Composition of blue swimming crab *Portunus pelagicus* and horseshoe crab *Limulidae* on the gillnet fishery in Mayangan Waters, Subang, West Java

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Abstract. Horseshoe crab (*Limulidae*) is a living fossil animal often captured in blue swimming crab (*Portunus pelagicus*) net fishing as a bycatch. The proportion between the blue crab as a main target and the horseshoe crab as a protected animal but also a bycatch in the gillnet fisheries is unclear. The objectives of the research were to assess the proportion and size of blue swimming and horseshoe crab in different depths in Mayangan's waters. The research used a survey by taking activity of bottom gillnet operated by local fishermen in 22 trips in August 2017. The total catch of blue swimming crab was 419 (30%) individuals and horseshoe crab was 957 (70%) individuals. The different depths data analyzes showed that the blue swimming crab under 5 m depth was caught 20.28% with carapace width of 10 cm and the horseshoe crab was caught 79.72% with total length of 21.63 cm. Over 5 m depth the blue swimming crabs was caught 64.56% with carapace width of 11.43 cm and 35.44% of horseshoe crab was caught with total length of 35.14 cm. The average ratio of Catch per Unit Effort (CPUE) between blue swimming and horseshoe crab in each net panels under <5 m depth was 1.1:3.9% individuals and in >5 m depth was 3.37:1.63% individuals. Blue swimming crab of small size and low number was caught in the lower depth, while the big size and high number of individuals were caught in the deeper waters.
Key Words: fishery, bycatch, proportion, size, CPUE.

Introduction. The bottom gillnet is an artisanal fishing gear that is usually operated by small-scale fishers. Its operation contributes to some bycatches which involve not only blue swimming crab (as catch target) but also horseshoe crab (Fazrul et al 2015; Robert et al 2014; Cartwrigt-Taylor 2011). Studies on horseshoe crab in Indonesia usually focuses on aspects such as morphometric (Suparta 1992; Meilana 2016), biological reproduction (Eidman 1992; Muslihah 2004), genetic preservation (Mulya 2004), and populational (Rubiyanto 2012; Mashar et al 2017). However, there is a lack of information on horseshoe crab as bycatch in bottom gillnet fishery.

The horseshoe crab is a valuable genetic resource following the Ministerial decree of Forestry No. 12/KPS-II/1987. Indeed, it became one of the protected animals corresponding to the regulation of Forestry Affair of the Republic of Indonesia No. 7 the year 1999, with particular reference to *Tachypleus gigas* (Muller 1785). Horseshoe crab plays an essential ecological role (Smith et al 2016) in that it is a benthic feeder (Harrington 2005; Smith et al 2007), a bait for eel (Wakefield 2012; Smith et al 2016) as well as sea catfish (Rubiyanto 2012). Besides, it is also a bio-medical resource (Hurton 2003). Based on economic goals, the horseshoe crab is an exclusive culinary dish in Thailand (Shin et al 2009). Studies on both its proportion and size in the coastal area of North Java were conducted by Mashar (2017). However, a survey on horseshoe crab as the main bycatch in the blue swimming crab fishing industry, i.e., catch composition, size, deep and catch per unit effort has not been conducted yet based on the available information.

The practice of bottom gillnet operation not only leads to the catch of blue swimming crab but also horseshoe crab which is classified as a protected animal by local fishermen in Mayangan Subang, West Java. The data on horseshoe crab as bycatch and protected animal in Indonesia is subtle as the horseshoe crab is an unmarketable commodity. Thus, this study aimed to assess the proportion, size and fishing ground of both the blue swimming and horseshoe crabs in Mayangan waters.

Material and Method

Description of the study sites. The study was conducted in August 2017 in Mayangan coastal waters, Subang regency which is a part of Coastal North Java of Indonesia (06°13'08.7'' S, 107°44'46.4'' E) as shown in Figure 1. Mayangan's area is covered by mangrove forests up to 489.1 ha with muddy flat area and a narrow sandy beach located between the sea and mangrove (Hermanto 2004).

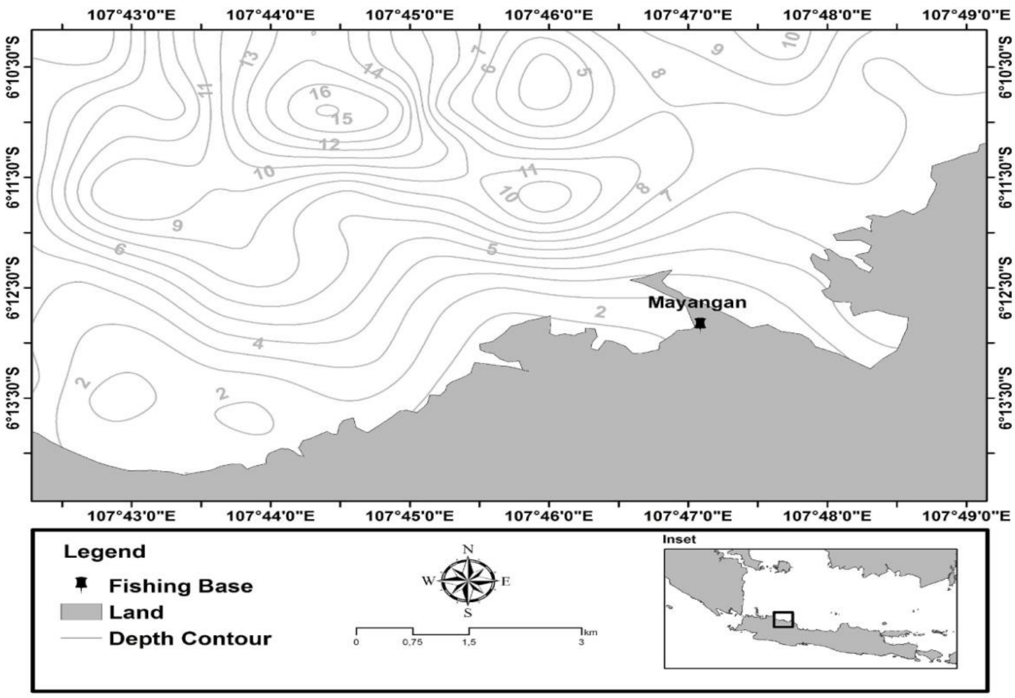

Figure 1. The study site.

The trials were undertaken using general fishing practice and as part as regular fishing traps were applied. Fisherman are generally using approximately 4.5-7 m length fishing boats, carrying 414-529 m gillnet (18-23 unit net panel). One unit net was 23 m long, 0.75 m high with 4 inch (10.16 cm stretch mesh) approximately, composed of monofilament. The bottom gillnets were set each evening slightly varying depending of the tide or wave and wind and normally is 3-12 m depth. Nets were typically soaked overnight 6-12 hours and retrieved the following morning.

The total trials were conducted in 22 trips with two different fishing grounds under 5 m and over 5 m in deep. The recorded observations were: data of gear characteristics (size and panes), number and size of blue and horseshoe crabs, location, time set and haul, temperature, salinity, and water depth using GPS, thermometers and specific tools. The catches were removed from net after haul on the way back to the land and continued to be sorted on the land (Figure 2). The blue swimming crabs were immediately preserved in sea water buckets and as soon as possible the measurements of total individuals and carapace width were made (Figure 3A), before transport them to the seller. The target catch was shortly sorted to keep the freshness and quality, while the horseshoe crabs were removed the last because it took a few hours. The horseshoe crabs were slowly removed one by one from the net to reduce the net damage and torn. The total catch, consisted of blue and horseshoe crab were measured based on carapace width and total length, respectively (Figure 3B).

Figure 2. The fisherman removes horseshoe crabs after hauling process on the land.

A B

Figure 3. Measuring of total length to (A) blue swimming crab and (B) horseshoe crab.

Statistical analysis. A non-parametric statistical analysis was applied to compare the related sample between blue swimming crab and horseshoe crab in two different depths. Wilcoxon two-sample test using SAS University Edition program were used to compare: (1) blue swimming crab and depth, (2) horseshoe crab and depth, (3) blue swimming crab size and depth and, (4) horseshoe crab size and depth.

CPUE analysis. In order to compare the catch rate between main and bycatch we used catch per unit effort (CPUE) analysis. Standardization of soaking time and net length have been proposed to standardize the different soaking times and net lengths. The total catch rates both main and bycatch were analyzed in 12 hours soaking time and at 1000 m (1 km) length net. The calculation of catch per unit effort was standardized by the soaking time and net length for all trips. The soaking time was conducted in two time periods (6 hours and 12 hours), then standardized to 12 hours soaking time. The net was set from 18-23 pieces with (length x depth: 23 x 0.75 m) total of 414-529 m, then standardized to 1000 m length. The calculations of bycatch CPUE on gillnet (Wang et al 2010 and Prasetyo 2017) were computed as:

CPUE per trip:

$$Xi = \frac{Ci}{\frac{ti}{ts} \, x \, \frac{Li}{Ls}}$$

Total average of CPUE:

$$X = \frac{\sum_{i=1}^{n} xi}{n}$$

where:
X: average CPUE
xi: CPUE per trip
Ci: total catch (individuals)
ti: real soaking time per trip (hours)
ts: standard soaking time (12 hours)
Li: real net length (km)
Ls: standard net length (1 km)
i: 1,2,3,…. ,n
n: total repetitions.

CPUE per net (net panels):

$$Xp = \frac{X}{p}$$

where:
Xp: CPUE per net panels
X: average CPUE
P: total net (20 net).

Results. The physical properties of seawater in Mayangan in the summer were recorded within the ranges of 22-28°C for temperature and 24-30‰ for salinity. There was no significant difference between temperature and salinity in the early until middle summer in seawater. The results of the present study consisted of catch proportion and catch per unit effort, the size and frequency of blue swimming crab and horseshoe crab at the different depths. The outcomes of the analysis indicated that the abundance of blue swimming crab was not significantly affected by the depths ($P > 0.05$), while the depths influenced that of the horseshoe crab ($P < 0.05$). On the other hand, the sizes of both blue swimming crab and horseshoe crabs were significantly ($P < 0.05$) affected by depths.

Catch proportion. The results revealed that the total catch during the 22 trips was 30% (419 individuals) blue swimming crab and 70% (957 individuals) horseshoe crab with a ratio (blue swimming crab to horseshoe crab) of 1:2.3 (Figure 4).

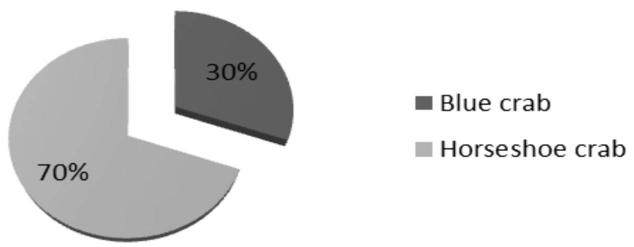

Figure 4. The percentage of blue and horseshoe crab on the gillnet catch.

The catch proportions were divided into two different depths, i.e., <5 m and >5 m. 845 horseshoe crabs and 215 blue swimming crabs were observed at the <5 m depth, while the >5 m there were only 112 individuals of horseshoe crab and 204 of blue swimming crab. The results from non-parametric analysis indicated that the total blue swimming crab catch was not significantly affected by depths (*P* >0.05), while that of horseshoe crab was altered considerably by depths (*P* <0.05).

The spatial distribution of blue swimming crab and horseshoe crab is shown in Figure 5. The large spot shows their values. The high catch of horseshoe crab is shown in the triangular spot on trips 10 and 11 at the <5 m depth, while that of blue swimming crab is shown in the rounded spot on trips 19 and 21 at the <5 m depth.

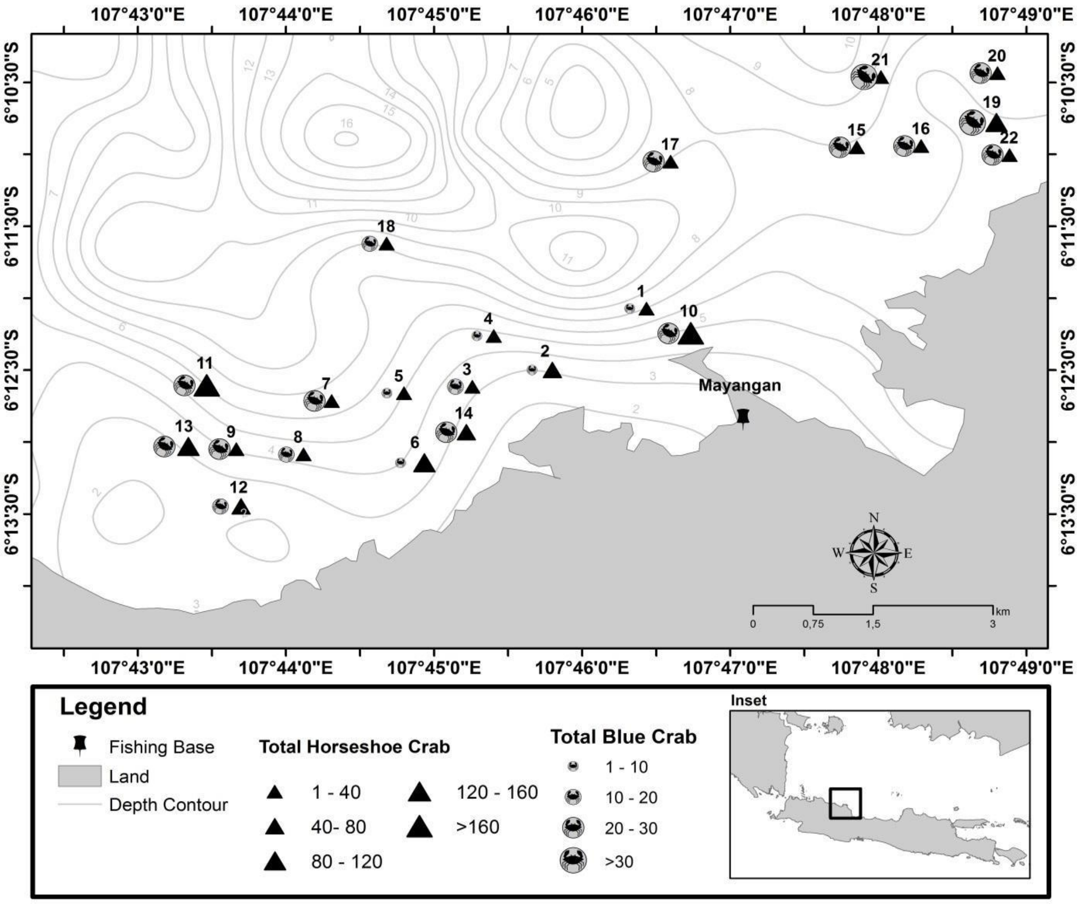

Figure 5. Spatial distribution of fishing ground of blue swimming crab and horseshoe crab at different depths.

The maps represent two different marks, i.e., the size and density for both blue swimming crab and horseshoe crab catch on the site. The average catch and presentation at two different depths are shown in Table 1.

Table 1

Average number of catches in two different depths

Depth (m)	*Average of number individuals catch*			
	<5 m		*>5m*	
Species	*Blue swimming crab*	*Horseshoe crab*	*Blue swimming crab*	*Horseshoe crab*
Individuals	15.36	60.36	25.50	14.00
Percentage (%)	20.28	79.72	64.56	35.44

Catch per unit effort (CPUE). The average catch per unit effort for the two species at different depths is shown in Figure 6. The results were similar to the proportion and frequency before standardization, where the average catch at <5 m was dominated by horseshoe crab (75.36±17.26 individuals) while blue swimming crab was dominant at >5 m (39.38±3.68 individuals).

The average ratios between blue swimming crab and horseshoe crab in every piece of the net were 0.95:3.77 (1:4, blue crab to horseshoe crab) at <5 m and 1.97:1.06 (2:1, blue crab to horseshoe crab) at >5 m.

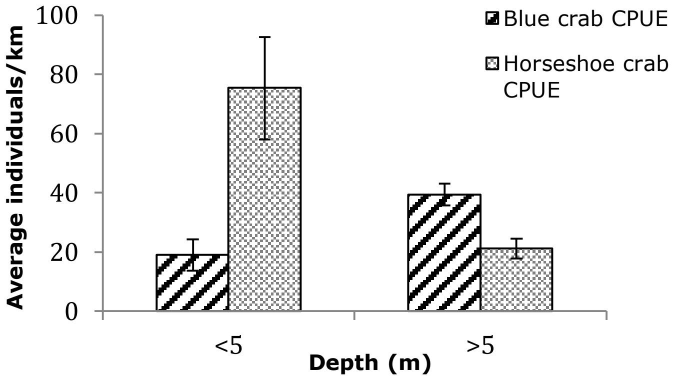

Figure 6. Average catch per unit effort per km of blue crab and horseshoe crab at different depths.

The average ratio between blue crab and horseshoe crab in every 1 piece of net showed that <5 m the ratio was 0.95:3.77 (1:4), while >5 m it was 1.97:1.06 (2:1) (Figure 7).

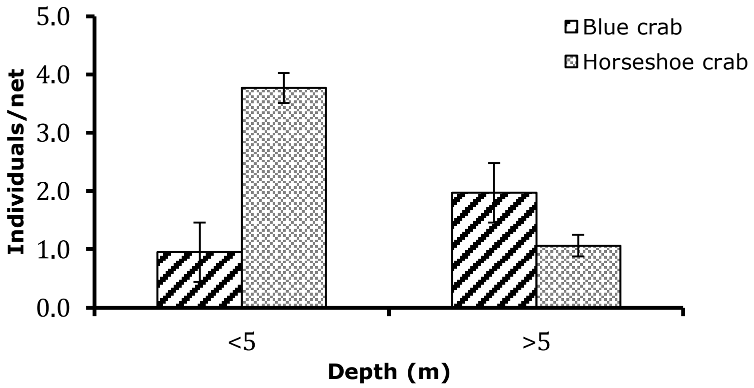

Figure 7. Catch per unit effort per net in blue crab and horseshoe crab at different depths.

Sizes. The average sizes of both blue crab and horseshoe crab at two different depths are shown in Figure 8. The average blue crab carapace width (CW) and frequency of blue crab at <5 m depth was 10±0.32 cm while total length (TL) of horseshoe crab was found of 21.63±0.26 cm. Meanwhile in the >5 m depth, the average carapace width of blue swimming crab was 11.43±0.46 cm and total length of horseshoe crab was 35.14±0.67 cm. The biggest sizes for both species were observed in deeper waters. The size comparison between the crabs revealed that they were significantly affected by the depths ($P<0.05$).

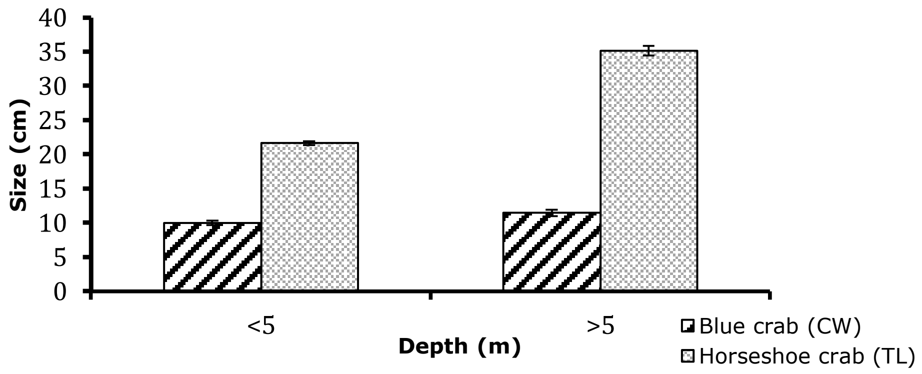

Figure 8. Sizes of blue crab and horseshoe crab at different depths. CW = carapace width; TL = total length.

Discussion. Crabs (blue swimming and horseshoe) are the intertidal animals that can be found in tropical waters (FAO 1990; Zairon et al 2015). Based on the present study, the horseshoe crab as bycatch was easier to find than the blue crab at a ratio of around 1:2.3. The local fishermen had more bycatch in their fishing operations, which eventually could be a threat to the fishermen as the nets are easily damaged. It also takes more time to detach the horseshoe crabs in the fish landing facility. The number of crabs entangled in the gillnet operation was explicitly grouped based on the depths as follows: <5 m and >5 m depth, located at 30-45 minutes from the fishing base. The fishermen in Mayangan usually cluster the fishing ground into two different categories, i.e., shallow and deep waters. There were fewer blue crabs at the <5 m depth compared to the >5 m, even though it was not statistically significant. This condition indicated that horseshoe crab could still be found at depths up to 10 m which are in line with Cartwright-Taylor (2015) results. Indeed, they found that the highest population density was observed at 10-50 m from the shore.

The low proportion of blue crab catch can be affected by seasons, as the study was conducted in August that was in the summer (Hermanto 2004). Meanwhile the abundance of blue swimming was in the rainy season (January-March) as the peak season for blue spawning crab usually occurs in the transitional seasons between rainy to summer. Indeed, blue crabs can be found throughout the year in the tropical areas (Kangas 2000). On the other hand, the higher proportion of horseshoe crab found near the estuary can be correlated to the increase in water temperature in the summer where crabs prefer to migrate to the estuary to spawn or grow through moulting, occurring from May to June (Cheng et al 2015). There were many horseshoe crabs caught at the <5 m depth, although not statistically significant. According to Sekiguchi et al (1988), the intertidal areas such as estuary are places for the juvenile horseshoe crab to grow up and reach maturity after moulting. Thus, it can be concluded that the proportion of horseshoe crabs entangled is higher than that of blue crabs with regards to the effects of seasonal operations.

The size of the blue crab at <5 m was smaller than that of the >5 m. The number of catches, based on the results of the present research, was similar to that of Prasetyo et al (2014), i.e., smaller blue crabs were abundant at a lower depth. Furthermore, Agus (2016) stated that the bigger size of blue crab was found at >12 m during the east season on Lancang Island. Also, Sara et al (2017) mentioned that mature blue crabs were abundant at >20 m in Tiworo Strait, Sulawesi, Indonesia. That was similar to Lasongko Bay (Hamid 2016), Pangkep (Ihsan 2014), Brebes (Sunarto et al 2000), Pati (Ernawati et al 2014) and East Lampung (Kurnia et al 2010). Zairon et al (2015) demonstrated that the differences in both number and size in blue crabs were affected by the life cycle where mature and ovigerous blue crabs migrate to deeper water for spawning. Also, fishing ground between the estuary and the offshore influenced the size of mature blue crabs due to their migration from estuaries to offshore. The smallest average size was 10 cm, following the carapace size presented in the Ministerial Decree on Marine Affairs No. 1/2015 (PERMEN KP No 1/2015).

The presence of horseshoe crab at Mayangan was mentioned in previous research by Eidman (1992); Suparta (1992) and Meilana (2016). Indeed, the former research identified 3 Asian species of horseshoe crab *Tachypleus gigas* (Müller 1785), *T. Triendatus* (Leach 1819) and *Carcinoscorpius rotundicauda* (Latreille 1802) at Mayangan. The present study was conducted in the summer, with August as the peak spawning period (phase), similar to Sabah Malaysia (Robert et al 2014), Singapore (Cartwrigt-Taylor et al 2009), and Thailand (Fazrul et al 2015). The results revealed an abundance of horseshoe crabs. The horseshoe crab of smaller size was abundant at <5 m depth. Meanwhile, it was less abundant at >5 m, but with a bigger size. The horseshoe crab entangled in the gillnet was 21.63±0.26 cm at the juvenile stage, where the juveniles congregate on mud flats rather than deep water (Faridah et al 2015). The most dominant catch had a soft and weak shell, indicating the molting phase. According to Cartwright-Taylor et al (2011), juveniles were more abundant in the summer than in the rainy season.

The ratio of catch per unit effort (after standardization of the soaking time) to the length was significantly different in the two depths. The lower depth had a dominant ratio of small size horseshoe crab, while the dominant ratio was blue crab with bigger sizes at deeper depths. That indicated in the present study that Mayangan has a high potential for horseshoe crab to be caught by bottom gillnet, which becomes a problem for fisherman as they catch both blue and horseshoe crabs at the same time. The blue crab is one of the intertidal species with low migration (Robert et al 2014) and both blue and horseshoe crab are found in similar habitats (Cartwrigt-Taylor et al 2011; Fazrul et al 2015). The dominant number of caught horseshoe crab in blue swimming crab net operation is affected by habitat (Fazrul et al 2015). Where their habitat is similar also the feeding habits seems to be similar as gastropod feeders (John et al 2012; Robert et al. 2014), benthic feeders, omnivorous and scavenger (Villee et al 1973 in Muslihah 2004). *Portunus pelagicus* live in sandy mud habitat until shallow water down to 50 m (Fazrul et al 2015), and horseshoe crab can be found in sandy mud land (Chatterji 1993; Shin et al 2009; Mulya 2004).

The abundance of horseshoe crab in the gillnet fishery became a major problem for fishers in Mayangan. During the peak season of horseshoe crab, many horseshoe crabs will be entangled in blue swimming crabs net, so the fisherman should postpone to set their nets since it will be very challenging to remove it. On the other hand, as living fossil and protected animal, the existence of horseshoe crabs is threatened and the fishermen throw them away into the sea or rivers on their way back to fishing base, harming or even killing them. The present study suggests that fishers should move their fishing ground in more than 5 m deep water which would be better for increasing the number and size of blue swimming crab compared to horseshoe crab.

Conclusions. This study shows that the proportion of horseshoe crab was higher than that of the blue swimming crab. The size of horseshoe crab was bigger at >5 m depth and smaller at <5 m depth. The blue crab was found to have a higher number and bigger size at >5 m than <5 m. The fishing operation should be conducted at depths >5 m to catch more blue crab as target catch and avoid <5 m depths as they act as the nursery ground for both blue and horseshoe crabs.

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