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Characteristics and density of the horseshoe crab (*Tachypleus gigas*) from gillnet fishery in Pamekasan, Madura Island

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Abstract. The horseshoe crab is included in the category of protected species (ETP) because of its rare existence. Therefore, it is essential to identify the characteristics and density of horseshoe crabs. This study aimed to examine horseshoe crabs' morphometric characteristics and density (*Tachypleus gigas*) on the coast of Polagan Village, Pamekasan Regency, Madura. This study was conducted from November to December 2020. Results showed that 45 horseshoe crabs were found in Pamekasan waters during the study period, consisting of 30 males and 15 females. The total average length was 164.57 ± 40.92 mm and 163.67 ± 31.30 mm for males and females, respectively. Males than females dominated horseshoe crabs. The density was based on the size class, consisting of 9 ind of small size (73-132 mm), 31 ind of medium size (133-222 mm), and 5 ind of large size (223-282mm). The water quality was classified as good for the growth of the horseshoe crab population, with sediments dominated by sand and silt. Further study is needed regarding the seasonal variation of horseshoe crab in Pamekasan Water.

Keywords: density, horseshoe crab, morphometric, sex type, size class

1. Introduction

The horseshoe crab is a protected animal under the regulation Minister of Environment and Forestry (No. P.20/MENLHK/SETJEN/KUM.1/6/2018) [1]. This species is called the horseshoe crab, an intertidal organism from the phylum Arthropoda and the order *Xiphosurida* with body characteristics such as a steel shell. The morphology of the horseshoe crab is divided into three parts, namely the front (*prosoma*), which resembles a horseshoe crab, the middle part (*opisthosoma*), and the back (tail) [2]. Horseshoe crab is classified as a protected species (Endangered, Threatened, and Protected / ETP) because of its rare presence in Indonesia and is considered a primitive marine animal [3]. The high risk of extinction is due to habitat degradation, reclamation, pollution, commercial hunting, loss of habitat and food sources, changes in water conditions, and increased predation [4]. Ecological and economic roles of the horseshoe crab include 1). Biota that serves as a provider of food sources in intertidal ecosystems; 2). Bioturbator and control of other benthic invertebrates [5], 3). Consumed by mangrove monkeys (*Macaca fascicularis*) [6]. Based on interviews with Mr. Sarkawi, a fisherman in Polagan Village, Pamekasan Regency, information was obtained that if the horseshoe crab is caught in their nets, they are released back into the sea. Therefore, it is necessary to identify the characteristics and density of the



horseshoe crab to obtain in-depth information regarding its presence in the waters of Polagan Village, Pamekasan Regency. The results of this study are expected to be useful for local fishermen in minimizing the possibility of catching horseshoe crab in the waters of Polagan Village, Pamekasan Regency. Moreover, this research aims to identify the morphometric character of the horseshoe crab, the total population of the horseshoe crab based on sex type and size class, and the characteristics of the waters in Polagan Village, Pamekasan Regency.

2. Methodology

This research was carried out from November 10 to December 3, 2020, in the Candi Hamlet of Polagan Village, Galis District, Pamekasan Regency. This period includes literature study, site survey, field data collection, sample identification, and data analysis. Data collection was carried out every 2 days for 10 times in the waters of Polagan Village, Pamekasan Regency, especially in the area where the largest number of horseshoe crabs were caught in gillnet fisheries, as determined from the results of site surveys and interviews with local fishermen. By following 1 fisherman for weeks every 2 days and using crab nets by throwing them into the waters, there were 45 individuals of horseshoe crabs as samples. The captured horseshoe crab was then identified with morphometric characters, and the density was calculated. The type of horseshoe crab is identified by matching the physical characteristics obtained with the results of the description of the horseshoe crab in the world [7]. While the number of horseshoe crab populations is obtained by counting the individual horseshoe crabs caught in gill nets. This data describes and analyzes the proportion of male and female horseshoe crabs caught in gill net fisheries and the total population.

The measurement of morphological characters refers to the [8] method with a caliper. The horseshoe crab that has been measured is marked with a pin label to avoid repeated measurements when the sample that has been measured is recaptured. After these measurements, the horseshoe crab was released back into the sea at the research site. The following are the parts of the horseshoe crab body whose morphological character (Figure 1).

The observed aquatic environmental parameter data included sediment fraction, organic matter, water pH, DO, salinity, temperature, and current velocity. Water quality parameters were measured in situ in the field using a digital thermometer, refractometer, pH meter, and DO meter.

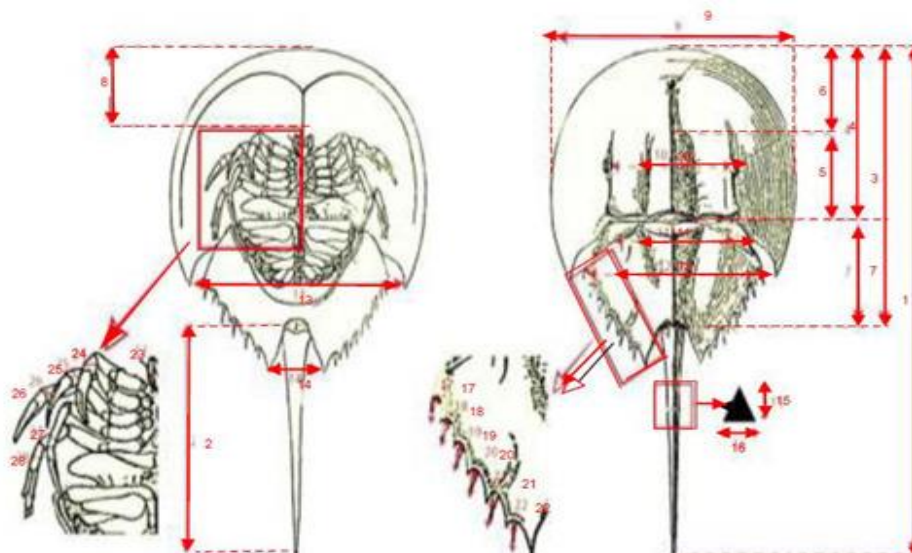


Figure 1. The body of the horseshoe crab [8]. Description: XX1: character body size (1. Total length (X1), 2. Telson length (X2), 3. Body length (X3), 4. Prosoma length (X4), 5. Median ridge length (X5), 6. Length of front ocelli (X6), 7. Length of ophistoma (X7), 8. The thickness of ventral mesel (X8), 9. Maximum width of prosoma (X9), 10. Distance between compound eyes (X10), 11. Distance between

auricula spine (X11), 12. Distance between marginal processes (X12), 13. Distance between posterior angles (X13), 14. Distance between anal angles (X14), 15. Mid-telson height (X15), 16. Mid-telson width) (X16). XX2 is the character of the size of the limbs (17. Length of marginal spine I (X17), 18. Length of marginal spine II (X18), 19. Length of marginal spine III (X19), 20. Length of marginal spine IV (X20), 21. Length marginal spine V (X21), 22. Length of marginal spine VI (X22), 23. Diameter of cheliceral claw (X23), 24. Pedipalpi claw diameter (X24), 25. Diameter of walking claw I (x25), 26. Diameter of walking claw II (X26), 27. Diameter of walking claw III (X27), Diameter of walking claw IV (X28).

3. Results and discussion

3.1. Morphometric characters

The results of the identification of the horseshoe included as many as 45 individuals as research samples in the waters of Polagan Village, Pamekasan Regency, with males and females having a total average length and standard deviation of 164.57 ± 40.92 mm and 163.67 ± 31.30 mm, respectively (Table 1). The morphometric characteristics, especially the length of the horseshoe crab, can also be observed by looking at the length of the telson, the prosoma, and the opisthosoma. The length of the telson of the horseshoe crab females in the waters of Polagan Village is 149.13 ± 30.34 mm; the length of the male prosoma is 94.03 ± 25.17 mm; and the length of the female opisthosoma is 69.13 ± 11.72 mm. The morphometric characteristics of the horseshoe crab in the waters of Polagan Village, Pamekasan Regency, can be seen in Table 1.

The results of the morphometric measurements of the horseshoe crab based on Table 1 shows that the overall average of the male horseshoe crab was greater than that of the female horseshoe crab in the waters of Polagan Village, Pamekasan Regency. Meanwhile, based on research conducted by [9], female horseshoe crabs have a larger character than males. The size of the female horseshoe crab can grow larger than the male size because the growth phase from juvenile to adult is influenced by hormones. According to [10], female horseshoe crabs may perform molting activities throughout their lives until they reach a larger size than males. According to [7], morphometric characters can identify individual diversity between species and the characteristics of each species, male and female, the determination of sexual dimorphism, and the geographical diversity of horseshoe crab habitat. Information about the morphometric character of the horseshoe crab is one of the important pieces of information that must be known to compare the size of the horseshoe crab, such as the width, length, and weight. Morphometric measurements are also useful for knowing the growth pattern of the horseshoe crab, eating habits, and shellfish group and as a basis for identifying horseshoe crabs in the waters of Polagan Village, Pamekasan Regency.

Morphometric characters can identify individual diversity between species and the characteristics of each species, male and female, the determination of sexual dimorphism, and the geographical diversity of horseshoe crab habitat [7]. The variation in the size of the morphometric character of the horseshoe crab, in particular, is the length and width found in the waters of Polagan Village, Pamekasan Regency (as shown in Table 1). The width of the prosoma carapace was used to estimate the growth phase of the horseshoe crab, namely the juvenile, juvenile, and adult stages [11]. The total length of the male horseshoe crab is, on average, between 125.00 ± 5.00 mm to 164.57 ± 40.92 mm, which indicates that the horseshoe crab in the waters of Polagan Village, Pamekasan Regency, is mostly found in the adult phase. Size 120 to more than 130 mm and is classified as an active adult horseshoe crab. [12] added that the total length range for males is 26-28.5 cm with an average of 27.38 cm, while for females, the total length range is 24-28 cm with an average of 25.8 cm. This indicates that the longest range of the male horseshoe crab is lower than that of the female. [13] stated that the body size of the horseshoe crab is influenced by population density, food availability, and environmental conditions. Research conducted by [9] showed that the increase in carapace length and width was influenced by food availability and population density.

Table 1. Average Measurements of the Morphometric Characters of the Horseshoe Crab (*Tachypleus gigas*) in Polagan Village.

Anatomy	Unit	Male	Female
Total length	mm	164.57±40.92	163.67±31.03
Telson length	mm	145.30±41.12	149.13±30.34
Prosoma length	mm	94.03±25.17	94.53±19.62
median ridge length	mm	48.60±15.89	46.33±10.27
Length of front ocelli	mm	51.70±12.98	52.53±13.13
Length of ophistoma	mm	70.53±16.67	69.13±11.72
Length of SpineI	mm	17.60±4.51	17.53±3.40
Length of SpineII	mm	20,10±4.57	19.60±6.07
Length of SpineIII	mm	20.73±4.51	21.20±3.47
Length of SpineIV	mm	19.53±6.99	19.67±7.80
Length of SpineV	mm	19.70±7.49	19.00±7.30
Length of SpineVI	mm	17.70±7.49	19.47±7.00
Thick of Ventral messel	mm	33.47±6.97	36.60±7.46
Maximum width of Prosoma	mm	144.90±58.59	163.27±44.90
Mid-telson height	mm	8.10±1.58	7.80±1.74
Distance between Compound eyes	mm	83.30±20.21	81.80±16.60
Distance between Compound Marginal process	mm	95.23±16.06	97.53±16.12
Distance between Compound Posterior angle	mm	117.33±18.09	121.00±15.99
Distance between Compound Anal angle	mm	46.03±10.45	45.20±7.24
mid telson	mm	31.90±6.15	30,20±4.99
Diameter of Chelicera claws	mm	3.97±1.16	3.40±1.18
Pedipalpi claw diameter	mm	7.17±2.59	5.73±2.40
Diameter of walking clawI	mm	6.67±2.12	5.67±2.72
Diameter of walking clawII	mm	6.00±1.97	5.00±2.72
Diameter of walking clawIII	mm	5.90±1.71	5.70±1.79
Diameter of walking clawIv	mm	6.40±1.79	5.80±1.37
Heavy	gram	278.17±176.06	321.93±218.12
Total	Ind	30	15

The results of simple linear regression analysis (Table 2) of horseshoe crab in the waters of Polagan Village, Pamekasan Regency, the determinant coefficient value (R^2) is close to 1. This indicates a close relationship between the total length and weight of the horseshoe crab. The relationship between the length and weight of the horseshoe crab that lives in the waters of Polagan Village, Pamekasan Regency, has a value of $b = 0.21$, which indicates that the horseshoe crab that lives in the waters of Polagan Village, Pamekasan Regency, has negative allometric growth properties ($b < 3$) where the length increase is faster than the increase in length.

These results are in line with [14], which shows that the growth pattern of the horseshoe crab is

negative allometric, which means that the total length increase is faster than the weight gain. [15] added that the results of the calculation of the growth pattern of the horseshoe crab showed that the determinant coefficient (R^2) was close to 1, which means that there is a close relationship between the total length and weight of the horseshoe crab.

Table 2. The relationship between length-weight and biological conditions of the horseshoe crab in Polagan Waters, Pamekasan Regency.

Station	Length-Weight Relationship		Biological condition horseshoe crab
	b (coefficient of growth)	R^2 (coefficient of determinant)	
Polagan	0.21	0.99	Telson broken The prosoma was damaged, the carapace was overgrown with barnacle spats, the left and right legs were broken, and the marginal spine was fractured.

3.2. Meristic characteristics

The results of the observations and identifications that have been carried out on the horseshoe crab's character show that the prosoma carapace's shape is round and convex, tall, and has no spines. The carapace of the opisthosoma has marginal spines scattered in the cardiac area. Six pairs of marginal spines differ in size for each male and female. The I-VI marginal spines on the male horseshoe crab are the same length, while the female is only long on I-III marginal spines, and IV-VI spines degenerate or get smaller and shorter. According to [12], the meristic character of the horseshoe crab has a convex, round prosoma shape.



Figure 2. Marginal thorns of the horseshoe crab (*Tachypleus Gigas*) (a) male and (b) female.

The telson of the horseshoe crab is short in size and widens in the middle of the telson, and on the surface of the telson, there are fine or jagged spines, as shown in Figure 3 below.



Figure 3. The Horseshoe Crab (*Tachypleus gigas*) Telson.

Pedipalpi claws of males and females have different shapes; the claws of the pedipalpi and the first walking leg of the male have a round shape and look like muscles, while the claws of the female have the same slender shape as the other walking legs. Figure 4 shows a close-up of the pedipalpi claws for more information.



Figure 4. Pedipalpi claws of Horseshoe Crab (*Tachypleus gigas*) (a) Males and (b) Females.

3.3. Total number of horseshoe crab (*Tachypleus gigas*) Caught

The shellfish data was taken every morning at 04.30 WIB by lifting the net that had been stretched overnight. The number of horseshoe crab individuals obtained in the waters of Polagan Village, Pamekasan Regency, for 3 weeks was 45 individuals. The high number of horseshoe crabs in this location is due to its proximity to the mangrove area. The mangrove vegetation area is where horseshoe crabs forage for food [16]. The high density of mangroves around the study site makes the substrate contain much organic matter, a food source for the horseshoe crab [17]. The total number of horseshoe crabs caught in the waters of Polagan Village, Pamekasan Regency, was 30 males and 15 females (as shown in Figure 5), differences between females and males from the horseshoe crab caught in Polagan Village, Pamekasan Regency, as shown in Figure 6.

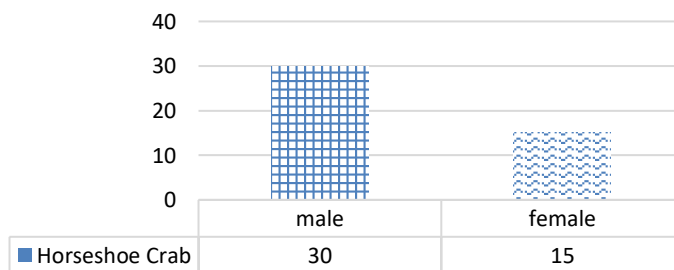


Figure 5. The number of horseshoe crabs (*Tachypleus gigas*) based on sex type in the waters of Polagan Village, Pamekasan Regency.

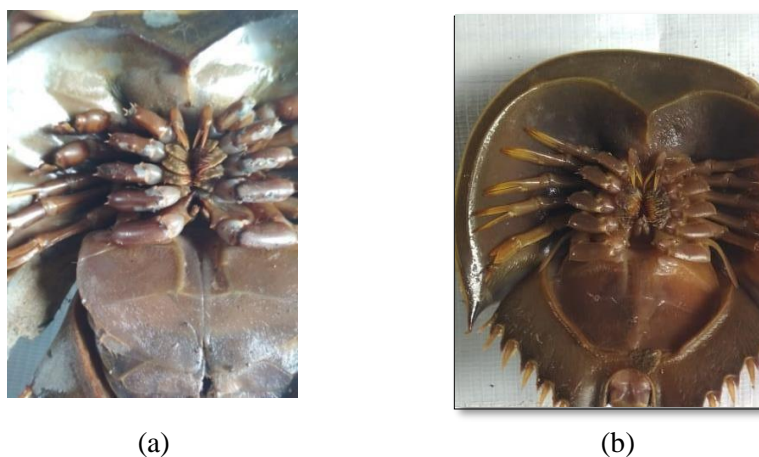


Figure 6. Sex Type Differences Horseshoe Crab (*Tachypleus gigas*), (a) male and (b) female.

The number of horseshoe crabs caught in the waters of Polagan Village, Pamekasan Regency, was grouped into three size classes based on indicators of the total length of the crab, namely small size (73 to 132 mm), medium size (133 to 222 mm), and large size (223 mm to 282 mm). The horseshoe crab in the waters of Polagan Village, Pamekasan Regency, has 9 individuals in the small size class (7 males and 2 females), 31 individuals in the medium size class (20 males and 11 females), and 5 individuals in the large size class (3 males and 2 females). The highest number in the waters of Polagan Village, Pamekasan Regency, is the medium-sized class. The number of horseshoe crabs by size class is shown in Figure 7,

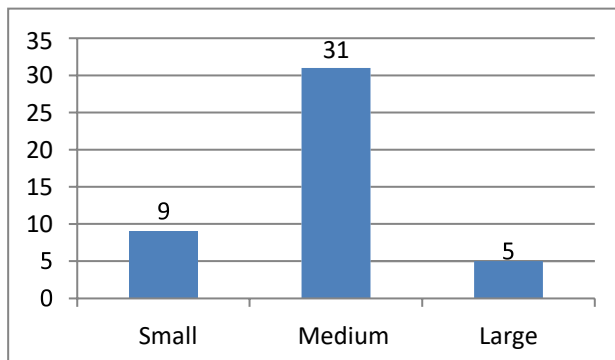


Figure 7. Number of Horseshoe Crab (*Tachypleus gigas*) Based on Size Class in Polagan Village, Pamekasan Regency.

The density of the horseshoe crab caught in the waters of the village of Polagan, Pamekasan Regency, every day for 3 weeks and data collection every 2 days obtained different results. The results of the daily measurement of the number of horseshoe crabs caught in Polagan village can be seen in Table 3 below,

Table 3. Daily number of Horseshoe Crab (*Tachypleus gigas*) caught in Polagan village, Pamekasan Regency.

Date	Amount (ind)
10/11/2020	9
12/11/2020	8
14/11/2020	8
15/11/2020	5
17/11/2020	3
19/11/2020	4
21/11/2020	4
22/11/2020	2
01/12/2020	1
03/12/2020	1
Total	45
Average	4.5

Based on the research results and interviews with fishermen in Polagan Village, Pamekasan Regency, it was determined that the number of horseshoe crabs caught in the gill net fishery was still relatively small. This is because the data collection time is short, namely 3 weeks.

3.4. Environmental characteristics

In this case, environmental characteristics are the water quality and sediment fraction that influence the growth of the horseshoe crab. Waters can significantly affect the growth or number of horseshoe crabs and their ability to grow and develop optimally. The water quality parameters that were measured and considered to affect the growth of the horseshoe crab were temperature, DO, pH, brightness, current velocity, and sediment fraction. The results of the measurement of water quality parameters in Polagan village, Pamekasan Regency, can be seen in Table 4 following,

Table 4. Characteristics of the aquatic environment at the research station.

Parameter	Results	Standard	Information
DO (mg/l)	7.29±0.30	> 5*	Suitable
Salinity (ppt)	33.15±0.77	%0*	Suitable
Temperature (oC)	29.67±0.88	28-32*	Suitable
pH	7.61±0.44	7-8*	Suitable
Current (ms-1)	0.23±0.09	0,5*	Not suitable
Brightness(m)	0,23.89±17.95	>3*	Not suitable
Depth (m)	5±0	>3*	Suitable
Sand (%)	83.14±27.72	57.36%**	Not suitable
Silt (%)	16.84±27.70	65.47%**	Not suitable

Source : *Standard by [25]

**Standard by [12]

The average value of the physical characteristics of the waters at the study site was classified as good for the growth and total population of the horseshoe crab. The dissolved oxygen (DO) content of the waters at the study site ranged from 7.29±0.30 mg/l; according to [15], a good DO for the growth of the horseshoe crab is 5.7 mg/l. The salinity of the waters is 33.15 ± 0.77 psu; according to [13], the salinity classified as optimal for the life of the horseshoe crab is 27%. The temperature is 29.67°C±0.88; according to [12], the temperature that supports horseshoe crab life is 28°C–30°C. The pH of the water is 7.61±0.44; according to [15], a good pH for the growth of the horseshoe crab is 7.8. The surface water current velocity is 0.23±0.09 ms⁻¹, and according to [15], a good current velocity for horseshoe crab growth is 0.5 m/s. The brightness of the water is obtained at 237.89±17.95cm; according to [15], a good brightness for the growth of the horseshoe crab is 160cm. The water depth is 5±0; a good depth for horseshoe crab growth is 1.6 m [15]. The water quality parameter values needed by horseshoe crabs for growth include salinity of 27-37 [18], pH of 7-9 [19], current velocity, and strong waves that are not suitable for the spawning process [20]. According to [12], the composition of the type of sediment fraction and the chemical quality of the sediment in Polagan waters that support horseshoe crab growth is 57.36% sand and 65.47% mud, with sandy sediments accounting for 83.14±27.72% and silt 16.84±27.70%. A percentage of sand sediment is found in the waters of Polagan Village, Pamekasan Regency. The organic matter content in the location is 0.50±0.22. Sediment and organic matter fractions are environmental parameters that play an important role in horseshoe crab life. The measurement results show that the sediment in Polagan Village, Pamekasan Regency's waters are dominated by sand, so the sediment type in these waters has a solid texture (sand).

The life cycle of the adult horseshoe crab tends to stay at the bottom of the water and move to the coast to carry out the reproductive process [21]. [22] stated that changes in the month's phases affect the movement of the horseshoe crab. This influence is related to the pattern of survival at a certain depth due to changes in tidal height that affect the depth and affect the movement to reproduce. Characteristics of the aquatic environment, namely sediment, play an important role in the life and sustainability of the horseshoe crab [9]. Habitat horseshoe crab usually lives in the sea with muddy or sandy sediment types

at a depth of 40 m and is often found swimming at sea level. The horseshoe crab is also often found in river mouths [22]. [13] states the strong tolerance for environmental conditions, relatively homogeneous environmental conditions, and low competition and dependency relationships between individuals. In general, the presence of horseshoe crabs is influenced by the presence of food, characterized by high organic matter content and the type of polychaeta in the sediment [23]. According to [24], horseshoe crab food is available in many places; the types of horseshoe crab food include dead fish, Polychaeta, bivalves, mollusks, and algae.

4. Conclusion

Horseshoe crabs in Pamekasan, Madura Island, were dominated by males and medium-sized classes. Pamekasan Regency is classified as good for the growth and total population of horseshoe crabs, with sediments dominated by sand and silt. Further study is needed about the effect of seasonal differences on fishermen's catch and the possibility of the horseshoe crab being caught again after being released into the sea.

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