Abundance of three coexisting gastropod species (*Cerithidea cingulata*, *Cerithium coralium* and *Batillaria zonalis*) in the lagoon area of Setiu Wetlands, Terengganu, Malaysia

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Abstract

The lagoon area of Setiu Wetlands, Terengganu, functions as essential habitat for gastropods. Nevertheless, little ecological research on the coexisting gastropod species in the habitat has been conducted in this area. This study was conducted to determine the abundance of the coexisting gastropods species (*Cerithidea cingulata, Cerithium coralium* and *Batillaria zonalis*) in the lagoon area of Setiu Wetlands and to investigate the factors that allowed the gastropod species to coexist in the lagoon area of Setiu Wetlands. The samples were collected at three stations selected along the Setiu Lagoon. The Transect Lines and Quadrat technique was used to estimate the abundance of the gastropod species in each station. *C.coralium* was found to be the most common coexisting species (45 % of the total number of gastropods sampled), followed by *C.cingulata* (39%) and *B.zonalis* (16%). The interaction between each gastropod species has resulted in different composition for all three species. The Bray-Curtis similarity by PRIMER V6 revealed that the coexisting gastropod species studied are divided into two main clusters with 67% similarities. *C.cingulata* and *C.coralium* are grouped in one cluster. At the same time, *B.zonalis* is alone in the other cluster. The similarities are due to their niche, which is the habitat preferences. The types of interaction that occur is competition, which is interspecific competition. The increase and decrease in the abundance of a species in a habitat affect the abundance of other species in the habitat. The factors that allow the coexistence of all the three gastropod species are resource partitioning, where they have different feeding modes (deposit-feeding and suspension-feeding) and different times of feeding (feed during high or low tide). Microhabitat is also one of the factors which the gastropods are found in patches and far away from each species to decrease the competition among them. The findings are expected to be helpful as a basis for the ecology and taxonomy study of gastropod species in the future.

Keywords: Coexisting gastropod, Setiu Wetlands, Abundance, Lagoon, Competition

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Introduction

Terengganu is located at East Coast of Peninsular Malaysia. Setiu Wetlands is one of Terengganu's largest wetland, located in the northern part of the district facing the South China Sea with total water surface area about 880 ha (Ong *et al*., 2009). Setiu Wetlands is among the most productive and unique ecosystems in Malaysia. The sea, sandy beach, mudflat, tidal flat, lagoon, estuary, river, islands, coastal forest, and mangrove forest all exist in the Setiu Wetland. Setiu Wetlands provides significant benefits and habitats for diverse species of flora and fauna (Nakisah and Fauziah, 2003). Flora and fauna found to include various taxa, many of which are vulnerable and threatened as a result of human activities in the area. Setiu Wetlands serves many ecological functions, such as flood control and shoreline stabilization. Other than that, Setiu Wetlands is a major site for many activities, such as brackish water cage culture, pond culture, pen culture and oyster farming (Nakisah *et al*., 2008). Lack of research is a significant obstacle to the evaluation of the ecosystem's status. Therefore, it is crucial to study the roles of different fauna communities in different habitats in the Setiu Wetlands.

The Setiu Wetland's primary feature is the lagoon. Setiu lagoon is one of Terengganu's largest and most important lagoons. The examples of habitat occurs in the Setiu lagoon are intertidal and subtidal areas. Both habitats are influenced by the tidal cycle. The intertidal area is an area where the structure of the landscape changes several times a day. The rise and fall of the tides turn this area into the most dynamic environment. This area is covered by water during high tide and exposed to the air at low tide (Molles, 2005). Unlike the intertidal area, the subtidal area is also influenced by the tidal current, but it remains submerged during low tide (Vorberg *et al*., 2009).

Gastropod molluscs are the most numerous, accounting for more than half of all living molluscs. Snails, whelks, cowries, limpets, sea hares, and their allies make up the gastropods. Most gastropods only have one shell. Eyes, tentacles, and a mouth are among the sensory organs on the head (Swennen *et al*., 2001). The spiral-shaped shells of gastropods serve to protect their interior organs. The snail is protected from danger by an operculum, a flap or a door that can close the shell (Walker and Wood, 2005). The size of its shell determines the size of the gastropod's body. Patterns on the shell indicate the growth of the gastropod. The Gastropod community is one of the most numerous and essential invertebrate communities in the lagoon area (Filippenko, 2011). According to Rockwood (Rockwood, 2015), the term "population" refers to a collection of interbreeding organisms found in the same location at the same time. The focus of population ecology is on groups of individuals and their survival and reproduction, as well as their relationships with competitors and predators.

Organisms can interact in various ways, either competing with one another or relying on one another. Competition,

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predator-prey interaction, and symbiosis are examples of organism interaction. Competition is a situation where organisms need to compete for the same resources in order to survive. On the other hand, predation is the act of one organism eating another. In contrast, symbiosis is organisms living together and depending on each other (Peter and Michael, 2013). Interactions among organisms alter the effects of abiotic factors on distribution and abundance in two ways: by constraining habitat distribution or abundance due to competitive or predatory interactions, and by alleviating otherwise limiting circumstances by expanding habitat distribution or abundance due to beneficial interactions (Rockwood, 2015). It is critical to comprehend species interactions, particularly interspecific interactions, as well as how individuals in a community behave. The laws of ecosystem functioning can be derived from this. The information is required for the conservation of biodiversity.

One of the most crucial basic data for understanding species interactions is abundance. The abundance of an organism may reflect its status and functioning and serve as an ecological indicator of habitat changes. The results of the study can be used as the basic data for any further research in the lagoon of Setiu Wetlands. It is critical to track the abundance of gastropods over time. The abundance of gastropod species were measured every two months for a year (2014–2015). This study was conducted in order to determine the composition and abundance of the three coexisting gastropod species in the lagoon of Setiu Wetlands, Terengganu, to determine the factors that allowed the gastropod species to coexist in the lagoon of Setiu Wetlands and to determine the relationship between the abundance of coexisting gastropods species and physico-chemical parameters. Finally, the findings of this study could provide strategies for the conservation and management of this ecosystem to maintain its ecological functions.

Materials and methods

Study site

The samples were collected from Station 1, 2 and 3 (Fig. 1) in the lagoon of Setiu Wetlands. The selected stations have similar characteristics in tidal areas and are dominated by the same coexisting gastropod species (C. *cingulata*, *C. coralium* and *B. zonalis*).

Samples collection

The selected stations have similar characteristics in tidal areas and are dominant. The samples were taken six times: during the South-West monsoon (25 and 26 August 2014), the Inter monsoon (29 and 30 October 2014), the start of the North-East monsoon (15 and 16 December 2014), the end of the North-East monsoon (27 and 28 February 2015), the Inter monsoon (28 and 29 April 2015), and the South-West monsoon (17 and 18 June 2015).

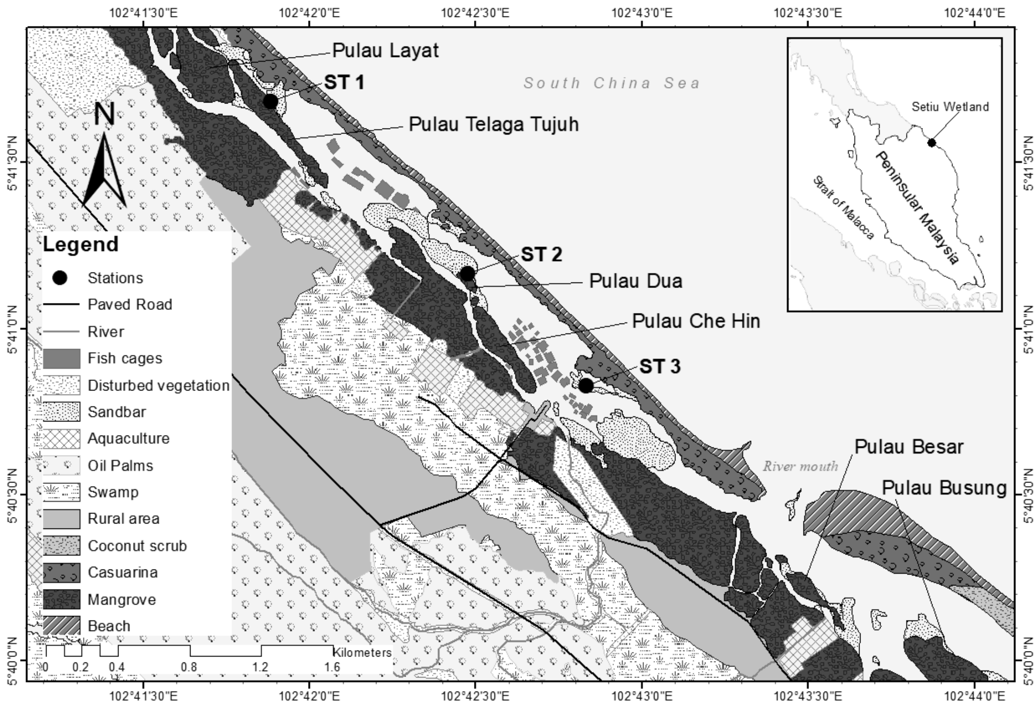

Figure 1L A map of Peninsular Malaysia showing the sampling stations for coexisting gastropods (ST1, ST2, and ST3) in the lagoon of Setiu Wetlands in Terengganu (ST1, ST2, and ST3). ST=Station

The coexisting gastropods were determined using collected samples from a previous study in Setiu Wetlands by Nurul-Zalizahana (Nurul-Zalizahana, 2013). The samples were collected at a Two-month interval from July 2011, September 2011, November 2011, January 2012, Mac 2012 and May 2012. The sampling was carried out during low tide by using the Universiti Malaysia Terengganu speed boat. From the results obtained, the coexisting gastropods selected for the study were *C. cingulata*, *C. coralium* and *B. zonalis.* Three gastropod target species were collected from each station (Station 1, 2, and 3). Only snails in good condition were collected. The gastropods were collected using the Transect Lines and Quadrat technique, a modification of the Sasekumar (Sasekumar, 1974). This technique was used to estimate the abundance of the gastropod target species at each station. A 50 m transect line was made at each sampling site, divided into four points with a 10-meter gap between them. A 0.5 m×0.5 m quadrat was set at each position. The target gastropod species were sampled in the quadrat with five replicates. The gastropod target species covered within the quadrat were collected using a sieving method by collecting the sediment (10 cm depth) and a sieve with a 1 mm mesh size. The gastropods collected were put in plastic bags and labelled.

The sediment in this study were taken for grain size analysis and total organic matter (TOM) analysis. The sediment

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samples were randomly collected by scraping approximately 1 to 2 mm of surface sediments during low tide. The samples were then put in aluminum foil and labelled plastic bag, then were brought to the laboratory for further analysis. Triplicate sediment samples were taken at each plot in the station. Sediment for TOM analysis were immediately placed in the freezer to prevent degradation of organic materials by microorganisms in the sediment samples.

The YSI 6600 multiparameter was used to monitor the pH, salinity, dissolved oxygen (DO), and temperature of the water. At each sampling station, the parameters were measured on the water's surface.

Laboratory analysis

The collected gastropod samples were sorted according to their species and station. The individuals of gastropods in each species and station were counted. The coexisting gastropods were identified. Grain size analysis was conducted using the Buchanan (1984) and Bale and Kenny (2005) methods. The samples were then re-dried in the oven and re-weighed (Bachok *et al*., 2018). The Moment method was used after obtaining the weight. The "Microsoft Excel 2007" program was used to process the data. Percentages of total organic matter (TOM) content was determined by using the method recommended by Greiser and Faubel (Greiser and Faubel, 1988). A simple estimate of the organic contents can be derived from the mass of loss of ignition (LOI).imate of the organic contents can be derived from the mass of loss of ignition (LOI). This method involves drying the samples at a low temperature, then combusting the organic content at a high temperature. The samples were dried at 60°C in an oven (Model Memmert UM500) to determine the dry weight values. The sediment samples were crushed with a pestle and mortar to break up the clumps. Then, the dry sediments were placed into a pre-weighted crucible and burnt in the furnace ignited at 550°C for 8 hours. The sediment samples were re-weighed after the crucible cooled down. The loss of weight indicated the amount of total organic matter (TOM) in the samples.

Data analysis

The composition of the coexisting gastropod species was compared between the stations. The mean density of gastropod species was compared among stations and seasons using a one-way ANOVA using the SPSS 15 software. The pos-hoc test was then performed to determine the significance of differences between stations and seasons. Biotic data similarity matrices were constructed using the Bray-Curtis similarity. The sample relationships from the similarity matrices were displayed using non-metric multi-dimensional scaling (MDS) and CLUSTER analysis. Differences in univariate measures between stations were tested using a one-way analysis of variance (ANOVA) followed by a pos-hoc test (Macintosh *et al*., 2002).

The grain size distribution was measured. The statistics were then calculated using the grain size distribution data (mean, sorting and skewness). Based on the data obtained, statistical measures were calculated, and computation of mean size (Ø), sorting (Ø), skewness and kurtosis were carried out using the Moment method (Bale and Kenny, 2005). The data was then compared across stations and months using a one-way analysis of variance (ANOVA) and a pos-hoc test. The Moment method formulas are as Eqn. 1:

$$\text{Mean}=x=\sum(fm)/\sum(f)$$
$$\text{Standard deviation}=\sigma=\sqrt{(\sum f(m-x)^2)/100}$$
$$\text{Skewness}=(\sum f(m-x)^3)/(100*\sigma^3)$$

(Eqn. 1)

One way analysis of variance (ANOVA) was used to compare the mean percentage of total organic matter (TOM) among stations and seasons. The Eqn. 2 was used to compute the percentage of organic matter.

$$\text{Percentage of TOM} = \frac{\text{(Initial weight-final weight)}}{\text{Initial weight}} \times 100\%$$

(Eqn. 2)

The correlation between the abundance of coexisting gastropod species and environmental parameters was used in the one-way analysis of variance (ANOVA) followed by a post-hoc test using SPSS 15 software. The correlation was also done by using Pearson correlation and linear regression analysis using Excel 2007. PRIMER v6 was used to coordinate the grain size distribution data using a correlation-based principal component (PCA) analysis.

Results and discussion

Species composition

In the recent study (August 2014 to June 2015), a total of 9886 individuals of gastropods representing three coexisting species (*C. coralium*, *C. cingulata* and *B. zonalis*) were collected and identified in the lagoon area of Setiu Wetlands, Terengganu, Malaysia (Table 1). This study revealed that the most dominant coexisting species were *C. coralium* (45% of the total number of collected gastropods), followed by *C. cingulat*a (39%) and *B. zonalis* (16%) (Fig. 2). According to Barnes (2003), *C. coralium* is usually found in high densities up to 848 m^2 and is associated with *C. cingulata*, which also has a high population. Kamimura and Tsuchiya (Kamimura and Tsuchiya, 2004) stated in their study that *C. cingulata* could also coexist with *B. zonalis*. Interestingly, all three species can coexist in a single habitat in the Setiu wetland. All three species in a habitat with different compositions may be caused by the interaction occur between species and some abiotic or environmental factors (Barnes, 2003). The species coexistence and composition of each species influenced by the changing in environment temporally and spatially. *B. zonalis* was absent from Station 1 for all sampling periods.Spatial and temporal factors might be the factors that influenced the percentage abundance of coexisting gastropod species (Chesson, 1994).

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Table 1: Number of individuals of coexisting gastropods species collected from August 2014 to June 2015 in each station. ST=station

Family	Species	ST1	ST2	ST3	TOTAL
Potamididae	*Cerithidea cingulata*	1147	1695	1030	3872
Cerithiidae	*Cerithium coralium*	1820	529	2127	4476
Batillaridae	*Batillaria zonalis*	0	1163	375	1538
		2967	**3387**	**3532**	**9886**

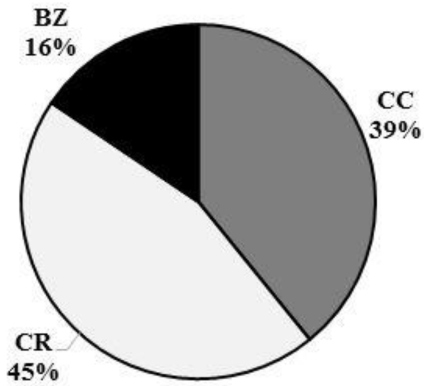

Figure 2: Percentage abundance of coexisting gastropods species found in the lagoon of Setiu Wetlands in two sampling series. a) July 2011 to May 2012 b) August 2014 to June 2015. CC: *C. cingulata*, CR: *C. coralium*, BZ: *B. zonalis*

The dominant species differ at each station as well (Fig. 3). *C. coralium* was the most abundant species at Station 1 (61% of the total coexisting gastropod species collected) and Station 3 (60%). Although there was interaction that allowed species to coexist in a habitat, according to Zhang *et al*. (2021), the composition or species that coexist will change over time as the environment changes. *C. cingulata* was found as the most abundant species only in Station 2 with 50% of the total coexisting gastropod species collected, followed by *B. zonalis* (34%) and *C. coralium* (16%). The results showed that when *C. coralium* was dominant at a station (Station 1 and 3), the percentage abundance of *B. zonalis* would decrease. On the other hand, if the station had a high percentage abundance of *B. zonalis* (Station 2), *C. coralium* would have a low percentage abundance. The clustering analysis of coexisting gastropod species based on Bray-Curtis similarity by PRIMER V6 software revealed that the coexisting gastropods were divided into two main clusters with 67% similarities.

C. cingulata and *C. coralium* were grouped in one cluster (due to their niches such as habitat preferences), while *B. zonalis* was alone in the other cluster (absent from Station 1) (Fig. 4). This might be due to the interaction between these two species (*C. coralium* and *B. zonalis*), an interspecific competition. According to Molles (Molles, 2005), interspecific competition is competition between two species that reduces the fitness of both. The effects of competition between the two species may not be equal.

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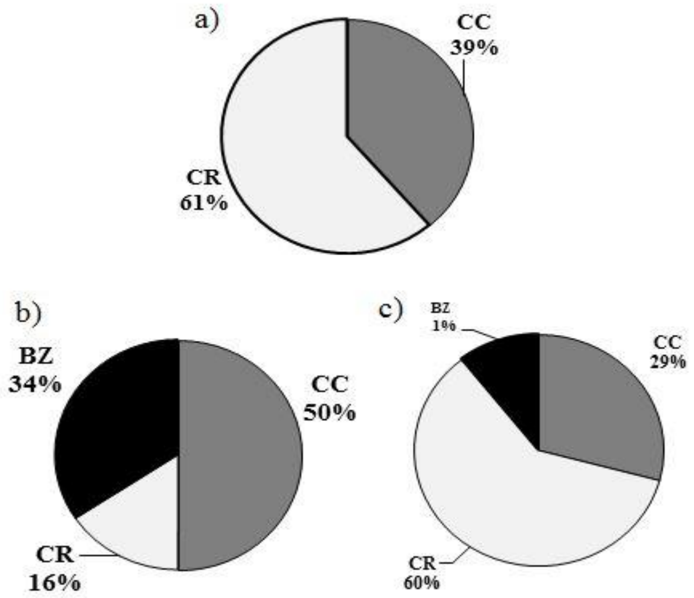

Figure 3: Percentage abundance of coexisting gastropod species present in the lagoon of Setiu Wetland, Terengganu, Malaysia by the station: a) Station 1, b) Station 2, c) Station 3; CC: *C. cingulata*, CR: *C. coralium*, BZ: *B. zonalis*

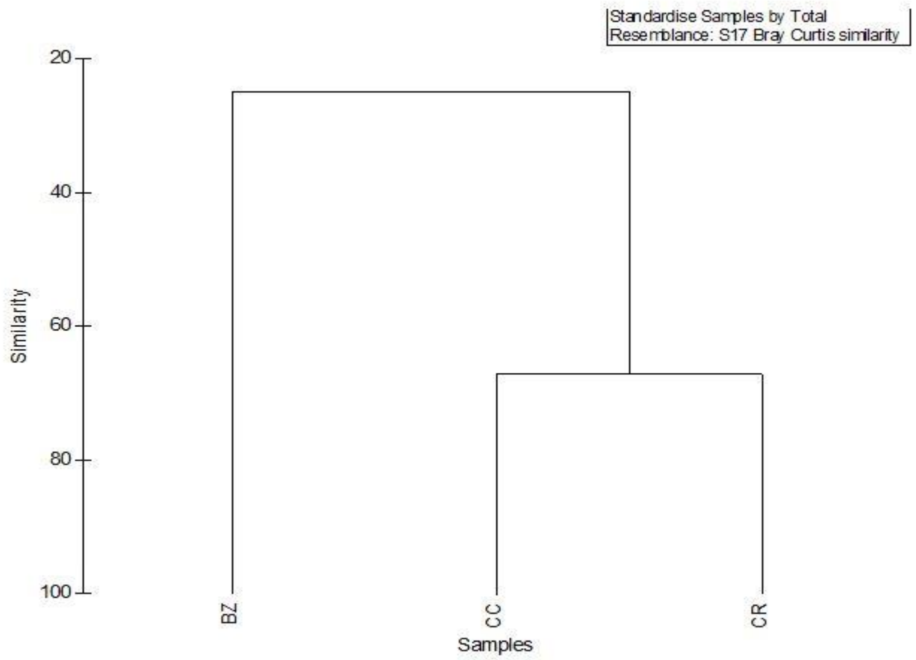

Figure 4: Clustering analysis of coexisting gastropods species based on Bray-Curtis similarity by PRIMER V6. BZ= *B. zonalis*, CC= *C. cingulat*a, CR= *C. coralium*

The individuals of one species may suffer greatly, and the other may less. The first concept of interspecific competition, which stated that an increase or reduction in the abundance of one species induces a drop or increase in the growth rate of its competitors (Rockwood, 2015). This was also the caused for *B. zonalis* absent from Station 1, which was due to a competition exclusion. When a superior competitor removes a poorer competitor from a

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competition, this is known as competition exclusion. When competition is high in a habitat due to limiting factors, there is no stabilizing (niche differences among species), and the inferior competitor with high fitness will eliminate the poorer competitor with low fitness (Castro and Huber, 2013; Zhang *et al*., 2021). According to Hardin's (1960) competition exclusion principle, full competitors, or species whose niches completely overlap, cannot coexist (Rockwood, 2015). Gause (1934) Principle stated that it is also difficult for two species with the same niche to coexist in the same habitat (Costa *et al.*, 2011; Gordon, 2000; Rockwood, 2015).

These findings indicated that there was an interaction between the gastropod species that coexisted. The interaction might be an interspecific competition that competes for the same resource to survive in a habitat. According to Byers (Byers, 2000), high-density snails can reduce food supply availability, affecting other species with similar food demands. In addition, Peter and Michael (2013) stated that when two species use the same resource, and the resource is limited, they must compete to survive in the habitat. One of the species usually turns out to be better at the competition called an inferior competitor. In some cases, species avoid excluding each other and coexist in the same habitat by sharing the same resources, but they may feed at different times and avoid each other. This situation is called resource partitioning (Rockwood, 2015). According to Levine and HilleRisLambers (Levine and HilleRisLambers, 2009), resource partitioning is one of the elements that allows species to coexist in a habitat. Resorce partitioning happened between these three coexistence gastropod species due to their different feeding modes and feeding at different times. *C. cingulata* and *C. coralium* are deposit-feeding gastropods but they actively feed at different times, which is *C. cingulata* feeds during the low tide, while *C. coralium* feeds during the high tide. *B. zonalis*, on the other hand, is a dual-feeding gastropod that feeds in both modes (suspension-feeding and deposit-feeding). As a result, resource partitioning is possible for all three gastropods, allowing them to coexist. Resource partitioning allows species that share the same preferences to coexist in a habitat, but the size of each species tends to be smaller.

Different microhabitat or patches also allow coexistence among the species (Schlägel *et al*., 2020; Zhang *et al*., 2021). From the observation in the field, these two species were found far from each other but still in a station or habitat. Each species would integrate patches or microhabitat in response with their resource needs and preferences, as well as the environmental structure available, selecting different sites and moving between them with varying frequency and time lags (Schlägel *et al*., 2020).

Correlation of coexisting gastropods species with environmental parameters

A variety of factors influenced coexisting gastropod species in Setiu Wetlands. Pearson correlation analysis

[DOI: 10.18331/SFS2022.9.1.10]

revealed a significant correlation between the abundance of *C. cingulata* and dissolved oxygen (r=0.33, *p*=0.05). Furthermore, the abundance of *C. coralium* was correlated to temperature and dissolved oxygen with *p*<0.05, but no significant correlation was found for *B. zonalis* (Table 2 and Fig. 5).

Table 2: Pearson-Linear correlation between abundance (A) of coexisting gastropods species (*B. zonalis* (BZ), *C. cingulata* (CC) and *C. coralium*) with environmental parameters

Environmental parameters		BZ	CC	CR
Sediment				
Mean Ø	r value	-0.17	-0.16	0.01
	p value	0.31	0.35	0.94
Sorting coefficient	r value	0.13	-0.22	0.18
	p value	0.46	0.20	0.28
Skewness	r value	-0.07	0.15	0.06
	p value	0.67	0.37	0.73
Silt + clay	r value	-0.06	-0.25	0.12
	p value	0.73	0.15	0.50
Total Organic matter (TOM)	r value	0.05	-0.25	-0.03
	p value	0.77	0.65	0.86
Water parameters				
pH	r value	-0.07	-0.07	-0.13
	p value	0.68	0.67	0.46
Temperature (°C)	r value	-0.01	-0.06	-0.40
	p value	0.97	0.71	0.02*
Salinity (PSU)	r value	0.14	0.07	-0.30
	p value	0.40	0.05*	0.08
Dissolved oxygen (mg/L)	r value	0.11	-0.33	0.43
	p value	0.54	0.05*	0.01*

* Indicates a significant difference at *p*=0.05/*p*<0.05.

As stated above, C. *cingulata* and *C. coralium* were related to dissolved oxygen (DO) but in different ways. The abundance of *C. cingulata* had a significant inverse relationship with dissolved oxygen (DO), but *C. coralium* was directly proportional to dissolved oxygen (DO). All study sites in this study had high oxygen concentrations, ranging between 4.72±0.56 to 5.26±0.43 mg/L. Kuk-Dzul and Díaz-Castañeda (Kuk-Dzul and Díaz-Castañeda, 2016) stated that organisms found in high oxygen concentrations were sensitive. These organisms are oxygen-dependent, and any changes in the concentration of oxygen may impact their abundance or distribution. Dissolved oxygen is essential for the survival of all aquatic organisms. This is because dissolved oxygen is one of the limiting factors for the metabolic rate of an organism (Chabot and Guénette, 2013). Oxygen is important for the respiration of organisms (Castro and Huber, 2013). The dependence of the gastropod species

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on dissolved oxygen concentrations can be used to monitor environmental health.

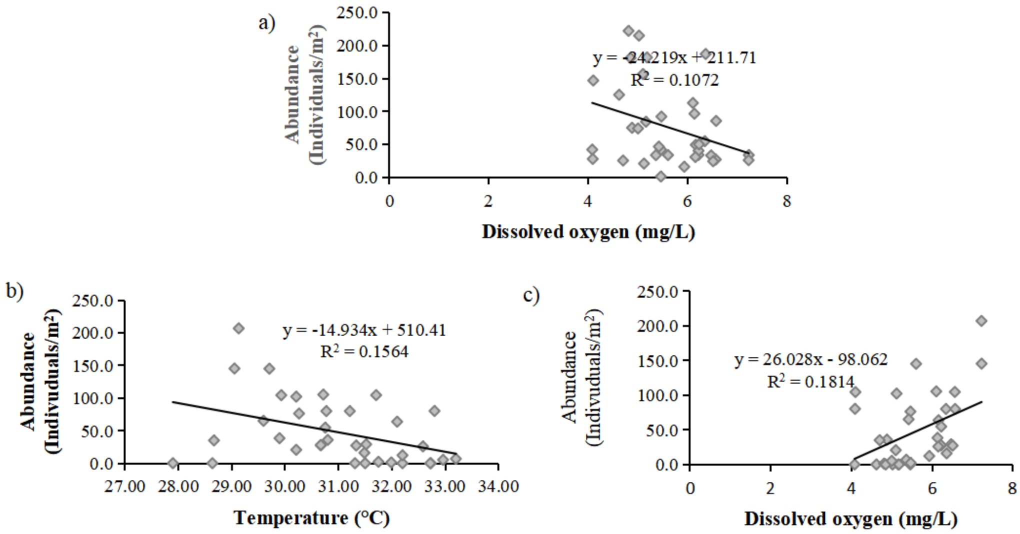

Figure 5: Simple linear regressions plots. a) *C. cingulata* against dissolved oxygen (mg/L) (R^2=0.107) (*p*=0.05) b) *C. coralium* against temperature (°C) (R^2=0.156) (*p*=0.02) c) *C. coralium* against dissolved oxygen (mg/L) (R^2=0.181) (*p*=0.01)

The abundance of *C. coralium* had a significant inverse relationship with temperature (Fig. 5). Temperature values ranged from 27.9±0.04 (December 2014) to 32.96±0.01°C (August 2014). The temperature values differ between the months. This might be due to the different seasons in Setiu Wetland, which are the North-East monsoon, Inter monsoon and South-West monsoon. The lowest temperature value was during the North-East monsoon, and the highest value was during the South-West monsoon. Extreme rainfall events occurred in Terengganu, including Setiu Wetland, during the North-East monsoon (December 2014), causing low temperatures in the area. The results obtained showed that *C. coralium* preferred low temperatures for their habitat preferences. Chabot and Guénette (Chabot and Guénette, 2013) stated that water breathers, including marine invertebrates, are ectotherms and temperature-dependent. Therefore, *C. coralium* are strongly influenced by temperature and have a range of temperatures that help their survival in the environment. Ectotherms are organisms with an internal body temperature similar to their surroundings (Garrison, 2013). Besides, the temperature of the water and dissolved oxygen are highly related to each other. According to Garcia and Gordon (Garcia and Gordon, 1992), high temperatures of water have a low oxygen solubility. As mentioned before, *C. coralium* also prefers habitats with a high concentration of oxygen. Climate warming is one of the elements that impacts the coexistence of different species (Zhang *et al.*, 2021). High

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temperatures in the environment can cause changes in species distribution patterns (Parmesan and Yohe, 2003). Furthermore, temperature is important since warming of the environment affects the vital rate of individuals, and most species have a limited thermal tolerance (Rohr *et al.,* 2018).

Conclusion

C. coralium was found to be the most common coexisting species followed by *C. cingulata* and *B. zonalis.* The interaction between each gastropod species and some abiotic or environmental elements has resulted in different composition for all three species. Each station has a different dominant species. The number and dominant species in the habitat were determined through interactions between coexisting species. As the environment changes, the composition and species coexisting in a habitat change. There were interactions occur among the coexist gastropod species in order to survive in the habitat. The increase and decrease in the abundance of a species in a habitat will affect the abundance of other species in the habitat.The limiting factor or resources that the coexist gastropods compete for is the same food sources. The factors that allow the coexistence of all the three gastropod species are resource partitioning, where they have different feeding modes (deposit-feeding and suspension-feeding) and different times of feeding (feed during high or low tide). Microhabitat is also one of the factors, which the gastropods were found in patches and far away from each species to decrease the competition among them.The abundance of the coexisting species is influenced by a variety of factors. The abundance of the coexisting species is influenced by a variety of factors. A significant relationship was found in *C.cingulata* with dissolved oxygen (DO). *C.cingulata* has a significantly inverse relationship with DO. Meanwhile, *C.coralium* has a significant relationship with DO and temperature. *C.coralium* preferred low temperature. The dependence of the gastropod species on DO concentration and temperature can be used to monitor environmental health. The findings of a recent study are helpful to evaluate habitat suitability, food availability, or the influence of management activities on target species and provide a formulating strategy for conservation and management of this ecosystem to maintain the ecological functions

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References

Bachok, Z., Mfilinge, P.L., Tsuchiya, M. and Meziane, T., 2006. Food source of coexisting suspension-feeding bivalve as indicated by fatty acid biomarkers,subjected to the bivalves abundance on a tidal flat. *Journal of Sustainability Science and Management*, 1, 92-111.

Bale, A.J. and Kenny, A.J., 2005. Sediment Analysis and Seabed Characterisation. In Eleftheriou, A., and McIntyre, A., (Eds.), Methods for the Study for Marine Benthos. (3rd ed.). Blackwell Scientific Publication.

Barnes, R.S.K., 2003. Interactions between benthic molluscs in a Sulawesi mangal, indonesia: The cerithiid mud-creeper *Cerithium coralium* and potamidid mud-whelks, *Terebralia* spp. *Journal of the Marine Biological Association of the United Kingdom*, 83(**3**), 483–487.

Buchanan, J.B., 1984. Methods for the study of marine benthos. Blackwell Scientific Publications, London.

Byers, J.E., 2000. Competition between Two Estuarine Snails: Implications for Invasions of Exotic Species. *Ecology*, 81(**5**), 1225.

Castro, P. and Huber, M.E., 2013. Marine Biology. (9th ed). McGraw-Hill, Inc.

Chabot, D. and Guénette, S., 2013. Physiology of water breathers: effects of temperature, dissolved oxygen, salinity and pH. *Climate Change Impacts, Vulnerabilities and Opportunities Analysis of the Marine Atlantic Basin*, 16–44.

Chesson, P., 1994. Multispecies Competition in Variable Environments. *Theoretical Population Biology*, 45(**3**), 227–276.

Costa, G.C., Franca, K.L., Oliveira-Junior, T.M. and Pichorim, M., 2016. Habitat use and coexistence in two closely related species of *Herpsilochmus* (Aves: Thamnophilidae). *Cogent Environmental Science*, 2(**1**).

Filippenko, D., 2011. Fauna of gastropod molluscs in the Curonian Lagoon littoral biotopes (Baltic Sea, Kaliningrad region, Russia). *Malacologica Bohemoslovaca*, 10, 79–83.

Garcia, H.E. and Gordon, L.I., 1992. Oxygen solubility in seawater: Better fitting equations. *Limnology and Oceanography*, 37(**6**), 1307–1312.

Garrison, T., 2013. Oceanography an invitation to marine science. (8th ed.). International Edition. Brook/Cole, Cengage Learning.

Gause, G. F., 1934. The Struggle for Existence. Baltimore: Williams & Wilkins.

Gordon, C.E., 2000. The coexistence of species. *Revista Chilena de Historia Natural*, 73, 175–198.

Greiser, N. and Faubel, A., 1988. Introduction to the Study of Meiofauna. Smithsonian Institution Press Washington.

Hardin, G., 1960. The competitive exclusion principle. Science (New York, N.Y.), 131(**3409**), 1292–1297.

Kamimura, S. and Tsuchiya, M., 2004. The effect of feeding behavior of the gastropods *Batillaria zonalis* and *Cerithideopsilla cingulata* on their ambient environment. *Marine Biology*, 144(**4**), 705–712.

Kuk-Dzul, J.G. and Díaz-Castañeda, V., 2016. The Relationship between Mollusks and Oxygen Concentrations in Todos Santos Bay, Baja California, Mexico. *Journal of Marine Biology*, 1–10.

Levine, J.M. and HilleRisLambers, J., 2009. The importance of niches for the maintenance of species diversity. *Nature*, 461(**7261**), 254–257.

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Macintosh, D.J., Ashton, E.C. and Havanon, S., 2002. Mangrove rehabilitation and intertidal biodiversity: A study in the Ranong mangrove ecosystem, Thailand. *Estuarine, Coastal and Shelf Science*, 55(**3**), 331–345.

Molles, M.C., 2005. Ecology Concept and Applications. (3rd ed.). Mc Graw Hill, Higher Education.

Nakisah, M.A. and Fauziah, A.B., 2003. Setiu Wetlands: Tranquility Amidst Plenty (1st ed.). Kolej Universiti Sains dan Teknologi Malaysia (KUSTEM).

Nakisah, M.A., Pon, C.K. and Choi, K.S., 2008. The Identification and Distribution of Naked Amoebae in the Water and Sediments of Setiu Wetlands, Terengganu. *Journal of Sustainability Science and Management*, 3(**1**), 23–29.

Nurul-Zalizahana, Z., 2013. Ecology of Gastropod in Setiu Lagoon, Terengganu, Malaysia. (Master Thesis). Universiti Malaysia Terengganu.

Ong, M.C., Kamaruzzaman, B.Y. and Joseph, B., 2009. Geochemical studies of Setiu lagoon, Terengganu, Malaysia. *Malaysian Journal of Science*, 28(**2**), 217–222.

Parmesan, C. and Yohe, G., 2003. A globally coherent fingerprint of climate change impacts across natural systems. *Nature*, 421(**6918**), 37–42.

Peter, C. and Michael, E.H., 2013. Marine Biology. (9th ed.). Mc Graw Hill, Higher Education.

Rockwood, L.L., 2015. Introduction to Population Ecology (2nd ed.). John Wiley & Sons Ltd.

Rohr, J.R., Civitello, D.J., Cohen, J.M., Roznik, E.A., Sinervo, B. and Dell, A.I., 2018. The complex drivers of thermal acclimation and breadth in ectotherms. *Ecology Letters*, 21(**9**), 1425–1439.

Sasekumar, A., 1974. Distribution of macrofauna on a Malaysian mangrove shore. *Journal of Animal Ecology*, 43, 51–69.

Schlägel, U.E., Grimm, V., Blaum, N., Colangeli, P., Dammhahn, M., Eccard, J.A., Hausmann, S.L., Herde, A., Hofer, H., Joshi, J., Kramer-Schadt, S., Litwin, M., Lozada-Gobilard, S.D., Müller, M.E.H., Müller, T., Nathan, R., Petermann, J.S., Pirhofer-Walzl, K., Radchuk, V., Rillig, M.C., Roeleke, M., Schäfer, M., Scherer, C., Schiro, G., Scholz, C., Teckentrup, L., Tiedemann, R., Ullmann, W., Voigt, C.C., Weithoff, G., Jeltsch, F., 2020. Movement-mediated community assembly and coexistence. *Biological Reviews*, 95(**4**), 1073–1096.

Swennen, C., Moolenbeek, R.G., Ruttanadakul, N., Hobbelink, H., Dekker, H. and Hajisamae, S., 2001. The Molluscs of the Southern Gulf of Thailand. *The Biodiversity Research and Training Program (BRT), Thai Studies in Biodiversity*, 4, 1–210.

Vorberg, R., Fey, F. and Jansen, J., 2009. Subtidal habitat. *Quality Status Report Thematic Report*, 13, 1-18.

Walker, P. and Wood, E., 2005. Life in the Sea, the Saltwater Wetland. Facts on file, Inc. NY.

Zhang, P., Wang, H., Jackson, M.C. and Zhang, M., 2021. Warming and Predation Alter Consumer Coexistence. *Research Square*, 1–22.