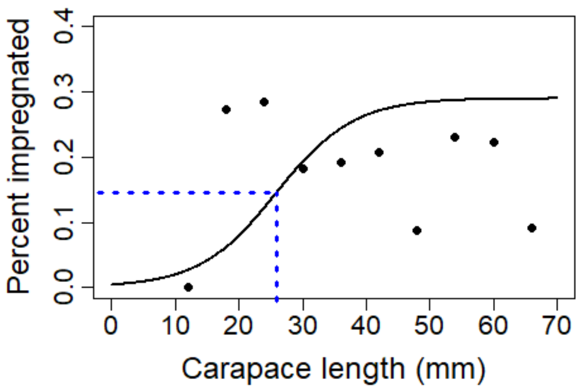

Figure 6. The proportion of female *P. merguensis* carrying egg for each carapace length (CL) and the estimated size at first impregnatin (L_p).

Figure 6 shows that on average *P. merguiensis* lays eggs for the first time (L_p) at 25.9 mm CL. This is in accordance with the previous study that found the proportion of mating among *P. merguiensis* increases rapidly at sizes 22-28 mm CL and that the smallest individual carrying eggs is 16 mm (Crocos and Kerr 1983). The maximum proportion of pregnant adult shrimps in (Figure 6) did not reach 100%, whereas the samples included the largest individuals ($CL_{max}> L_\infty$). This might have occurred because different shrimp individuals did not lay eggs simultaneously. As revealed by Suman and Umar (2010), *P. merguiensis* mate all year round, despite the peak season occuring in August till October. Likely, the reasons of some adult female shrimps did not carry eggs when caught are either the eggs had hatched or the shrimps were just about to lay eggs, and not because they had not reached sexual maturity.

The Lysack (1979) model was used in place of Bakhayokho or White models which are more popular in estimating L_p. This model was suitable for *P. merguiensis* due to the assumption that the shrimp individuals found to carry eggs at the time of sampling were only a portion of the total individuals mating that year. Parameter G which is the maximum proportion of the egging shrimps is a scaling factor to accommodate some other mating shrimps which were not observed. Lysack model was originally developed to estimate length at first maturity (L_{50}), yet, it is also relevant to estimate L_p. The result of Suman and Umar (2010) showed that from May until July, the percentage of female shrimps mating were 27, 18, and 18% respectively. Meanwhile, in this study shrimps were caught in May 2011. The result shows that the proportions of egging female shrimps greater than 40 mm CL is 19%, a good agreement with Suman and Umar's result. Only individuals of 40 mm CL or greater were accounted for in the analysis because impregnation ogive (Figure 6) indicates that almost all shrimps have carried eggs for CL greater than 40 mm.

To determine the SPR of *P. merguiensis* and *M. ensis* in Trenggalek and Tulungagung (Damas and Sidem Water), the length-frequency data of the two species were required. With sufficient data, the LBSPR analysis could generate the SPR and F/M ratio at the same time. However, the sample size was low in this study, therefore, estimating the two parameters simulataneously could generate very biased results. Because of this, F was estimated outside the LBSPR method, i.e based on the Z from the linearized length-converted catch curve (LCC, Sparre and Venema 1998). Furthermore, this was only carried out for *P. merguiensis*. For *M. ensis*, its length frequency data was not sufficient for the LCC method to work. To anticipate this, the F value was borrowed from that of the *P. merguiensis*. This was justified since the two shrimps inhabit the same water, were caught by the same fishing gear, and had similar habit. Therefore, it is expected that the effects of fishing were similar for both species. Because the LCC method is not applied for the *M. ensis*, the values for logistic selectivity parameters (SL_{50} and SL_{95}) were estimated subjectively based on the histograms of carapace length from the samples.

Table 5 showed that *P. merguiensis* and *M. ensis* had high SPRs (the value for *M. ensis* was a bit higher). Furthermore, the probabilities of the SPRs dropping below 0.4 are extremely low for both species, even close to 0 for *M. ensis*. SPR of 0.4 is regarded as the lower bound of acceptable exploitation level. Lower value indicates overexploitation. So, for the case of shrimps in Trenggalek and Tulungagung, the current level of exploitation has not reduced significantly the spawning capacities of *P. merguiensis* and *M. ensis*. This indicates the populatons of the two species in nature have not been endangered. This conslusion was also corroborated by few outputs of SPR simulations shown in (Figure 8).

For the two species, the mean length at first capture (SL_{50}) was lower than the mean length at first maturity (L_{50}). This implies that the shrimps were caught before they reproduced (Figure 8a.1 and 8a.2). Despite this condition, surprisingly, the SPR distributions indicated that the stocks of the two shrimps were still underexploited. It could be ascertained from (Figure 8b.1& 8b.2) that the frequency of each size class in the current fishing scenario was not significantly different from the condition without exploitation. Furthermore, the portion of caught shrimps in each length class was still low compared to the abundance in nature. (Figure 8c.1 & 8c.2) show that the current yields of the two shrimp species were not yet optimal, as the yield curve did not reach the peak. Therefore, the fishing mortality rates could still be increased to boost the yields, while the populations are still maintained.

The fact that the populations of *P. merguiensis* and *M. ensis* were still underexploited contrasts with the fact that their SL_{50} were lower than L_{50}. This might happen because even though the juvenile shrimps have been caught, the fishing intensities were still very low such that individuals that were not caught could still reproduce and their offspring are more than enough to replace the adult shrimps. Since the two populations were still underexploited, then fishing intensity could be maintained or even increased in order to maximize the economic benefit to the fishermen around Trenggalek and Tulungagung.

Table 5. The results of SPR analyses for *P. merguensis* and *M. ensis* in Damas and Sidem Waters

Parameter	*P. merguiensis*	*M. ensis*
SPR	0.66 (0.43, 0.98)	0.73 (0.52, 0.98)
Pr[SPR<0.4]	0.004	0

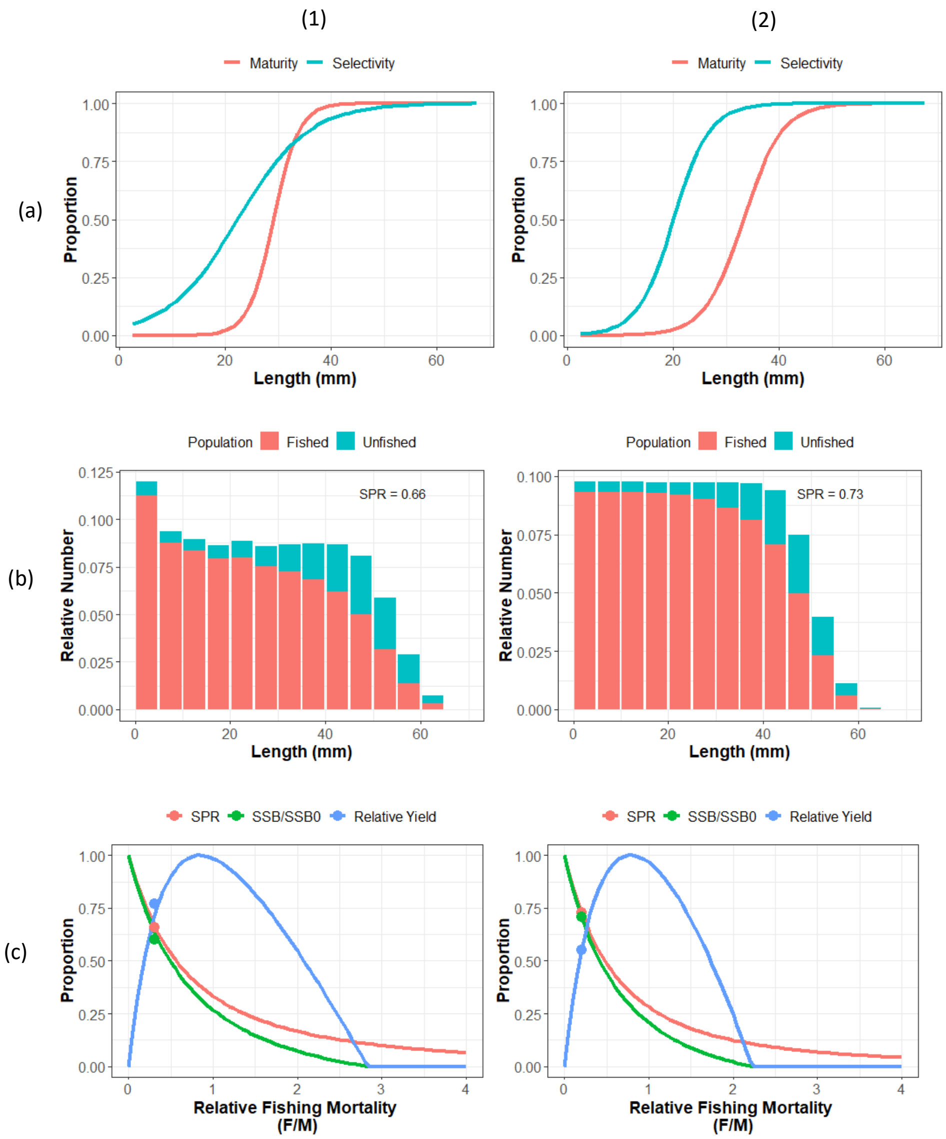

Figure 8. Simulation results of SPR (a) maturity vs selectivity ogive, (b) size distribution of shrimps in population with and without fishing, (c) curves of SPR, relative SSB, and relative yield for (1) *P. merguensis*, (2) *M. ensis*.

CONCLUSIONS

The current study recorded eight species of shrimps in southern waters of Java, i.e *p.* monodon (with the percentage of abundance 10.17%), *P. mergueiensis* (53.21%), *P. semisulcatus* (13.49%), *M. ensis* (15.85%), *P. latisulcatus* (4.60%), *M. palmensis* (1.50%), *P. japonicus* (0.43%) and *M. lysianassa* (0.75%). The most and least abundant species were *P. merguiensis* and *P. japonicus* respectively. The abundance of these shrimps was also related to the muddy substrate, which is a suitable habitat for some of the dominant shrimp species. The significantly different coastal profiles along the southern waters of Java (steep coast in Central Java and gentle coast in West Java), determines oceanographic characteristics which affect the shrimp distributions. Apart from that, this study found the shrimp *P. merguiensis* in Trenggalek and Tulungagung laying eggs for the first time at 25.9 cm CL. Furthermore, SPR analyses show that the current exploitation level of *P. merguiensis* and *M. ensis* in these waters were still low such that fishing intensity could be maintained or even increased to maximize the yield.

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