OCEANOGRAPHIC STUDY OF TURTLE ISLANDS MARINE PARKS

Coastal and Marine Resources Management in the Coral Triangle–Southeast Asia (TA 7813-REG)

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Tehcnical Report

OCEANOGRAPHIC STUDY OF TURTLE ISLAND MARINE PARK

Final Report[1]

Photo Credit: Sabah Parks

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LIST OF ABBREVIATIONS

GPS	Global Positioning System
HAT	Highest Astronomical Tides
NE	Northeast
SCCC	Sabah CTI Coordinating Committee
SE	Southeast
SLR	sea level rise
SSE	South-Southeast
SW	Southwest
TIHPA	Turtle Islands Heritage Protected Areas
TIP	Turtle Island Park
TIWS	Turtle Islands Heritage Protected Areas

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I. INTRODUCTION

A. Turtle Islands Marine Parks

1. The Sabah government fully acknowledges that its natural environment, especially its marine and terrestrial biodiversity, is the State's great tourism assets. Turtle Islands consists of five islands, three of which belong to Malaysia, under the jurisdiction of Sabah Parks, and the rest belong to the Philippines (UPM, *et al.,* 1996). Sabah Parks estimates that Turtle Islands Park (TIP) covers an area of 17.4 km^2 (Figure 1). The biggest island is Bakkungan Kechil, followed by Selingaan and Gulisaan Islands, which provide the most important nesting areas for two endangered species of marine turtles. This feature of the islands has elevated their touristic value, thus requiring a unique approach to tourism development that ensures their sustainability (Lasuin, *et al.* 2011). A major threat to these islands is beach erosion, as the land elevation of the islands is less than 3.5 m above mean sea level (Abdullah and Musta, 1999).

2. UMS, et al. (1996) reported that the landmasses of Bakkungan Kechil, Selingaan, and Gulisaan islands used to be 8.5 hectares, 8.1 hectares, and 1.6 hectares, respectively. In 2011 the landmasses of the islands were reduced to 6.5 hectares, 7.8 hectares, and 1.5 hectares, respectively (Sabah Parks and UMS, 2014). Bakkungan Kechil Island has experienced the highest land loss (2 hectares) among the three islands. In 2007, Sabah Parks deployed the hard shoreline protection: the use of reef balls and the stones revetment to protect the infrastructure in Selingaan Island (Figure 1).

3. TIP is one of the important tourist destinations in Sandakan, Sabah, for watching turtles landing and laying their eggs. A small resort has been built to support a group of tourists' overnight stay in this island. Day-trip visitors from nearby Libaran Island come to this area for swimming, coral viewing with glass-bottomed boat during the day, and turtle watching at night. Lasuin et al. (2011) reported that tourist arrivals in Turtle Islands Park can reach 14,000 in a year. The peak travel season is from March through September. The number of visitors decreases between October and February due to rough seas during the northeast monsoon season.

Figure 1: Location of the reef balls and stone revetment
(Photo Credit: Sabah Parks)

4. As part of the turtle egg laying area, sandy beaches are considered one of the most economically valuable areas in TIP. However, severe beach erosion in the past has decreased the size of the islands and, consequently, that of sandy beaches. The loss of sandy beaches is the main problem in TIP, and it is feared to create great impact on Sabah's turtle conservation activities and tourist revenues.

5. A good understanding of the sediment sources and supply, as well as environmental change, within Turtle Islands is an important key to projecting beach stability at present and in the future. This study was conducted to gather information from past studies related to physical oceanography in TIP, to facilitate a field survey of the reef balls that possibly produce a negative impact on the islands, to measure current speed and direction within the islands, and to determine whether a sea level rise or the presence of reef balls causes the loss of nesting beaches. The report needs to be presented and submitted to Sabah Parks and the Sabah CTI Coordinating Committee (SCCC) as baseline information for their next action.

B. History of Reef Balls in Selingaan Island

6. According to the field assessment done by the Reef Ball Foundation (2006), the islands in Turtle Islands Park are experiencing the effects of active geomorphological processes short-term, seasonal and long-term movements that change the shoreline configuration and result in a certain degree of erosion. As solution, reef balls as submerged breakwaters were identified the best option for the Gulisaan Island after considering the turtles' access, aesthetics, and tidal range issues.

7. There was no guarantee that the installation of shoreline structures would give coastal protection to the Selingaan Island. Stone revetment was built parallel to the beach at the southeast of the island (Figure 1). However, the adjoining beach was eroded, affecting not only the turtle nesting area but also some infrastructure in the island. In 2007, the Sabah State Government allocated about RM 1,880,000.00 for the installation of 290 sets of reef balls (Goliath balls) south of the stone revetment (Figure 1). The reef balls were supplied by the Reef Ball Asia Sdn. Bhd. to reduce current and wave action toward the beach and promote sand accretion behind the protection structures. Therefore, this study was conducted to assess the effectiveness of the reef balls as shoreline protection for the Selingaan Island.

C. Coastal Protection Structures

8. There are two main methods of coastal protection: soft and hard engineering. The soft engineering method of coastal protection (e.g., beach nourishment program) is a natural defense against erosion and replaces beach or cliff material that has been removed by erosion. The hard engineering method utilizes man-made structures to control disruption of natural processes. While soft coastal protection gives natural defense to the beach, it can affect sea turtle nesting areas. Since nest temperature determines the sex of the sea turtle hatchlings, beach nourishment can alter the properties of a beach and affect incubation temperatures, thus resulting in altered and unnatural sex ratios. Moreover, it can affect the ability of a female to effectively dig a nest (Seaturtles.org, 2016).

9. Construction of protection structures in coastal areas has advantages and disadvantages. It is beneficial because it stabilizes the upland, protects infrastructure, maintains property values, and reduces or halts the erosion process. However, according to O'Connell (2010), coastal structures have negative effects on the shoreline, such as source sediment

impoundment, passive or active erosion, loss of beach access, marine habitat degradation, and changes in ecology.

10. Coastal structures (seawalls, bulkheads, revetments, and other hard structures) that are built to protect beach, dune, or back beach development create visual impact. The impact is much greater on the beach users and general public than the owner of the property (Griggs, 2005b). Hard structures (groins, seawalls, revetments, jetties and geotextile tubes) on open coast have the capability to alter the hydrodynamics and modify the flow of water, wave regime, sediment dynamics, grain size, and depositional processes on exposed sandy beaches (Fletcher et al., 1997; Miles et al., 2001; Runyan and Griggs, 2003; Martin et al., 2005). Structures built alongshore (seawalls and revetments) and other hard surfaces reflect wave energy and constrain natural landward migration of the shoreline, resulting in the loss of beach area and width and probably leading to flanking erosion of adjacent shorelines (Hall and Pilkey, 1991; Griggs, 2005a, 2005b). Offshore structures (jetties, groins and breakwaters) can affect the beach process (erosion and accretion), as well as sediment transport and deposition at adjacent shorelines (French, 1997; Nordstrom,2000).

11. In TIP, there are two types of coastal protection structures: the reef balls and the stone revetments built parallel to the shoreline to reflect wave energy and constrain natural landward migration of the shoreline.

D. Beach Erosion Due to Coastal Protection

12. As the protected shore continues to erode, beaches become narrow and eventually vanish at a certain time. This affects public (fisherman, beach goers and other people) access to the shoreline, either vertically or laterally, which is restricted by the coastal protection structures (Griggs, 2005b; O'Connell, 2010).

13. The presence of coastal protection structures affects the existing adjacent property through active erosion, including end scour and flanking erosion. As the unprotected beach at both ends of protection structures continuously erodes and finally moves landward, the frequency of interaction between waves and the protection structures increases. This happens because the hardened faces of seawalls reflect, rather than dissipate, wave energy (Dugan et al., 2011). Continuous interaction between strong waves and daily tide could eventually affect the adjacent property through the process of end scour and flanking erosion (O'Connell, 2010). The capability of scouring at the ends of coastal protection structures is related to the end configuration of the protection structure, approaching wave angle with wave height and period (Griggs, 2005b). Lower hard structures have higher physical impacts associated with scouring processes (Dugan et al., 2011).

E. Impact of Coastal Protection Structures on Marine Ecology

14. Soft-bottom habitats are changed in several ways by the installation of coastal structures. Wave field and current have been affected, causing scour and changes in sand ripple patterns and sediment grain size. Coastal structures may also entrap drift algae and other organic materials, which can result in organic buildup in the sediment. Thus barnacles' shells and other fouling biota enter and modify sediments. Predators that are attracted by the structure may also forage on plants and animals that live in adjacent sediments (Davis et al., 1982).

15. Hard structures sometimes cause loss and disturbance of natural sedimentary habitats, including the assemblages of animals (soft substrate benthos) and plants (seagrass). They also

disrupt surrounding soft seabed environments. Furthermore, hard structures turn into a new artificial hard substrate that is colonized rapidly by new or current algae, marine animals, and birds (Bacchiocchi and Airoldi, 2003; Martin et al., 2005, Airoldi et al., 2005; Moschella et al., 2005). They also become a new habitat for rocky shore flora and fauna. So far no study has been done about the impact of coastal protection structures on marine ecology in TIP.

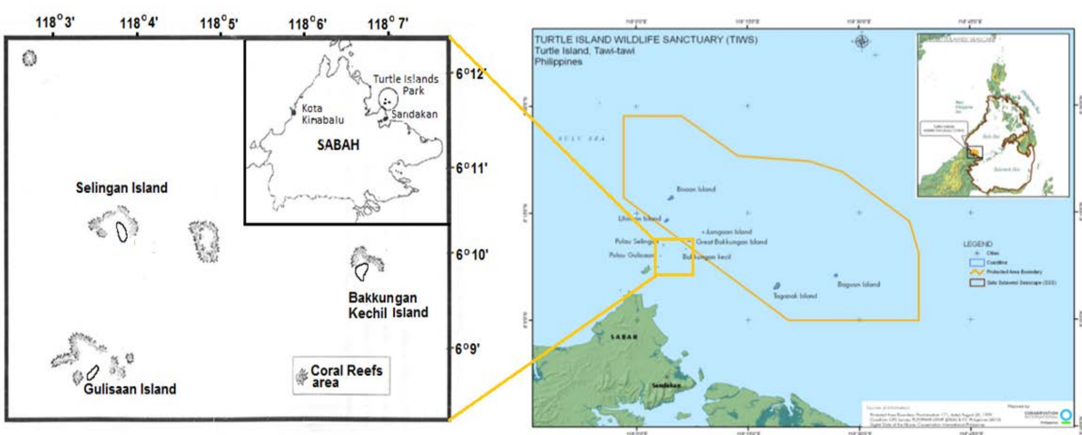
II. METHODOLOGY

16. Turtle Islands Heritage Protected Area (TIHPA) is a protected marine area located in Sulu Sea (Figure 2). It was jointly established by the Philippines and Malaysia for the conservation of sea turtles. TIHPA covers the six islands of Turtle Islands Wildlife Sanctuary (TIWS) and three islands of Sabah, Malaysia, known as Turtle Islands Park. Collectively, these islands comprise the most important nesting areas of green turtles (Chelonia mydas) or Penyu Hijau and hawksbill turtles (Eretmochelys imbricata) or Penyu Sisik in Southeast Asia (CI-Philippines, 2013).

17. Field work was done between 11 and 13 May 2017 (inter-monsoon). The purpose of this trip was to conduct a field survey of the reef balls that possibly create negative impacts on turtle nesting ground and to measure the speed and direction of the current within Turtle Islands. The assessment was done through informal interviews with the tourist guides and staff of Sabah Parks, field observations, and investigations of the reef balls. In situ current speed and direction were also measured at six sampling sites in the three islands. The recent field trip findings were compared with the information collected during a trip made in 2011.

18. Analysis of water level data taken from Sandakan Tidal Station (latitude 5.81 and latitude 118.067222) from 1985–2011 (18.6 years) was done by Anthony (2017) to predict sea level rise with the Sandakan waters. The Sandakan tidal station is the nearest water level data available for the TIP. The analysis of sea level trends from historical data was done to predict if the sea level would rise or fall in the future.

Figure 2: Location of the Turtle Islands Heritage Protected Area (TIHPA), Philippines, and the Turtle Islands Marine Parks, Malaysia (CI-Philippines, 2013)



19.

The coastal structures in the form of reef balls and revetments are located in Selingaan Island. Therefore, this report is mainly focused on this island. Secondary data, such as Global Positioning System (GPS) reading and aerial photos from different Government Departments, were analyzed for a better understanding of how the islands have changed in the past. Aerial photos taken on 26 September 1970 and in 2006 were collected from the Land and Survey Department and Forestry Department, while photos taken in August 2000 and in 2008 were provided by Sabah Parks. Multispectral Digital globe Satellite Imagery in 2010 was overlaid with the coordinates from GPS (Garmin, model GPS Map 60CSX) for vegetation line and land areas taken during the field trip in 2011. Available data were analyzed and overlaid using ArcGis 9.2 software. Results of site visits and maps in 2011 (Sabah Parks and UMS, 2014) and 2017 are presented in this study.

III. RESULTS

A. Field Surveys on Coastal Structures in Selingaan Island

20. According to the Sabah Parks' rangers who worked in this island for many years, the sediment at the island would shift according to the seasonal monsoon. During the northeast monsoon, the beach in the east side would be basically eroded and the sediment loss would accumulate in the southern part of the island. Most of the sediment would be back to the original location when wind direction changed to the southwest monsoon.

21. The field survey on coastal structures in Selingaan Island in 2011 indicates that sand covered part of the reef balls (Figure 3A). However, all of the reef balls were exposed in May 2017 (Figure 3B). There is a larger gap between the stone revetment and the beach in 2011 with exposed the beach (Figure 3C). However, vegetation and coconut trees grow parallel to the stone revetments observed in 2017. The beach next to the coconut trees was used for turtle nesting area (Figure 3D).

22. Before the installation of the reef balls, the southern part of Selingaan Island suffered from severe beach erosion and part of the Sabah Parks office building was damaged by strong waves (Figure 3E). In May 2017, the top of the sand bar and the upper part of the beach were covered by coastal vegetation (Figure 3 F-H). Based on the informal interviews with the staff of Sabah Parks in Selingaan Island, the sand from the sand bar seems to slowly migrate toward the right section of the island and accumulate between the reef balls and the beach in front of the Sabah Parks office building. A boat can reach the beach through the opening area at the other end of the reef balls.

23. From 2011 to 2017, no extreme events happened in TIP. This has allowed the natural condition of island to adjust its shoreline according to local forces (tides and currents). However, significant morphological changes occurred in Gulisaan Island. Long bars were formed in the southern part of this island in 2011. However, they were gone in 2017 and high accumulation of sand appeared near the Sabah Parks office. In Bakkungan Kechil Island, signs of beach erosion appear on the left side of the jetty (from the sea), while creeping vegetation can be seen covering a large part of the sand on the right.

Figure 3: Comparison of beach condition in Selingaan Island

in 2011 (A) and in 2017 (B)

A: Photos taken in 2011	B: Photos taken in 2017
 **Figure 3A: Some reef balls are covered by sand.**	 **Figure 3B: All reef balls are exposed at low tide.**
 **Figure 3.1C: Vegetation and coconut trees grow parallel to the stone revetments.**  **Figure 3E: Exposed beach and part of the Sabah Parks office building have been damaged by strong waves.**	 **Figure 3D: Turtle nesting activities have reduced the vegetation cover.**  **Figure 3F: Trees surround the Sabah Parks office.**
 **Figure 3G: Sand accumulates behind the reef balls.**	 **Figure 3H: Sand deposit is covered by creeping vegetation.**

1. Impact of Coastal Protection Structures on Sea Turtles

24. Man-made structures built on the beach mostly to act as barrier have negative effects on sea turtles and their nests. Such structures include sand fences, recreational equipment, temporary buildings, and coastal protection structures (seawalls, rock revetments, and sandbags). Coastal protection and other sand-retaining structures have a high potential to become nesting barriers due to their solid, lengthy configuration and shore-parallel construction (Witherington et al., 2011).

25. Sea turtles trying to nest on protected beaches have a higher rate of abandoning their attempts than turtles nesting on beaches without protection (Mosier, 1998). Barriers prevent sea turtles from nesting landward of the structure. As a result, turtles nest at the lower part of the beach. Small change in nest elevation could bring negative consequences on the eggs due to weather conditions such as sea level rise and intense storms, which may inundate lower beach areas and destroy turtles' nests (Hawkes, et al., 2009; Poloczanska, et al., 2009; Witherington, et al., 2011).

26. So far no scientific study has been done about the impact of the reef balls and stone revetments on turtles in TIP. However, the staff of Sabah Parks in Selingaan Island stated that turtles are able to reach the beach as the reef balls submerge during high tide. Being short, this coastal protection protects only a small part of the island. Turtles can swim to both ends of the structure to reach the beach.

2. Historical Shoreline Change of Selingaan Island

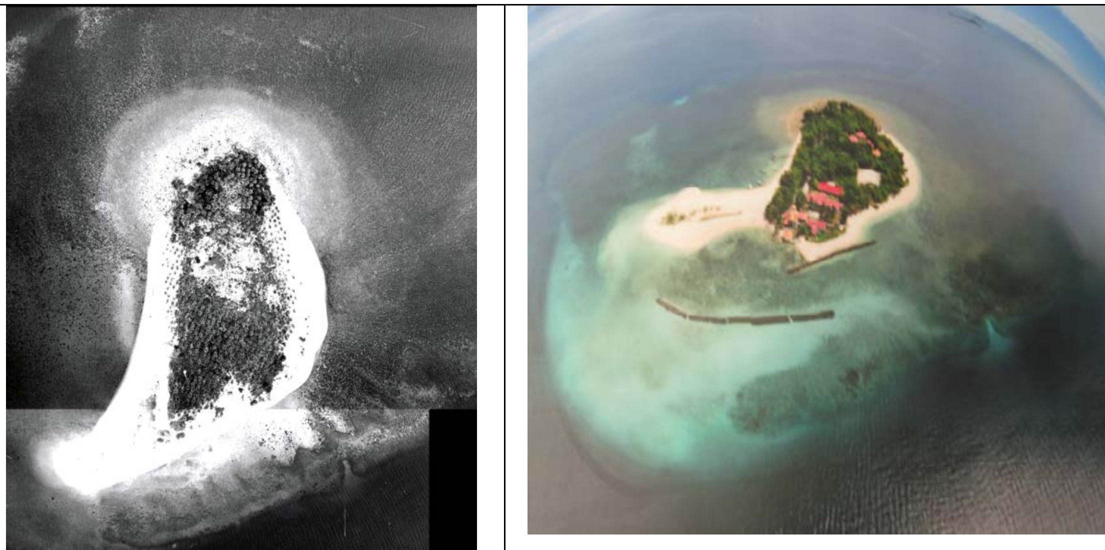
27. The oldest aerial photo of Selingaan Island was taken on 26 September 1970 (Figure 4A). It shows that the land area was mainly covered by coconut trees and was formed by a large area of sandy beach in the southern and eastern parts of the island. However, there is no landmark identified for mapping purposes. A look at the sizes and heights of the coconut trees indicates that most of them are young. Some of the trees are difficult to recognize as the photo is printed in black and white. This island is surrounded by coral reefs, which are an important source of beach sediment.

28. Basic infrastructure, including the office and accommodation of the Sabah Park staff, was built in the southeastern part of the island. Dense vegetation could be seen in the surrounding area. An aerial photo of Selingaan Island in 2008 showed that the southeastern part of the island was eroded (Figure 4). Severe beach erosion has damaged the vegetation areas and Sabah Park's basic facilities in the island. Reef balls and stone revetments have been built to stabilize and shelter the island from strong waves and currents.

29. Comparison of the Selingaan Island images from different sources indicates that the shoreline has changed and some part has been eroded (Figure 5). Generally, a large part of the sand deposited at the south of the Island, forming a sand bar. Positions of sediment have slightly changed due to changes in seasonal monsoon or water level in areas where the images were captured. Based on the aerial photo in 2006 (aerial vegetation-2006), the vegetation area was shrinking due to beach erosion. But a widening of the beach was also observed in some areas, probably due to increased sediment from offshore. Sediment accumulated in the south spread further southwest, with a small connecting area to the island (aerial shoreline, 2006). According to park rangers, strong winds in 2007 eroded most of the fringing trees of island. The eroded area was replaced by creeping vegetation, and increase of vegetation cover was detected in remote sensing data in 2010 (RS vegetation-2010).Sediment accumulated at the

west side of the southern part of the island (RS shoreline-2010). A site visit in 2011 showed that creeping vegetation was covering the same area, as what was observed in 2010, but accumulated sediment at the south had slightly shifted to the left (GPS shoreline-2011) compared to the remote sensing photos in 2010.

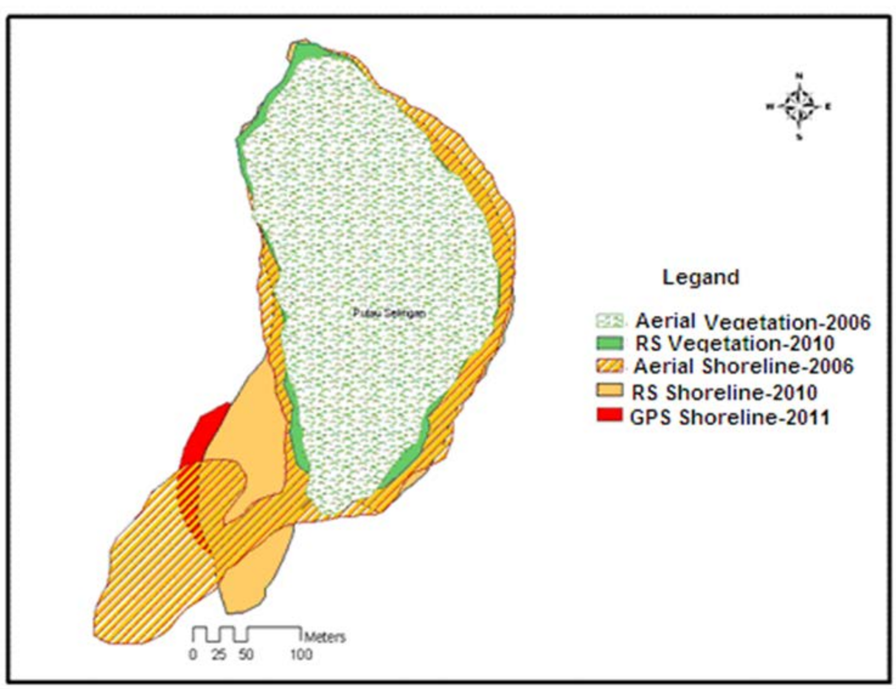
Figure 4: Selingaan Island in 1970 (A) and 2008 (B)
(Sabah Parks and UMS, 2014)



A: Aerial photo of Selingaan Island in 1970

B: Aerial photo of Selingaan Island in 2008 with coastal protection (Photo Credit: Sabah Parks)

Figure 5: Changes of Selingan Island between 2006 and 2011
(Sabah Parks and UMS, 2014)



30.

Images extracted from Google Earth indicate that the beach erosion in the south of the Selingaan Island (Figure 6a) has recovered. The sand has accumulated in the area protected by the reef balls. In 2017, it was observed that vegetation has covered some part of the sand bar and sand has accumulated in front of the beef balls (Figure 6b).

Figure 6: The shape of Selingaan Island in 2010 (a) and in 2017 (b)

a. Image on 2 October 2010

b. Image on 23 May 2017

3. Source of Sediment in Selingaan Island

31. During the site visits on 17 February and 19 June 2011, the northeastern part of the Selingaan Island was found to have a steep slope and short beach. Coral rubble and rocky beaches had formed in the northern part of the island. Fine sand sediment was clearly seen as having accumulated in the southern part and serving an important role as a nesting area for turtles (Sabah Parks, 2014).

32. Almost all shoreline areas of Selingaan Island were formed by sandy beaches and dominated by coral rubbles and broken shells. Turtles laying eggs and coastal vegetation cover are among the biological factors that have been identified to possibly contribute to sediment dynamics on the beach. The high frequency of turtle landings on the island and the presence of tourists were seen as possible causes of changes in the composition of the beach. According to Abdullah and Musta (1999), the size of the Selingaan Island was about eight hectares, but no further information on the size referring to shoreline or the vegetation line of the island was given. Beach sediment in near-shore areas mainly formed from eroded sediment of nearer coastal landforms (Pinet, 1992). Sometimes protection structures prevent sediment from entering the beach, thus reducing the sediment budget and resulting in the loss or reduction of the sizes of beaches. The reduction of sediment budget can lead to increased erosion of the front and adjacent beaches.

33. Since all the islands in TIP are under the protection of the Sabah Parks, human activities are limited and erosion due to land use change is minimized. With the current facilities available in Selingaan Island, only 50 tourists each day are allowed to stay in the island (Lasuin, et al., 2011). Tourists use the beach at eastern side of this island for swimming, snorkeling, and sunbathing while waiting for the sunset, when they can watch turtles laying eggs.

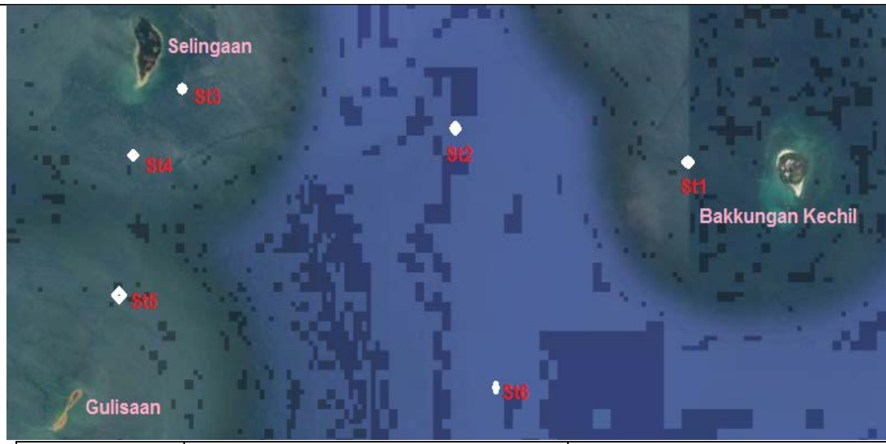
34. Based on the field observation, the beach sediment supply of Selingaan Island comes from its surrounding area. Coral and shell fragments are predominant in some parts of the beach. Change of current patterns and wave actions may transport the beach sediment somewhere else.

4. Current Speed and Direction Within TIP

35. Based on the report by Sabah Parks and UMS (2014), the speed of currents during the field measurement ranged from 71.0 cm/s to 72.7 cm/s, with an average current direction of 226 degrees toward the southwest. Selingan Island showed a relatively slight decrease in salinity (approximately 0.6 psu) and a little increase in total suspended solid (0.01 mg/L) compared to Gulisaan and Pulau Bakkungan Kechil islands. This indicates that water around Selingaan Island may be affected by freshwater and may contribute to a higher volume of suspended solid in the water column.

36. During the field trips on 11-13 May 2017, the measurement of current speed from six sampling sites within TIP indicated that the range of current speed was 31-46 cm/s (Figure 7). The current speed was higher at the middle (e.g St 2 and St 6) between islands. The measurement was done during high tide with an average current direction of 216 degrees. The dynamics of the water in TIP are affected by many factors such as different tidal phases, wind speeds and extreme events, and equatorial climate with warm and humid conditions. The islands forming TIP experience heavy rainfall and different wind regimes during seasonal monsoons.

Figure 7: Location of the current measurements within the TIP



Station	Coordinates (North/East)	Current speed (cm/s)
St1	6 ^{0}10'03" / 118^{0}06'02"	34.7
St2	6 ^{0}10'08" / 118^{0}04'60"	43.4
St3	6 ^{0}10'17" / 118^{0}03'43"	31.2
St4	6 ^{0}10'06" / 118^{0}03'32"	39.0
St5	6 ^{0}09'22" / 118^{0}03'26"	40.1
St6	6 ^{0}09'02" / 118^{0}05'17"	46.

IV. OCEANOGRAPHIC FEATURE OF SULU SEA

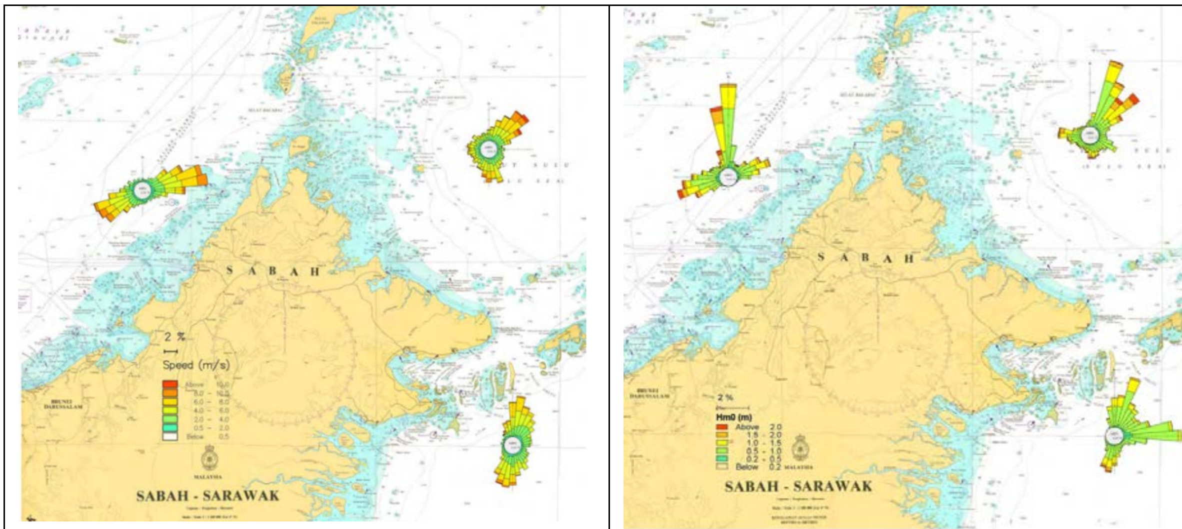
A. Wind and Wave Conditions

37. The state of Turtle Islands is mainly influenced by wind and wave conditions within the Sulu Sea. The main driving forces for winds and waves in this area are related to the Northeast (NE) and Southwest (SW) monsoons. Strong surface winds occur at the peak of the monsoon periods, during typhoon events, and during combinations of tropical cyclones and monsoons. The SW monsoon prevails from June to September and basically arises from the reversal of the NE monsoon. The NE monsoon is generally stronger and less variable than the SW monsoon. The staff of Sabah Parks reported that sometimes they are unable to travel to Sandakan to replenish their food supply, while fishers in small boats are unable to go to sea due to bad weather. Rough sea conditions lead to less tourist arrivals in TIP. The impact of the SW monsoon could be seen between July and October. Although the weather is unpredictable at this time, the sea is not as rough as when the NE monsoon prevails. This wind system is believed to significantly contribute to shoreline changes and sand distribution in TIP.

38. Figure 8A shows that the prevailing wind direction in the Sulu Sea turns slightly northward compared to that in the South China Sea during the NE monsoon. The prevailing wind direction of this monsoon period is NE. For the SW monsoon conditions, the prevailing wind directions in Sulu Sea are the south (S) and the south- southeast (SSE) (Figure 8B).

39. The Sulu Sea responses to the monsoonal and cyclonic surface winds are governed by the strength and duration of the winds, the bathymetry, and the free fetches over which waves can be generated from the wind forces. The normal wave conditions along most of Sabah's shorelines are dominated by the waves generated by the monsoon winds, whereas the typhoon-generated sea conditions often dominate the design wave conditions. The normal wave conditions are generally the most important for the littoral transport and coastal morphological conditions.

Figure 8: Directional distribution of offshore wind (A) and waves (B) in the South China Sea, Sulu Sea and Celebes Sea derived from the British Met Office's hind cast data base (Chew et al., 2005)



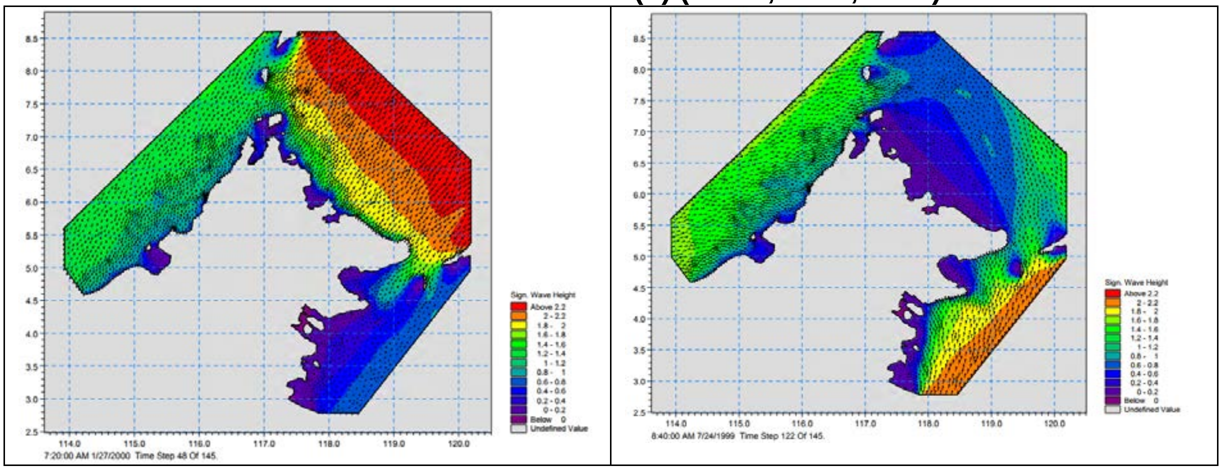
A. Offshore wind B. Wave Condition

40. During the NE monsoon, the long free fetch for wave growth and the alignment of the wind and the waves increase wave energy. The waves propagate directly toward the coastline of Sabah facing the Sulu Sea (Figure 9A). However, the coastline in the Sulu Sea is sheltered during the SW monsoon (Figure 9B). The coastline is, however, protected by numerous reefs and islands off the coast, and much of the shoreline is, in fact, a low-impact coastline fringed with mangroves. At the northern part of the east coast, which faces the Sulu Sea, the coast is sheltered against offshore waves due to the many reefs and islands off the coast, as previously mentioned.

41. The typical offshore wind and wave conditions (Figures 9A and 9B) provide general oceanographic features in the Sulu Sea. However, the wind strength and wave height and may be difficult to predict once they approach the shallow waters in the coastal area. Therefore, it is important to have some local data to create a model and predict the real condition of the oceanographic features in TIP.

Figure 9: Typical wave conditions during the NE Monsoon (a) and

SW Monsoon (b) (Chew, et al., 2005)



42. Chiew (2008) reported that Sabah experienced more than 10% higher annual rainfall during 2000-2007 than during 1990-1999. In the Sulu Sea, high rainfall sometimes accompanied rough seas and strong waves to the shoreline.

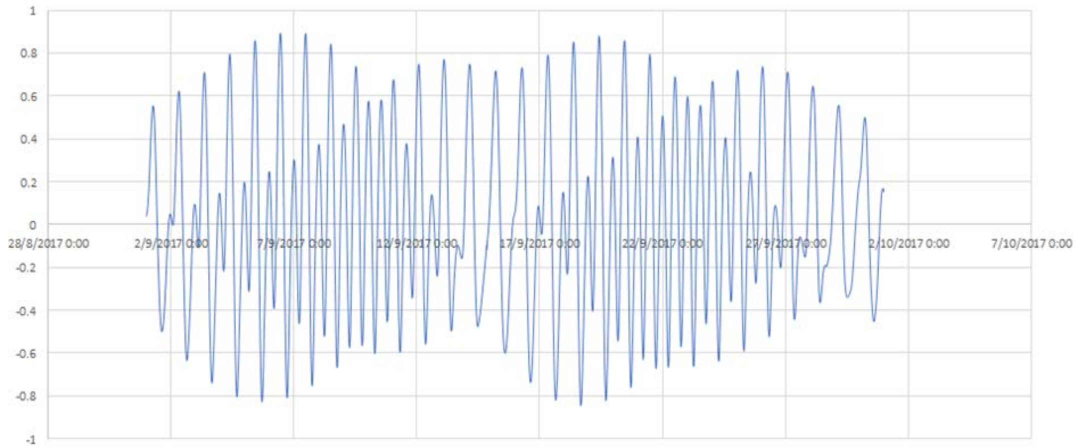
43. Limitation of sediment source could lead to beach erosion in Turtle Islands. Chiew (2008) also reported that Malaysia experienced positive annual mean temperature trends from 1968 to 2002, with an estimated air temperature increase from 0.7 o C to 1.3 o C every half century. During the dry season, the environment of the island is hotter than usual as air temperature increases. Creeping vegetation growing at upper part of the beach dries easily with a high air temperature. Turtles usually choose the upper part of the beach as nesting area. However, it takes a longer time for them to prepare the nests as dry sand tends to collapse. Sometimes turtles leave the beach without laying eggs. During the rainy season, the trees in the island look greener and coastal vegetation cover increases. Shade from the trees can influence the temperature of the sand by reducing direct exposer to the sun. Temperature affects the sex ratio of sea turtles. Female's sea turtles need warmer temperatures in order to develop. There is also an increase in the number of unhatched turtles' eggs due to high water content in the sand.

44. Beach erosion highly affects the exposed area of the islands. Changes in meteorological condition may also influence the current patterns and wave characteristics around the islands, which indirectly contribute to the distribution of the beach sediment. The staff of Sabah Parks observed that the beach sediment in exposed areas of Selingaan Island is eroded during the SW monsoon (angin selatan). However, during the NE monsoon (angin utara) the elevation of the beach increases, creating a steep slope, due to strong winds and waves.

B. Tidal Elevation and Sea Level Rise Prediction

45. The tides of the Pacific Ocean influence the water levels in the Sulu Sea. DHI (2005) reported that the Sulu Sea is dominated by diurnal (daily) tide cycle: one high and one low tide every lunar day. However, the Celebes Sea is dominated by the semi-diurnal (twice daily) tides. Large water level differences between the Sulu and Celebes seas create locally strong currents in this area. However, complex bathymetry with the presence of islands and shallow water reduces the currents generated by tidal flow near the coastline. (Analysis of predicted water level at Sandakan Tidal Station can give general information on tidal cycle in TIP [Figure 10]). The results show that Sandakan waters experience mixed semi-diurnal tide (two high tides and two low tides in a day).

Figure 10: Analysis of Sandakan tidal data



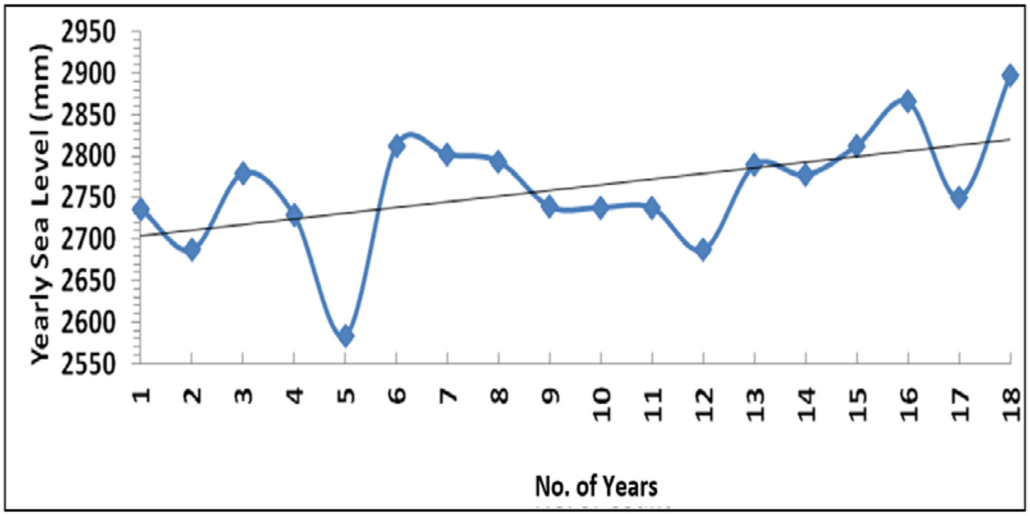
46. Based on tide gauge record data, the National Hydraulic Research Institute of Malaysia (2010) reported that the general trend in sea level rise along Malaysia's coastlines in the last five years was significantly higher than the general trend in the previous 20 years when Sandakan, the closest tide gauge station to Turtle Islands, had an average sea rise rate of 4.1 mm/year more than twice the global average value of 1-2 mm/year (IPPC, 2007). The sea level rise and other meteorological events contributed to faster sediment loss than expected.

47. Linear regression analysis of Sandakan yearly sea level data was used to identify trends and slope from 18 years of sea level data (Figure 11). This indicates that the sea level is increasing, as shown by the positive trend (upward direction of the line) in the graph. The slope of linear regression indicates that sea level at Sandakan is rising at a rate of 6.78 mm/yr. Based on the average of all available 18 years water level of hourly data at Sandakan station, Mean Sea Level (MSL) value was estimated 2.706 m (Anthony, 2017).

48. The Highest Astronomical Tides (HAT) level in 2012 (1.58 m) was used as baseline data to predict the future HAT level in Sandakan waters. The HAT values projected for the years 2020, 2040, and 2060 are 1.75 m, 1.91 m, and 2.15 m, respectively (Figure 12). Based on UMS and Sabah Parks (2012) report, the highest spot height of Selingaan, Gulisaan and Bakkungan Kechil are 0.9 m, 1.4 m and 5.5 m, respectively. It is predicted that most part of the TIP's beach will be eroded or submerged by water as the dry land area is relatively flat with elevation mainly less than 3.5 m above MSL.

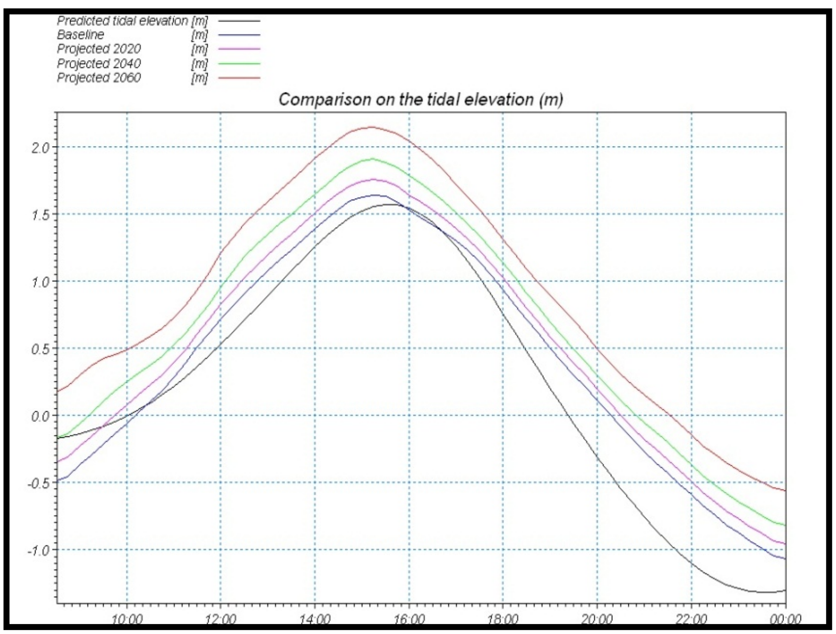
Figure 11: Linear regression analyses for yearly Sandakan sea level data

(Anthony, 2017)



F

igure 12: Comparison of predicted and future HAT simulated for Sandakan Tidal Station (Anthony, 2017)



C. Impacts of Sea Level Rise on Coastal Areas

49. Common sea level rise (SLR) has direct effects on coastal areas. Its impacts on natural systems are: (1) inundation and displacement of wetlands and coastal low lands, (2) increased damage caused by floods and storms, (3) increased coastal erosion, and (4) salt water intrusion into surface water and aquifers (McLeod et al., 2010). Meanwhile, from the perspective of socioeconomics, common effects are the destruction of properties along the coast and changes

in land use pattern, water management system, navigation, and waste water management (James and Chua, 1991).

50. Sea level rise may inundate large, low coastal areas and islands with seawater during high tides accompanied by strong winds. Such condition is likely to disrupt the life cycles of coastal flora and fauna. In TIP, the most affected resource would be sea turtles, which use beaches as nesting ground. There were instances in the past when Selingaan and Gulisaan islands were inundated by seawater, causing damage not only to the turtle hatcheries but also to some infrastructure in the islands. Saltwater inundation may also affect the embryonic developmental stages of turtles (Pike, et al., 2015). More frequent nest inundations associated with sea level rise will increase variability in sea turtle hatching success, spatially and temporally, due to direct and indirect impacts of saltwater inundation on developing embryos.

V. ISSUES AND CHALLENGES

51. The ecotourism business in Turtle Islands Park runs its course as usual as long as turtles use the islands as nesting ground. However, beach erosion is the main challenge in TIP. It affects the turtle nesting ground, which supports more than 1000 turtles landing yearly (Isnain, 2008). Coastal structures have been placed in front of Sabah Parks' office to maintain infrastructure, but not on the beach, which is highly important for turtle nesting. However, detailed studies of TIP's surrounding environment; coastal processes, including beach profiling; and current dynamics need to be considered before the implementation of any hard protective structures in the island.

52. Solid wastes such as cans, bottles, and plastics both from the mainland and the sea area are drifted by current to TIP. The amount of solid wastes stranded on the beach increases, especially when strong winds hit. Floating waste and degradation of water quality due to high suspended sediment have been observed on the west side of Selingaan and Gulisaan islands. Accumulation of solid wastes on the beach will prevent turtles to lay eggs. This will also give tourists a bad perception of Sabah Parks as guardian of the islands.

53. TIP is dependent on rainwater for operational use and bottled water from the mainland for consumption. Currently, there is no freshwater in Selingaan Island. While Bakkungan Kechil Island gets freshwater from wells, the taste and clarity of the water have changed. The water problem is probably due to high consumption of the residents in the islands (staff of Sabah Parks and the army) and change in the rainfall pattern. Lack of underground freshwater and dry season may affect the vegetation cover on the island. Islands without tress and vegetation are prone to erosion by winds and waves. Other non-climatic issues identified during the field trip were the outbreak of crown of thorn and illegal fishing (mainly long line and hook and line) in neighboring communities.

VI. SUGGESTIONS AND RECOMMENDATIONS

54. Long-term and cost-effective shoreline protection needs to be implemented to maintain the beach and vegetation in TIP. Beaches in the islands are highly important for turtle nesting. However, detailed studies on their surrounding environment (e.g., environmental impacts assessments), coastal processes, and current dynamics need to be considered before installation of any coastal protection structure in the islands. The current patterns and coastal processes (e.g., longshore transport) contribute to the islands' morphological change. Therefore, simulation of local current pattern by considering the sea level rise and seasonal

monsoons is required for any development less than 60m or any sea reclamation. Hydrodynamic study requires details data on bathymetry, current, and water level in TIP

55. Preservation of the beach and vegetation should be given higher priority in the management plan for TIP before the islands disappear from the earth's surface. The most importance natural asset of these islands is its beaches, which serve as nesting area for the endangered green and hawksbill turtles. Turtles are one of the main tourist attractions in Sandakan.

56. Full cooperation of park rangers and the army is needed to stop illegal fishing in the park. Activities to promote conservation through ecotourism (e.g., adopting turtles) and awareness program may be directed to or may involve tourists (local and foreign) during their visits to TIP. These may also be extended to neighboring communities. A trap for solid waste can be installed in a strategic area to prevent floating garbage from reaching the beach. Collection of floating garbage can be done in a small area where the trap is installed.

VII. CONCLUSIONS

57. TIP is one of the areas with a high potential for hosting recreational and leisure sand-sun-sea (3s) activities in the east coast of Sabah. The beach dynamics around the islands are clearly affected by many factors, including changes in seasonal monsoons. The dynamics of erosional and deposition areas in each island are due to a combination of individual exposed areas to the monsoonal wind direction, wind speeds, and current patterns. Loss of beach can be clearly seen in the southeastern parts of Selingaan Island. Unexpected extreme events, such as strong winds due to a typhoon in the Philippines, have a high potential to change the water level and the dynamics of sandy beach in the Turtle Islands.

58. Coastal habitat protection (sea grass and coral protection), beach tree planting, and stricter law enforcement (e.g., through intensified patrols), are among the recommended measures for reducing vulnerability of TIP. Protecting the natural habitat, such as seagrass and coral reefs, through monitoring and regulation can help improve the natural habitat of the islands. Beach tree planting can help stabilize the coastal area, encourage tourist participation, and maintain the turtle nesting area.

59. A field trip in May 2017 showed that coastal vegetation cover has improved in some parts of TIP. There was a change in beach sediment in all islands, but there were no signs of severe beach erosion. This study, the installation of reef balls, and stone revetments in Selingaan Island have improved the condition of the beach and protected Sabah Park's structures from beach erosion.

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