THE RELATIONSHIP OF SEDIMENT GRAIN SIZE AND ASIAN HARD CLAM DISTRIBUTION AS SUSTAINABLE MANAGEMENT INDICATOR

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ABSTRACT

Setiu Wetland located in Northern Terengganu is a highly important site for conservation and at the same time provides sustenance to the local communities. The wetland is under immense environmental pressure from growing population, agriculture and fishery activities. Asian hard clam (Meretrix meretrix) is one of many bivalve species that is consumed and provide income to the local communities, has been declining in numbers. This study aimed to identify habitat preferences indicator for the Asian hard clam and used as the indicator of sustainable management. The relationship between grain size and the clam was evaluated using Spearman correlation and simple linear regression. Results show that the population of the clam decreases as the location distant further from the river mouth. Medium coarse grain size (MC355) and coarse grain (C500) are significantly correlated with the clam population (MC355: r=0.360 & C500: r=0.361; P<0.05). These study findings provide a new viewpoint for practical management tools to determine Limit of Acceptable Changes to maintain Setiu Wetland’s natural resources and safeguarding local communities’ sources of livelihood.

Keywords: Asian Hard Clam, Limit of Acceptable Changes, Sediment Grain Size, Sustainable Development
The Relationship of Sediment Grain Size and Asian Hard Clam Distribution as Sustainable Management Indicator


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1. INTRODUCTION

Molluscs are ecological and commercially important. These organisms play a major role in nutrient cycling and structuring of estuarine food web (Shumway, 2011) [13]. They are also used as bio-indicators to indicate pollution and other stresses (Wan et al., 2018) [15]. Highly dynamic hydrology patterns and landscape changes occurred around Setiu lagoon could impose negative impact on the abundance of bivalves and eventually local community’s livelihood. Setiu Wetland is a unique and important ecosystem that needs to be conserved and sustainably developed. Setiu Wetland complex is one of the most bio diverse sites in the east coast of Peninsular Malaysia but face intense threat from infrastructural development & population growth (Salam et al., 2017) [8]. Majority of Setiu local communities is classified as Ecology Based Communities where they are highly dependent on natural resources from the wetlands such as fishermen, traditional craft making or aquaculture operators (Salim et al., 2015) [9].

There are countless studies on bivalves focused on feeding behaviour and ability to predict mollusc growth offers the prospect of a commercial activity that is economically stable (Sara and Mazola, 2004) [10]. In addition, molluscs are known to play important roles in transforming nutrients in sediments, however, guidelines to optimize sediment restoration are not available to maintain its population (Shen et al., 2016) [12]. Water quality particularly salinity is not the most important variable determining zonation in estuaries especially in temporarily open/closed estuaries that have very dynamic changes such as in Setiu Wetland (Teske and Wooldridge, 2003) [14]. Rare storm events could cause temporary changes but do not significantly affect bivalves, however continuous changes due to anthropogenic activities, on the other hand, has negative impact on bivalves (Norkko et al., 2006) [7]. Changes to sediment structure could compromise the existing benthic diversity (Chen & Bendell, 2013) [2]. These suggest that the crucial role of these habitats must be integrated into management perspectives (Barbier et al., 2007) [1] and currently, available information are difficult to be applied for management of an estuary.

The challenge for sustainable development is identifying what constitutes unacceptable environmental change, with little or no information about how long effects will last (Cooper, 2013) [3]. Limit of acceptable changes is variation or threshold changes allowed to occur without causing any changes in ecosystem’s characteristics. The approach taken in this study offers a simple and cost-effective means of assessing the acceptability of changes in sediment composition that help outlines the management actions. This study objective is to correlate the relationship between the species abundance with sediment grain size and carbon content for better understanding the threat of changing substrate and support the idea to develop a practical monitoring tool without laborious and expensive laboratory analyses.
2. MATERIALS AND METHODS

2.1. Study Area

Setiu Lagoon is located in the northern part of Terengganu facing the South China Sea as shown in Figure 1. Setiu lagoon is an important location for fishery industry and majority of the fishermen in Setiu are still using traditional, small scale fishing techniques (Jani, 2015) [6]. The lagoon stretch about 13km and subjected to strong coastal current that flows relatively parallel to the coastline and strong wind during monsoon season that usually occurs at the end of the year (Yaacob and Mustapa, 2010) [16]. A common and highly valuable bivalves species selected for the study, *Meretrix meretrix* L. or Asiatic hard clam, is a triangular-shaped clam with smooth, glossy and multi-coloured shells that inhabits sandy substrates in the lower intertidal and shallow subtidal areas of Asia (Zhuang & Wang, 2004) [17].

![Figure 1 Location of sampling station in the Setiu Lagoon.](image)

This study was conducted at 5 sampling stations (Figure 1 and Table 1) with distances of approximately 1 km apart in an area along Setiu Lagoon stretching approximately 8km in length from the permanent river mouth of Kuala Setiu.

<table>
<thead>
<tr>
<th>Station</th>
<th>Coordinates</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5°39’38.5”N; 102°44’30.8”E</td>
<td>Setiu wetland lagoon has a total length of approximately 13km. The lagoon is feed with freshwater from Sg. Setiu and Sg Ular in the south and Sg Dendong in the north. The lagoon is active with aquaculture activity in the north near to Station 5 and 4. A jetty for local fishermen is located near to Station 3, whereas Station 2 and 1 locations are frequently dredged to enable fishing boats to traverse the lagoon to the jetty.</td>
</tr>
<tr>
<td>2</td>
<td>5°40’07.43”N; 102°43’ 56.45”E</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>5°40’21.58”N; 102°43’21.72”E</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>5°40’45.86”N; 102°42’44.95”E</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>5°41’38.27”N; 102°42’08.07”E</td>
<td></td>
</tr>
</tbody>
</table>

Samples were collected on sand banks during low tides 20m from shores. Three 10m transect lines were prepared and 3 quadrants in each transect line that cover about 100m² in each station. The sampling areas were scrape using garden rake until 20cm in depth to collect the species. Sediment samples also collected on for grain size analysis. Sediment samples were brought to laboratory was air dried prior to analyses. Fifty grams of dried sediment then were crushed with mortar and sieved through a stack of 7 different mesh size on an
automated sieve shaker starting with 1000µm for very coarse grain (VC1000), followed by coarse: 500µm (C500), medium coarse: 355µm (MC355), medium: 250µm (M250), medium fine: 125µm (MF125), fine: 63µm (F) and ultra-fine: <63µm (UF). The weight of sediment in each sieve was then calculated in percentage for grain size composition. Total carbon in sediment samples was determined by lost on ignition method where 10 grams of sediment samples were ignited in a furnace at temperature of 700°C for approximately 5 hours before the final samples were weighed again when cooled to obtain the amount of carbon that has been lost. The amount of carbon also represented in percentage. The distribution of all parameters is non-Gaussian, thus the Kruskal-Wallis and Spearman correlation analysis were applied in analysing the data. The statistical analysis is deemed for the 95 % confidence level. Statistical analyses were conducted with the help of SPSS® version 25.

3. RESULTS AND DISCUSSION

The composition for different grain size at each station was depicted in Figure 2. The Kruskal-Wall test revealed there exist statistically significant difference of grain size composition among sampling stations (p<0.05), except for coarse grain sediment (C500) size which has similar percentage (p>0.05). Overall, the composition is ranging from 13% to 27%. Station 1 which is nearer to the permanent river mouth was observed to compose of approximately 53% of very coarse to medium coarse grain and 47% of medium to ultra-fine grain. Station 4 and 5 have approximate 60:40 ratio of coarse and fine grain. This result is expected because usually station near to river mouth has more coarse grain as the lagoon-estuary hydrodynamic system which is mainly a combination of tide and river outflow. The distribution of sediment was also influenced by stronger wave and wind energy during the northeast monsoon season (Yaakob, 2010) [16]. Station 4 and 5 are located in the northern part of the lagoon where the Dendong River flows in. The rivers discharging into the lagoon originated from higher ground which usually has high flow and erosion rate (Satyamurthi, 2015) [11].

Station 2 has the lowest coarse grain which consists of 35% but the rest is the medium to ultra-fine grain. Although Station 2 is near to Ular River discharge, the river flow, however, has been altered due to construction of a dam at the upstream for irrigation purpose. Station 3 has extremely high coarse grain size with over 77% is very coarse grain. This sampling station is near to a sand pumping station that was positioned, close the break of the sand bank that occurred during the last monsoon season on several months before the sampling conducted. This station has very coarse sediment due to the anthropogenic relocation of sand from the beach and the sand pumping activity has re-worked of the sediment where the fine grain particles are churned up in the water column and moved elsewhere to calmer water.
The number of *M. meretrix* individuals and total carbon is tabulated in Table 2. It shows that Station 1 has the highest average number of *M. meretrix* collected with average of 10 individuals/m² while Station 2 and 3 have the lowest number collected with average of 1 individual. Total carbon, however, was observed at high percentage in station 2 and 4 with average of 1.23% and 1.15%, respectively. Station 1, 3 and 5, however, have slightly lower total carbon with average of 0.72%, 0.87% and 0.86%, respectively. It was found that there exists statistically significant different (p<0.05) of total carbon in each station.

Table 3 shows that a positive and significant relationship between the species abundance with the presence of medium course (MC355) and coarse sediment (C500). Positive correlation between sediment structure and bivalves distribution is important to achieve long-term restoration of coastal ecosystems (Donadi et al, 2014) [4]. Although Station 3 has highest very coarse sediment (VC1000), it is not preferred by the species.

### Table 2 The evaluated chemical and physical contaminants at study area

<table>
<thead>
<tr>
<th>Station</th>
<th>S1</th>
<th>S2</th>
<th>S3</th>
<th>S4</th>
<th>S5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average number of individual (per m²)</td>
<td>10.33</td>
<td>1.11</td>
<td>1.00</td>
<td>2.78</td>
<td>2.56</td>
</tr>
<tr>
<td>Total carbon (%)</td>
<td>0.72</td>
<td>1.23</td>
<td>0.87</td>
<td>1.15</td>
<td>0.86</td>
</tr>
</tbody>
</table>

### Table 3 Spearman correlation coefficient (r) between sediment grain size and *M. meretrix* abundance

<table>
<thead>
<tr>
<th></th>
<th>UF</th>
<th>F63</th>
<th>MF125</th>
<th>M250</th>
<th>MC355</th>
<th>C500</th>
<th>VC1000</th>
<th>MMeret</th>
</tr>
</thead>
<tbody>
<tr>
<td>UF</td>
<td>1</td>
<td>-.254</td>
<td>-.512</td>
<td>-.384</td>
<td>-.137</td>
<td>-.184</td>
<td>.412</td>
<td>.111</td>
</tr>
<tr>
<td>F63</td>
<td>1</td>
<td>.761</td>
<td>.370</td>
<td>.219</td>
<td>-.204</td>
<td>-.763</td>
<td>-.004</td>
<td>.233</td>
</tr>
<tr>
<td>MF125</td>
<td>1</td>
<td>.561</td>
<td>.293</td>
<td>.444</td>
<td>.551</td>
<td>.052</td>
<td>-.468</td>
<td>.033</td>
</tr>
<tr>
<td>M250</td>
<td>1</td>
<td>.561</td>
<td>.293</td>
<td>.444</td>
<td>.551</td>
<td>.052</td>
<td>-.468</td>
<td>.033</td>
</tr>
<tr>
<td>MC355</td>
<td>1</td>
<td>.561</td>
<td>.293</td>
<td>.444</td>
<td>.551</td>
<td>.052</td>
<td>-.468</td>
<td>.033</td>
</tr>
<tr>
<td>C500</td>
<td>1</td>
<td>.561</td>
<td>.293</td>
<td>.444</td>
<td>.551</td>
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<td>-.468</td>
<td>.033</td>
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<tr>
<td>VC1000</td>
<td>1</td>
<td>.561</td>
<td>.293</td>
<td>.444</td>
<td>.551</td>
<td>.052</td>
<td>-.468</td>
<td>.033</td>
</tr>
<tr>
<td>MMeret</td>
<td>1</td>
<td>.561</td>
<td>.293</td>
<td>.444</td>
<td>.551</td>
<td>.052</td>
<td>-.468</td>
<td>.033</td>
</tr>
</tbody>
</table>

*Correlation is significant at the 0.05 level
The Relationship of Sediment Grain Size and Asian Hard Clam Distribution as Sustainable Management Indicator

**Correlation is significant at the 0.01 level**

The simple linear regression was established based on the MC355 grain size and C500 grain size with the M. meretrix. It shows that the MC355 has high $R^2$ compared to C500. Thus the medium coarse grain is more preferred by the *M. meretrix*. Hence, it is possibly composition of medium coarse, MC355 play an important role for the drifting *M. meretrix* larvae to settle down. Nonetheless, estuaries are highly dynamic ecosystem which experiences daily tidal rhythms, storm and surge events. Though the larvae may settle down in any of the stations that have the suitable composition of preferred grain size, the growth and mortality of the larvae are affected by other factors such as food sources, temperature and salinity. Sediment grain size and sampling date had greater influence on benthic community (Goldberg et al., 2014) [5]. Thus, this study set a merit for an in-depth study of *M.meretrix* growth in the future.

**Table 4** Simple linear regression analysis of significant correlation for MC355 and C500 grain size

<table>
<thead>
<tr>
<th>Grain size</th>
<th>R²</th>
<th>Equation</th>
</tr>
</thead>
<tbody>
<tr>
<td>MC355</td>
<td>0.279</td>
<td>$M. meretrix = 0.313(MC355) − 0.684$</td>
</tr>
<tr>
<td>C500</td>
<td>0.026</td>
<td>$M. meretrix = 2.270(C500) + 0.060$</td>
</tr>
</tbody>
</table>

4. CONCLUSION

Preparing a management plan for sustainable development of Setiu Wetlands is a daunting task. This study provides important information needed to set the limit of acceptable changes of Setiu Lagoon. Although MC355 and C500 were identified as the preferred size for *M. meretrix* to settle, there is a need to correlate this study outcome with the species ecology and biology perspective. In addition, the existence of other bivalves’ species also requires an in-depth study to determine possible competition or invasive species impact on the overall ecosystem. Results of this study provide new perspective for practical tool for coastal ecosystem restoration. Future studies urgently needed and have to consider several different time scales, the range of habitats and other environmental conditions.

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