Beach erosion: Threat and adaptation measures of communities in the Tun Mustapha Park (TMP), Sabah, Malaysia

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Abstract. Beach erosion is among the main phenomena affecting small islands in the Coral Triangle region, particularly in the Tun Mustapha Park (TMP), Malaysia. This study was done to investigate the level of beach erosion and to determine the adaptation measures for the coastal communities to beach erosion. Field trips were carried out in May and July 2017 at seven islands (Banggi, Tiga, Balambangan, Malawali, Molleangan, Tigabu and Mandidarah) of TMP. Semi-structured interviews were conducted with 50 respondents who were the coastal inhabitants of the islands, to gain local knowledge about island beach erosion. Results indicate that beach erosion occurred during the peak of monsoon seasons and extreme events. Wind-induced high waves during the end of the year (northeast monsoon) eroded beaches, damaged houses, fishing structures and uprooted trees. Six of the islands are affected by beach erosion, whereas Mandarah island is experiencing accretion. Karakit beach is the only study site protected by seawall and beach revetment. The identified coastal adaptations to beach erosion were traditional shoreline protection by piling dead corals, sand sacks and woods on the beaches, modification and improvement to damaged building structures. Some local communities opted to move further inland and relocate to other islands or mainland Sabah to avoid the impacts of erosion. This study emphasizes the value of local knowledge shared by the coastal communities which can be incorporated with scientific baseline data for improved sustainable coastal development, protection, and management of the marine protected area.

Keywords: beach erosion, vulnerability, adaptation, island, Tun Mustapha Park

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1. Introduction

Beach erosion is the loss or the long-term removal of sediment and rocks from the island due to the action of waves, currents, tides, and extreme events. Beach erosion has affected sources of livelihood and displaced settlements in the coastal communities. Small islands are more vulnerable to climate change because there are limited options for the local communities to move and protect themselves when the sea-level rise (SLR) or when extreme events occur. The SLR rate (mm/year) at Marudu Bay (Figure 1) and the adjacent area is estimated to be 5.27 mm/yr and SLR is projected to be 0.43 m – 1.06 m in the year 2100 [18]. SLR has directly affected the coastal areas such as inundation and displacement of coastal lowlands, saltwater intrusion into aquifers, increased damage caused by storms and coastal erosion [15]. Even though the SLR is a slow process, it can increase greatly during the events of storm surges associated with tropical cyclones. As an example, the sea level in Hong Kong coastal waters rose by 1.0 m during tropical cyclones [13]. The western Pacific, including the northwest Pacific Ocean and part of the South China Sea (SCS), are the most active cyclogenesis basins with an average occurrence of 27 cyclones per year, with which almost half of these reach typhoon intensity [19]. The TMP's geographical location at the tip of Borneo Island exposes the islands to changes that occur due to seasonal monsoons and other extreme events such as tail-end effects of tropical cyclones, as well as storm surges. As a result, rising sea-level may inundate low coastal areas and small islands, particularly during the high tide. TMP experiences mixed tide with a tidal range between 0.2-2.2 m [14][20], which is also an important contributing factor to the beach erosion along the shoreline of islands.

TMP experiences two distinct monsoon seasons that are characterised by strong winds and rough sea conditions. The strongest winds occur from July to September during the southwest monsoon (SWM) and from December to March during the northeast monsoon (NEM) [27]. This area is also influenced by the weather system in the South China Sea (SCS) and the Sulu Sea. Based on historical wave data extracted between 1999 and 2008, the annual wave direction over the SCS is ranged from 30° to 60° during the NEM and the wave direction changes to 150° to 210° during the SWM [9]. A larger range of historical wave direction (from 40° to 80°) was recorded in the Sulu Sea during the NEM and shifted from 210° to 260° during SWM. Wave height is usually higher than 1 m in the SCS during NEM and about 0.5 m in the Sulu Sea for both monsoons [25]. Global warming causes sea-level rise as oceans expand and generate extreme weather events such as large storms, floods, and strong wave actions. Consequently, it affects about 70% of the world's sandy beaches through inundation and increased coastal erosion [5], and the small islands in the TMP are certainly no exemption. The local communities inhabit certain islands in TMP, especially in areas that are well sheltered from strong wind, availability of freshwater supply, and are suitable for mariculture activities such as sea cucumber culture, fish cages and seaweed farming. These communities can provide information on surrounding environment changes and impacts on their livelihood. The right combination of wisdom, knowledge, and practices of the community is gained over time through experience evolving by adaptive processes and orally passed on from generation to generation [3][26]. Therefore, a supplemental of the local knowledge to the scientific research is playing a pivotal role in effective coastal erosion management as the local communities have a well-rooted understanding and history of the local area and environment. In the case of local communities within TMP, there is very little documentation available related to the local knowledge related to coastal erosion. It is further complicated due to their poor level of understanding of shoreline dynamics and variability at different geographical locations over a long period. This study was carried out to investigate the seriousness of the coastal erosion threats at selected islands in the TMP and to determine how the local communities adapt to this changing environment. This study is crucial in providing valuable input to the livelihood of the local communities in dealing with unprecedented future environmental change and for the local authority in designing the best coastal management plan.

2. Methodology

Tun Mustapha Park (TMP) is known to be the second-largest marine protected area (MPA) located in the northern part of Sabah, Malaysia. The TMP marine area is estimated at 898,762.76 hectares (ha) covering the District of Kudat, Kota Marudu and Pitas. TMP was gazetted as a multipurpose MPA in 2016 as the communities were found to be scattered within its islands and shoreline of mainland Sabah. TMP is part of the Coral Triangle region, a marine area acknowledged as having the richest marine biodiversity in the world. The marine resources such as mangrove forests, coral reefs and seagrasses ecosystems support more than 187 000 people living within the TMP [11]. It is estimated that 50 islands and islets exist in TMP [12].

Field surveys on the selected islands and assessments of local knowledge on the threat and adaptation of the local community due to coastal erosion were carried out between May and July 2017 by holding focus group discussions and face-to-face interviews. The members of the group discussions consist of the village leaders, fishers, senior citizens, and housewives who are residing on the islands of Banggi; Karakit (7°06'35.28" N / 117° 05'13.07" E) and Dogoton (7°20'03.14" N / 117°17'05.81" E), Tiga (7°20'22.78" N /117°02'53.81" E), Balambangan; Batu Sirih (7°11'53.37" N /116°52'07.71"E), Teluk Long (7°18'28" N / 116°58'45" E), Molleangan Besar (7°05'.00" N /117°02'36.41"E), Malawali (7°05'19.83" N / 117°16'38.45" E), Tigabu (6°53'07.27" N /117°28'13.46" E), and Mandidarah (6°55'52.90" N / 117°20'07.33" E). There are nine locations selected where the surveys and assessments were conducted (Figure 1). The unstructured questionnaire was applied to collect information on local knowledge related to the threats of erosion on the islands and adaptation measures carried out by the communities. Information on their age, impacts of beach erosion and adaptation were asked during the interview session. Local knowledge, perception, and experience as well as historical extreme events occurring in TMP were used to determine the physical forces and the natural factors that influence the life of communities. Morphological changes and beach erosion impacts were reported based on the information recorded from the focus group interviews.

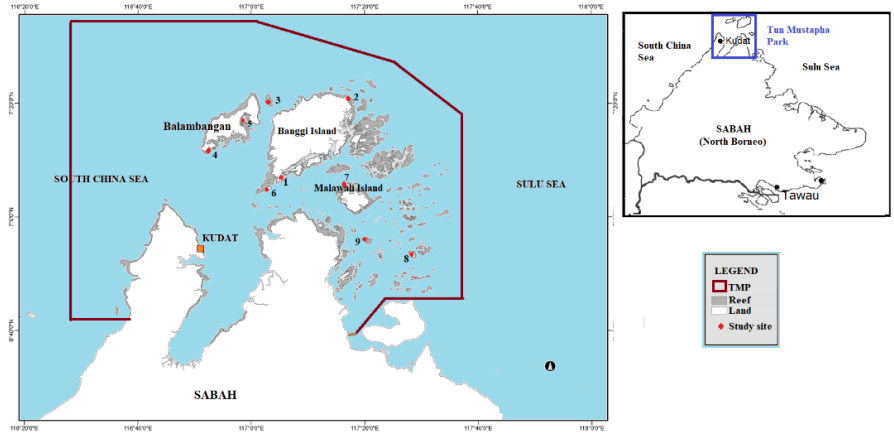

Figure 1. Location of the surveyed islands and study sites within the TMP. 1: Karakit, 2: Dogoton, 3: Tiga, 4. Batu Sirih, 5. Teluk Long, 6. Molleangan, 7. Tg. Manawali, 8. Tigabu and 9. Mandidarah

The conditions of the erosions at the study sites were categorised using the National Coastal Erosion Study (NCES) 1986 [7]. These erosion categories are based on the threats to the livelihood and existing shore-based facilities of substantial economic value. The categories are defined as Category 1: Shorelines currently in a state of erosion and where shore-based facilities or infrastructure are in immediate danger of collapse or damage, Category 2: Shoreline eroding at a rate whereby the value of

the public property and agricultural land is becoming threatened within 5 to 10 years unless remedial action is taken, and Category 3; Undeveloped shoreline experiencing erosion but with no or minor consequent economic loss if left unchecked. The results were compared and evaluated with the climate change vulnerability using the coastal integrity vulnerability assessment (CIVAT) carried out on the same islands in 2017 [24]. This assessment tool detects the coastal vulnerability levels (low, medium and high) against sea-level rise and stronger storms.

3. Results and discussion

3.1 Island communities

The 50 respondents were made up of about 11 females and 39 males (Table 1). About 80% of the respondents had lived on the respective islands for more than 20 years whilst only 20% had lived there for less than 20 years. Beach erosion contributes to the loss of social-economic and changes in environmental conditions (Table 2).

Table 1. Information of the island and villages of the study sites.

Island	Banggi		Tiga	Balambangan		Molleangan	Malawali	Tigabu	Mandi darah
[a]Size (km^2) / perimeter (km) [10]	450/ Nil		0.13/ 0.50	107.43 / 87		1.87/ 5.6	37.93/ 42.40	1.43/ 5	0.12/ 2
Villages	Karakit	Dogoton	Tiga	Batu Sirih	Teluk Lung	Molleangan	Malawali	Tigabu	Mandi darah
[b]Number of individuals	110	237	0	210	0	37	219	671	76
No of respondent	4	6	0	14	4	4	6	8	6

[a] JUPEM.
[b] Number of individuals provided by District office Kudat.

The uneven number of communities living on the islands of TMP (as shown in Table 1) is based on the availability of space, resources, and basic facilities. The main source of freshwater in TMP is groundwater and harvesting rainwater during the rainy season. Banggi Island is the largest island in Malaysia covering an area of 450 km^2 and surrounded by about 50 small outlying islands [10]. Karakit, the largest town on this island comprises more than 10 villages with basic facilities such as schools, electricity, and a hospital. This study focused only on Kg Karakit to represent the southern part of the Banggi Island and Dogoton which is in the northern part of the island (Figure 1). The assessment was carried out in the coastal area of Dogoton as the community is mixed with Kg Rahmat. Tiga Island is located between Balambangan Island and Banggi Island with several individuals reported living in the area. However, none was found living on the island during the site visit.

DHI (2013) reported that there are nine villages documented on Balambangan Island, but this study is only focusing on two villages, namely Batu Sirih and Teluk Lung (Figure 1). The main source of income for the villagers is fishing. Batu Sirih is located in a pocket of sandy beaches with 210 inhabitants. No permanent community is reported in Teluk Lung, but during the site visit, four respondents from two families were temporarily living in this area to take care of the sea cucumber farms.

Molleangan Besar Island is located in the southwestern of Banggi Island with 37 local inhabitants and occasionally foreign tourists arriving on a small resort on this island. Malawali Island and Tigabu Island have a larger population per area as compared with other islands within TMP. Sea cucumber farming is commonly found as the main economic activity of the local communities on these islands. On-stilt houses are commonly found in these villages. Mandidarah Island is also home to a small fishing community with a population of about 76 inhabitants. Interestingly, the younger generation has left the island for the mainland for pursuing education and better job opportunities. Most of the respondents are women who are mostly involved in sea cucumber farming activities.

3.2 Threats to the beach morphology

Almost all respondents had noticed significant changes in the shoreline morphology at their respective islands. The beaches are used for different activities such as building houses, fishing landing sites, temporary shelter for their boats, and fishing materials. Comparatively, extensive human activities were observed along the coastline in Karakit compared to the other study sites. The seafront was reclaimed for the town's expansion, and some permanent and temporary structures were built on the reclaimed area such as the basic infrastructure facility such as the jetty. Some sort of shoreline protection (e.g seawall) was built along the shoreline to mitigate coastal erosion. Significant beach erosion was observed in areas with no coastal protection installed. CIVAT analysis indicates that this island has a medium vulnerability to sea-level rise and stronger storms [24]. Several houses in Dogoton were built on-stilt. The unpredicted offshore strong wind had damaged structures along the seafront (jetties, houses, and uprooted coconut trees), and contributed to the extensive loss of beach sediment. Many houses have been built on land, and several structures (i.e small wood bridges) that connected the houses on land and on-stilt were damaged or partly collapsed due to coastal erosion (Figure 2a). A fence of woods and dead corals were used as temporary shoreline protection from strong winds and waves to reduce the impact of the beach erosion (Figure 2b).

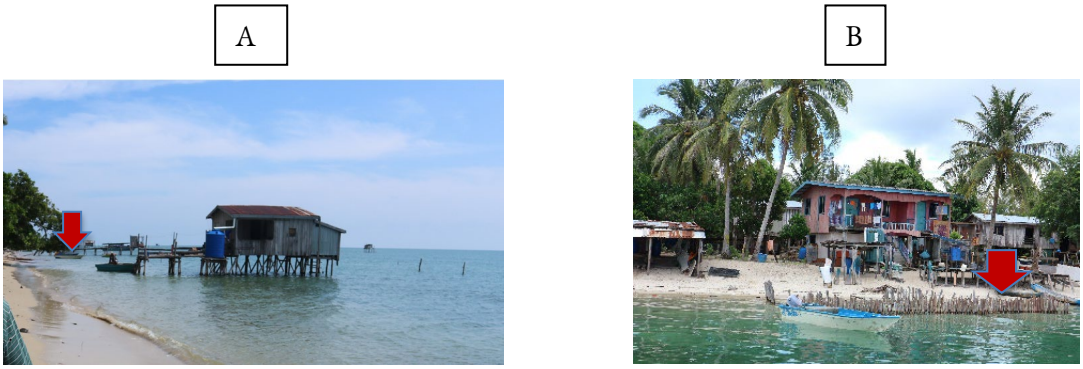

Figure 2. Beach erosion at TMP: Bridge collapsed disconnecting the house and land (a) and a row of woods was placed to protect the house (b).

Tiga Island is a low-lying island with predominantly sandy beaches and is covered with primary forest, coconuts and other coastal vegetation. In 2013, minor erosion was observed by DHI [6]. During the site visit, there was no inhabitant on this island. There was severe erosion that affected vegetation and a jetty near the burial ground in the northeastern part of the island. CIVAT indicates that this island has a high vulnerability as it has a high potential impact and low adaptive capacity to sea level rise and stronger storms [24].

Balambangan Island is the second-largest island in TMP covered by grassland and limestone forest. Several small islands around this big island such as Kalautan Island, Bakung Island and Mandasiang Besar Island. During the site visit at Kg Batu Sirih (Figure 1), evidence of past coastal erosion was identified based on fallen trees and damaged houses or jetties, coconut trees, and burial sites. Several seafront houses were abandoned by the affected communities. The available backshore space is now becoming overcrowded with new built-up structures. About five burial plots were also relocated further inland due to beach erosion. Since the late 70s, three rows of coconut trees (about 10 m from the current beach) have disappeared due to beach erosion. During the dry season in 2016, the only well available for drinking water is contaminated by seawater intrusion and thus unsuitable for drinking water. A new well was dug further inland to provide a freshwater supply for the community. Meanwhile, the coastal area of Teluk Lung consists of mainly coastal vegetation. The occurrence of beach erosion is notable based on the large trees' trunks in the sea about 5 m from the current shoreline. Fresh indications of beach erosion and fallen trees along the shoreline were observed and likely due to the SWM which generated strong waves from the south. It also damaged the fence of the sea cucumber culture. CIVAT assessment indicates low vulnerability (Table 2) in Teluk Lung as its' geographical location located further inside the bay and the present coral reefs contribute to high adaptive capacity [24].

Molleangan Besar Island is surrounded by sandy beaches and rocky shorelines. SWM induced waves may have contributed to severe beach erosion and threatened the house structures as well as the orchard area a few meters from the watermark. The presence of the Maliangin Resort increases the number of communities and visitors to the island. Sea travelling from Kudat to this island would be occasionally affected by rough and limited sea activities during the peak of the NEM. Conservation of the beach is an important asset of the island as this area can be a great potential for tourism development. CIVAT indicates that this island has medium vulnerability [24].

Malawali Island has only one village (Tg. Manawali) with 219 inhabitants. The majority of the community works on the sea cucumber farms. In 2017, a strong wave and heavy rain as a result of the tail-end of Typhoon Lan moving from the east of the Philippines, have inundated low land areas with seawater including the village of Malawali Island. This event has affected the basic amenities such as jetty structures, sources of fresh water, and burial grounds. To date, there are about 10 graves that have been relocated further inland on this island. During the peak of monsoons, sand was accumulated on the beach and impeded the streamflow to the sea. The stagnant saline water eventually killed the plants further inland. As part of the co-existence option, the communities removed the sand blocking to allow a free flow of water to the sea. Saleh et al (2018) reported that this site has a medium vulnerability, medium potential impact, and low adaptive capacity.

Tigabu Island is mainly covered with grassland or sparse vegetation and small patches of mangrove. There are about 671 residents who reside on the island (Table 1). The lack of vegetation on this island may reduce the availability of freshwater The main issues faced by the community are the lack of freshwater to support the increasing population and coastal flooding. Strong wind coinciding with the highest astronomical tide contributed to severe beach erosion at the end of 2016. The beach slowly recovered after the NEM. During the site visit on 25 August 2017, displaced forehead creeping vegetation was observed near the jetty due to strong waves that coincide with high tides. There was no new serious beach erosion reported by the communities. Another island, Mandidarah Island is about 0.12 km^2 and is mostly agricultural (coconuts and mango trees) and grassland areas [10] [23]. Only 76 people are living on the island as most of the extended family are living in Kudat to gain better education and job opportunities. Most of the people living on this island are fishermen and involved in sea cucumber farming. Only minor displacement of forehead creeping vegetation, beach erosion threatening burial sites, and loss of beach sediment were observed on the islands. Mangrove and seagrass were found around the island while coral reefs were located further offshore. From the site visit, there

was accretion (accumulation of sand on the beaches). This island has medium potential Impact and high adaptive capacity leading to low vulnerability to climate change [24].

Based on the NCES, 1986 [7], the results indicated that the beach erosion in Dogoton, Batu Sirih, and Tigabu are categorised as Category 1 (Table 2). Shore-based facilities such as the jetty and buildings were damaged and probably led to immediate danger to the communities. These sites are also highly vulnerable to climate change as each site has a low adaptive capacity [24]. However, Tigabu has a medium potential impact and adaptive capacity. Karakit, Molleangan Besar, Malawali and Mandidarah are in Category 2 as agricultural land is most likely threatened by coastal erosion within 5 to 10 years. The communities in these islands can adapt or have to be relocated. However, the land area for settlement is limited to certain islands. The shoreline protection in Karakit needs proper maintenance to support its function as shoreline protection. Tiga Island and Teluk Lung fall under Category 3 as the area is an undeveloped shoreline and is considered a minor consequence of economic loss.

Table 2. The beach erosion category, vulnerability, and observed adaptation measures at villages in TMP.

Villages	Beach category based on [7]	Vulnerability [24]	Adaptation observed during sites visit
Karakit	2	Medium	-Hard structures-seawalls and stone revetments built at the reclaimed coastline.
Dogoton	1	High	-Shoreline protection using dead corals and woods. -Retreat and relocate house further inland.
Tiga	3	High	-No action was taken as no permanent community living on the island.
Batu Sirih	1	High	-Garden protected by zinc panels from strong wind and seawater. -Woods or sacks of sand placed in front of the affected houses to defend against waves. - Coconut trees were planted to strengthen the sediment from erosion. - Retreating further inland as the house was damaged. -Families relocate to other islands (e.g. Banggi) or mainland (Sabah)
Teluk Lung	3	Low	-No adaptation and mitigation measure as the community are only temporarily living in that area
Molleangan	2	Medium	-Uproot coastal trees and loss of beach sediment
Tg. Manawali	2	Low	-Repair houses by increasing the height of the floor higher than the old structures. -Use stronger materials to withstand the next incoming storm. - Relocated the most affected houses and burial grounds inland
Tigabu	1	Medium	- Repair houses by increasing the height of the floor higher than the old structures. - Use stronger materials to withstand the next incoming storm. -Relocated the most affected houses and burial grounds.
Mandidarah	2	Low	-New coconut trees were planted along the shoreline.

3.3 Adaptation strategies to address beach erosion

The low-land and its adjacent water areas of several islands in TMP are mainly developed for villages or residential areas, maricultural activities (sea cucumber, fish cage) and fish landing sites (jetty) as the main livelihood depends on fisheries and fisheries-related activities. Extreme weather can be a challenge to the communities, such as strong winds and high waves, particularly during the peak of the NEM (August to February). The weather conditions have contributed to beach erosion, damage to the coastal foreshore structures and coastal vegetation on the beach, house foundations and building structures, fish/sea cucumber cage structures, and fishing gears. Rough sea conditions have also prevented fishermen from going out to the sea. The level of beach erosion depends on its exposure to strong wind and waves. For example, serious beach erosion occurs at Batuh Sirih compared to Mandidarah Island. Significant impacts of beach erosion can be seen mainly on the sandy beach areas. Beach erosion has tremendously affected the well-being of the local communities.

Adaptation measures that have been applied by the communities to tackle the impact of beach erosion are co-existence, defence, and retreat (Table 2). Communities are trying to co-exist by adapting to cope with the new changes in the surrounding environment and accepting their losses. In Karakit coastal armouring was employed by using seawalls and stone revetments to protect the coastal areas and infrastructures such as roads, mosques, and jetties. Generally, this shoreline protection has successfully reduced coastal erosion. The communities in Dogoton and Batu Sirih were using traditional shoreline protection (dead corals and woods). Several families relocated further inland to stay with extended family members or migrated to a nearby island such as Banggi Island. There was also an issue that the village is overcrowded and lacks suitable lands for a new settlement in Batu Sirih. So far, there is no attempt was made to stop beach erosion in Tigabu and Mandidarah islands. No adaptation and mitigation measures for beach erosion in Teluk Long as the community is temporarily living in that area while having no direct impact on the property on Tiga Island. Communities at Molleangan Besar Island chose to be relocated to Karakit for a better life.

Almost all the respondents identified that fishing activities and sea cucumber cage culture were affected by extreme events that seriously caused coastal erosion. Another threat is the availability and accessibility of freshwater on several islands such as Batu Sirih Island and Tigabu Island, especially during the dry season. Saltwater intrusion has occurred in well waters at Batu Sirih Island as most parts of the seafront were experiencing severe beach erosion. Communities in TMP are considered amongst the poorest communities in Malaysia as there are a high number of stateless and undocumented individuals living within this area [4][8]. Damages to marine ecosystems caused by fish bombing and cyanide poisoning and land lost due to beach erosion are not the main concerns of the community compared to the damage to their houses and cages. However, [21] reported that declining of fish caught as a result of climate change and eroding natural fish landing sites can be a major issue in the communities.

The local knowledge, influenced by the coastal dwellers' familiarity with the coastal environment over a relatively long time and the displacement of households in the communities, is an important management resource that cannot be overlooked [1]. Incorporating local knowledge into scientific knowledge can lead to the development of effective adaptation strategies that are cost-effective, participatory, and sustainable [16][22]. The experience and long-term observation from the community call for a holistic management approach to the island. The scientific data that is used in designing coastal structures should take into consideration the threats of beach erosion and its impact on livelihoods. Several islands such as Molleangan Besar Island are considered to be ideal for conservation with conditional eco-tourism development. TMP is earmarked for tourism development in the northern part of Sabah in line with the national launching of 'The Tip of Borneo' attraction in the town of Kudat in 2004 [27].

4. Conclusion

The impacts of the higher waves and rough sea conditions in TMP can be easily detected through beach erosion. The local communities experienced extreme events and seasonal monsoons that affect their life, damaged houses or jetties fishing structures and uprooted trees. In this study, beach erosion has been identified as one of the major threats to the community livelihood and the morphology of the islands. Six of the islands are affected by beach erosion, whereas Mandarah island is experiencing accretion. Three sites fall under Category 1 with high vulnerability to sea-level rise and stronger storms.

The local government has yet to take any concrete action to tackle the coastal erosion in TMP except in Karakit. The communities on the affected islands are trying to adapt and co-exist by protecting their properties with materials available around their area, modifying structures, retreating or relocating to a nearby village, islands, and even on mainland Sabah. The findings of this study can be part of baseline data for the implication of NPOA-CTI particularly Goal 1: priority seascapes designated and effectively managed and Goal 3: marine protected areas (MPAs) established and effectively managed. This paper is useful for the local government, policymakers, and other government agencies to manage the coastal communities and islands in TMP. However, this study requires more in-depth scientific data to support the initial findings and further be applied to the implementation of the Integrated Management Plan as a multi-purpose MPA in Malaysia.

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