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Growth Performance of Blood Cockle (*Tegillarca granosa*) within Kongkong Laut Estuaries, Masai, Johor

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ABSTRACT

A non-coastal cockle farming area such as an estuaries zone might become an alternative for continuous and sustainable cockle supply in the future. The main objective of this research is to determine the growth and mortality rate of *Tegillarca granosa* (*T. granosa)* within an estuary area. Three cockle plots were allocated along the estuary area of Kongkong Laut (P1, P2, P3) based on the geographical area, from upper to lower part of estuaries. Cockle monitoring activity was conducted from August to December 2015 for both in-situ water parameters and the cockles' growth increments. This study shows that within a brackish estuarine environment, the highest cockle growth increment was recorded within the highest water salinity trend area (26.92 ± 4.79 ppt; P2), with a shell increment of 2.70 ± 0.52 mm per month, while the lowest cockle growth increment was recorded within the lowest water salinity trend area (17.65 ± 5.73 ppt; P1) with the shell increment of 2.05 ± 0.86 mm per month. One-way ANOVA shows that there was significant difference ($p<0.05$) in growth increments among all sites of cockle plots, with significant positive correlation between the salinity level and the cockle's growth rate ($p<0.05$, $r=0.65$). This indicates that salinity level within a brackish environment plays an important role towards cockle's growth rate. Additionally, high turbidity level for a prolonged period leads to lower cockle survival rates within an area. However, further studies need to be done to look for other environmental factors that may affect cockle growth rate within an estuarine environment.

Keywords: Blood cockle, estuary, growth performance, Kongkong Laut, *Tegillarca granosa*

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INTRODUCTION

The blood cockle *Tegillarca granosa* (formerly known as *Anadara granosa*) is one of the major aquaculture species in Malaysia, dominating 93% of the total shellfish species production (Department of Fisheries Malaysia [DOFM], 2013). Within the west coast region of Peninsular Malaysia, blood cockle aquaculture flourishes due to the large number of juvenile cockles naturally developed in the tidal flats of this region, and many of them are collected for aquaculture. These juveniles have been supplied as seeds for aquaculture grounds within the west coast zone (Yurimoto et al., 2014a). However, since 2010, this particular sector has been significantly impacted by multiple stressors driven by the combined influence of hydrometeorological and land use change. Annual reports from the Department of Fisheries Malaysia notes that while *T. granosa* production in Malaysia has been erratic over the long term, it has dropped significantly in the past decade, specifically from 2010 onwards. At the same time, despite strategic expansion of production, productivity within licensed aquaculture plots along coastal areas has also dramatically declined (Yurimoto et al., 2014b).

Several research bodies have conducted a small number of studies aiming to have a deeper understanding regarding this issue (Harith et al., 2016; Pahri et al., 2016; Ramli, 2005; Ramli et al., 2013; Yurimoto et al., 2014a; Yurimoto et al., 2014b). Although initial findings were inconclusive, the pattern suggests that decline in *T. granosa* production may be attributed to the combined effects of a large number of environmental stressors, including pollution of coastal waters; degradation and erosion of mudflats and deterioration of shallow coastal habitats due to extreme weather events (Izura & Hooi, 2008); overstocking of *T. granosa* seed (Yurimoto et al., 2014b); high ammonia concentrations in the aquaculture systems; and rapid changes in sea surface temperature (Fadzil et al., 2010).

Therefore, since most of the major cockle's aquaculture activities in Malaysia are located within coastal area, a non-coastal zone such as estuary area may become an alternative solution for continuous and sustainable cockle supply in the future. However, as noted above, studies on the effectiveness of cockle aquaculture within a Malaysian estuarine environment remain inadequate and not well understood, particularly in terms of growth and mortality. Despite the fact that it is such valuable information, little work has been done to collect and standardize data in these two major factors as it may be utilised to predict yield under varying conditions within an estuarine environment. As part of programme to provide additional data on cockle's aquaculture within an estuary ecology, Kongkong Laut, Johor was selected as a study site, since natural cockles are present within this area but at very low abundance. Therefore, this study aims to determine the growth and mortality rate of blood cockle *T.granosa* within Kongkong Laut estuarine environment.

MATERIALS AND METHODS

Cockle Plot Set Up and Growth Measurement

Cockle plots were set up in three different locations along Kongkong Laut before starting with cockle growth measurement. These plots were labeled P1, P2 and P3 (Figure 1). This study was conducted from August 2015 until December 2015. Each plot was constructed of 4 mangrove wood pieces of 5 m height and 3 cm width as standing anchors at each corner of the plot. The mangrove wood was embedded 3 m below from the surface sediment before being enclosed with the mesh fence with an area of 1 m^2. The cockles were measured (Table 1) before being translocated from the commercial cockle farming area and about 60 cockles were dispersed into each of the plot within the Kongkong Laut estuary. Cockle growth and survival rates were collected for a 4-month period (August - December 2015). Naturally, bivalve's anterior and posterior part of the shell extend outwards as it grows, (Ubukata, 2003). Cockle growth rate was determined by measuring the shell length from the anterior to the posterior part of the shell by using the Von Bertalanffy Growth (VBG)

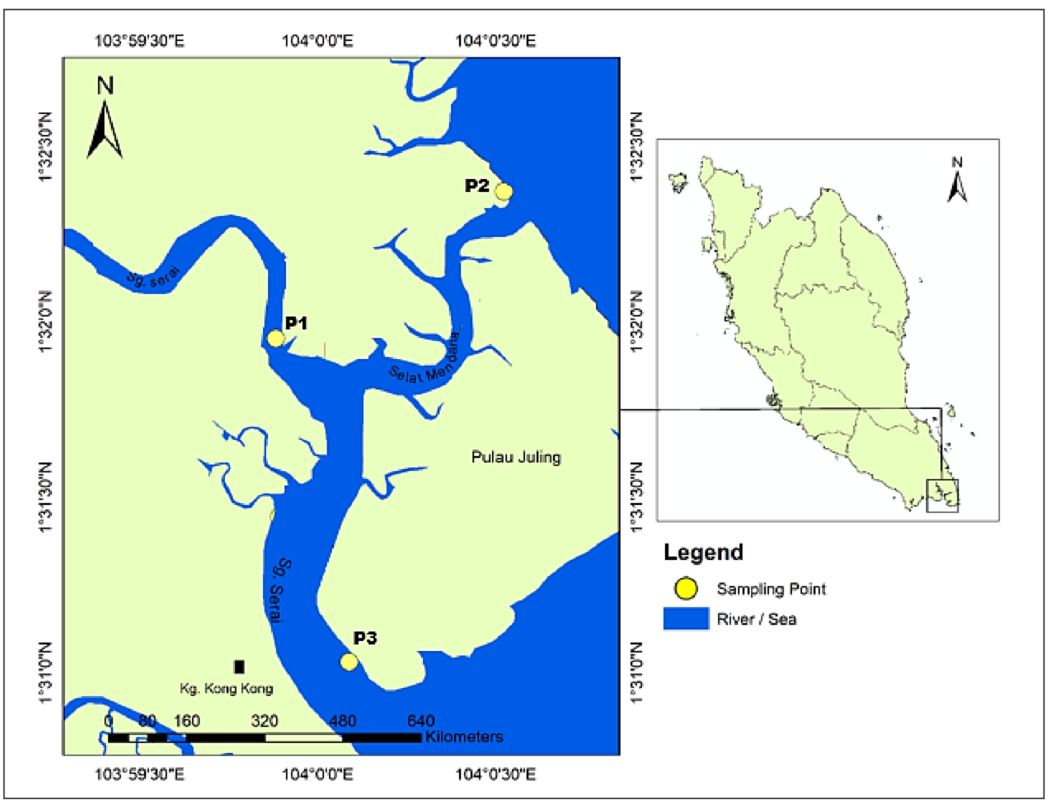


Figure 1. Location of all the cockle plots within Kongkong Laut estuary area (P1-P3)

model, as proposed by Pathansali (1966) and Broom (1982b). The VBG model has also been widely used in other fisheries related studies (De Graf & Prein, 2005). The equation is as follows:

$$\mathbf{I_t = L_i\,(1\text{-}\ e^{-Kt})} \qquad (1)$$

where;

$\mathbf{I_t}$ is length at time t (Days); $\mathbf{L_i}$ is the asymptotic length (mm); and **K** is a constant indicating the rate at which the maximum size is approached.

Table 1
Total and average length (mm) of T.granosa in each of the study plot

Plot	Total Length (mm)	Average Length (mm)
P1	18.32 - 24.51	20.08
P2	17.20 – 25.22	20.29
P3	18.50 – 23.51	20.89

Water Sampling and Physicochemical Measurement

Seven water parameters were measured in this study: temperature, pH, salinity, conductivity, dissolved oxygen (DO), turbidity and water current. Unlike the data collection for cockle's growth increment, water parameter measurements were taken earlier every month within all cockle plot area (P1, P2, P3) for 8 month period (April - December 2015) in order to elucidate the pattern of water parameter (before the allocation of cockle within the plot) and clarify the factors that may influence the cockles' growth within an area (after the allocation of cockle within the plot). pH and DO were measured by using Mettler Toledo Model Sevengo Pro-SG78 (Mettler Toledo International. USA), while salinity, conductivity, temperature, turbidity and water current were measured using a Mettler Toledo Model Sevengo Pro-SG7 (Mettler Toledo International, USA) probe meter.

Statistical Analysis

Statistical analysis was performed by using IBM SPSS version 22 (SPSS Inc., Chicago, IL, USA.). One-way ANOVA was applied in order to identify the significant difference that existed within the sediment and water dataset at each sampling location. ANOVA was also used to determine the degree of similarity of the mean on the data that are continuous or normally distributed and with homogenous variance (Sekabira et al., 2010). Pearson's correlation coefficient was used in this study to determine the degree and the strength of a linear relationship between the parameters measured.

RESULTS AND DISCUSSIONS

Descriptive Statistics on Water Physicochemical Parameter

A statistical summary (mean, standard error of the mean, and standard deviation) of the selected parameters for the water samples is presented in Table 2. A total of six physicochemical variables were analysed from 10 sampling points along Kongkong Laut estuary area. Water temperature varied from 29.84 °C in P1 sampling station to 30.04 °C in P3 sampling station, which is within the portable range of 25-32°C by the World Health Organization. The pH value is within the acceptable limit of 6.5-8.5, varying between 6.79 and 7.22, with the maximum limit of 7.22 at P3 sampling station. Generally, pH value is one of the most important parameters, as it affects chemical and biological processes and temperature affects the availability of oxygen concentration in the water (Chen et al., 2006).

The concentrations of conductivity ranged from 25.58 to 43.24 ms (millisiemens). Salinity varied from 16.12 to 22.48 ppt and turbidity ranged from 16.21 to 23.97 NTU. The concentrations of these parameters were above the threshold limits of the WHO. The higher concentrations of conductivity, salinity, and turbidity indicate that these parameters were from a common source of origin (Onojake et al., 2011) and might be due to a high level of dissolved ions in the Kongkong Laut estuaries due to dissolved salt.

Table 2
Descriptive statistics; Mean and standard deviation (S.D) of water physicochemical parameters within cockle plots in 8 months period in Kongkong Laut sampling area (n=168)

Site	P1	P2	P3
Temperature (^{o}C)	29.84 ± 1.22	29.38 ± 0.52	30.04 ± 0.74
pH	6.79 ± 0.16	7.06 ± 0.34	7.22 ± 0.23
Salinity (ppt)	16.12 ± 3.90	22.33 ± 2.93	22.48 ± 2.53
Conductivity (ms)	25.58 ± 6.81	42.60 ± 3.66	43.24 ± 3.06
Dissolved Oxygen (mg/l)	6.64 ± 0.80	4.63 ± 1.97	5.11 ± 1.86
Turbidity (NTU)	21.66 ± 3.35	16.21 ± 5.98	23.97 ± 6.75
Water current (m/s)*	0.092 ± 0.001	0.199 ± 0.001	0.124 ± 0.001

Note: *3 decimal places

Physicochemical Parameter Relationship

The Pearson's correlation matrix is presented in Table 3. The correlation between the physiochemical parameters under study showed a significant positive relationship between conductivity and salinity ($r=0.894$, $p<0.01$). Conductivity is the ability of water to conduct an electric current, and the dissolved ions are the conductors. In this case, the concentration of sodium ion that derived from the brackish water might become the main contributor for the significant correlation.

There was a moderate negative relationship between DO with salinity (r= -5.02, p<0.01), conductivity (r= -5.04, p<0.01) and temperature (r= -5.07, p<0.01). This result was expected, as solubility of oxygen decreases in both warmer and saline water due to the maximum limit of air saturation within these two circumstances (Langland & Cronin, 2003; Wetzel, 2001; Yin et al., 2004). Since there was significant positive relationship between conductivity and salinity as mention earlier, a negative relationship between DO and conductivity is considered to be inevitable.

Table 3
Correlation matrix of all water physicochemical parameters within the all of the cockle plot area

	Turbidity	Conductivity	pH	Temperature	DO	Salinity	Current
Turbidity	1						
Conductivity	0.280	1					
pH	-0.051	0.160	1				
Temperature	0.457	0.524	-0.140	1			
DO	-0.470	-0.504	0.271	-0.338	1		
Salinity	0.402	0.894	0.114	0.432	-0.502	1	
Current	0.267	0.321	0.257	-0.049	-0.401	0.448	1

Cockle Growth Performance within Plot Study

The average increment of cockle growth in Plot P1, P2 and P3 is 2.05 ± 0.16, 2.70 ± 0.32 and 2.09 ± 0.27 mm per month, respectively (August - December), as can be seen in Figure 2. Among all three plots, plot P2 shows the highest average growth increment, followed by plot P3 and P1 as the lowest average growth increment. One-way ANOVA reveals that there was a significant difference (p<0.05) in growth increment of cockle between plot P2 with two other cockle plots (P1 and P3), indicating that the growth increment within the P2 plot is significantly higher compared to P1 and P3 plot. However, there was no

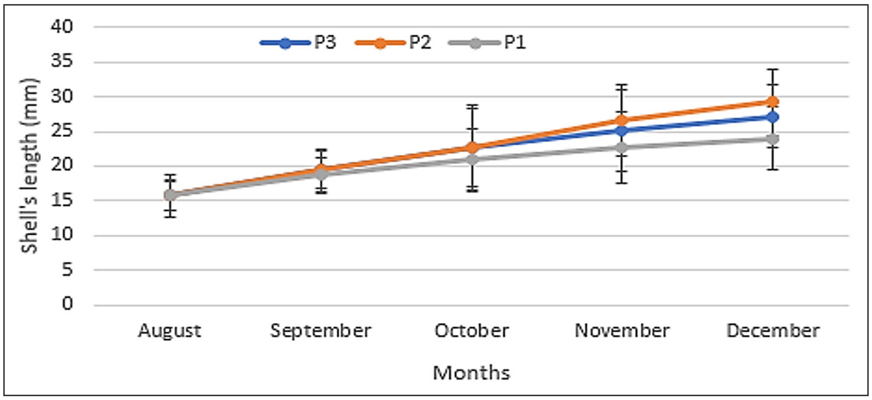


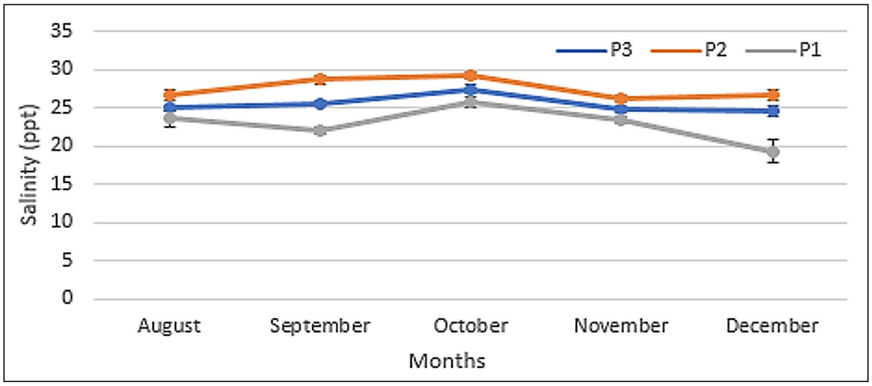
Figure 2. Growth curve of *Tegillarca granosa* within each study plot from August to December 2015, based on Von Bertalanffy growth equation

statistically certain pattern on most of the water parameters that was recorded to explain the variations of the cockle's growth, except for salinity and turbidity. Pearson's correlation analysis revealed a moderately positive correlation between the salinity level and growth rate ($p<0.05$, $r=0.65$), suggesting that salinity might be the main reason for higher cockle's growth increment within Plot P2. This result is in agreement with a study by Pathansali (1963). In his study, it was reported that the cockles' feeding rate was reduced within a lower salinity condition within a laboratory experiment, causing a slower cockle growth rate.

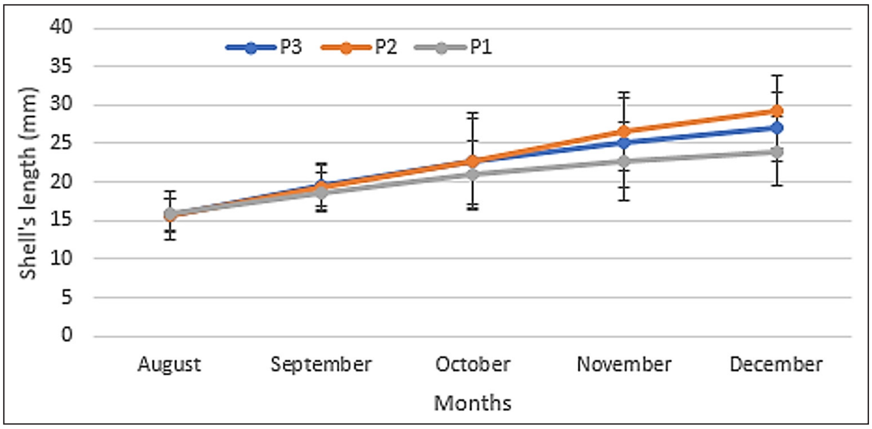
Generally, the blood cockle *T.granosa* is usually found within a coastal area or estuary area with a range of 26 to 31 ppt (Broom, 1980, 1982; Pathansali, 1963; Yurimoto et al., 2014a). In the Kongkong Laut estuary area, the water salinity ranged from 17 to 30 ppt. Among all of the cockle plots, P1 shows the lowest water salinity trend (17.65 ± 5.73 ppt), followed by P3 (23.21 ± 5.46 ppt), and P2 (26.92 ± 4.79 ppt) as the highest salinity condition within the 4-month period. Water salinity within an estuary area is not always constant, as it is also exposed directly to river and land water. During the rainy season, water salinity in some bivalve settlement area may drop as low as 10 ppt during low water of neap tides or as low as 15 ppt at high water tides (Broom, 1980; Crain et al., 2004; Day et al., 2012; Davenport & Wong, 1986). During these low salinity environments, *T. granosa* tends to close their shell valves in order to sustain the osmotic gradient between its tissue and the external medium, thus halting the feeding process until a favourable condition emerge (Davenport & Wong, 1986; Pathansali & Soong, 1958). This circumstance, however, is only restricted to a short period of time, as a prolonged low salinity environment will cause these blood cockles to be fatal (Broom, 1982a; 1982b; 1985). In this study, cockle plot at P1 area experiences the lowest average salinity (17.65 ± 5.73 ppt) within 4-month monitoring period due to the direct freshwater input from the upper stream of the estuary. The cockles in the P2 area experienced the highest average salinity (24.73 ± 5.63 ppt) within the monitoring period, as it is located nearer the Sungai Johor area which has higher salinity level compared to the inner part of the estuaries. Furthermore, the salinity trend in the cockle plot during the monitoring period indicates that the growth of the cockle increases as the salinity increases, as can be seen in Figure 3. Hence, this clearly shows that different water salinity does have an influence on the cockles' growth increment.

The average cockle survival rates in Plot P1, P2 and P3 decreased by about 15.5, 3.75 and 7.25% per month, respectively (August- December), as shown in Figure 4. Among all three plots, Plot P2 had the highest average survival rate (92 % per month) while P1 had the lowest average survival rate (73 % per month) from August to December 2015.

High turbidity trend during the four-month monitoring period (August – December 2015) suggested that turbidity might be the main reason that affecting cockles' survival within all of the plots (Figure 5). This is because of high levels of turbidity for a prolonged period have the potential to negatively affect cockle survival within a habitat drastically, as high turbidity within an environment can also potentially restrict cockle filtration activity,



(a)



(b)

Figure 3. Comparison between cockle growth (a) and salinity trend (b) in all cockle plot at Kongkong Laut area (P1, P2, P3)

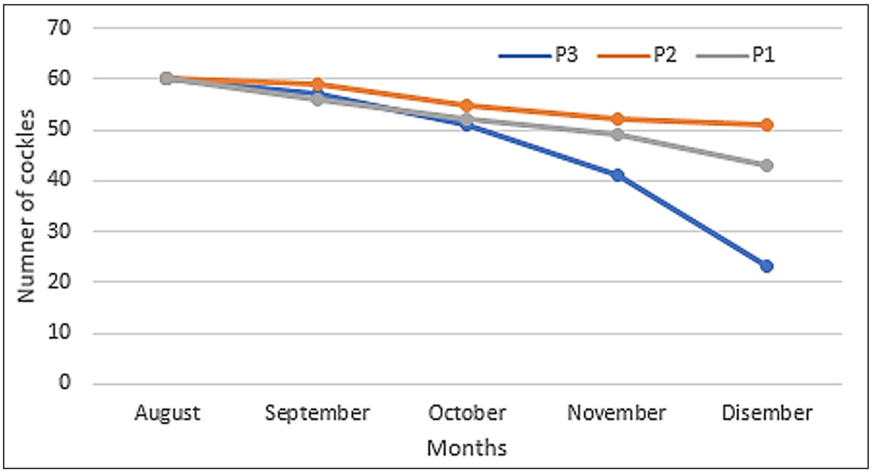


Figure 4. Survival rate comparison of *Tegillarca granosa* in plot P3, P2 and P1, based on Von Bertalanffy growth equation

thus indirectly affecting cockle feeding rate (Broom, 1980; 1985; Yurimoto et al., 2014a, 2014b). Furthermore, one-way ANOVA revealed that there was significant difference in turbidity level ($P<0.05$) between P1 and other plot study, indicating higher level or turbidity trend compared to P2 and P3. In other words, this shows that higher turbidity levels within an aquatic environment do lead to lower cockle survival within an area.

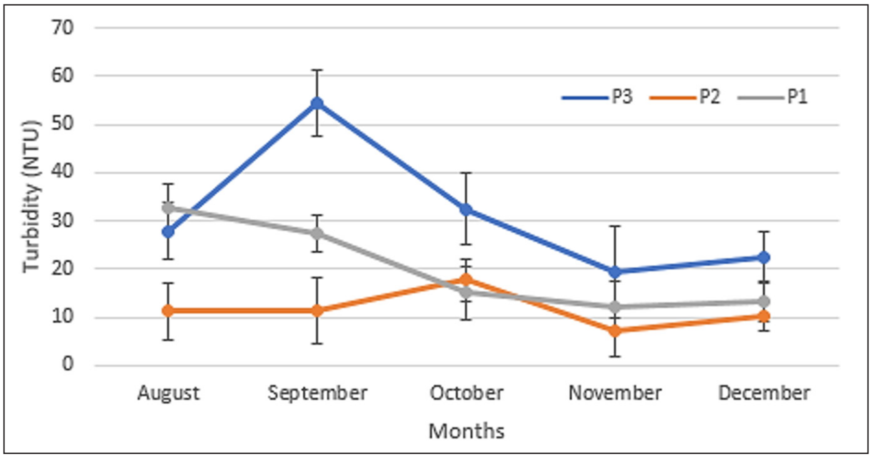


Figure 5. Turbidity level comparison within plot P1, P2 and P3 from August to December 2015

CONCLUSIONS

This study indicates that within an estuary environment, different water salinity levels have a significant influence on cockles' growth pattern, while cockle survival within an aquatic environment does influence by water turbidity level. The results suggest that lower water salinity leads to slower cockle growth increments, as it potentially affects their feeding rate negatively. On the other hand, high turbidity levels for a prolonged period lead to lower cockle survival rate within an area. Although other water parameters show no certain statistically effects on cockle growth within the study site, the range value for brackish conditions indicates that there were no extremities, and values remained within an acceptable range for cockle farming activity. A longer period of cockle growth measurement and a broader scope of environmental data are highly recommended to adapt this study in future.

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REFERENCES

Broom, M. J. (1980). *Community and production ecology of Anadara granosa* (L.) *with particular reference to its gastropod predators* (Doctoral thesis), University of Malaya, Kuala Lumpur, Malaysia.

Broom, M. J. (1982a). Structure and seasonality in a Malaysian mudflat community. *Estuarine, Coastal and Shelf Science*, *15*(2), 135-150.

Broom, M. J. (1982b). Analysis of the growth of *Anadara granosa* (Bivalvia: Arcidae) in natural, artificially seeded and experimental populations. *Marine Ecology Progress Series. Oldendorf*, *9*(1), 69-79.

Broom, M. J. (1985). The biology and culture of marine bivalve molluscs of the genus Anadara. *ICLARM Studies and Reviews, 12*(1985)*,* 32-37.

Chen, S., Ling, J., & Blancheton, J. P. (2006). Nitrification kinetics of biofilm as affected by water quality factors. *Aquacultural Engineering*, *34*(3), 179-197.

Crain, C. M., Silliman, B. R., Bertness, S. L., & Bertness, M. D. (2004). Physical and biotic drivers of plant distribution across estuarine salinity gradients. *Ecology*, *85*(9), 2539-2549.

Day, J. W., Yáñez-Arancibia, A., Kemp, W. M., & Crump, B. C. (2012*).* Introduction to estuarine ecology. In J. W. Day, B. C. Crump, W. M. Kemp, & A. Yanez-Arencibia (Eds.), *Estuarine ecology* (pp. 1-18). Hoboke n, New Jersey: John Wiley & Sons, Inc.

Davenport, J., & Wong, T. M. (1986). Responses of the blood cockle *Anadara granosa* (L.) (Bivalvia: Arcidae) to salinity, hypoxia and aerial exposure. *Aquaculture*, *56*(2), 151-162.

Department of Fisheries Malaysia. (2013). *Annual fisheries statistics book 2013*. Department of Fisheries Malaysia. Putrajaya: Author.

De Graff, G., & Prein, M. (2005) Fitting growth with the von Bertalanffy growth function: A comparison of three approaches of multivariate analysis of fish growth in aquaculture experiments. *Aquaculture Research*, *36*(1), 100-109.

Harith, H., Husain, M. L., & Akhir, M. F. M. (2016). Coastal oceanographic processes associated with blood cockle (*Anadara granosa*) induce spawning season in Kapar, Selangor, Malaysia. *Journal of Ocean Engineering and Science*, *1*(4), 289-299.

Izura, S. N., & Hooi, T. K. (2008, July). Shaping the future of cockle industry in Malaysia. In *Proceedings of the National Fisheries Symposium (NAFIS)* (pp. 14-16). Kuala Terengganu, Terengganu.

Langland, M., & Cronin, T. (2003). *A summary report of sediment processes in Chesapeake Bay and watershed* (No. 2003-4123). Virginia, US: United States Geological Survey.

Pahri, S. D. R., Mohamed, A. F., & Samat, A. (2016). Preliminary water quality study in cockle farming area in Malaysia: A case study in Jeram, Selangor. *Aquaculture, Aquarium, Conservation and Legislation-International Journal of the Bioflux Society, 9*(2), 316-325.

Pathansali, D., & Soong, M. K. (1958). Some aspects of cockle (Anadara granosa L.) culture in Malaya. *Proceedings of the Indo-Pacific Fisheries Council*, *8*(2), 26-31.

Pathansali, D. (1963). On the effect of salinity changes on the activity of the cockle, *Anadara granosa* (L). *Malaysian Agricultural Journal, 44*(1963)*,* 18-25.

Pathansali, D. (1966). Notes on the biology of the cockle, *Anadara granosa* L. *Proceedings of the Indo-Pacific Fisheries Council*, *11*(2), 84-98.

Ramli, M. F. S. B. (2005). *Impacts of coastal land reclamation on the fisheries of Mukim Lekir, Malaysia* (Doctoral thesis), University of Hull, Cottingham, United Kingdom.

Ramli, M. F. S., Abu Hassan, F. R., & Saadon, M. N. (2013). Declining production of cockles in relation to ammonia concentrations in Sungai Buloh River, Selangor. *Journal of Environment and Earth Science*, *3*(10), 1-5.

Sekabira, K., Origa, H. O., Basamba, T. A., Mutumba, G., & Kakudidi, E. (2010). Assessment of heavy metal pollution in the urban stream sediments and its tributaries. *International Journal of Environmental Science & Technology*, *7*(3), 435-446.

Ubukata, T. (2003). A theoretical morphologic analysis of bivalve ligaments. *Paleobiology*, *29*(3), 369-380.

Wetzel, R. G. (2001). *Limnology: Lake and river ecosystems* (3rd Ed.). San Diego, USA: Academic Press.

Yassin, Z. (2016). *Environmental destruction cause of decline in cockle production*. Retrieved May 7, 2018, from https://www.consumer.org.my/index.php/ development/environment/1012-environmental-destruction-cause-of-decline-in-cockle-production

Yin, K., Lin, Z., & Ke, Z. (2004). Temporal and spatial distribution of dissolved oxygen in the Pearl River Estuary and adjacent coastal waters. *Continental Shelf Research*, *24*(16), 1935-1948.

Yurimoto, T., Kassim, F. M., Fuseya, R., & Man, A. (2014a). Mass mortality event of the blood cockle, *Anadara granosa*, in aquaculture ground along Selangor coast, Peninsular Malaysia. *International Aquatic Research*, *6*(4), 177-186.

Yurimoto, T., Kassim, F. M., Man, A., & Fuseya, R. (2014b). Spawning season and larval occurrence of blood cockle (*Anadara granosa*) off the Selangor coast, Peninsular Malaysia. *International Journal of Aquatic Biology*, *2*(6), 299-304.