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Original Article

Abundance of blood cockle (*Tegillarca granosa*) at Kuala Juru River Estuary, Penang, Malaysia♣

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Abstract

The quality of culture beds plays a significant role in the production of blood cockles (*Tegillarca granosa*), particularly the sediment, which affects the survival of *T. granosa*. The sediment composition, nutrient concentration, and the abundance of *T. granosa* were monitored at Kuala Juru, Penang (Malaysia), on the northern Straits of Malacca. The collected sediment samples showed that clay has the lowest sediment composition in Kuala Juru, at 10.90–11.50%, followed by silt at 12.85–13.40%, and sand at 75.30–76.25%. Meanwhile, the nutrient concentration of ammonium, nitrate, and nitrite were 0.292–0.522 mg/L, 0.084–0.263 mg/L and 0.084–0.129 mg/L, respectively. The average abundance of cockle and shell length of *T. granosa* was lowest at Station 3 (19.5 individuals per 5 m^2 and 22.67 ± 0.71 mm), followed by Station 1 (31 individuals per 5 m^2 and 23.36 ± 0.45 mm). The highest was at Station 2, which had 48.5 individuals per 5 m^2 and 24.69 ± 0.35 mm in shell length. Therefore, monitoring and improving the sediment quality in culture beds are needed to increase the production of *T. granosa* in the future.

Keywords: blood cockle, *Tegillarca granosa*, sediment, nutrient, abundance

1. Introduction

The blood cockle (*Tegillarca granosa*) production contributes to more than 50% of the national aquaculture production in Asia (Sugiyama, Staples & Funge-Smith, 2004). Cockle culture areas here, in Penang, are considered the third-largest producer of *T. granosa* on the northern Straits of Malacca in Malaysia (Hassan, 2004). It is a valuable shellfish for human consumption and is extensively cultured on the west coast of Malaysia in the state of Kedah, Penang, Perak, Selangor, and Johor (Izura & Hooi, 2008). Production of blood cockles depends on the status of culture areas, particularly on the nutrients in the sediment, food availability, and water quality of the culture environment. However, Gosling (2003) reported that seasonal differences in *T. granosa* growth activities are also influenced by turbidity, light, food composition, nutrient status, and water chemistry. Since *T. granosa* are filter feeders, they accumulate toxins, viruses, and bacteria in the surrounding environment (Wan Norhana, Yurimoto, Intan Nurlemsha, Roziawati, & Saadon, 2016). Thus, it is crucial to avoid polluting the cockle culture areas for the consumers' safe consumption. The study by Araujo and Nunes (2006) has shown that the diversity of breeding cycles in marine bivalve species was related to their geographical location. Nutrient levels in the *T. granosa* culture areas indicated a physicochemical condition for producing natural food for *T. granosa* (Treece, 2002). Lack of study on the ecological aspects of *T. granosa* has led to unstable production of *T. granosa*. Therefore, this study aims

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to provide an overview of physicochemical properties of water, nutrients in sediment pore water, sediment composition, and abundance of *T. granosa* from a culture area in Kuala Juru, Penang, Malaysia in the northern coast of the Straits of Malacca.

2. Materials and Methods

2.1 Sampling location and method

This study was conducted at Kuala Juru, Penang (Malaysia), during the northeast monsoon season, in November and December 2019. As shown in Figure 1, Station 1 (5°19'58" N, 100° 23'60" E) was located near the Juru River estuary, Station 2 (5°19'8" N, 100°24'0" E) was an active production area of *T. granosa*, and Station 3 (5°19'3" N, 100°24'2" E) was further away and towards the sea. The distance between each station was approximately 50 m. The cockle seed sizes used at the culture site were between 15 to 17 mm. The cockle seed was stocked at each station simultaneously in May 2019 with five sacks of cockle seed which contain 60 kg/sack. The cockles were cultured for six months before sampling. The cockle cultures were harvested twice a year. In this study, *T. granosa* were collected using a wire basket-shaped device. The basket was swept through the surface mud down to a depth of about 3 cm in a 5 m^2 area. The total number of individuals and the size of *T. granosa* were recorded. Shell length was measured with a 150 mm Digital Caliper ID32206 to the nearest 0.01 mm following the method in Sahin, Duzgunes, Mutlu, Aydin, and Emiral (1999). The cockle was determined by measuring the furthest point from the anterior to posterior shell margins, as shown in Figure 2. Physicochemical parameters such as water temperature, pH, and salinity were recorded in-situ at each station by using the Yellow Spring Instrument (YSI) meter.

2.2 Sediment grain size

Sediment samples were collected by using a sediment grab. The sediment grab was released slowly into the water until it reached the top layer of sediment without disturbing the natural conditions of the sediment. Each sediment sample was packed and secured in a sealed plastic bag and was sent to the laboratory for further analysis. Three sample replicates were collected within 5 m^2 of the sampling site at each station. The sediment grain size analysis was conducted at the laboratory using the hydrometer method (Reddy, 2002), which targeted the percentage composition of sand, clay, and silt from each sample. The standard reference of sediment grain size analysis used was ASTM D422 - standard test method for particle-size analysis of soils. Sediment samples were oven-dried at 100 °C for 24 hours. 50 g of the oven-dried sample was mixed with 25% Sodium hexametaphosphate and soaked for 24 hours. After the soaking period, the mixture was mixed using a mechanical stirring tool for three minutes and transferred into a 1,000 ml measuring cylinder. The measuring cylinder was turned upside down for one minute. The time, temperature, and hydrometer readings were recorded. The hydrometer was slowly immersed in the soil suspension to ensure the hydrometer was at rest before the readings were taken. All the steps were repeated to other sample replicates from three stations. The hydrometer calibration was done by using a stock solution (40 g/L) as a standard (Reddy, 2002).

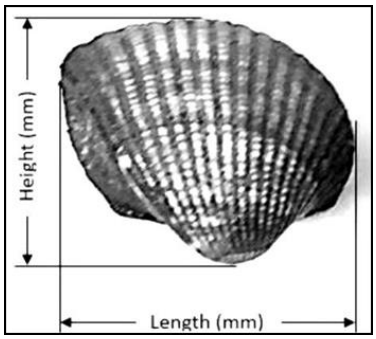

Figure 2. Shell length measurement of *Tegillarca granosa*

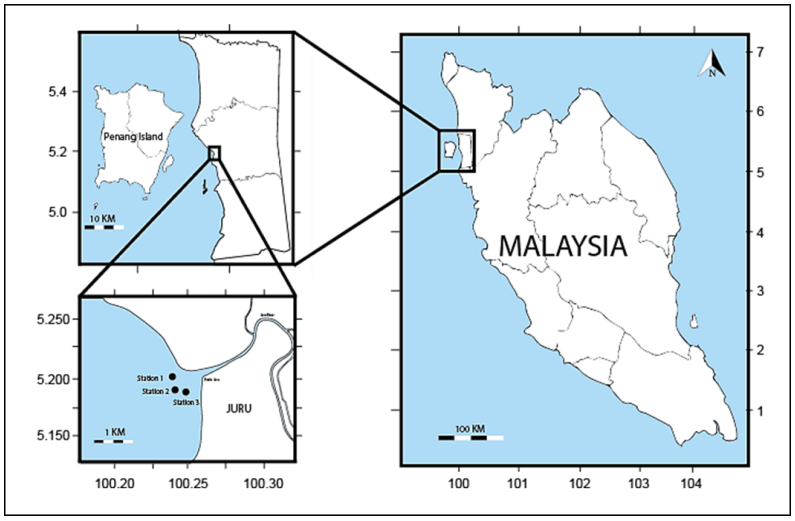

Figure 1. Location of three sampling stations at Kuala Juru, Penang

2.3 Nutrients in sediment pore water

In this study, nutrients such as ammonium, nitrate, and nitrite were analyzed using methods described by Strickland and Parsons (1972) (Table 1). For nutrient analysis, pore water from sediment samples was extracted with a piston corer. A standard curve of absorbance against the concentration of the standard solution was plotted. The concentration of nutrients was calculated from the equation of the standard curve plotted.

2.4 Statistical analysis

Statistical analysis was assessed by using IBM SPSS Version 24. One-way ANOVA with Tukey *post hoc* analysis was applied to identify the significant difference within the parameters recorded at each station at Kuala Juru, Penang. Pearson's correlation coefficient was conducted to determine the linear relationship between the ambient environmental parameters and the shell length and abundance of *T. granosa*.

3. Results and Discussion

Table 2 summarizes the seawater physicochemical parameters, sediment pore water nutrient analysis, percent grain size composition, shell length, and abundance of *T. granosa* from Kuala Juru, Penang. The lowest average seawater temperature was recorded at Station 1 (30.53 ± 0.87 °C), and the highest was recorded at Station 2 (31.39 ± 0.73 °C). A Tukey *post hoc* test revealed that the seawater temperature at Station 1 was significantly lower than at Station 2 ($p<0.05$). In contrast, there was no significant difference between seawater temperature recorded at Station 3 and other stations ($p>0.05$). The lowest pH reading was recorded at Station 1 (pH 8.17 ± 0.58), and the highest was recorded at Station 3 (pH 8.68 ± 0.10). The lowest average salinity was recorded at Station 3 (25.36 ± 0.40 ppt), and the highest was recorded at Station 2 (27.53 ± 0.47 ppt). However, there were no significant differences in the pH and salinity between stations ($p>0.05$). Both pH and temperature recorded in this study are within the range required by *T. granosa*, which are pH 7.9 – 8.5 (Oon, 1980) and 29–32 °C (Vakily, 1992), respectively. However, there was no correlation between these (pH and temperature) parameters with the shell length and abundance of *T. granosa* (Table 3). A study by Yurimoto, Kassim, Fuseya, & Man (2014) showed that the salinity levels of a cockle culture site at an estuary area in Malaysia are between 26 to 31 ppt. A strong positive correlation can be found between the shell length ($r=0.985$) and the abundance ($r=0.994$) of *T. granosa* with salinity (Table 3). This is clearly shown at Station 2, where the highest salinity was recorded with the most number of individuals and the largest average size of *T. granosa*. In contrast, Station 3, which recorded the lowest salinity, has the lowest number of individuals and the smallest average size of *T. granosa*. Other studies also have shown that low salinity can negatively affect the feeding rate and growth of *T. granosa* (Md Joni, Mohamat Yusuf, Mohamed, Mohd Kusin, & Zulkifli, 2019).

From the analysis, sediment samples from all three stations were characterized as sandy loam – dominated by sand (75.30–76.25%), followed by silt (12.85–13.40%) and clay (10.90–11.50%). There was no significant difference ($p>0.05$) in the grain size composition between the sampling stations. However, a strong positive correlation can be found between the abundance of *T. granosa* and sand composition ($r=0.937$). In contrast, a strong negative correlation can be found between the abundance of *T. granosa* and clay composition ($r= -0.999$) (Table 3). Oon (1980) has reported sandy to sandy loam sediment type in the cockle culture plots situated along the west coast of Peninsular Malaysia. The fine sediment grain size may be necessary for the drifting cockle larvae since they typically settle down on muddy shore (Yurimoto, Kassim, Man, & Fuseya, 2014).

The average abundance of blood cockle and average shell length of *T. granosa* was lowest at Station 3, with 19.5 individuals per 5 m^2 and 22.67 ± 0.71 mm, respectively. This is followed by Station 1, with 31 individuals per 5 m^2 and an average shell length of 23.36 ± 0.45 mm. The highest was at Station 2, which had 48.5 individuals per 5 m^2 and 24.69 ± 0.35 mm. One-way ANOVA shows a significant cockle abundance difference ($p<0.05$) between stations. Other than that, the Pearson correlation analysis also shows a strong positive relationship between the shell length and abundance of *T. granosa* ($r=0.998$) (Table 3).

Table 2 shows the nutrient concentrations recorded in the sediment pore water between the sampling stations. The lowest ammonia concentration was at Station 3 (0.362 mg/L), while the highest was at Station 2 (0.447 mg/L). The lowest nitrate concentration was at Station 2 (0.132 mg/L), while the highest was measured at Station 1 (0.212 mg/L). The lowest nitrite concentration was at Station 3 (0.093 mg/L), and the

Table 1. Reagent and spectrophotometer reading set up for each nutrient analysis (Strickland & Parsons, 1972)

Nutrient	Unit	Equipment	Reagent
Nitrate	mg/L	Spectrophotometer (543 nm)	1) Sulfanilamide solution 2) N-(1-Naphthyl) Ethylenediamine Dihydrochloride solution 3) Ammonium chloride stock solution 4) Dilute ammonium chloride
Nitrite	mg/L	Spectrophotometer (543 nm)	1) Sulfanilamide solution 2) N-(1-Naphthyl) Ethylenediamine Dihydrochloride solution
Ammonium	mg/L	Spectrophotometer (640 nm)	1) Alkaline citrate solution 2) Phenol solution 3) Sodium hypochlorite solution 4) Sodium nitroprusside 5) Oxidation solution

Table 2. Mean ± SD (minimum-maximum) of seawater physicochemical parameters, sediment pore water nutrient analysis, percent grain size composition, shell length, and abundance of *Tegillarca granosa* determined at three stations in Kuala Juru, Penang

Parameter	Station 1	Station 2	Station 3
Salinity (ppt)	26.43 ± 0.45[a] (26.33 – 26.87)	27.53 ± 0.47[a] (27.07 – 27.90)	25.36 ± 0.40[a] (25.00 – 25.71)
Temperature (°C)	30.53 ± 0.87[a] (29.10 – 32.40)	31.39 ± 0.73[b] (30.10 – 33.20)	31.19 ± 0.33[ab] (30.30 – 31.90)
pH	8.17 ± 0.58[a] (7.31 – 8.79)	8.27 ± 0.81[a] (7.21 – 9.08)	8.68 ± 0.10[a] (8.54 – 8.79)
Average concentration of nutrients (mg/L)			
Ammonium	0.364 ± 0.076[a] (0.310 – 0.417)	0.447 ± 0.106[a] (0.372 – 0.522)	0.362 ± 0.098[a] (0.292 – 0.431)
Nitrate	0.212 ± 0.065[a] (0.166 – 0.258)	0.132 ± 0.067[a] (0.084 – 0.179)	0.196 ± 0.095[a] (0.129 – 0.263)
Nitrite	0.113 ± 0.22[a] (0.097 – 0.129)	0.101 ± 0.23[a] (0.084 – 0.117)	0.094 ± 0.004[a] (0.091 – 0.096)
Clay (%)	11.25 ± 0.35[a] (11.00 – 11.50)	10.90 ± 0.21[a] (1080 – 11.00)	11.50 ± 0.35[a] (11.00 – 11.90)
Silt (%)	13.40 ± 0.35[a] (13.20 – 13.80)	12.85 ± 0.21[a] (12.70 – 13.00)	13.20 ± 0.63[a] (12.80 – 13.70)
Sand (%)	75.35 ± 0.77[a] (74.20 – 75.80)	76.25 ± 0.42[a] (76.00 – 76.40)	75.30 ± 0.91[a] (75.00 – 76.20)
Shell length of *T. granosa* (mm)	23.36 ± 0.45[a] (18.80 – 36.90)	24.69 ± 0.35[a] (18.90 – 35.90)	22.67 ± 0.71[a] (15.90 – 29.60)
Abundance of *T. granosa* (individuals/5 m2)	31.00 ± 0.72[a] (27.00 – 35.00)	48.5 ± 0.93[b] (42.00 – 55.00)	19.5 ± 0.57[c] (17.00 – 22.00)

Remark: Values with different superscript letters in a row are significantly different (P<0.05)

Table 3. Correlation coefficients between shell length and abundance of *T. granosa* and selected ambient environmental parameters at the study area

Parameter	Shell length	Abundance
Salinity	0.985*	0.994*
Temperature	0.394*	0.336*
pH	-0.629*	-0.676*
Clay	-0.996*	-0.999*
Silt	-0.758*	-0.716*
Sand	0.957*	0.937*
Shell Length	na	0.998*

*Correlation is statistically significant at the 0.05 level.

highest was at Station 1 (0.113 mg/L). There were no significant nutrient concentration differences ($p>0.05$) between the stations. Low ammonia (0.34 ± 0.11 mg/L) and nitrate (0.29 ± 0.14 mg/L) concentrations in the bottom water have been recorded in an active cockle farming area in Perak near the estuary (Md Joni *et al.*, 2021). The low ammonia and nitrate concentration readings have been attributed to the dilution by the seawater (near river mouth) and considerable rainfall precipitation within the study area.

Kuala Juru river estuary is classified as one of Malaysia's most polluted river basins (Lim & Kiu, 1995). The river pollutants are primarily from the waste discharge of the industrial area along the riverbank in Perai (Mat & Maah, 1994). Besides that, several small rivers flow into the Juru River through polluted urban environments, and residential waste is discharged directly into these areas (Al-Shami, Md Rawi, Ahmad, Abdul Hamid, & Mohd Nor, 2011). Neal *et al.* (2005) state that agriculture may be one of the primary sources of nitrates in the rivers. The nitrate found in this study might have been derived from the discharge of agricultural fertilizer at the paddy fields located along the Permatang Rawa River, one of the tributary rivers in the Kuala Juru basin. Excessive use of chemical fertilisers and livestock manure on agricultural land was also recognised as the primary source of water contamination. Other possible sources of pollutants to the Kuala Juru River are wastewater effluents from municipal and industrial areas.

4. Conclusions

The lowest average abundance of blood cockle, 19.5 individuals per 5 m^2, was at Station 3, followed by Station 1 with 31 individuals per 5 m^2. It was highest at Station 2 with 48.5 individuals per 5 m^2. The abundance of blood cockle at Kuala Juru was heavily influenced by salinity and the composition of sand in the sediment, as shown by the strong positive correlation. However, the abundance of *T. granosa* was negatively correlated with the composition of silt in the sediment. Although the cockle culture area in this study is exposed to various anthropogenic and natural stressors, regular and thorough monitoring of the ambient environmental parameters is essential in reducing the mortality rates of *T. granosa* at the Kuala Juru River estuary. This would be the way forward for the sustainable production of *T. granosa* in Malaysia.

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