APPLICATION OF SPATIAL ANALYSIS IN ASSESSING THE EFFECT OF COASTAL LAND RECLAMATION AND DEVELOPMENT ON SEAGRASS *Halophila ovalis* AND *Halophila becarrii* DISTRIBUTIONS IN PENANG WATERS

Anisah Lee Abdullah* and Anastacia Amanda Anscelly
Geography Section, School of Humanities, Universiti Sains Malaysia
*Corresponding author's e-mail: anisah@usm.my

ABSTRACT: The aim of this study is to ascertain the possible effects of coastal land reclamation and development on existing seagrass spatial distribution of *Halophila ovalis* and *Halophila beccarii* surrounding a man-made islet within Penang waters. The hypothesis was that coastal land reclamation and development has a negative effect on existing seagrass distribution and density. 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 distribution. Seagrass shoot densities data used were from year 2003, 2006 and 2009; where 2003 and 2006 represented pre-coastal development period, while 2009 represented on-going coastal development period. Results showed SDE of seagrass experienced shifts from west to north-west direction from 2003 to 2009, which is away from the coastal land reclamation site. In addition, SD result showed seagrass distribution in the islet had shifted from west to east, and was more compacted and concentrated in 2009. 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 2009. The shifts in seagrass SDE, SD and mean centres strengthened the hypothesis that the coastal land reclamation and development had a negative effect on seagrass spatial distribution and density in Penang waters. The directional trend, compactness and mean centre of seagrass observed to be directed away and concentrated further from the coastal development site by 2009.
Keywords: coastal reclamation, Halophila ovalis, Halophila beccarii, standard deviational ellipse, standard distance

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. Losses have occurred all over the world. Land reclamation had always been thought to denudate seagrass in its nearby area (Isobe, as cited in Terawaki et al., 2003). They were normally found to be in poor condition within the vicinity of reclaimed area and healthier further away (Bianchi et al., as cited in Montefalcone et al., 2007). Fine sediment released from reclamation sites were thought to increase turbidity and reduction in benthic vegetations, which includes seagrass (Zainal et al., 2012). Apart from that, increased in water velocity resulted from reclamation sites also lead to seagrass decline (Park et al., 2009).

Omran and Wah (2012) on a study of the possible impact of waterfront projects in Penang Island found out that the projects had thought to be destroying the nature beach and affecting its ecosystem. In addition, a study by Ramly (2008) 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 in front of the study area 'Pulau Gazumbo' (see Figure 1), had caused concern to the seagrass status in the islet due to its proximity. The Light Waterfront development is feared to have affect and deteriorate the seagrass and marine lives in the islet. GIS had been associated with seagrass mapping. Nevertheless, studies on spatial analysis particularly SDE and 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 particularly in terms of spatial analysis.

MATERIALS AND METHODS

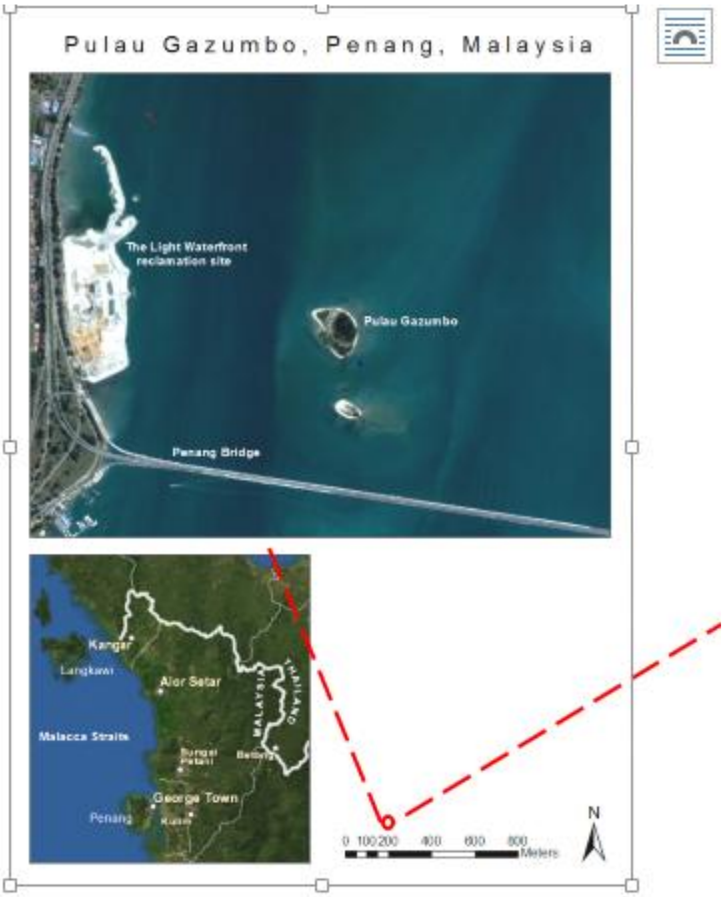

Figure 1: Location of the study area 'Pulau Gazumbo', Penang

Study site

The study site 'Pulau Gazumbo' (5˚21'N, 100˚19'E, 3482m^2) is a man-made island situated on the north east of Penang Island, Malaysia. It is a pea-shaped man-made islet as a result of dumped dredged materials from the South Channel when the Penang Bridge was constructed in October 1985 (Razalli et al., 2011). 'Pulau Gazumbo' has a climate similar to Penang Island due to its proximity; sunny throughout most of the year with temperature between 23˚C to 32˚C.

The coastal vegetations in the islet was landscaped by main contractor responsible for the Penang Bridge construction (Hyundai Company) which are mostly Casuarinas, Coconut palm, Sumatran Pine (*Pinus merkusii*) and Sea Hibiscus (*Hibiscus tiliaceus*) (Choong, 2003). Apart from that, Sea Morning Glory (*Ipomoea pes-caprae*), nature's answer as the ideal perennial creeper plant for coasts across the tropics, grew just above the high tide line.

In addition to this, a small mangrove stand, mainly of *Avicennia* sp., is located at the western-southwestern 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 vegetations occurred over the years through a series of succession around the coastal waters of the islet. These submerged vegetations are mostly: seagrass species of *Halophila ovalis* (Razalli et al., 2011) and *Halophila becarri* (Yasin and Tan, cited in Razalli et al., 2011); *Halophila spinulosa* (Yasin et al., cited in Razalli et al., 2011) and *Enhalus acoroides* (Nadiah, 2008) which are seasonally spotted. Apart from that, the islet is also home for other marine lives such as horseshoe crab *Tachypleus gigas* (Mohammad, 1994), gastropods (Bong, 2008), bivalves (Nur Najmi, 2001) and sea anemones (Looi, 2003; Fathen, 2011).

Data analysis

Standard Deviational Ellipse (SDE) and Standard Distance (SD) from GIS software ArcGIS 10 was applied in this study. Secondary data of seagrass shoot density year 2003 (Choong, 2003), 2006 (Abdullah et al., 2010) and 2009 (Krishnan, 2009) were used. Seagrass data were obtained from two littoral zones around the waters of 'Pulau Gazumbo': (1) upper littoral zone and (2) lower littoral zone. Eight stations were designated in each zone, and each station has 5 quadrat samples (see Figure 2). Maps of seagrass growth area and 'Pulau Gazumbo' that were used in this study were digitized earlier with ArcGIS 10.

Two steps were needed in these analyses. First, seagrass shoot density data which was 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. 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 movement of SDE and SD, while mean centre calculates the centre of concentration of seagrass shoot density. Four quadrants were divided across the centroid for scientific measurement purposes where it serves as a reference for the directions of both SDE and SD ellipses.

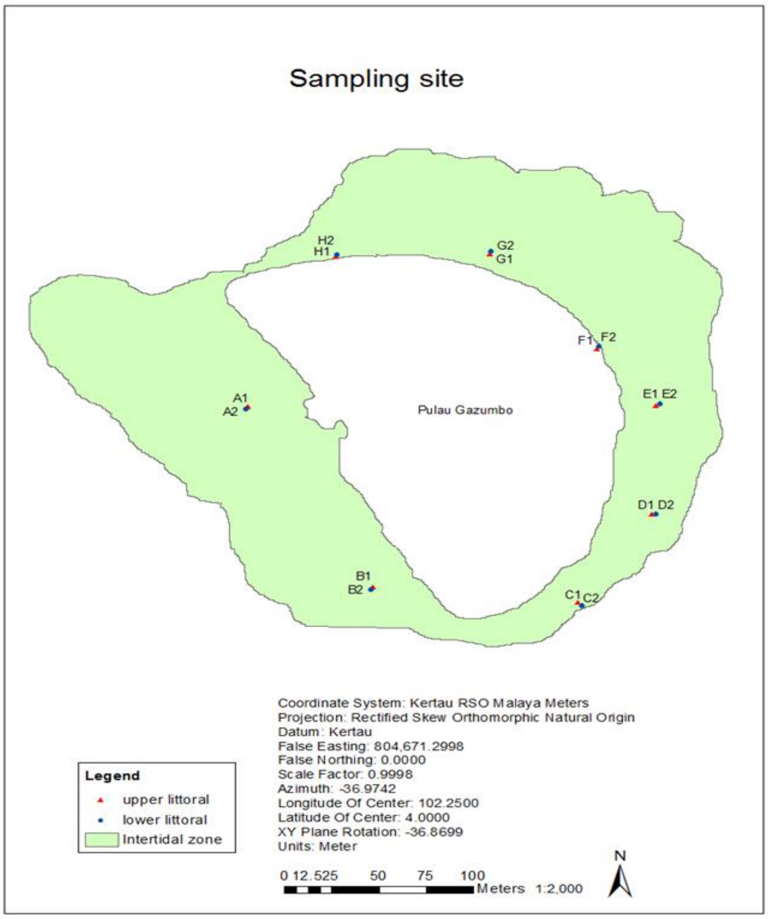

Figure 2: Sampling stations in 'Pulau Gazumbo', Penang

RESULTS

SDE ellipses which depict the directional trend of seagrass abundance had shifted from west to the north-west direction as it goes along from 2003 to 2009 (see Figure 3). Meanwhile, the SD ellipses which depict the compactness of the seagrass abundance had shifted from west to the east as it goes along from 2003 to 2009. The SD ellipse was observed to be more compact in 2009 than in 2003 and 2006 (see Figure 4).

The mean centre which depicts the concentration of seagrass abundance had also shifted from west to the east as it goes along from 2003 to 2009. 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 2006; and 28.21m in the east of the centroid in 2009.

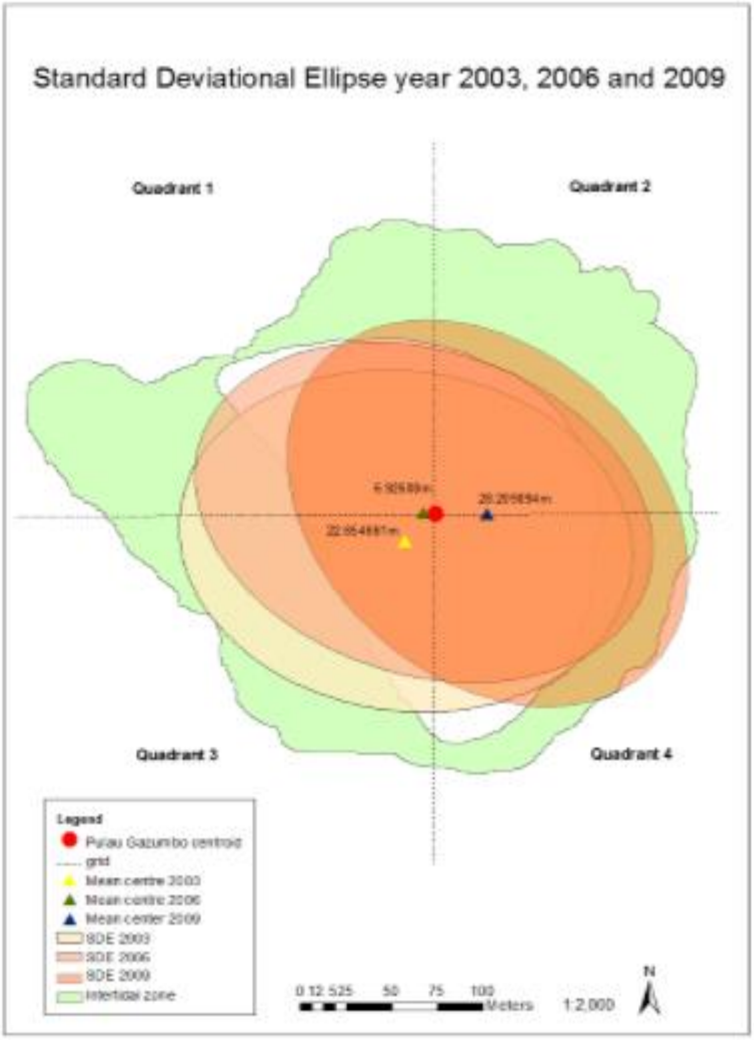

Figure 3: Temporal changes of Standard Deviational Ellipse and mean centre of seagrass mean shoot density year 2003, 2006 and 2009

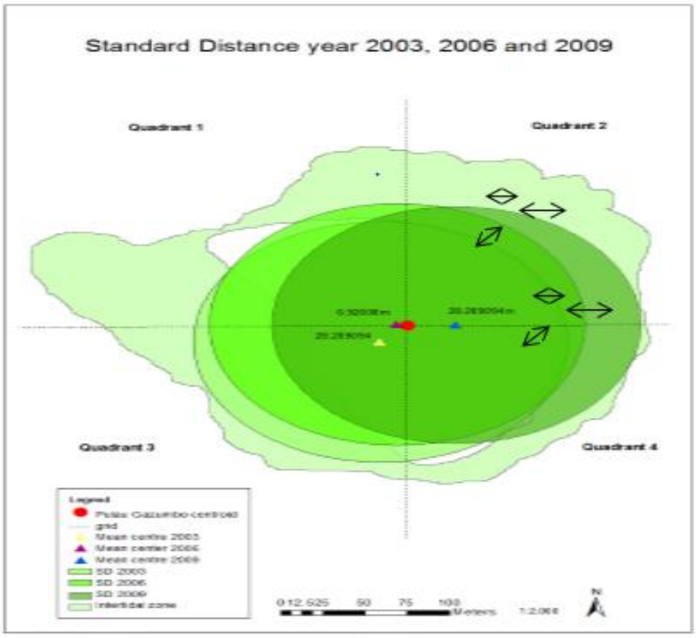

Figure 4: Temporal changes of Standard Distance and mean centre of seagrass mean shoot density year 2003, 2006 and 2009

DISCUSSION

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' directions show that seagrass in 'Pulau Gazumbo' had experienced shifts in its directional trend. A higher abundance of seagrass in station 1 was thought to have influenced the directional trend of the ellipse in 2003. In 2006, the direction of ellipse turned slightly to the north. High seagrass abundance recorded at station 1 was thought to influence the predominant orientation of the ellipse in the west. However, the increment of seagrass abundance in station 8 could have caused the ellipse to tilt towards the north direction in 2006. In 2009, the ellipse had completely tilted towards the north-west direction. Decrement of seagrass abundance in station 1, and increment of its abundance in station 5 and 4 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 2009 which is during the 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 abundance in 'Pulau Gazumbo'.

CONCLUSION

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 2006 and 2009. Additionally, SD analysis also showed that seagrass abundance was more concentrated in the east of the islet in 2009 (during reclamation) compared to 2003 and 2006 (before 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 abundance and/or density 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.

Acknowledgement

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