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POPULATION DENSITY AND SIZE OF BLOOD COCKLE, *Anadara cornea* IN SETIU WETLANDS, TERENGGANU DURING NORTHEAST MONSOON SEASON

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Abstract: Blood cockle, *Anadara cornea* locally known as 'Kerang Bulu' is one of the bivalves in Setiu Wetlands, Terengganu. They were retrieved from the wild to be traded by the coastal communities for more than 20 years. This bivalve plays role in contributing as income resources for the local community caused by the continuous harvesting from their habitat. There is a lack of research in determining the population density and size of *A. cornea* in Setiu Wetlands Therefore, this study aims to determine the population density and size of *A. cornea* in Setiu Wetlands during Northeast monsoon season from November 2015 to March 2016 by using line transect method. A total of 1,506 individuals of *A. cornea* were collected with the lowest population density recorded in December 2015 (2.83 ± 0.64 individuals /m^2). The highest was in March 2016 (4.37 ± 0.97 individuals /m^2). Mean size of *A. cornea* recorded was 23.92 mm shell length, 20.69 mm height and 16.39 mm width. The largest *A. cornea* was recorded in November with shell length, height and width of 56.16 mm, 45.13 mm and 39.77 mm, respectively. This report on the population density and size of *A. cornea* during Northeast monsoon season in Setiu Wetlands could serves as a reference by local communities and authorities for sustainable management

KEYWORDS: Population density, bivalves, Malaysia, Northeast Monsoon, *Anadara cornea,* Setiu Wetlands

Introduction

Southeast Asia has the highest diversity of bivalve compared to 29 regions around the world as 1211 species were recorded (Crame, 2000). *Anadara cornea* is one of the bivalves, in Phylum Mollusca under family Arcidae, which consists of about 200 species (Zupan *et al.,* 2012; Mohd & Bachok, 2017). Several ark shells or 'blood cockle' such as *Arca* and *Anadara* spp have significant economic value in fisheries (Power *et al.,* 2004; Tanaka & Aranishi, 2013).

Setiu Wetlands are located at northeast of Peninsular Malaysia, elongated from Kampung Penarik to Kampung Beting Lintang with nine inter-connected ecosystems including sea, beach, mudflat, lagoon, estuary, islands, river, mangrove forest and coastal forest (Nakisah & Fauziah, 2003). The wetlands also consists of narrow strip of vegetation growing next to the riverbank (Aznan *et al.,* 2017). There are 11 families of bivalves found in the lagoon of Setiu Wetlands (Yahya *et al.,* 2017). Some of the species are *Crassostrea iredalei* (tiram), *Anadara cornea* (kerang bulu), *Meretrix meretrix* (kepah minyak), *Marcia japonica, Clausinella chlorotica, Saccostrea* sp. and *Polymesoda expansa* (lokan) (Wan Omar & Kassim, 2015; Mohd & Bachok, 2017). *A. cornea* has been traded and eaten by the local community in Setiu as their food source. The population density and size of *A. cornea* have been decreased over time (personal communications with the locals), suggesting that these species are exploited from the lagoon without control.

Malaysia has two types of monsoon which are Southwest Monsoon and Northeast Monsoon. Suhaila *et al.* (2010) stated that the Northeast Monsoon season occurs from November to February. During the Northeast monsoon, the eastern part of Peninsular Malaysia including Kelantan, Terengganu, Pahang and Johor received intense rainfall. Meanwhile, Southwest monsoon started from May to August with intense rainfall at the western part of Peninsular Malaysia.

Previous studies revealed that *A. cornea* can be found at Black Sea (Turkey) (Erdogan *et al.,* 2010), Minicoy Lagoon and Digha Coast (India) (Prabhakaran *et al.,* 2012), China Sea (Yennawar & Tudu, 2014), Beibu Gulf (Bernard *et al.,* 1993) and Phukan province, Vietnam (Evseev & Lutaenko, 1998). Poutiers (1998) reported that *A. cornea* belongs to the tropical western pacific region, distributed from Thailand to the Philippines; north to Japan and south to Indonesia. However, in Black Sea Turkey, the species had been reported to be an introduced species and had replaced *Mytilus galloprovincialis* (Erdogan *et al.,* 2010). In Malaysia, studies conducted on *A. cornea* was mainly focused on microplastics ingestion (Ibrahim *et al.,* 2016), taxonomy (Mohd & Bachok, 2017) and feeding ecology (Bachok, 2017).

A. cornea in Setiu Wetlands are harvested without any control from the authorities and the wetlands can be accessed by anyone. Unregulated and uncontrolled harvesting, in long term, will lead to over-exploiting and threatening the resilience of the bivalve populations (Rodrigues, 2013; Dolorosa & Dangan-Galon, 2014). Meanwhile, information regarding the population density and size of *A. cornea* is very little. During the northeast monsoon season, the bivalve harvesting activities in Setiu Wetlands are reduced compared to pre and post monsoon season. Therefore, human intervention are minimized during this period. This study was conducted to assess the population density and size of *A. cornea* in the lagoon of Setiu Wetlands, Terengganu, and providing the database in order to understand the population density and growth of this species.

Materials and Methods

Sampling Sites

A. cornea was collected from three sampling stations of different characteristics in the Setiu Wetlands (Figure 1). These stations were referred to as Mangrove, Beach and Mariculture (Table 1).

Table 1: Coordinates of the sampling stations.

Station	Coordinates	Descriptions
Mangrove	05˚ 41' 08.7" N 102˚ 42' 25.1" E	Sandy deposit and no seagrass.
Beach	05˚ 41' 10.0" N 102˚ 42' 31.6" E	Sandy and muddy deposit, with seagrass
Mariculture	05˚ 40' 58.6" N 102˚ 42' 44.5" E	Muddy deposit, with seagrass.

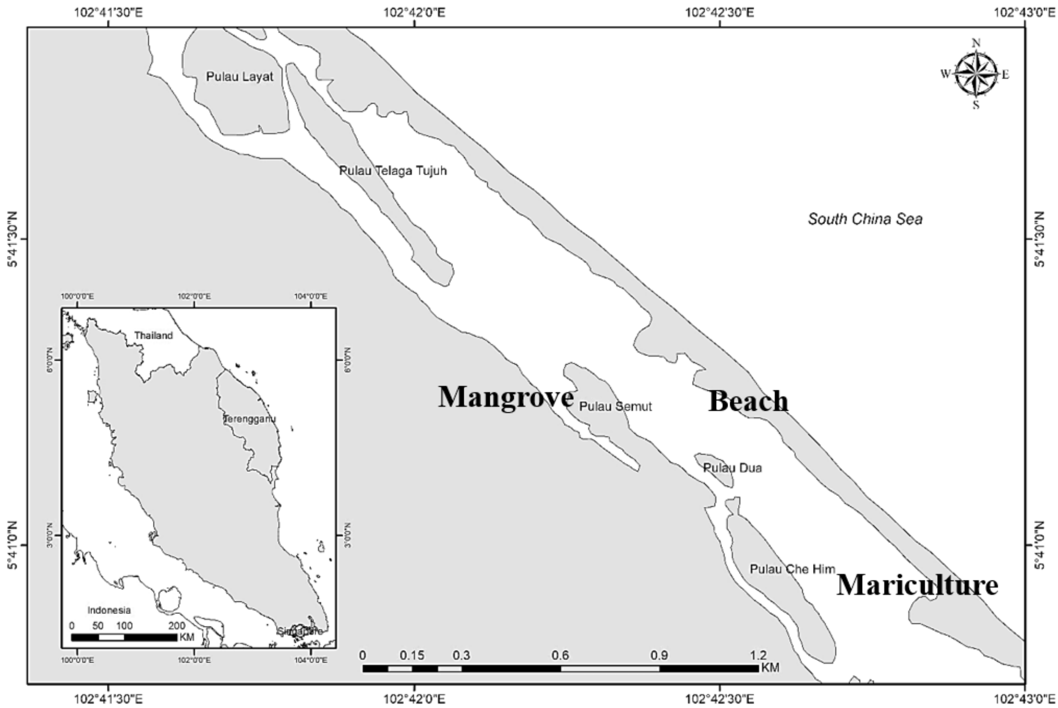

Figure 1: Location of the sampling stations in Setiu Wetlands. The map was edited using ArcGIS.

The environmental parameters (water temperature, salinity, dissolved oxygen (DO) & pH) were measured three times at each sampling site using a YSI Meter. The rainfall data were retrieved from Monthly Weather Bulletin provided by Malaysian Meteorological Department (MMD, 2016) for Setiu district.

Sample Collection

A. cornea was collected in Setiu Wetlands monthly from November 2015 until March 2016. Samples were collected during the lowest tide of the month referring to the tide tables with regards to two stations, Kuala Terengganu, Terengganu and Tok Bali, Kelantan (National Hydrographic Centre, 2015; National Hydrographic Centre, 2016).

Six transect lines (30 m) were set up in every sampling sites parallel to the shoreline at the different distance, 0 m, 10 m, 20 m, 30 m, 40 m and 50 m. Five 1.0 m x 1.0 m quadrats were placed randomly along each transect and all *A. cornea* in the quadrat were handpicked. The number of individuals collected for each site were recorded. Data were reported as the total number collected and density of individuals per square metre.

Shell size was determined by measuring three shell axes, shell length, shell height and shell width following the method by Sahin *et al.* (1999). Shell size of each sample collected from November 2015 to March 2016 was measured to the nearest 0.01mm by using digital Vernier caliper. Shell length is the furthest point measured from anterior to posterior shell margins (Figure 2). Shell height is measured from the umbo to the ventral valve margin. Shell width is the furthest distance on the outside of closed valves.

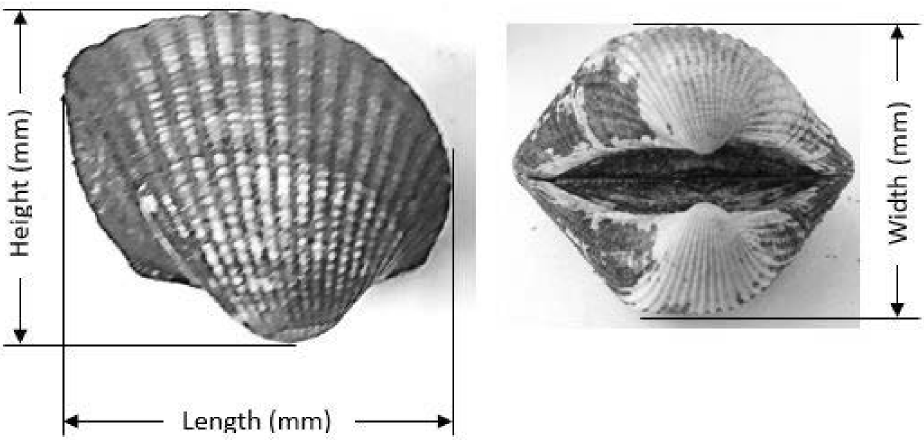

Figure 2: The shell size measurement of *A. cornea.*

Statistical Analysis

Normality test was checked by using Kolmogrov Smirnov. Levene test was carried out to check the data homogeneity. Data obtained for *A. cornea* abundance were pooled according to months. The non-parametric data were analyzed with Kruskal Wallis and Mann-Whitney for the pairwise comparisons. The size measurement of *A. cornea* was analyzed by using the Kruskal Wallis test. Relationships between *A. cornea* population density and water salinity were analysed with Pearson correlation.

Results and Discussion
Environmental Parameters

In monsoon season, the lower salinity in November resulted from intense precipitation during the months. The freshwater was flushed from the nearby river. The salinity increase across the monsoon season as the rainfall declined. During this monsoon, wave current and water run-off discharge from nearby rivers influence the physical, chemical and biological processes in a coastal region (Kimani & Mavuti, 2002). The rainfall data were collected from November 2015 until March 2016 for Setiu, Terengganu. November 2015 showed the highest reading of rainfall. It was supported by the water salinity in *Anadara* sp. culturing ground in Mae-no-umi, Japan recorded between 26 psu to 30 psu for the survival of the cockles (Nakamura, 2005).

Generally, the dissolved oxygen (DO) recorded in those sites range from 2.73 mg/L to 6.7 mg/L. There are fluctuations observed in DO during monsoon season. In the previous study, Pahri *et al.* (2016) reported the DO around cockles farming area in Jeram, Selangor ranged between 4.028mg/L to 5.895 mg/L. According to Malaysia Marine Water Quality Criteria and Standard (MWQCS), categorized in Class 2 which is DO must be at 5 mg/L to serve marine life, fisheries, coral reefs, recreational and mariculture. While the Class E category needs the DO to be 4 mg/L to fit for mangroves, estuarine and river-mouth water. Lower than that, 3 mg/L is beneficial for ports, oil and gas fields. Particularly, there is a lack of research regarding on how the concentration level of dissolved oxygen influence the blood cockles. However, most bivalves possess the LC_{50} <2 mg/L (Vaquer-Sunyer & Duarte, 2008). Since the minimum DO in Setiu Wetlands is 2.73 mg/L, it can be concluded that the study sites are favourable as *A. cornea* habitat.

In this study, water temperature recorded range from 27.0°C to 33.65°C. Water temperature is considered to have an impact on bivalve recruitment and growth (Mahapatro *et al.,* 2009). Water temperature recorded in Setiu Wetlands lagoon is similar to cockle farming site in Jeram, Selangor which reported between 29.54 °C to 32.48 °C. Other physical parameter, pH recorded in three station range from 6.45 to

9.09. In the previous study, pH range from 7.67 to 8.03 was recorded in Chilika lagoon, India which is home to several bivalves (Mahapatro et al., 2009). Meanwhile, the *A. granosa* farming in Jeram, Selangor recorded pH range from 6.57 to 7.82 (Pahri *et al.,* 2016).

Table 3: Environmental parameter; salinity, pH, dissolved oxygen, water temperature and soil temperature recorded from November 2015 until March 2016.

	2015		**2016**		
Parameter	**November**	**December**	**January**	**February**	**March**
Salinity (ppt)					
Mangrove	9.32	11.94	13.63	27.35	29.23
Beach	11.15	12.42	13.83	28.97	29.47
Mariculture	10.85	12.95	14.44	29.16	30.23
pH					
Mangrove	7.45	7.53	6.45	8.6	7.01
Beach	8.36	8.11	7.1	8.75	7.61
Mariculture	8.18	8.20	7.02	9.09	7.22
Dissolved Oxygen (mg/L)					
Mangrove	4.46	3.14	3.76	4.12	3.26
Beach	6.12	4.51	4.87	3.54	4.3
Mariculture	6.7	5.32	4.96	6.45	2.73
Water temperature (°C)					
Mangrove	32.2	30.84	30.78	31.64	27.0
Beach	33.65	31.95	31.55	29.99	28.0
Mariculture	33.19	31.92	32.96	33.37	29.0

Population Density

A total of 1,506 individuals of *A. cornea* were collected from all sites throughout the study period. Only November to February is considered as periods of Northeast Monsoon. Data collected in March was intended to provide an early prediction about the abundance of *A. cornea* in the post monsoon periods.

The population density of *A. cornea* in Setiu Wetlands changed between months, showing slight increases across the Northeast monsoon periods (Figure 3). The *A. cornea* population density in November 2015 recorded 2.88 individuals/m^2 (253 individuals) and maintain in December 2015 with 2.83 individuals/m^2 (249 individuals). The lowest population density is in December (Table 2). Starting from January, the population gradually increased until March. In January, the population density increased to 3.13 individuals/m^2 (274 individuals). While in February the population density grew to 3.80 individuals/m^2 and the total individuals collected were 339. The *A. cornea* population reached a peak in March, 4.37 individuals/m^2 as there were 391 individuals collected

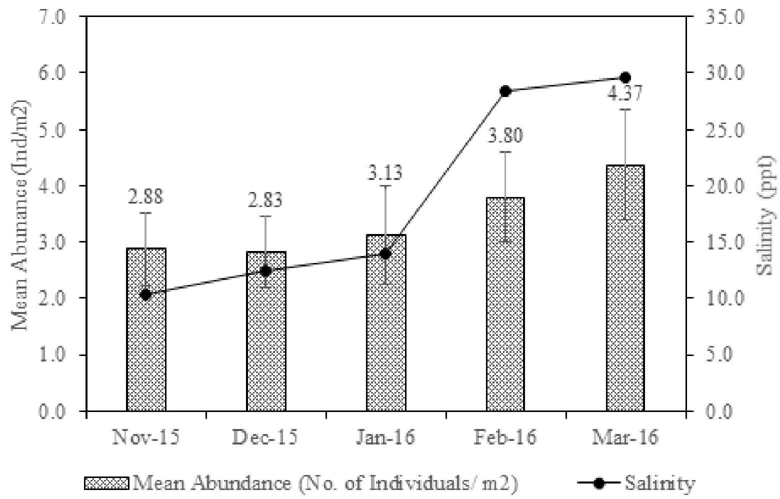

Figure 3: Mean population density of *A. cornea.* in Setiu Wetlands and the salinity measurements from November 2015 to March 2016. No significant differences between months (Kruskal Wallis, (p=0.486).

In this study, *A. cornea* population spatial patterns range between zero to 219 individuals /m^2. The highest individuals were recorded in March 2016 at station Mariculture followed by Beach. Meanwhile, Mangrove has significantly the lowest population density (Figure 4). The *A. cornea* population density observed in this study is similar to Cerastoderma edule (cockles) practicing similar quadrat and transect method, along Dutch Eastern Wadden Sea (Netherlands) during two months field survey which revealed population density range from zero to 225 individuals/m^2 in 2009 before the density increased up to approximately 1300 individuals /m^2 in 2011 (Donadi *et al.,* 2013).

Monthly records revealed that *A. cornea* population was most affected by water salinity (Figure 3). Salinity recorded in the Setiu Wetlands increased in February 2016 for all three stations (Table 3). Mangrove recorded salinity range from 9.32-29.23 psu for November 2015 to March 2016. Beach and Mariculture recorded salinity range from 11.15 psu to 29.47 psu and from 10.85 psu to 30.23 psu, respectively. In early February 2016, Terengganu coastal regions faced a phenomenon of the sudden rise of sea level and huge wave currents. The consequences off the incident cause the water from the open sea to flow into the Setiu Wetlands lagoon. Thus the water salinity in this lagoon increased abruptly (Figure 3). The population density of *A. cornea* showed an increasing trend as the water salinity measurement increased (Figure 3). There was a positive correlation between population density and water salinity (r=0.958; n=5; p=0.01). This pattern is agreeable to previous studies demonstrate that bivalve abundance and survival are influenced by salinity (Mahapatro *et al.,* 2009; Acarli *et al.,* 2012; Rodrigues *et al.,* 2012; Yurimoto *et al.,* 2014). Thus, a rainy season probably disturbed bivalve recruitment in their habitat (Mahapatro *et al.,* 2009; Rodrigues *et al.,* 2013). The previous study by Roy and Nandi (2012) stated that bivalves from family Arcidae are exclusively inhabit at the high saline condition of estuaries. Khade and Mane (2012) reported cockles to have a high sensitivity to salinity as they possess self-dilution body fluid. Drastic salinity changes in their ecosystem lead to massive fatality event (Yurimoto *et al.,* 2014). Facing the low salinity challenge, cockles are incapable to regulate the fluctuating osmotic balance (Khade & Mane, 2012), that explained the low population density in the early monsoon season (Figure 3).

There was a lack of information on the population density study among bivalve in family Arcidae in Malaysia. The previous study on other bivalves inhabit estuarine habitat in Northeastern Brazil, *Anomalocardia flexuosa* population densities varied from 100 individuals/m^2 to 1813 individuals/m^2 between March 2007 to May 2008 and was influenced by water salinity (Rodrigues *et al.,* 2012).

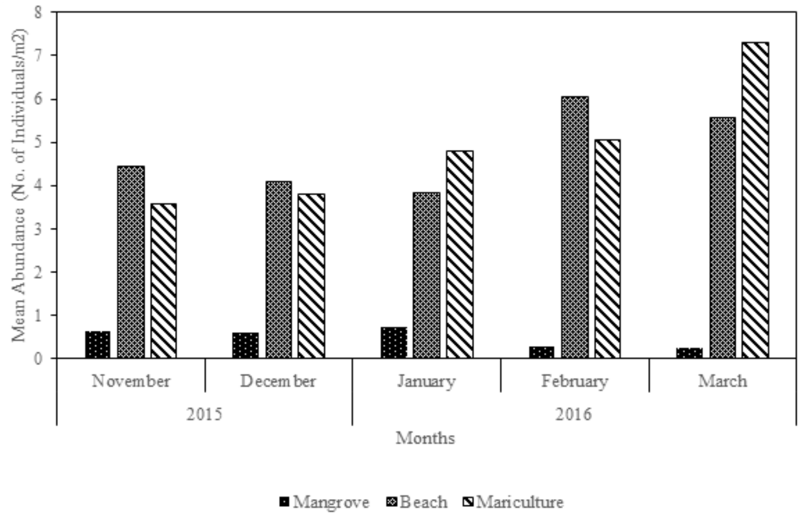

Figure 4: Graph showing the abundance of *A. cornea* in Setiu Wetlands in each site (Mangrove, Beach & Mariculture) from November 2015 to March 2016). *A. cornea* densities in those three sites were significantly different ($\chi 2$=52.458, P<0.05).

Monthly Size Variation of A. Cornea.

During the five months study period, the largest and smallest *A. cornea* were both recorded in November. Largest sample possessed shell length, height and width of 56.16 mm, 45.13 mm and 39.77 mm, respectively while the smallest sample shell length, height and width were measured as 8.66 mm, 7.02 mm and 5.27 m, respectively. Mean size of *A. cornea* recorded in Setiu Wetlands during the Northeast Monsoon, was 23.92 mm, 20.69 mm and 16.39 mm for each shell length, height and width, respectively. The previous report in Minicoy Lagoon, India, the size range of *A. cornea* collected from 25.0 to 80.0 mm (Prabhakaran *et al.,* 2012). In the Black Sea, Turkey, *A. cornea* were recorded to possess size range from 20.0 mm to 69.0 mm (Sahin *et al.,* 1999).

There are very a strong correlation between the increments of shell length and increments of shell height, r= 0.984, p< 0.001. Strong positive correlation also indicated between the increment of shell length and shell width (r= 0.974, p< 0.001).

A. cornea size variation show high significant different in across the monsoon, as revealed through statistical analysis, Kruskal Wallis (p<0.001). The data were not normally distributed and the Levene test showed that the data is not homogenous. Pairwise comparisons showed that only December and January were similar, while the others were significantly different (p<0.05) (Figure 5).

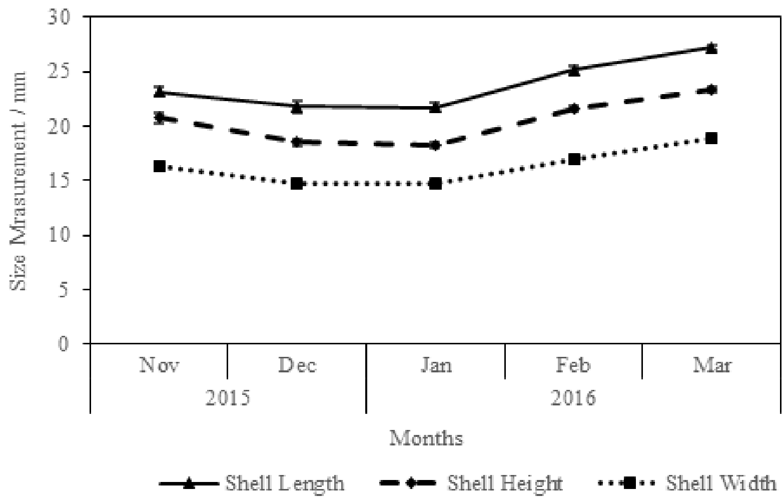

Figure 5: Monthly mean size variation of *A. cornea* across the monsoon (November 2015 to March 2016).

Based on the data, we can predict that the *A. cornea* increases in size during the Northeast monsoon. It could be related with the cockles spawning season as stated by Suwanjarat *et al.* (2009), cockles at East Coast Peninsular Malaysia as well as Pattani Bay, Thailand were observed to spawn in September and from December to June. The previous study in India, the juvenile size recorded was 10.2 ± 1.5 mm (Prabhakaran *et al.,* 2012). Meanwhile in this study, the juvenile was only observed in November. Based on our observations, larger size cockles dominated deeper water, which only accessible during low tide. Thus, limited the local people from harvesting in that particular area.

Water temperature in Setiu lagoon recorded between 27 °C to 33.65 °C. In the previous study at three bays in Japan (Mutsu, Nanao & Sendal), *Anadara* sp. growth was discovered to be positively correlated with water temperature as rapid shell growth observed from spring to summer (5°C to 25°C) (Sugiura *et al.,* 2014). However, Malaysia possesses tropical climate and maintain warm throughout the year. Other environmental parameters might be the factors affecting the *A. cornea* size variation in Setiu Wetlands such as food availability and anthropogenic factor such as fishing pressure can affect the size of bivalve in their habitats (Ezgeta-Balic *et al.,* 2011).

Conclusion

Our study shows the density of *A. cornea* continuously maintain across the Northeast monsoon. However, the *A. cornea* size increase throughout the monsoon season. We suggest monsoon season is the growth period for *A. cornea*. This could be a recovery period for *A. cornea* population and for the management and preservation of the species in Setiu Wetlands. The data gained from this study help describe current status of *A. cornea* in Setiu Wetlands and contribute to enforce policies and conservation measures towards sustainable fishing of the species.

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