Population study of the mangrove horseshoe crab

Carcinoscorpius rotundicauda (Lattreille 1802) in

Kuala Tungkal, Tanjung Jabung Barat, Jambi, Indonesia

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Abstract. Population and morphological data of the mangrove horseshoe crab Carcinoscorpius rotundicauda was collected off the coast of Kuala Tungkal, Tanjung Jabung Barat, Jambi, Indonesia from November 2011 to January 2012. The study site was divided into two areas: Station I (Parit 10) and Station II (Boyar), where the water was 4–8 m and 15–25 m deep, respectively. Four belt transects (5 m × 1000 m), 100 m apart, were set parallel with the shoreline in each area. Shrimp nets (5 m × 20 m), towed along the seabed by a fishing boat were used to capture crabs. The crabs were enumerated and measurements were taken of their carapace size and body weight. Abiotic factors were also measured, including water temperature, salinity, depth, and visibility. The population density of the crabs was 0.62 ± 0.23 individuals/100 m², and their distribution pattern was random. We found correlations between depth, visibility, and crab density only at Station I.

Keywords: Boyar, correlation, density, distribution, parit

1. Introduction

The horseshoe crab is an arthropod, known as a living fossil because its present form is almost identical to that of its ancestors 500 million years ago [1-3]. In the wild, the horseshoe crab is categorized as near threatened by the International Union for Conservation of Nature [4]. This is due to habitat degradation in Asia, including in India [5], Hongkong [6-8], Singapore [9], and Malaysia [10]. In addition, commercial hunting for food poses a serious threat to horseshoe crab populations [8, 10].

Although various types of horseshoe crab have been studied around the world, for example Limulus polyphemus in Pleasant Bay, USA [11] and Tachypleus tridentatus in the Philippines [12], studies of horseshoe crab populations in Indonesia are still very rare. However, one species that has been recorded off the coast of Sumatra, Indonesia, is the mangrove horseshoe crab, Carcinoscorpius rotundicauda [4, 7, 10, 11]. The mangrove horseshoe habitat of the crab is brackish water with a muddy substrate, in which they immerse themselves 2–3 cm deep at low tide [12, 13]. At the time of writing, there was no information available regarding horseshoe crab populations off the coast of Jambi. Therefore, we aimed to acquire ecological data on the mangrove horseshoe crab populations inhabiting these waters.
In addition to population data, morphometrical data provide a useful resource for studying changes and variations in the body shape of an organism. Morphological characteristics are significantly different between different habitats [14]; for example, in Balaramgari, India, the length and width of the taro horseshoe crab was influenced by the density and availability of food [15]. Therefore, morphometric analysis can explain variations in body size among populations of the same species living in different ecosystems, and morphometric studies can provide valuable information about reproductive success, food availability, and environmental conditions.

The purpose of the present study was to determine the density, frequency, and distribution pattern of the mangrove horseshoe crab *C. rotundicauda* and how its populations were influenced by a range of abiotic factors in the waters of Kuala Tungkal, Tanjung Jabung Barat, Jambi. We also aimed to examine the differences in morphological characteristics, including the length and width of the carapace relative to body weight, between males and females in the population.

### 2. Methodology

Our research was conducted from November 2011 through January 2012 in the territorial waters of Kuala Tungkal, Tanjung Jabung West, Jambi (00°53'–01°41'S 103°23'–104°21'E). The study site was divided into two areas: Station I (Parit 10) in the coastal mangrove forest (0.5 miles from the shore) and Station II (Boyar) at sea (~5 miles from the shore).

We used a modified version of the random sampling method described by [16]. The research location was divided into two areas, which were then further divided into four belt transects (5 m × 1000 m), 100 m apart, arranged parallel to the coastline. Sampling was performed from a fishing boat (10 m long with a 29 PK engine) using shrimp nets (20 m × 5 m wide, corresponding to the width of the belt transects, with 2.5 cm inner mesh). The nets were lowered to the seabed and pulled through the water parallel to the shore for 1 km. Horseshoe crabs caught in the net were collected in a bucket filled with seawater, identified using [9, 15, 17]. Environmental data, including water temperature, salinity, depth, and visibility, were measured and recorded during sampling.

The horseshoe crab data obtained from the field were used to calculate frequency and population density and analyze distribution patterns [18]. The relationship between the abiotic environment and the horseshoe crab density was calculated using Spearman’s statistical test.

### 3. Results and discussion

#### 3.1. Density and frequency

Two types of horseshoe crab were recorded in the present study: *C. rotundicauda* and *T. gigas*. *T. gigas* was caught only at Boyar Station (8 individuals), while *C. Rotundicauda* was found at both Parit 10 Station (151 individuals) and Boyar Station (95 individuals). The total number of *C. rotundicauda* individuals caught was 246, with an average density of 0.62 ind./100 m² (n = 246, SD = 0.23). The highest average *C. rotundicauda* density at the Parit Station 10 was 0.76 ind./100 m² (n = 151, SD = 0.26) (table 1).

| No | Station | Individuals per belt | Total | Density (ind./100 m²) | Frequency (%) | Male:female ratio |
|----|---------|---------------------|-------|----------------------|--------------|------------------|
| 1  | Parit   | 21 35 45 50         | 151   | 0.76 ± 0.26          | 100          | 0.74:1           |
| 2  | Boyar   | 22 18 26 29         | 95    | 0.48 ± 0.96          | 100          | 0.70:1           |
|    |         |                     | 246   | 0.62 ± 0.23          | 100          |                  |
The frequency of *C. rotundicauda* at both Parit 10 Station and Boyar Station was 100%; in other words, the horseshoe crab was found in every belt transect. This tells us that the muddy sediment around the Kuala Tungkal coast provides a suitable habitat for the horseshoe crab [8, 9, 19]. A greater number of crabs were caught at Parit 10 Station because it was closer to the shoreline and mangrove forest, where the mud substrate is thicker.

The horseshoe crab density recorded in the present study was lower than that reported in studies conducted elsewhere. For example, the density of *L. polyphemus* in Pleasant Bay, USA has been reported as 1.9 ind./100 m² [11], this bay is a well-used horseshoe crab spawning ground. In the Philippines, the density of *T. tridentatus* has been reported as 1.47 ind./100 m² [12]. However, the horseshoe crab density that we recorded in Kuala Tungkal was higher than has been reported in Hong Kong, where the density of *T. tridentatus* was found to be only 0.31 ind./100 m² [8].

The relatively low population density recorded in Kuala Tungkal may be because of sampling being conducted when the reproductive activity of the horseshoe crabs was high, so individuals were more likely to have been nearer the shoreline. High tides, full moons, and new moons are the most suitable times for horseshoe crab migration to the shore and reproduction [12, 19, 20]. This hypothesis may be supported by the ratio of male to female horseshoe crabs caught. At Parit 10 Station, the ratio of male to female horseshoe crab was 0.74:1, whereas at Boyar Station it was 0.70:1. The ratio of *L. polyphemus* males to females in Pleasant Bay, USA has been reported as 2.3:1 [11], and the male:female ratio of *C. rotundicauda* on Kranji beach, Singapore has been reported as 3:1 [9]. Our result may challenge the previously accepted notion that Asian horseshoe crabs (including *T. gigas*, *T. tridentatus*, and *C. rotundicauda*) are monogamous [12, 21]. The fact that we caught more female than male crabs in Kuala Tungkal may be due to a higher number of *C. rotundicauda* males near the shore. Females return to deeper waters immediately after laying their eggs, whereas males remain in the shallows to fertilize the eggs externally [19]. Johnson and Brockmann [22] claimed that a low proportion of male horseshoe crabs in deeper water may be due to high numbers of uncoupled male crabs waiting on the beach to spawn. According to Botton et al. [23], when the ratio of male to female *T. tridentatus* is 1:1, spawning activity is low. Alternatively, it may be that the male *C. rotundicauda* is more able to flee and escape from the shrimp nets used for sampling due to its smaller body size, resulting in a skewed ratio [9, 17].

### 3.2. Distribution patterns

Using the Morisita Index of Dispersion, we determined that the average value of ID for *C. rotundicauda* in our study area was 1.09. Thus, it can be concluded that the horseshoe crabs in Kuala Tungkal were randomly distributed [18]. This pattern of dispersion was in accordance with that of horseshoe crabs in Singapore reported by [9]. Random distribution is caused by several things, including uniform environmental conditions and food availability across a habitat. The horseshoe crab is a scavenger; it consumes whatever it encounters, including bivalves, mollusca, polychaeta, dead fish, and algae on the seabed [15, 17]. Horseshoe crab food is available in many places, so its presence is not concentrated in one particular area, and causes the pattern of horseshoe crab distribution to be random.

Records of water temperature, salinity, depth, and visibility during our study are shown in table 2. The abiotic factors were in the range that is suitable for the life of crabs in their habitat. Horseshoe crab density was not correlated with temperature or salinity, but was significantly correlated with

| Station | Temp (°C) | Salinity (%) | Depth (m) | Visibility (cm) |
|---------|-----------|--------------|-----------|-----------------|
| Parit 10 | 28–29     | 27–31        | 4–8       | 30–46           |
| Boyar   | 26–28     | 32–34        | 15–25     | 103–137         |

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depth and visibility at Parit 10 Station (Spearman, P < 0.01). The depth and visibility at Parit 10 Station was ideal for the development of horseshoe crabs. Cartwright-Taylor and Hsu [24] caught more *C. rotundicauda* from depths below 10 m in Kranji, Singapore. Juvenile horseshoe crabs in intertidal zones migrate to deeper waters as they age and as the width of their prosoma increases [17, 25]. Chiu and Morton [6] suggested that mature *T. tridentatus* and *L. polyphemus* individuals are commonly found in the deep ocean [19].

The average depth at Boyar Station was 20.5 ± 4.2 m, but the Spearman correlation test showed that depth was not correlated with *C. rotundicauda* density. The deeper the water, the fewer adult mangrove horseshoe crabs are present, as deeper waters are further away from mangrove habitat. This relationship can also be seen in American horseshoe crabs; in one study, as many as 74% of crabs caught in the Atlantic Coast were caught at a depth of less than 20 m [26].

3.3. Conservation

Adult horseshoe crabs migrate from deep waters to the shore to spawn and lay their eggs [3, 17, 19]. Spawning activity peaks at night during full moons, new moons, and high tides [14, 17, 19, 23, 27]. The mangrove horseshoe crab lays its eggs in muddy areas of mangrove forests [14, 19]. Maintaining or increasing the availability of spawning sites will help increase the number of horseshoe crabs around Kuala Tungkal. This can be achieved by maintaining the existing mangrove forests along the Kuala Tungkal coast and not modifying their function.

Fishing in the waters of Kuala Tungkal is intensifying, resulting in many horseshoe crabs being caught and killed in fishing nets. It is necessary prevent fishing with nets on the seabed near the shore so as not to disturb horseshoe crab habitat. If horseshoe crabs are caught, they must be returned to the water immediately.

At Boyar Station, we found that *C. rotundicauda* and *T. gigas* co-existed in the same area, although *T. gigas* was present in lower numbers. Similar patterns have been observed in Hong Kong and Singapore [8, 13]. This indicates that we also need to maintain areas with sandy substrates to be used as spawning sites for *T. gigas*.

4. Conclusion

The density of the mangrove horseshoe crab *C. rotundicauda* in Kuala Tungkal was 0.62 individuals/100 m², and the crabs were distributed randomly. The depth and visibility affected the density of horseshoe crabs at Parit 10 Station. At Boyar Station, we found that *C. rotundicauda* and *T. gigas* co-exist, although much fewer of the latter were observed.

Based on our research results and the knowledge of local fishermen, we conclude that the area around Parit 10 is a suitable habitat for *C. rotundicauda*. Therefore, conservation measures are required in the area, including limits on activities that may interfere with the presence of horseshoe crabs.

In the future, research on horseshoe crabs needs to be conducted in deeper waters so that the density of juvenile crabs may be determined. It is necessary to replicate periodically this study of horseshoe crabs in the waters of Kuala Tungkal, then we have actually population data.

References

[1] Riska B 1981 *Evolution* 35 647-58

[2] Sekiguchi, K and Shuster C N Jr 2009 Limits on the global distribution of horseshoe crabs (Limulacea): Lessons learned from two lifetimes of observations: Asia and America *Biology and Conservation of Horseshoe Crabs* ed Tanacredi J T (Heidelberg: Springer Science & Business Media) 5-24

[3] Shuster Jr C N, Barlow R B and Brockmann H J 2003 *The American Horseshoe Crab* (Cambridge: Harvard University Press)
[4] International Union for Conservation of Nature (IUCN) 2010 Red List of Threatened Species available at www.iucnredlist.org

[5] Mishra J K 2009 Horseshoe crabs, their eco-biological status along the north-east coast of India and the necessity for ecological conservation Biology and Conservation of Horseshoe Crabs ed Tanacredi J T (Heidelberg: Springer Science & Business Media) pp 89-96

[6] Chiu H M C and Morton B 2004 HongKong Hydrobiologia 523 29-35

[7] Lee C N and Morton B 2005 J. Exp. Mar. Biol. Ecol. 318 39-49

[8] Shin P, Li H Y and Cheung S G 2009 Horseshoe crabs in HongKong: Current population status and human exploitation Biology and Conservation of Horseshoe Crabs ed Tanacredi J T (Heidelberg: Springer Science & Business Media) pp 347-60

[9] Cartwright-Taylor L, Lee J and Hsu C C 2009 Aquat. Biol. 8 61-9

[10] Christianus A and Saad C R 2007 Fishery Mail 16 8-9

[11] Carmichael R H, Rutecki D and Valela I 2003 Mar. Ecol. Prog. S. 244 225-39

[12] Almendral M A and Schoppe S 2005 J. Nat. Hist. 39 2319-29

[13] Cartwright-Taylor L, Bing Y V, Chi H C and Tee L S 2011 Aquat. Biol. 13 127-36

[14] Chatterji A 1999 Indian J. Mar. Sci. 77 43-8

[15] Chatterji A and Abidi S A H J 1993 Journal Indian Ocean Study 1 43-8

[16] Hu M et al. 2009 Aquat. Biol. 7 107-12

[17] Sekiguchi K 1988 Biology of Horseshoe Crabs (Tokyo: Science House)

[18] Krebs C J 1989 Ecological Methodology (New York: Harper & Row Publishers)

[19] Rudloe A 1980 Florida Estuaries 3 177-83

[20] Chen C P, Yeh H Y and Lin P F 2004 Biodivers. Conserv. 13 1889-904

[21] Brockmann H and Smith M D 2009 Reproductive competition and selection in horseshoe crabs Biology and Conservation of Horseshoe Crabs ed Tanacredi J T (Heidelberg: Springer Science & Business Media) 199-21

[22] Johnson S L and Brockmann H J 2010 Anim. Behav. 80 773-82

[23] Botton M L, Shuster C N Jr, Sekiguchi K and Sugita H 1996 Zool. Sci. 13 151-9

[24] Cartwright-Taylor L and Hsu C C 2012 Aquat. Biol. 14 217-22

[25] Shuster Jr C N and Botton M L 1985 Estuaries 8 363-72

[26] Botton M L and Ropes J W 1987 Fish. Bull. 85 805-12

[27] Brockmann H J 1990 Behaviour 114 206-20