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TROPICAL SEAGRASS DENSITY PHASE SHIFT DETECTION USING SPATIAL ANALYSIS TOOLS

Anisah Lee Abdullah, Anastacia Amanda Anscelly
Geography Section, School of Humanities, Universiti Sains Malaysia, Penang, Malaysia

Abstract-* Coastal development activities, land use-cover change and agricultural practices occurring in phases and according to state plans may have its impact on the directional trend of seagrass abundance and its density, thus presumably causing 'phase shifts' in its distribution. This study was carried out to ascertain the possible 'phase shift' effect of coastal land reclamation and development on existing seagrass density spatial distribution of Halophila ovalis (R.Br.) Hook.f. and Halophila beccarii Asch. surrounding a man-made islet within Penang waters. The ArcGIS 10 spatial analysis tools, Standard Deviational Ellipse (SDE) and Standard Distance (SD), were applied to determine 'phase shifts' as an indicator of possible effect of coastal land reclamation on the seagrass density distribution. Seagrass shoot densities data used were from year 2003 and 2009 representing pre-coastal development period, and 2009-2012 representing on-going and ending of coastal development period. Results showed SDE of seagrass experienced shifts from west to north-west direction from 2003 to 2012, away from the coastal land reclamation site. SD result showed seagrass distribution in the islet shifted from west to east, and was more compacted and concentrated in 2012. The shifts of seagrass mean centre from west to the east also coincided with SD analysis where the largest distance value of 28.21m calculated from centroid occurred in 2012. The directional trend, compactness and mean centre of seagrass, i.e. the 'shift', observed to be directed away and concentrated further from the coastal development site by 2012.

Keywords - Coastal reclamation, *Halophila ovali, Halophila beccarii,* Standard Deviational Ellipse, Standard Distance

I. INTRODUCTION

Powerful and appropriate biological indicators have commanded vital roles in the measurement of ecological quality in the environment. In coastal waters seagrass has been suggested as a sensitive indicator for an overload of nutrient inputs from land use practices [1] (Burkholder et al., 2005). Losses of seagrass area have occurred all over the world. Land reclamation had always been thought to denudate seagrass in its nearby area [2, 3]. They were normally found to be in poor condition within the vicinity of reclaimed area and healthier further away [4, 5]. Fine sediment released from reclamation sites were thought to increase turbidity and reduction in benthic vegetation, which includes seagrass [6]. Apart from that, increased in water velocity resulted from reclamation sites also lead to seagrass decline [7].

Omran and Wah (2012) [8] on a study of the possible impact of waterfront projects in Penang Island found that the projects had thought to be destroying the natural beach and affecting its ecosystem. In addition, a study by Ramly (2008) [9] on the impact of Tanjong Tokong land reclamation project on the coastal areas of Penang showed that land reclamation had impacted the wave transformation, sediment transport, and coastal evolution of the nearby area. The project had increased wave erosion and change in sediment transport rates mainly due to the influence of incoming local wave height and direction.

In this case, the land reclamation of the Light Waterfront development, which was built on an approximately 30 hectares reclaimed land off the eastern coast of Penang Island opposite the study area 'Pulau Gazumbo' (Fig. 1), had caused concern to the seagrass status in the islet due to its proximity.

Source: Google Earth Satellite Imagery, 3 February 2016

Fig. 1 The seagrass study area of 'Pulau Gazumbo'

The Light Waterfront development is feared to have affected and deteriorated the seagrass and the delicate marine lives in the islet. It is deemed important to study the seagrass density shift in this case because the study area lies in the transition zone between larger seagrass meadows between Phuket and Tarutao in South Thailand and Merabung in Johor, south Peninsular Malaysia. GIS had been associated with seagrass mapping. Nevertheless, studies on spatial analysis particularly Standard Deviational Ellipse (SDE) and Standard Distance (SD) analysis in seagrass mapping have yet to be found to date. Due to this, the need to look further on the impacts is essential to gain a different perspective

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particularly in terms of spatial analysis. The objective of this study was to determine the possibility of density phase shift in the seagrass in relation to the coastal reclamation.

II. MATERIALS AND METHOD

Study site

The study site nicknamed ‘Pulau Gazumbo’ (5˚21’N, 100˚19’E, 3482m^2) is an officially-unnamed man-made islet situated on the north east of Penang Island, Malaysia. It’s pea-shape was a result of dumped dredged materials from the South Channel when the Penang Bridge was constructed in October 1985 [10, 11,]. The islet is home to common marine lives - horseshoe crab *Tachypleus gigas* [12], gastropods [13], bivalves [14] and sea anemones [15, 16]. Dugong feeding trails were seen before in this tiny seagrass area although the mammal itself was never spotted. This ascertained the importance of the tiny ecosystem.

A small mangrove stand, mainly of *Avicennia* sp., is located at the west-southwest section of this islet. Since mangroves are also nature’s own sediment trap it is also within this area that most mudflats are found. Colonization of submerged vegetation occurred over the years through a series of succession around the coastal waters of the islet. Submerged vegetation are mostly seagrass where the dominant species is *Halophila ovalis* (R.Br.) Hook.f [11] and *Halophila beccarii* Asch. [10, 11, 13] found at the mudflats of mangrove stand; while *Halophila spinulosa* [10] and *Enhalus acoroides* (L.f.) Royle [10, 17] are seasonally spotted but the coverage is negligible.

Halophila beccarii Asch., commony known as Ocean Turf Grass with Species Code: Hb, has been listed as Vulnerable under criterion B2ab(iii)c(ii,iii) ver 3.1 under the IUCN Red List Category & Criteria [18] where its global population trends is in decline. *Halophila ovalis* (R.Br.) Hook.f. with Species Code: Ho, has been listed as Least Concern with stable population by the IUCN Red List [18]. This species is known to be widespread and recovers quickly as it is quite resilient to disturbances. *Halophila spinulosa* with Species Code: Hn, too has a status of Least Concern under the IUCN Red List with population trend being reported as stable [18]. This species only appear occassionaly within the study area. Similarly, *Enhalus acoroides* (L.f.) Royle with Species Code: Ea is listed with status Least Concern but is reported to have a decreasing population trend by the IUCN Red List [18]. According to Green and Short (2003) [19], *E. acoroides* is slow-growing, persistent species with poor resistance to perturbation.

Data analysis

Data of seagrass shoot densities (number of shoots/m^2) for species *H. ovalis* and *H. beccarii* for year 2003 [12], 2009 [20] and 2012 are used in this study. *E. acoroides* and *H. spinulosa* data are not used as the shoot densities, which are < 7 shoots/m^2 are almost negligible. Seagrass shoot density was collected based on Line Intercept Transect (LIT) and NaGISA Protocol [21] from the upper (a) and lower (b) littoral zones. Eight stations (T1-T8) were positioned within each littoral zone (Fig. 2). Five quadrat samples were collected from each station. Standard Deviational Ellipse (SDE) and Standard Distance (SD) from GIS software ArcGIS 10 was applied in this study. Base map of ‘Pulau Gazumbo’ and its littoral zone was digitized earlier with ArcGIS 10.

Two steps were needed in these analyses. First, seagrass shoot density data stored in Microsoft Excel was transferred as an attribute data into ArcGIS 10. Next, SDE and SD analysis in the *Spatial Statistics Tools-Measuring Geographic Distributions* in ArcGIS 10 were applied.

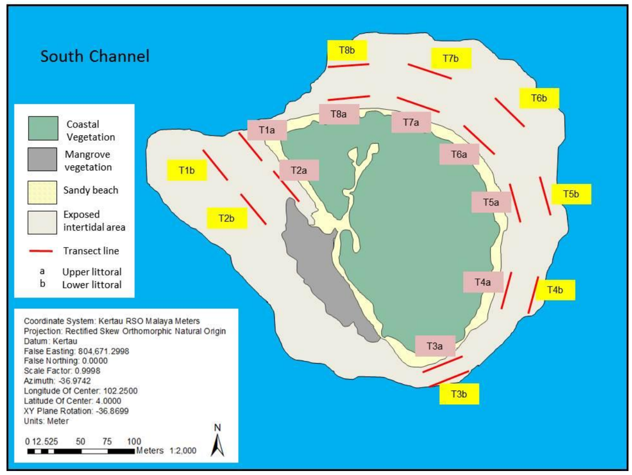

Fig. 2 Locations of transect lines and sampling stations for data collection

Centroid of ‘Pulau Gazumbo’ and mean centre of the seagrass shoot density data were calculated using the *Spatial Statistics Tool* in ArcGIS 10. Centroid which calculates the centre location of ‘Pulau Gazumbo’ sets as a reference point for the shift detection of SDE and SD, while mean centre calculates the centre of concentration of seagrass shoot density. Four quadrants (Q1-Q4) were divided across the centroid for scientific measurement purposes where it serves as a reference for the directions of both SDE and SD ellipses analysed.

III.RESULTS AND DISCUSSION

According to shoot density classification by Kirkman (1985) [22] shown in Table 1, density of seagrasses in the study area is considered to be between moderate to high.

Table 1. Categories of seagrass densities. (Source: Kirkman, 1985)

Seagrass density (shoots/m^2)	Category
< 1,000	Low
1,000-2,000	Moderately low
2,000-3,000	Moderate
3,000-4,000	Moderately high
>4,000	High

Shoot densities for seagrasses between year 2003, 2009 and 2012 are given in Fig. 3-5 respectively. Dominance of *H. ovalis* is evident in the charts shown. However, *H. beccarii* is only found at one location which is the small mangrove area located at the west-southwest section of the island. The charts showed a drastic decline in seagrass densities between 2003, 2009 and 2012. Most transect stations recorded shoot densities greater than 2000 shoots/m^2 between 2003 and 2009. Greatest decline is observed in 2012 with all transect stations recorded less than 800 shoots/m^2. The IUCN Red

List Vulnerable species, *H. beccarii*, showed a serious decline with a low density of 27 ± 61 shoots/m^2 in 2012 compared to its high densities of 15,968 ± 4,646 shoots/m^2 in 2003 and 11,477 ± 3,560 shoots/m^2 in 2009. The period of 2009-2012 is expected to have big impact on the seagrass density distribution within the study area because that marked the peak coastal development within the vicinity of the study area. Moreover, it will take time for the impact to be measured and detected for the seagrass area.

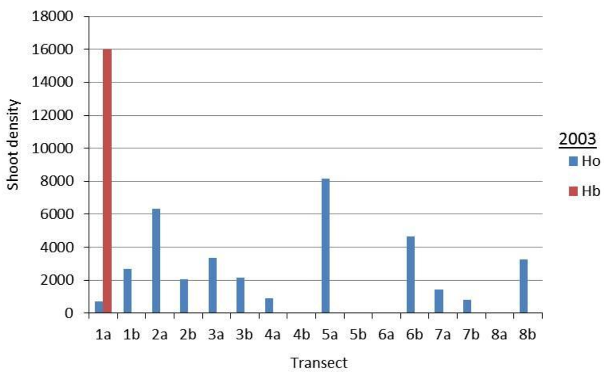

Fig. 3 Shoot densities (shoots/m^2) of *Halophila ovalis* and *Halophila beccarii* 2003

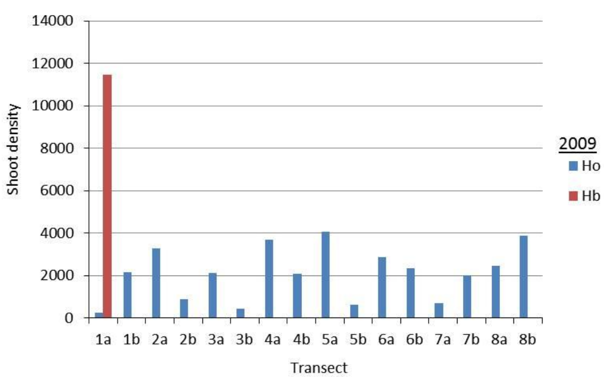

Fig. 4 Shoot densities (shoots/m^2) of *Halophila ovalis* and *Halophila beccarii* 2009

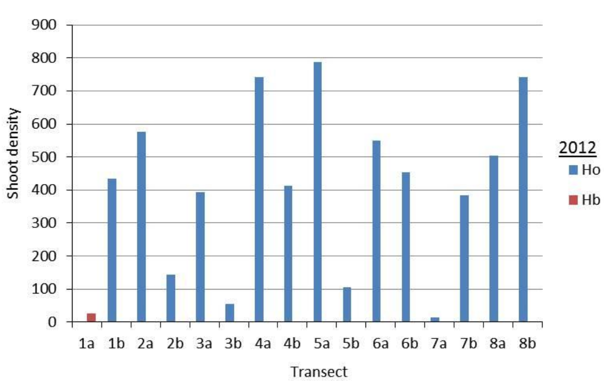

Fig. 5 Shoot densities (shoots/m^2) of *Halophila ovalis* and *Halophila beccarii* 2012

SDE ellipses depicting the directional trend of seagrass abundance had shifted from west to the north-west direction from 2003 to 2012 (Fig. 6). SD ellipses depicting the compactness of the seagrass abundance had shifted from west to the east from 2003 to 2012. The SD ellipse was observed to be more compact in 2012 than in 2003 and 2009 (Fig. 7).

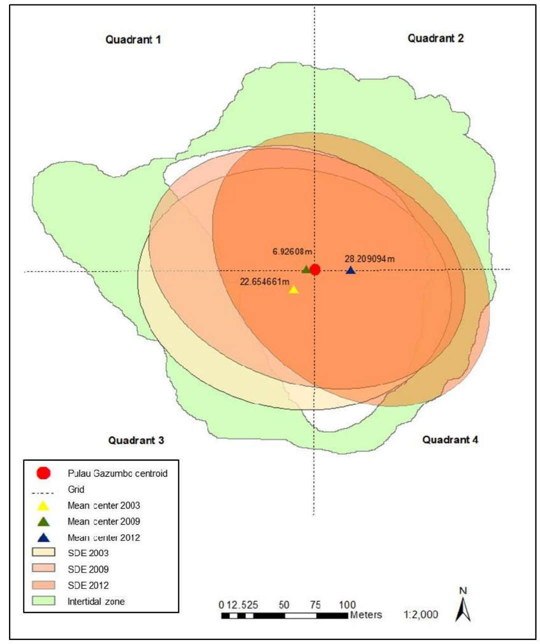

Fig. 6 Temporal changes of Standard Deviational Ellipse and mean centre of seagrass mean shoot density year 2003, 2009 and 2012

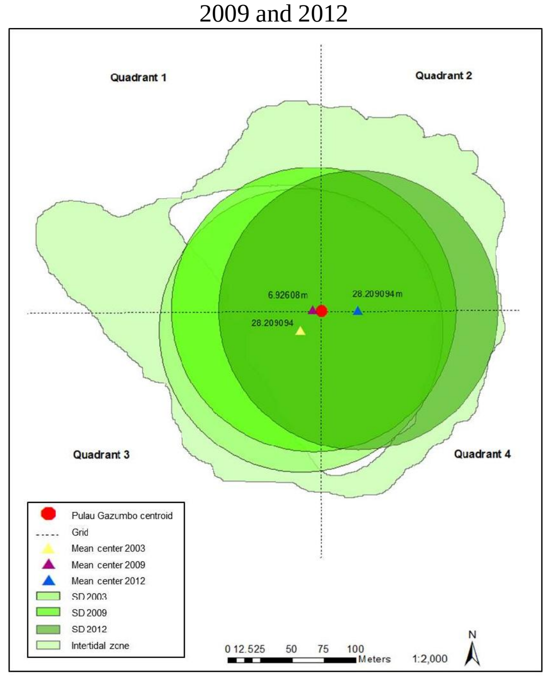

Fig. 7 Temporal changes of Standard Distance and mean centre of seagrass mean shoot density year 2003, 2009 and 2012

The mean centre which depicts the concentration of seagrass abundance had also shifted from west to the east from 2003 to 2012. The mean centre was at 22.65m in the south-west of the centroid in 2003; 6.93m in the west of the centroid in 2009; and 28.21m in the east of the centroid in 2012. Disturbance from the coastal development in the west might have contributed to the shift of both SDE and SD ellipses. The shifts of SDE ellipses' direction show that seagrass in 'Pulau Gazumbo' had experienced shifts in its directional trend. A higher abundance of seagrass in station 1 (Q1) was thought to have influenced the directional trend of the ellipse in 2003. In 2009, the direction of ellipse turned slightly to the north. High seagrass abundance recorded at station 1(Q1) was thought to influence the predominant orientation of the ellipse in the west. However, the increment of seagrass abundance in station 8 (Q1) could have caused the ellipse to tilt towards the north direction in 2009. In 2012, the ellipse had completely tilted towards the north-west direction. Decrement of seagrass abundance in station 1 (Q1), and increment of its abundance in station 5 (Q2) and 4 (Q4) had probably caused the SDE to shift from west to the east side of the islet.

Meanwhile, spatial analysis of SD shows that the dispersion of seagrass abundance in 'Pulau Gazumbo' had shrunk in 2012 which is at the last phase of coastal development. The movement of SD ellipses was similar as the movement of seagrass mean centre. The calculation of SD coincides with the mean centre. The movements of SDE, SD and seagrass mean centre strengthen the hypothesis where the Light Waterfront development had an effect on the spatial distribution of seagrass density in 'Pulau Gazumbo'. The density phase shift detected is probably due to two fundamental reasons: (1) the dense matte network of seagrass rhizomes beneath its substratum, and (2) their requirements mainly for sufficient light and sediment conditions. The high resilience of seagrass species *H. ovalis* is probably attributed to its ephemeral nature with very high turn-over and high seed set. This species is well adapted to high disturbance levels [19]. As a result, the spread of these seagrasses were naturally altered at its best possibility based on the modifications by disturbances in the requirements for survival.

IV. CONCLUSIONS

SDE analysis correspondingly showed changes of directional trend before and during the Light Waterfront coastal development. Directional trend of seagrass was towards the west in 2003 but had shifted to north-west in 2009 and 2012. Additionally, SD analysis also showed that seagrass abundance was more concentrated in the east of the islet in 2012 (after reclamation; last phase of coastal development) compared to 2003 (before reclamation) and 2009 (during reclamation) where they were more dispersed. SDE and SD spatial analysis adopted in this study proved that these methods are very informative and constructive in determining the effect of coastal development on seagrass density spatial distribution particularly where conservation and management of coastal and marine natural resources are concerned. The directional trends, degrees of compactness and the shift in distance of dispersion furnish informative data for decision making process to support conservation efforts. This is invaluable to conservation because with the world's fast dwindling seagrass ecosystems, every bit of even the smallest seagrass beds is worth conserving to maintain the ecosystem services which human beings rely and depend on.

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