

# Biodiversity and Distribution of Horseshoe Crabs in Northern Coast of Java and Southern Coast of Madura

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**Abstract.** Horseshoe crab is an important component of macro-benthos communities in the fine sand or mud substrate in coastal waters, both in the tropical and temperate region. This primitive animal consists of four species in the world, and three species can be found in Asian region, including Indonesia, namely *Tachypleus tridentatus*, *T. gigas*, and *Carcinoscorpius rotundicauda*. Scientific information about species distribution of three Asian horseshoe crab in Indonesia is limited, also about morphometric characters. This study aims to determine the morphometric characters and species distribution of three Asian horseshoe crab in north coast of Java and south coast of Madura Island. This study was conducted on July-August 2016. The total number of three Asian horseshoe crab obtained in this study was 260 individuals, distributed along north coast of Java and south coast of Madura Island, respectively 176 individuals of *C. rotundicauda*, 35 individuals of *T. tridentatus*, and 49 individuals of *T. gigas*. *Tachypleus gigas* has the largest size and widest class interval among three Asian horseshoe crab species. Morphometric characters is differences among three Asian horseshoe crab species. Carapace width and telson length were not significantly different among sampling locations only in *T. tridentatus*.

## 1. Introduction

Horseshoe crab is an important component of the macro-benthos community in the coastal waters with fine sand or mud substrate, both in the tropics and in season four worldwide. Actually, horseshoe crabs are more closely related to spiders and scorpions than to crabs. There are four species of horseshoe crab found around the world. *Limulus polyphemus* (Linnaeus, 1758) occurs along the Atlantic coast of North America, while *Tachypleus tridentatus* (Leach, 1819), *Tachypleus gigas* (Müller, 1785) and *Carcinoscorpius rotundicauda* (Latreille, 1802) found in Asia, from India to Japan and south to Malaysia and Indonesia [1-12]. The tri-spine horseshoe crab *T. tridentatus* and the coastal horseshoe crab *T. gigas* live in sandy to muddy habitats [13-15], while the mangrove horseshoe crab *C. rotundicauda* inhabits muddy areas, commonly in brackish waters [13-14, 16]. In India and Indonesia, some *T. gigas* co-exist with *C. rotundicauda* [17-19]. In several area in Indonesia, such as Subang, Indramayu, and Surabaya coastal area, three Asian horseshoe crab species could be found at the same location [20]. Unlike the other Asian horseshoe crab species, *C. rotundicauda* does not move out to sea with the receding tide. Instead, adults can be found buried from 2 to 3 cm deep in the wet mud, while sub-adults and juveniles remain on the sediment surface.



Horseshoe crab can survive long time periods without showing any significant morphological changes, so that horseshoe crabs are often called as living fossil. Horseshoe crabs have changed very little over 500 million years and have survived from two mass extinctions [6, 21]. Status of all 4 species of horseshoe crab according to the IUCN Red Data Book are classified near threatened for *Limulus polyphemus* and deficient for the other three species [4].

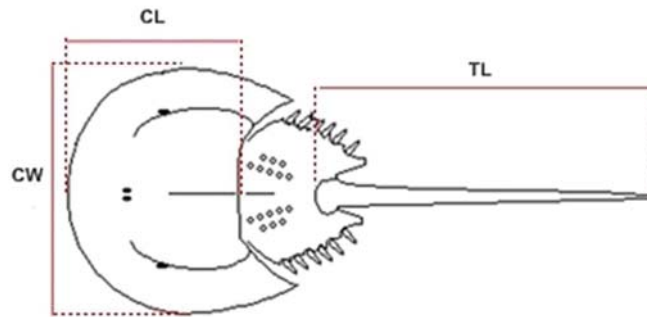
Habitat throughout Asia has been diminishing [15, 18, 22-23], and evidence from the current study and information from local fishermen suggest that all species are rarely found and the population is probably declining. For example, in India, spawning activity has been adversely affected by the degradation and destruction of spawning beaches of both *Carcinoscorpius rotundicauda* and *Tachypleus gigas* [18]. In Hong Kong, juvenile densities have been declining for some years [22, 23], and juveniles are found in fewer locations [15]. *T. gigas* is now thought to be extirpated locally around Hong Kong [1]. In addition to loss of habitat, entrapment in fishing nets in coastal waters and commercial harvest for food remain threats for crab populations. In Hong Kong *T. tridentatus* is sold in restaurants [15], and in Thailand and Malaysia all 3 Asian horseshoe crabs species are consumed as an exotic delicacy [2].

Indonesian coastal waters is one of important distribution areas of horseshoe crabs in the world. Three of four species of horseshoe crabs in the world can be found in Indonesian coastal areas. In Indonesia, horseshoe crab is one of priority protected marine species [24]. Although Indonesian coastal area is primary distribution area of three Asian horseshoe crabs species, scientific information about horseshoe crab species and its distribution are limited. Even though, information about species, distribution, and quantitative data of horseshoe crabs are urgently needed to confirm the conservation status of these species, to monitor emerging threats to the remaining horseshoe crab population in Indonesia, and to justify actions for protecting these species. One of approaches to identify species of aquatic species, such as horseshoe crab, is by morphometric characters. Morphometric characters are effective tool to learn change and variation of organism body shape [25]. Morphometric study explained change and comparison of quantitative measurement, especially from the part of organism body. Significant variation of morphology characters of species can be guidance to identify population or genus of organism. This study was aimed to determine the morphometric characters and species distribution of three Asian horseshoe crabs in north coast of Java and south coast of Madura Island.

## 2. Method

### 2.1. Sampling

This study was carried out on July-August 2016, and sampling was conducted on 25 to 31 July 2016 on northern coast of Java, including north of Subang, Indramayu, Semarang, Demak, Rembang, Tuban, Lamongan, Surabaya; and south of Sumenep in Madura Island. Horseshoe crab specimens were captured using net by local fisherman. The specimens originating from these regions were measured in situ. Specimens of horseshoe crab were collected and then identified using the taxonomic books [6, 17, 21, 26]. Three morphometric characteristics were measured, including carapace length, carapace/prosomal width, and telson length (Figure 1). The measurements were conducted using digital calipers to the nearest 0.01 mm.



**Figure 1.** Measurements of morphological characteristics of horseshoe crab (CL: carapace length, CW: carapace width, TL: telson length)

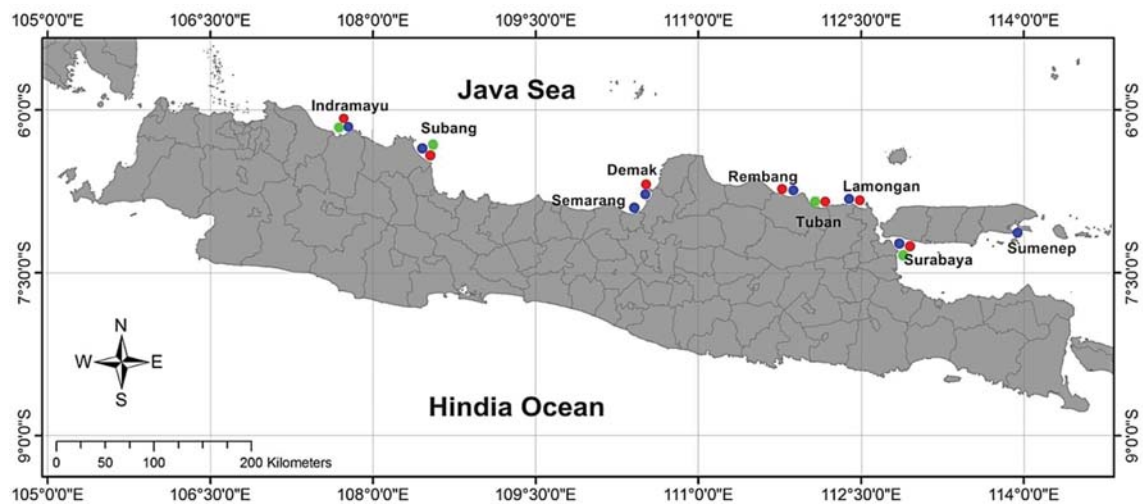
### 2.2. Data Analysis

All morphology data were corrected for length to make comparisons among locations. Morphological data among locations were compared using Mann-Whitney.

## 3. Results and Discussion

### 3.1. Horseshoe crab diversity and distribution

Three species were found on the north coastal of Java, there are *Tachypleus gigas*, *T. tridentatus*, and *Carcinoscorpius rotundicauda*. The total number of samples were obtained from nine sampling locations is 260 individuals. Number of female horseshoe crab more than male for all three species at all sampling locations. Horseshoe crab distribution of collected samples shown in Figure 2.



**Figure 2.** Distribution of horseshoe crabs on the north coast of Java (●: *Tachypleus gigas*; ●: *T. tridentatus*; ●: *Carcinoscorpius rotundicauda*)

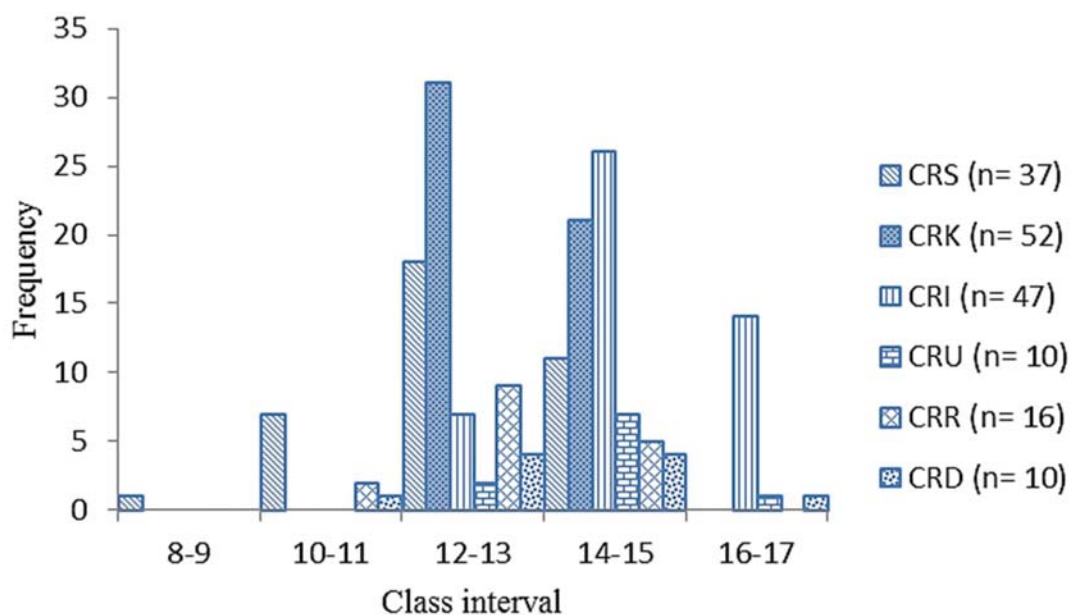
Based of Figure 2 the distribution pattern of the horseshoe crabs is as follow: in north coast of Subang, Indramayu, and Surabaya three Asian horseshoe crab species could be found; in north coast of Demak, Rembang, and Lamongan the coastal horseshoe crab *Tachypleus gigas* and the mangrove horseshoe crab *Carcinoscorpius rotundicauda* existed; in north coast of Tuban *T. gigas* and *T.*

*tridentatus* occurred; and in north coast of Semarang and south coast of Sumenep only *C. rotundicauda* was presence. The co-existence of three Asian horseshoe crab species at the same location is the quite unique because they are usually rarely found co-existing. Meilana [20] also reported the same finding in Semarang coast. In most cases many researchers found one or two horseshoe crab species at the same location [6, 17, 19, 20, 27].

In this study, *C. rotundicauda* was found almost in all locations, except in Tuban coast. This is not an uncommon phenomenon. This species commonly lives in shallow waters with soft, sandy bottoms or extensive mud flats or the mangrove-mudflat ecosystem [18]. The mangrove horseshoe crab spends most of its life close to or at the bottom of a body of their brackish-swampy water habitat. The characteristics of research locations in north coast of Java are believed to be very suitable as habitat for *C. rotundicauda* [6-7, 19]. Actually, *T. tridentatus* and *T. gigas* also almost found as well in all location but in substantially less number. This condition occurred because *T. gigas* and *T. tridentatus* prefer different habitat with *C. rotundicauda*. All sampling locations allegedly not suitable or ideal habitat for horseshoe crab from genus *Tachypleus*. So, both species *T. gigas* and *T. tridentatus* were not found in all study locations and could only be found in small number. This finding strengthens the previous study where *T. tridentatus* and *T. gigas* were almost always found in small number and lesser than *C. rotundicauda* [20].

### 3.2. Length Frequency Distribution

The carapace length of 246 individuals of horseshoe crabs were measured. Figure 3 shows carapace length frequency distribution of the three Asian horseshoe crab species of north coast of Java.



**Figure 3.** Distribution of frequency carapace length (a) *Carcinoscorpius rotundicauda*, (b) *Tachypleus tridentatus*, and (c) *T. gigas*. Note: Two letters at the beginning is the name of horseshoe crab species (CR= *Carcinoscorpius rotundicauda*; TT=*Tachypleus tridentatus*; TG=*T. gigas*) and One letter at the end is the name of sampling location (S=Semarang; K=Surabaya; I=Indramayu; U=Subang; R=Rembang; D=Demak)

Figure 3 showed that the cosmopolitan horseshoe ccarb species of along north coast of Java was *C. rotundicauda* with the highest number found in Surabaya coast. Overall, the number of *C. rotundicauda* were found in all study locations was 170 individuals, i.e. 9 individuals in Subang coast,

47 individuals in Indramayu coast, 37 individuals in Semarang coast, 9 individuals in Demak coast, 16 individuals in Rembang coast, and 52 individuals in Surabaya coast. The class interval of carapace length of *C. rotundicauda* ranged from 8-9 cm until 16-17 cm, with the highest number found in the class interval 14-15 cm (Figure 2a).

The total number of *T. tridentatus* was found from three locations during this study was 33 individuals, i.e. 16 individuals in Surabaya coast, 3 individuals in Indramayu coast, and 14 individuals in Subang coast. The tri-spine horseshoe crab from Surabaya and Subang tended to have the same carapace length, but was longer than those from Indramayu. The class interval of carapace length of *T. tridentatus* ranged from 9-10 cm until 17-18 cm, with the highest number found in the class interval 13-14 cm (Figure 2b).

The total number of *T. gigas* was found during this study is 43 individuals and they were collected from 5 study locations, i.e. 6 individuals from Surabaya coast, 12 individuals from Indramayu coast, 13 individuals from Subang coast, 2 individuals from Rembang coast, and 10 individuals from Demak coast. The coastal horseshoe crab from Subang had longer carapace length than other locations. The class interval of carapace length of *T. gigas* ranged from 15-16 cm until 25-26 cm, with the highest number found in the class interval 17-18 cm (Figure 2c).

In general, of the three species *T. gigas* had largest size and widest class interval. Size variation of horseshoe crab, including length and width of carapace, is probably influenced by the geographic location, population density, availability of food, and environmental condition [28, 29]. For example, carapace length of the mangrove horseshoe crab from Malaysia is longer than form India and Thailand [5].

### 3.3. Morphometric Characters

Comparison of morphometric characters of all three Asian horseshoe crab species in this study was performed by Mann-Whitney U-test ( $p < 0.05$  and  $p < 0.1$ ). The results are presented in Table 1, 2, and 3.

**Table 1.** Comparison of morphometric characters of *Carcinoscorpius rotundicauda* (mean±SE) among several sampling locations in this study

Character	Semarang	Surabaya	Indramayu	Subang	Demak	Rembang
Carapace width	1.38±2.42 <sup>ab</sup>	0.97±0.02 <sup>abcd</sup>	0.96±0.04 <sup>cde</sup>	0.96±0.98 <sup>bcde</sup>	0.95±0.04 <sup>bcdef</sup>	0.93±0.03 <sup>ef</sup>
Telson length	1.51±2.79 <sup>ab</sup>	1.06±0.12 <sup>ab</sup>	1.06±0.07 <sup>a*</sup>	1.08±1.08 <sup>ab</sup>	0.99±0.18 <sup>b*</sup>	1.01±0.25 <sup>ab</sup>

<sup>a,b,c,d,e,f</sup> within the same row, values with different superscript are significantly different ( $p < 0.05$  and  $*= p < 0.1$ ).

**Table 2.** Comparison of morphometric characters of *Tachypleus gigas* (mean±SE) among several sampling locations in this study

Character	Subang	Indramayu	Surabaya	Demak	Rembang
Carapace width	1.87±3.27 <sup>ac</sup>	1.03±0.11 <sup>b*</sup>	0.97±0.04 <sup>abc</sup>	0.97±0.04 <sup>ac</sup>	0.95±0.01 <sup>ac*</sup>
Telson length	0.92±0.28 <sup>ab</sup>	1.06±0.20 <sup>a</sup>	1.04±0.09 <sup>ab</sup>	0.97±0.15 <sup>b</sup>	1.04±0.19 <sup>ab</sup>

<sup>a,b,c</sup> within the same row, values with different superscript are significantly different ( $p < 0.05$  and  $*= p < 0.1$ ).

**Table 3** Comparison of morphometric characters of *Tachypleus tridentatus* (mean±SE) among several sampling locations in this study

Character	Subang	Indramayu	Surabaya
Carapace width	0.99±0.03	0.98±0.03	0.98±0.03
Telson length	1.05±0.17	1.08±0.04	1.08±0.15

<sup>a,b</sup> within the same row, values with different superscript are significantly different ( $p < 0.05$ ).

Table 1 shows that carapace width of *Carcinoscorpius rotundicauda* was significantly different among all study locations ( $p < 0.05$ ). Telson length of *C. rotundicauda* was significantly different between Indramayu and Demak ( $p < 0.1$ ). While in other sampling locations they were not significantly different, both carapace width and telson length ( $p < 0.05$  and  $p < 0.1$ ). Carapace width of *T. gigas* was significantly different between Indramayu and all sampling locations except Surabaya coast ( $p < 0.05$  and  $p < 0.1$ ). Telson length of *Tachypleus gigas* was significantly different between Indramayu and Demak ( $p < 0.05$ ). In other locations it was not significantly different both carapace width and telson length ( $p < 0.05$ ) (Table 2). Carapace width and telson length of *T. tridentatus* were not significantly different in all sampling locations ( $p < 0.05$  and  $p < 0.1$ ) (Table 3).

The variation and differences in morphometric characters of the horseshoe crabs might be affected by environmental and genetic factors. The significant difference in morphometric characters of the horseshoe crabs between two different habitats strongly suggests that these specimens might belong to two different independent stocks [5]. Krumholz and Cavanah [30] showed that differences in morphometric characters of *Carcinoscorpius rotundicauda* in different environments were due to environmental effects of the habitat or it might be related with genetic effect.

#### 4. Conclusions

The three Asian horseshoe crabs species were found and distributed along north coast of Java and south coast of Madura Island; they are the tri-spine horseshoe crab *Tachypleus tridentatus*, the coastal horseshoe crab *Tachypleus gigas*, and the mangrove horseshoe crab *Carcinoscorpius rotundicauda*. Those three species were found co-existing in north coast of Subang, Indramayu, and Surabaya. In term of size, the coastal horseshoe crab, *T. gigas* showed largest size and widest class interval among the three Asian horseshoe crab species. Morphometric characters of the three species showed variations and differences with locations.

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