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COASTAL RECLAMATION INFLUENCE ON BIOLOGICAL STATUS OF COASTAL WATERS IN NORTHERN STRAITS OF MALACCA

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Abstract* : This study was conducted to identify the physical changes before and after the coastal reclamation and to study the effects of the reclamation activity with special focus on the biological status of the Penang waters using the Geographical Information Science application. The study area is in Penang waters. Landsat satellite images were analyzed using IDRISI Kilimanjaro and ArcGIS 10. The water quality analysis was carried out using water quality optics model developed by Lim Hwee San et al., (2009). The results showed that the concentrations of Total Suspended Solids (TSS) during the reclamation were high at 75 mg/L - 150 mg/L, exceeding National Water Quality Standards (NWQS), Department of Environment < 25 mg/L - 50 mg/1 for class I and II that are not suitable for nature conservation, threatens sensitive aquatic life and are not suitable for water use. After reclamation, the TSS concentration was found to decrease to 75 mg/L - 100 mg/L but still exceeded the NWQS. The concentrations of chlorophyll-a before the reclamation overall were as high as 7 mg/L - 9 mg/L while after reclamation, the concentration of chlorophyll-a in Penang waters was moderate at 5 mg/L - 7 mg/L. A statistical test was conducted to see the relationship between chlorophyll-a concentration with TSS, SST, amount of rainfall and tidal level using regression analysis. The analysis results showed that chlorophyll-a has a significant relationship with TSS, SST, amount of rainfall and tidal level. As a whole, coastal reclamation activities do caused declination of water quality, thus affecting the biological status of Penang waters.

***Keywords* –** coastal waters, Straits of Malacca, reclamation, chlorophyll-a, total suspended solids, SST

I. INTRODUCTION

Coastal zones are commonly defined as the interface or transition areas between land and sea, including large inland lakes. Therefore, a coastal zone is rather a band than a line. Since this unique zone covers both the aquatic and the terrestrial region, reference can be made to it in general which covers both regions simply as coastal zone, or specifically as coastal zone terrestrial side if referring to the landward side and coastal waters if referring to the seaward side. They are diverse in function and form, dynamic and do not lend themselves well to definition by strict spatial boundaries. Coastal zones are continually changing due to its dynamic interaction between the oceans and the land.

The width of the coastal zone i.e. the band, varies from place to place and is profoundly determined by the interaction of marine and terrestrial coastal processes. It is largely depending on the topography of the terrestrial features which in turn affects how far inland the influence of the sea has. It can range from 5km to 200km. The worldwide average width of the coastal zone on the terrestrial side is said to be 60 km. The zone occupies less than 15% of the Earth's land surface, yet it accommodates more than 60% of the world's population. Furthermore, only 40% of the one million kilometer of coastline is accessible and conducive enough to be habitable. As a result, coastal zones are marked by above-average concentrations of people (as reflected in Fig. 1) and economic activity.

Peninsular Malaysia has an approximate land cover surface area of 131,590 km^2 with a coastline of 1970km. The coastal region of Peninsular Malaysia has special socio-economic significance and is home to 70% of its population as it is rich in its natural resources (Fig. 2) [1]. The uneven distributions of amounts of resources available in this given area or qualities of services the focus area potentially provide and received, hence spatial inequality, is foremost the influential justification for human settlement and/or migration [2, 3]. Major economic activities, urbanization, agriculture (e.g. crop cultivation, fisheries, and aquaculture), oil and gas exploration, transportation, and recreational are amongst the elements of attraction representing natural commodities, ecosystem services, assets and wealth housed within this region. These are intangible elements life depends on [2, 3, 4, 5].

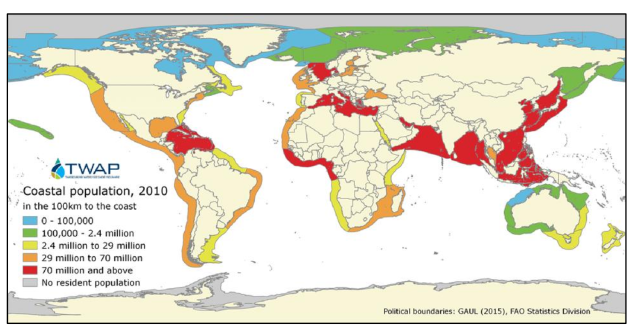

Fig. 1. Global coastal populations.
(Source: www.thegeographeronline.net)

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Inequalities in natural resources cannot be amended by making distribution more equitable or even between communities and populations [2]. Therefore, high demand areas like coastal regions tend to expand to accommodate larger human settlement and migration influx. The typical way of expansion is coastal reclamation for regions with coastlines and small islands are prime targets like the area in this study – Pulau Pinang, which is one of the oldest and famous locations in Malaysia's tourism. Pulau Pinang (*Pulau* = island. *Pinang* = beetle nut) is commonly known amongst tourists as 'Penang Island' or 'Pearl of the Orient' being the oldest British colonized location in Peninsular Malaysia.

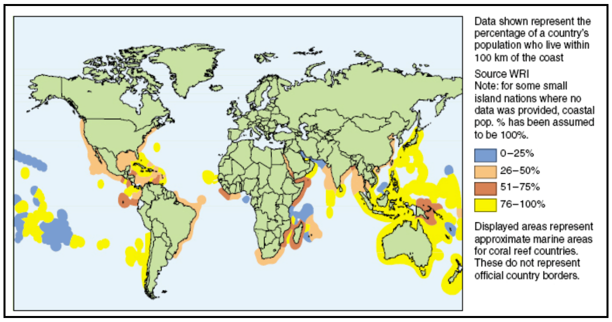

Fig. 2. Proportion of population living on the coast.
(Source: http://www.reefbase.org/)

Studies by Burke *et al.* in 2001 indicated that there is a correlation between coastal populations living within 100km of the coast and shoreline degradation [8]. This is shown in Fig. 3. In general, coastal regions inhabited by less than 30% of its population have the least altered shoreline; coasts inhabited by 30-70% of its population have both altered and most altered shoreline, and coasts with more than 70% of its population are mostly altered. However, in high population countries such as India and China, although there were coasts having less than 30% of their large populations, the shorelines were altered and mostly altered due to the number of people (in respective to their massive populations) within the coasts. Similar scenarios may be observed in developed countries like the United States of America and Europe but in these countries, the higher standard of living is probably one of the key factors influencing shoreline and coastal zone alterations. In Peninsular Malaysia, the shorelines are mostly altered.

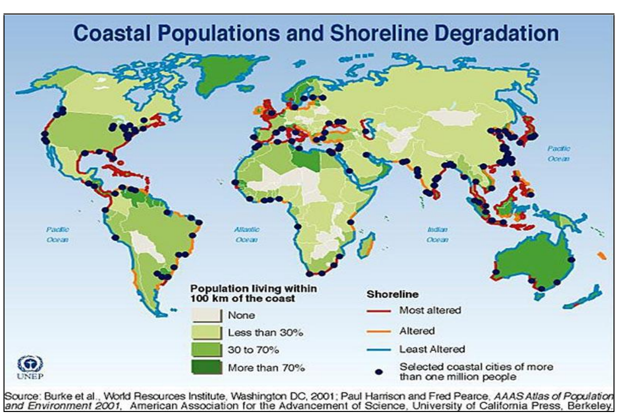

Fig. 3. The relationship between coastal populations and shoreline degradation.

In the past four decades, there has been an increase in the number of coastal land reclamation projects for residential, commercial and industrial development in many of the more developed coastal cities in Malaysia. Although the success of a coastal reclamation project firmly and distinctly built upon sound planning and designing practices to reduce environmental damage, negative impacts are inevitable. Coastal erosion, freshwater and seawater pollution, loss of biodiversity, loss of mangroves or wetlands, impedance of natural drainage, fragile and sensitive marine ecosystem destruction are some of the issues to be dealt with which can be of short-term or long term depending on the severity of unforeseen circumstances.

The scale of coastal reclamation in Malaysia is relatively small by comparison with Singapore, the neighbouring country [6]. Coastal reclamation aimed at economic transformation driven by population expansion and industrialization. Economic development is synonymous with urbanization and urbanization is believed to improve the overall quality of life. With the limited land space in Pulau Pinang, the city is fast coming up against the growing concern of overcrowding and keeping up with economic trend, what more with the present Industry 4.0. Land reclamation has been increasingly seen as a solution to this. The financial advantage of coastal land reclamation is easily demonstrated, however, environmental consideration is by far the greatest concern since alteration of coastal land form invariably leads to a disturbance on the hydrodynamic regime and the marine ecosystem. The magnitude of disturbance is difficult to predict and/or quantify, and may be irreversible. Ultimately the question lies in whether the benefits of reclamation are worth the environmental impact.

Pulau Pinang consisted of two larger divides – the island itself and the mainland (Fig. 4). The island has an area of 283 km^2 while the mainland section is 738 km^2. Population here is about 1.7 million with approximately 1,505 people per square kilometer. On the island, due to its topographical features, the population is mainly coastal oriented resulting in high demand for more land mass. This is one of the main reasons land reclamation plays a major role in its social and economic development.

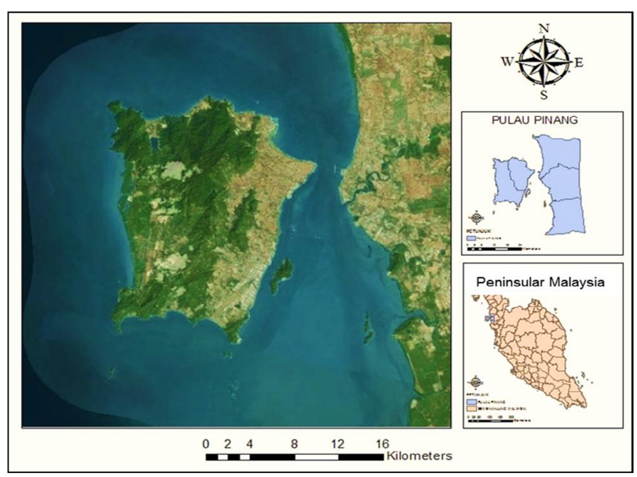

Fig. 4. The study area, Pulau Pinang, located within the northern Straits of Malacca.

This study identifies (1) the coastline change due to coastal reclamation of Pulau Pinang using GIS, and (2) to assess the influence of reclamation on the biological status of the surrounding waters using remote sensing. Parameters to determine biological status of the coastal waters are Total Suspended Solids (TSS), Chlorophyll-a and Sea Surface Temperature (SST).

II. MATERIALS AND METHOD

Identifying coastline change due to coastal reclamation of Pulau Pinang using GIS

The physical changes in coastline will be identified using GIS technique for selected temporal range of 1984, 1990 and 2010. These dates were selected for landuse maps available from the Urban and Rural Planning Department and the Agricultural Department. Maps were digitized using ArcMap 10 and saved as SHP file. Overlays were then performed to display regions with reclaimed areas within the coastline. The flow of this coastal reclamation spatial analysis is given in Fig 5.

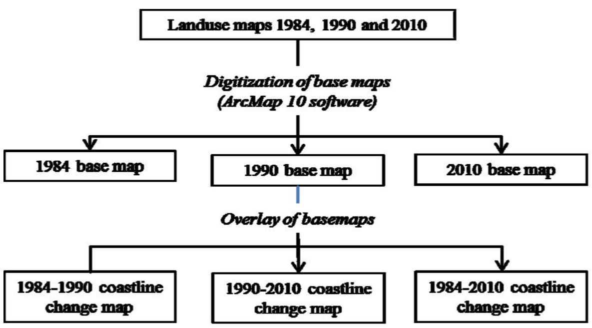

Fig. 5. The general flow of coastline changes spatial analysis using ArcMap 10.

Assessment of influence of reclamation on the biological status Pulau Pinang waters using remote sensing

To assess the biological status of Pulau Pinang waters, parameters used included Total Suspended Solids (TSS), Chlorophyll-a (Chl-a) and Sea Surface Temperature (SST).

(1) TSS and Chl-a distribution maps

Remote sensing technique is applied using optical models of TSS and Chl-a developed by Lim *et al.* in 2009 [9].

The optical models used:

TSS (mg/L):

$$(-731.11) + 30.31R_1 + (-39.32)R_2 + 5.70R_3 + 0.92R_1R_3\ (-0.05)R_2R_3 + (-0.37)R_1^2 + (-0.43)R_2^2 + (-0.0006)R_3^2$$

Chl-a (µg/L):

$$(-0.0411)R_1^2 + 7.5288R_1 + 327.1$$

Where, R_1 : reflectance of red band
R_2 : reflectance of green band
R_3 : reflectance of blue band

Optical modesl were applied to satellite imageries dated 17 January 2002, 3 August 2007, 17 October 2011 and 17 October 2017. Selections of these imageries were based on availability, clarity and temporal range of actual coastal reclamation activities within Pulau Pinang.

Tanjung Tokong reclamation (Seri Tanjung Pinang Phase 1) activity commenced in 2003 and satellite imagery dated 17 January 2002 will provide the pre-coastal reclamation biological status of coastal waters while imagery of 3 August 2007 will indicate the biological status of coastal waters after the Seri Tanjung Pinang Phase 1 reclamation project completed.

The imagery for 17 October 2011 was used to assess the ongoing of The Light Waterfront reclamation project while image of 17 October 2017 was for coastal waters biological status after The Light Waterfront project ended in 2016.
The flow of water quality analysis for TSS and Chl-a is shown in Fig. 6. IDRISI Kilimanjaro and ArcMap10 softwares were used for this study.

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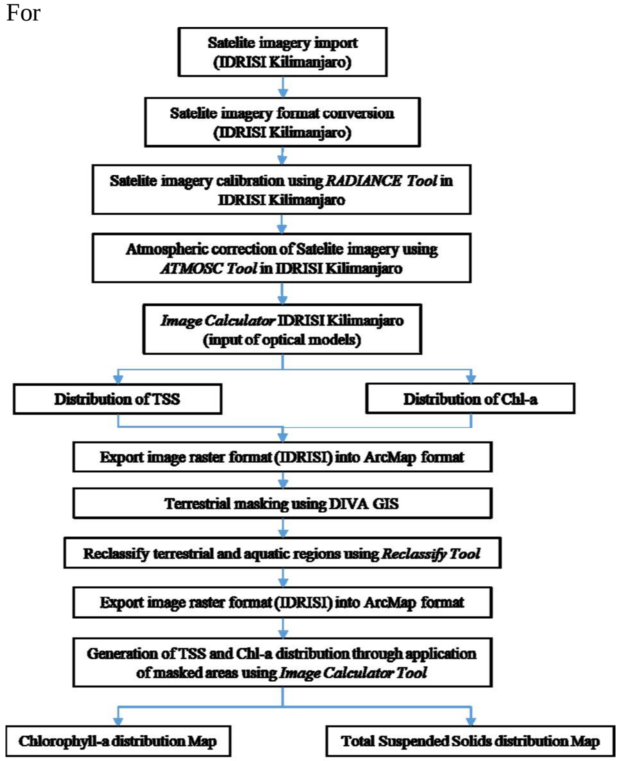

Fig. 6. An analysis workflow of Chl-a and TSS distribution maps generation adopted in this study.

(2) SST distribution

For SST assessment, readily available data from the National Oceanic and Atmospheric Administration (NOAA) were obtained for year 2002, 2007, 2011 and 2017 [10].

(3) Secondary Data: Rainfall and Tidal range

Rainfall and tidal heights secondary data coinciding with satellite imageries used in this study were required to establish the distributions of TSS and Chl-a with coastal reclamations. Rainfall data for Pulau Pinang (Weather Station: Penang International Airport) for the following dates were used: January 2002, August 2007, October 2011, and October 2017 (Table 1) [11].Tidal heights of Pulau Pinang (Kedah Pier, Georgetown) dated 17 Janaury 2002, 3 August

2007, 17 October 2011 and 17 October 2017 were used as reference for this study (Table 2) [12]. These data were necessary for regression analysis computation.

Table 1. Rainfall data of Pulau Pinang.

DAY	YEAR			
	JANUARY 2002 (mm)	AUGUST 2007 (mm)	OCTOBER 2011 (mm)	OCTOBER 2017 (mm)
1	-	-	-	-
2	-	4.06	10.92	0.00
3	-	-	0.51	0.00
4	0.00	0.00	0.76	-
5	-	-	0.00	-
6	0.00	-	-	10.92
7	-	-	-	6.10
8	-	-	41.91	2.03
9	-	-	1.02	3.05
10	-	-	7.11	0.00
11	-	-	0.00	0.00
12	-	2.03	-	1.02
13	-	0.00	-	41.91
14	0.00	-	-	-
15	-	0.76	-	-
16	-	-	6.10	-
17	-	0.00	22.10	-
18	-	0.76	35.05	-
19	-	11.94	18.03	-
20	-	0.00	3.05	-
21	0.00	0.00	7.87	-
22	-	-	7.11	-
23	-	3.05	2.03	-
24	0.00	0.00	0.51	-
25	2.4	0.76	5.08	1.02
26	-	0.00	10.92	0.00
27	2.4	0.00	1.02	10.92
28	-	88.90	18.03	25.91
29	-	10.92	0.76	0.00
30	0.00	-	27.94	26.92
31	-	-	22.10	0.00

*** 0.00: Light Rain   * ▭ : Satellite image date   * – : No Rain**

Table 2. Tidal heights of Pulau Pinang (Kedah Pier, Georgetown)

DATE	TIME	HEIGHT(Meter)
17/01/2017	2:45 AM	2.39 meter High Tide
	7:33 AM	Sunrise
	9:42 AM	0.49 meter Low Tide
	3:32 PM	2.01 meter High Tide
	7:24 PM	Sunset
	9:35 PM	0.94 meter Low Tide
03/08/2008	3:48 AM	2.45 meter High Tide
	7:14 AM	Sunrise
	10:04 AM	0.94 meter Low Tide
	3:42 PM	2.57 meter High Tide
	7:35 PM	Sunset
	10:28 PM	0.62 meter Low Tide
17/10/2011	2:57 AM	2.47 meter High Tide
	7:04 AM	Sunrise
	9:49 AM	0.81 meter Low Tide
	3:23 PM	2.08 meters High Tide
	7:03 PM	Sunset
	9:31 PM	1.06 meter Low Tide
17/10/2017	6:08 AM	0.99 meter Low Tide
	7:04 AM	Sunrise
	11:44 AM	2.23 meter High Tide
	6:19 PM	0.70 meter Low Tide
	7:03 PM	Sunset

Statistical Analysis

Regression analysis will be conducted in this study to determine the relationship between TSS, Chl-a, SST, rainfall and tidal heights. Models based on these regression analysis will be produced to indicated to possibilities of predicting the influence of coastal reclamation on water quality status within Pulau Pinang waters.

III. RESULTS AND DISCUSSION

Identifying coastline change due to coastal reclamation of Pulau Pinang using GIS

Results of coastline change spatial analysis of the reclaimed areas using ArcMap 10 are given in Fig. 7 for the periods of 1984-2000, 2000-2010, and 1984-2010 respectively. Based on spatial analysis, reclaimed areas was 870 acres concentrating within the southeast of the island between year 1984 and just before 2000, while between years 2000 and 2010 reclaimed areas was 392 acres at the northeastern coast. These reclaimed locations are also indicated in the satellite imageries (Fig. 9)

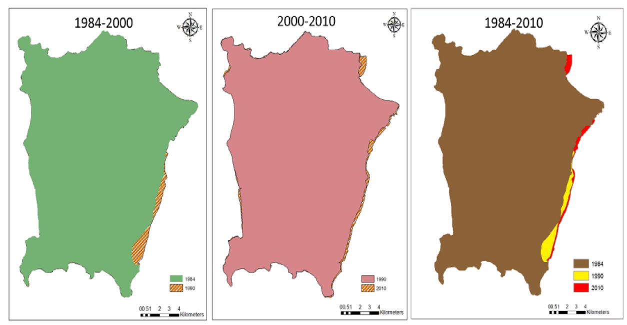

Fig. 7. Locations of coastal reclamation in Pulau Pinang between 1984-2000, 2000-2010, and 1984-2010.

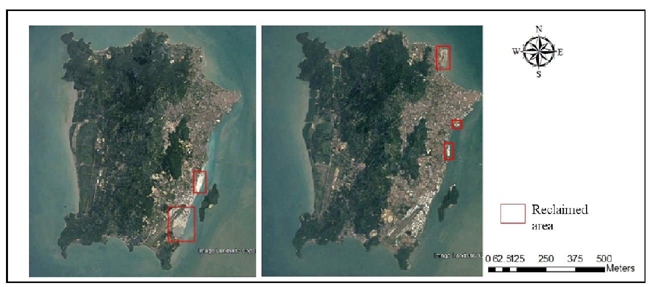

Fig. 8. Pulau Pinang coastal reclamation locations in satellite imageries between 1984 – 2010.

Assessment of influence of reclamation on the biological status Pulau Pinang waters using remote sensing

Total Suspended Solids (TSS) Distributions

Results of TSS distributions for 2002, 2007, 2011 and 2017 are given in Fig. 9. For year 2002, TSS within waters of coastal reclamation ranged between 75-150 mg/L; for 2007 TSS ranged between 75-100 mg/L; for 2011 TSS ranged between 75-100mg/L; and for 2017 TSS ranged between 75-100 mg/L. Higher TSS values were observed during on-going coastal reclamation activities within the study area of Pulau Pinang.

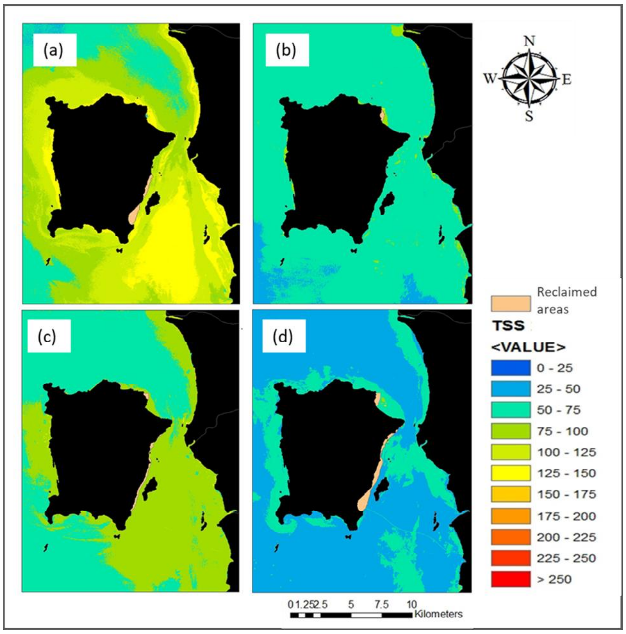

Fig. 9. TSS distributions of Pulau Pinang waters (a) 2002, (b) 2007, (c) 2011, and (d) 2017.

Chlorophyll-a (Chl-a) Distributions

Chl-a concentrations for the four dates are given in Fig. 10. From all the four data sets, 2002 Chl-a mapping showed highest level of concentrations where the range fell between 6-11 ug/L. This was during the ongoing of coastal reclamation activities. The most reasonable explanation to the elevated level of Chl-a would be the pathway of sediment carrying nutrients washed from the terrestrial region resulting in higher photosynthetic activity of the suspended phytoplankton. Similar scenario was observed by Lee Abdullah in her study in 2014 [13].

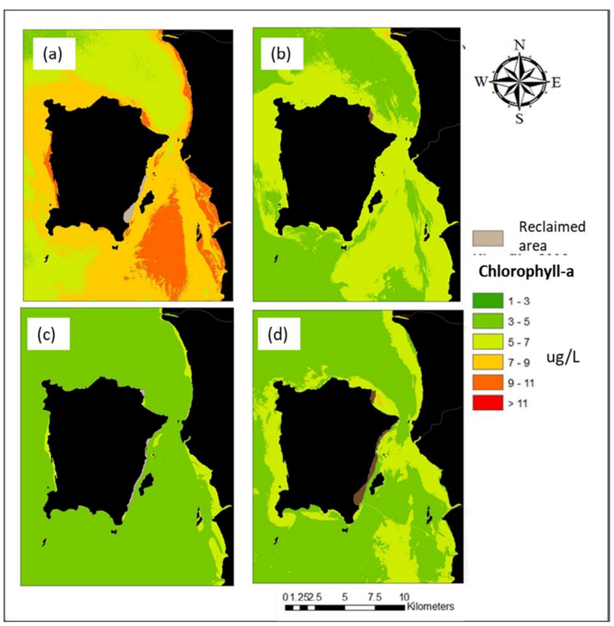

Fig. 10. Chl-a distributions of Pulau Pinang waters (a) 2002, (b) 2007, (c) 2011, and (d) 2017.

Sea Surface Temperature (SST)

Distributions of SST obtained from NOAA are given in Fig. 11. The range of SST for 2002 fell between 28-30°C, for 2007 SST was much higher at 30-34°C, for 2011 SST range just a little lower i.e. 29-31°C, while in 2017 SST rises to 30-34°C. Similar scenarios of SST range were observed for year 2007 and 2017 and these observations coincided with lower TSS and Chl-a contents shown in Fig. 9 and 10. Lowest range of SST was for year 2002 and during this period Chl-a concentrations were higher, ranging between 6-11 ug/L (Fig. 9(a) and Fig. 10(a)). This is explainable as colder waters tend to have more nutrients than warm waters, phytoplankton tend to be more plentiful where waters ware cold. Hence, Chl-a concentrations from phytoplankton were detected in 2002. TSS concentration, however, was also high in 2002. This is because TSS calculates the amount of suspended solids and this may include phytoplankton as these photosynthetic organisms are free floating within the water column and can be easily picked up as suspended particles from the optical model applied.

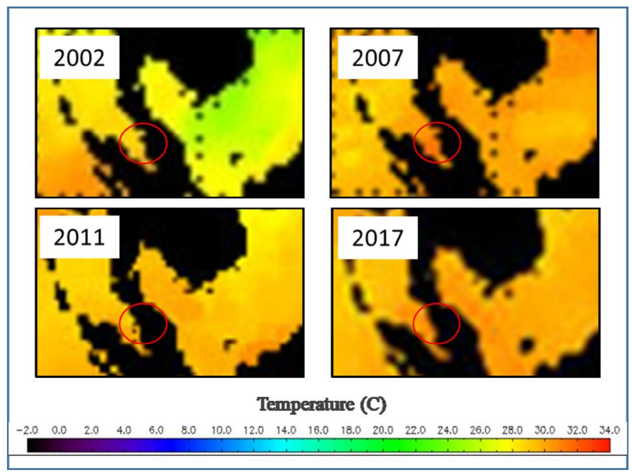

Fig. 11. SSTs of Pulau Pinang waters (a) 2002, (b) 2007, (c) 2011, and (d) 2017.

Statistical Analysis

(a) Total Suspended Solids (TSS)

Regression analysis conducted to determine the relationship between TSS and Chl-a, SST, rainfall and tidal height with correlation coefficient (R) is given in Table 3. Results showed p-values of variables are significantly < 0.05 and the regression analysis model is as follows:

TSS = 115.155 Tide + 3.177 Rain - 9.110 SST + 16.651 Chl-a

where :	Tide	= Tidal height (m)
	Rain	= Total rainfall (mm)
	TSS	= Total Suspended Solids (mg/L)
	SST	= Sea Surface Temperature (C)
	Chl-a	= Chlorophyll-a (ug/L)

With reference to the statistical analysis, there is significantly strong relationship between TSS with Chl-a, SST, rainfall and tidal height where R>1. Results obtained showed the high possibility of determining the influence of coastal reclamation on the water quality status within Pulau Pinang waters.

(a) Chlorophyll-a (Chl-a)

Regression analysis conducted to determine the relationship between Chl-a and TSS, SST, rainfall and tidal height with correlation coefficient (R) is given in Table 4. Results showed p-values of variables are significantly < 0.05 and the regression analysis model is as follows:

Chl-a = - 6.939 Tide - 192 Rain + 0.60 TSS + 551 SST

where : Tide = Tidal height (m)
Rain = Total rainfall (mm)
TSS = Total Suspended Solids (mg/L)
SST = Sea Surface Temperature (C)
Chl-a = Chlorophyll-a (ug/L)

Statistical analysis here too showed a significantly strong relationship between Chl-a with TSS, SST, rainfall and tidal height where R>1. Results obtained showed there is high possibility of determining the influence of coastal reclamation on the water quality status within Pulau Pinang waters.

Table 3. Results of regression analysis between TSS and Chl-a, SST, rainfall and tidal height.

Coefficient[a]

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std error	Beta		
(Constant)	-.287	.296		-.970	.355
Tide	115.155	5.066	1.976	22.733	.000
Rain	3.177	.209	.669	15.169	.000
SST	-9.110	.511	-2.394	17.831	.000
Chl-a	16.651	.448	1.196	37.180	.000

a. Dependent variable: TSS

Summary of Model[b]

Model	R	R^2	R^2 Change	Std Error of Estimate
1	1.000[a]	1.000	1.000	.97862

a.Predictors: (Constant), Chl-a, Rain, Tide, SST

Table 4. Results of regression analysis between Chl-a and TSS, SST, rainfall and tidal height.

Coefficient[a]

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std error	Beta		
(Constant)	.017	.018		.989	.346
Tide	-6.939	.160	-1.657	-43.350	.000
Rain	-.192	.008	-.564	-23.013	.000
TSS	.060	.002	.830	37.180	.000
SST	.551	.018	2.015	31.225	.000

a. Dependent variable: Chl-a

Summary of Model[b]

Model	R	R^2	R^2 Change	Std Error of Estimate
1	1.000[a]	1.000	1.000	.05856

a.Predictors: (Constant), TSS, Rain, Tide, SST

Table 5 shows the National Water Quality Standard for Malaysia (NWQS) issued as guidelines for Malaysian waters [12]. Based on TSS concentrations mapped using the optical model, Pulau Pinang waters fell within Class IIB (50 mg/L) and III 9150 mg/L). This would mean the waters are suitable for recreational use with body contact (Class IIB) and Fishery II which is for common, with economic value and tolerant species (Class III). Under the Department of Environment Water Quality Index Classification, the level of TSS would fall within Class III (50-150 mg/L) rendering it with Water Quality Index (WQI) of 51.9-76.5. This index range meant the waters around Pulau Pinang is slightly polluted and polluted during coastal reclamation.

Table 5. National Water Quality Standards for Malaysia

PARAMETER	UNIT	CLASS					
		I	IIA	IIB	III	IV	V
Ammoniacal Nitrogen	mg/l	0.1	0.3	0.3	0.9	2.7	> 2.7
Biochemical Oxygen Demand	mg/l	1	3	3	6	12	> 12
Chemical Oxygen Demand	mg/l	10	25	25	50	100	> 100
Dissolved Oxygen	mg/l	7	5 - 7	5 - 7	3 - 5	< 3	< 1
pH	-	6.5 - 8.5	6 - 9	6 - 9	5 - 9	5 - 9	-
Colour	TCU	15	150	150	-	-	-
Electrical Conductivity*	μS/cm	1000	1000	-	-	6000	-
Floatables	-	N	N	N	-	-	-
Odour	-	N	N	N	-	-	-
Salinity	%	0.5	1	-	-	2	-
Taste	-	N	N	N	-	-	-
Total Dissolved Solid	mg/l	500	1000	-	-	4000	-
Total Suspended Solid	mg/l	25	50	50	150	300	300
Temperature	°C	-	Normal + 2 °C	-	Normal + 2 °C	-	-
Turbidity	NTU	5	50	50	-	-	-
Faecal Coliform**	count/100 ml	10	100	400	5000 (20000)[a]	5000 (20000)[a]	-
Total Coliform	count/100 ml	100	5000	5000	50000	50000	> 50000

Notes :
N : No visible floatable materials or debris, no objectional odour or no objectional taste
* : Related parameters, only one recommended for use
** : Geometric mean
a : Maximum not to be exceeded

DOE Water Quality Index Classification

PARAMETER	UNIT	CLASS				
		I	II	III	IV	V
Ammoniacal Nitrogen	mg/l	< 0.1	0.1 – 0.3	0.3 – 0.9	0.9 – 2.7	> 2.7
Biochemical Oxygen Demand	mg/l	< 1	1 – 3	3 – 6	6 – 12	> 12
Chemical Oxygen Demand	mg/l	< 10	10 – 25	25 – 50	50 – 100	> 100
Dissolved Oxygen	mg/l	> 7	5 – 7	3 – 5	1 – 3	< 1
pH	-	> 7	6 – 7	5 – 6	< 5	> 5
Total Suspended Solid	mg/l	< 25	25 – 50	50 – 150	150 – 300	> 300
Water Quality Index (WQI)		< 92.7	76.5 – 92.7	51.9 – 76.5	31.0 – 51.9	< 31.0

Water Classes And Uses

CLASS	USES
Class I	Conservation of natural environment. Water Supply I – Practically no treatment necessary. Fishery I – Very sensitive aquatic species.
Class IIA	Water Supply II – Conventional treatment required. Fishery II – Sensitive aquatic species.
Class IIB	Recreational use with body contact.
Class III	Water Supply III – Extensive treatment required. Fishery III – Common, of economic value and tolerant species; livestock drinking.
Class IV	Irrigation
Class V	None of the above.

DOE Water Quality Classification Based On Water Quality Index

SUB INDEX & WATER QUALITY INDEX	INDEX RANGE		
	CLEAN	SLIGHTLY POLLUTED	POLLUTED
Biochemical Oxygen Demand (BOD)	91 - 100	80 - 90	0 - 79
Ammoniacal Nitrogen (NH_3-N)	92 - 100	71 - 91	0 - 70
Suspended Solids (SS)	76 - 100	70 - 75	0 - 69
Water Quality Index (WQI)	81 - 100	60 - 80	0 - 59

Source: Jabatan Alam Sekitar, Malaysia (2012)

The concern now speculated on whether the WQI and hence the status of the water quality within the study area will be deteriorating further as this will most probably have a significant influence on the natural habitats and ecosystems. These include the seagrass beds within nearby man-made islands and the middle bank on the east side of Pulau Pinang waters. These naturally occurring seagrass ecosystems have played an important role in maintaining the existing coastal biodiversity of Penang waters since 1984 when the Penang Bridge was constructed. Prior to the existing seagrass beds, Pulau Pinang lost its coral ecosystem when economic development rapidly picked up pace before 1980 due to various water contaminations from point-source and non-point source pollution. Coastal erosion may have also flushed nutrients into the water resulting in nutrient enrichment i.e. eutrophication leading to multitude of problems.

Sedimentation is no exception as this easily caused smothering of corals leading to coral ecosystem collapse.

The current coastal reclamation attributed to commercial and residential development in Pulau Pinang is now probably another repetition of coastal environmental destruction.

According to GDRC report [7]:

- Most of the world's coastal areas are polluted.
- Pollution and development are changing coastal habitats. Feeding and nursery areas are being destroyed, reducing fish and wildlife populations.
- Along some coasts, runoff enriches the water with too many nutrients, leading to oxygen-depleted water and fish kills.
- The two most widespread and serious sources of coastal pollution are sewage disposal and sedimentation from land-clearing and erosion.
- Coastal waters suffer from contamination from nonpoint-source pollution resulting in outbreaks of toxic algal blooms and red tides.
- Coral bleaching results from warmer surface water temperatures attributed to global warming.
- Loss of coastal wetlands has been attributed to commercial and residential developments.

Observations by this GDRC report is clearly reflecting the scenario Pulau Pinang is experiencing now. It is worth contemplating the short term and long term influence of coastal reclamation where natural environment, coastal processes and human are concerned. Pollutants generated may only be controlled to a certain extent. Similarly, ecological and environmental damage is inevitable and some damage simply cannot be restored. Such destruction will adversely affect not only the physical environment but will eventually affect the quality of life and the aims of achieving sustainability. There should be alternatives to solutions that can be less damaging. We need to recognize that every process on life on earth is interconnected and fundamentally intertwined with its abiotic drivers. A balance can be achieved through knowledge and a more holistic approach. In pursuing economic development and prosperity, hence a presumed better or a promotion of quality of life, we do not want to create another wicked problem.

IV. CONCLUSIONS

Is coastal land reclamation the only way to go? Are the benefits of such reclamation at the expense of natural habitats worth the cost? Is the belief that coastal land reclamation promotes quality of life overlooked? These are questions that need to be addressed before coastal reclamation project is implemented as the influences may provide long term impacts particularly when sustainable living is the main issue.

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