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# Climate Change Vulnerability Assessment of Lahad Datu's Coastline in Sabah

## WWF-Malaysia Semporna PCA Project Report with Universiti Malaysia Sabah


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# Climate Change Vulnerability Assessment of Lahad Datu, Sabah

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## Acronyms

| | |
|---|---|
| EAFM | Ecosystem Approach to Fisheries Management |
| ESSCOM | Eastern Sabah Security Command |
| CCA | Climate Change Adaptation |
| CIVAT | Coastal Integrity Vulnerability Assessment Tool |
| CT | Coral Triangle |
| CTI-CFF | Coral Triangle Initiative on Coral reefs, Fisheries and Food security |
| cm/year | Centimeters per year |
| DSMM | Department of Survey and Mapping Malaysia |
| *et al.* | And others |
| GDP | Gross Domestic Product |
| ha | Hectares |
| ICZM | Integrated Coastal Zone Management |
| IPCC | Intergovernmental Panel on Climate Change |
| km | Kilometre |
| $km^2$ | Kilometre square |
| LEAP | Local Early Action Plan |
| m | Metre |
| MPA | Marine Protected Areas |
| NAHRIM | National Hydraulics Research Institute of Malaysia |
| PCA | Priority Conservation Area |
| pers. comm | Personal Communication |
| REAP | Region-wide Early Action Plan |
| RM | Ringgit Malaysia |
| RSLR | Relative Seal Level Rise |
| SCCA | Silam Coast Conservation Area |
| SSME | Sulu-Sulawesi Marine Ecoregion |
| TWG | Technical Working Group |
| TURF | Tool for Understanding Resiliency of Fisheries |
| UMS | Universiti Malaysia Sabah |
| UPMSI | U.P. Marine Science Institute |
| WWF | World Wide Fund for Nature |
| % | Percentage |

# Preface

Climate change has been an ongoing debate since the mid-20th century; it refers to the change in climate patterns globally and is mainly attributed to the use of fossil fuel that directly causes an increase in atmospheric carbon levels. The impact of climate change can be seen and felt through changes in biodiversity and ecosystem services in both terrestrial and marine. Intense weather events such as typhoons and storms have been proven as a direct consequence of climate change. Some of the climate change impacts may negatively affect coastal communities, seagrass beds, mangroves, coral reefs, and coastal beaches. About 200, 000 metric tons of fish are produced by the fisheries and aquaculture industry in Sabah, which contributes to approximately 2.8% of Sabah's Gross Domestic Product (GDP). The destruction of seagrass beds, mangroves, coral reefs, and other coastal ecosystems that functions as vital nursery grounds may adversely affect coastal reef fisheries and aquaculture activities, thus reducing the income of local coastal communities. Some of the coastlines in Sabah are within the Coral Triangle scientific boundary. The Coral Triangle Initiative on Coral Reefs, Fisheries and Food Security (CTI-CFF) is a partnership between Malaysia, Philippines, Indonesia, Sabah, Timor Leste, Solomon Islands, and Papua New Guinea. A joint initiative between WWF-Malaysia and University Malaysia Sabah (UMS) employed the use of Coastal Integrity Vulnerability Assessment Tool (CIVAT) to assess the vulnerability of the coastlines in Lahad Datu, Sabah to the impacts of climate change as stated in one of the CTI targets in Goal 4 - which focuses on the development and implementation of Region-wide Early Action Plan (REAP) for climate change adaptation, for the near shore marine and coastal environment and small island ecosystems.

## Acknowledgements

This project was carried out in partnership with Universiti Malaysia Sabah (UMS). WWF-Malaysia is grateful for the financial assistance provided by WWF-Netherlands, Ministry of Science and Technology, Innovation (MOSTI), Malaysia (Gran No: GL 00086). We will also like to thank Sabah Foundation, the Marine Department, and the local communities of Parapat Island, Nala Village, and Sakar Island for providing support during field observations at the assessment sites. Other than that, we would also like to extend our gratitude to other governmental departments, agencies, private sectors, NGOs, and local communities for sharing necessary information and observations that made this study a complete success.

## Executive Summary

Coastal Vulnerability Assessment for Climate Change in Lahad Datu, Sabah was conducted by WWF-Malaysia in collaboration with Universiti Malaysia Sabah (UMS) between April – May 2015. The purpose of the study was to have a better understanding on climate change and its impact on low-lying areas. The objectives were to determine the vulnerability of coastlines and provide recommendations for climate change adaptation for the community in the coastal area of Lahad Datu District that are vulnerable to the impacts of climate change.

Coastal Integrated Vulnerability Assessment Tool (CIVAT) was applied in this study where (Vulnerability = Exposure + Sensitivity = Potential Impact + Adaptive Capacity). This tool is a semi quantitative approach to study shorelines where single or multiple sites may be studied to determine and rank shorelines according to vulnerability and adaptability to climate change. The vulnerability of the coast was measured by analysing physical characteristics of the coast where the sandy beaches were assigned as an indicator. The result showed a low, medium, and high vulnerability in Parapat Village, Nala village, and Sakar Island respectively. The vulnerability map produced from this study is useful for the local community that live on the coastal areas in taking appropriate action to adapt to climate change. The recommendations for community-based adaptations measured in high vulnerability areas are:

- Seasonal forecast and climate monitoring;
- Relocate communities who are living in highly vulnerable areas to less exposed or sheltered areas near the original site of the village, and
- Social protection or restoration of marine habitats to reduce impact of climate change.

## Ringkasan Eksekutif

Penilaian ancaman perubahan iklim menggunakan *Coastal Integrated Vulnerability Assessment Tool* (CIVAT) di Daerah Lahad Datu, Sabah telah dijalankan oleh WWF-Malaysia dengan kerjasama Universiti Malaysia Sabah (UMS) antara April – Mei 2015. Tujuan utama penilaian ini dijalankan adalah untuk memahami dengan lebih baik tentang perubahan iklim dan kesannya di kawasan rendah yang berhampiran laut. Objektif – objektif penilaian ini ialah menentukan kemudahterancam pesisiran pantai dan memberi cadangan adaptasi perubahan iklim yang bersesuaian kepada komuniti yang tinggal di sepanjang kawasan pesisir di Daerah Lahad Datu yang terdedah kepada kesan-kesan perubahan iklim.

CIVAT merupakan alat yang digunakan dalam kajian ini dimana (Vulnerability = Exposure + Sensitivity = Potential Impact + Adaptive Capacity). Alat ini menggunakan pendekatan secara semi kuantitatif untuk mengkaji garis pesisir iaitu satu atau berbilang tapak kajian akan dikaji untuk mengenalpasti dan menentukan kedudukan garis pesisir berdasarkan kemudahterancam dan kebolehsuaian terhadap perubahan iklim. Kemudahterancam kawasan pesisir diukur dengan menganalisis ciri-ciri fizikal pantai, dimana pantai berpasir menjadi penunjuk kepada analisis tersebut. Keputusan menunjukkan kemudahterancam yang rendah di Kg Parapat, sederhana di Kg Nala dan tinggi di Pulau Sakar. Peta kemudahterancam yang dihasilkan melalui kajian ini berguna untuk komuniti setempat yang tinggal di kawasan pesisir untuk membuat tindakan yang wajar bersesuaian dengan perubahan iklim. Cadangan adaptasi untuk komuniti di kawasan yang mempunyai tahap kemudahterancam yang tinggi iaitu:

- Membuat ramalan bermusim dan pemantauan iklim;
- Menggalakkan pemindahan komuniti yang tinggal di kawasan yang terancam ke kawasan dekat yang kurang terededah kepada kesan perubahan iklim, dan
- Memberi perlindungan sosial atau pemulihan habitat marin untuk mengurangkan kesan perubahan iklim.

## 1. Introduction

The definitions of weather and climate are different where weather refers to atmospheric conditions over a short period of time; while climate is an average of weather conditions over a long period of time. The Intergovernmental Panel on Climate Change (IPCC) defines climate change as a change in the state of the climate that can be identified (e.g. using statistical tests) through changes in the mean and/or the variability of its properties which persists for an extended period, typically decades or longer. According to Dimento & Doughman (2007), the word 'climate' is derived from the Greek word *klima,* a term that refers to the inclination of the sun's rays to the earth's surface. The ocean regulates our climate and drives the weather determining rainfall, droughts, and floods. Climate change is long term changes (decades or longer) caused by either natural variability or human activity. Many social, biological, and geophysical systems of the coastline are at risk due to climate change. Change to the natural system of the environment as the result of increased flooding events, coastal erosion, and increasing sea surface temperature are some of the few impacts of climate change.

Increasing land and sea surface temperature, sea level rise, and more intense and frequent typhoons are among the indicators of climate change resulting from increase in greenhouse gases (Hughes *et al.*, 2003). Besides that, changes in amount and pattern of rainfall and ocean acidification can also severely impact both natural and human coastal communities. Ocean acidification is directly correlated with the carbon dioxide concentration in the atmosphere. The ocean acts as a carbon sink, thus the pH of ocean water is reduced, intensifying the erosion of coral reefs. The worst event – coral bleaching, would also happen if there are significant changes on sea surface temperature, and any changes on the coral ecosystems can impact fisheries and tourism industries that depend on it. In addition, flooding events and erosions - that are most likely experienced by local communities who live in the coastal and low-lying areas, causes the loss of coastal ecosystems such as mangroves and seagrass and increases the vulnerability of coastal areas to climate change impact.

The Coral Triangle region located along the equator at the confluence of the Western Pacific Ocean and Indian Ocean and covers all or part of the exclusive economic zones of six countries: Indonesia, Malaysia, Papua New Guinea, the Philippines, the Solomon Islands, and Timor-Leste. Considered the global epicentre of marine life abundance and diversity, the region possesses 76% of all known coral species, 37% of all known coral reef fishes, 53% of the world's coral reefs, the greatest extent of mangrove forests in the world, as well as spawning and juvenile growth areas for the world's largest tuna fishery (CTI-CFF, 2009). The Coral Triangle (CT), which includes almost 4 million hectares of ocean and coastal waters, is home to 390 million people; 130 million of which directly depend on these resources for their livelihood and wellbeing. However, coastal communities in the CT region are already experiencing the impacts of climate change. Severe storms, coastal inundation, rising sea level and sea surface temperature are threatening the safety and food security of more than 120 million people that depend directly on local marine and coastal resources for their income and livelihood. The Coral Triangle Initiative on Coral Reefs, Fisheries and Food Security (CTI-CFF) is a multilateral partnership composed of six countries - Indonesia, Malaysia, Papua New Guinea, the Philippines, Solomon Islands, and Timor-Leste. This initiative consists of five goals which are; Goal 1: Priority Seascapes (large marine areas) designated and effectively managed, Goal 2: Ecosystem Approach to Fisheries Management (EAFM) and other marine resources fully applied, Goal 3: Marine Protected Areas (MPAs) established and effectively managed, Goal 4: Climate change adaptation measures achieved, and Goal 5: Threatened species status improving. To address climate change, one of the CTI-Goal 4 targets in the regional level is the development and implementation of Region-wide Early Action Plan (REAP) for Climate Change Adaptation (CCA) for the nearshore marine and coastal environment and small islands. As a response to this target, the Coral Triangle Initiative (CTI) Climate Change Adaptation (CCA) Technical Working Group (TWG) has developed various CCA Toolkits as guidance to support the local implementation of the CTI-REAP-CCA.

The local implementation of the CTI-REAP-CCA includes determining the vulnerability of coastal communities and resources towards climate change and implementing adaptation strategies to reduce risk from climate change impacts. Vulnerability is defined as "the degree to which a system is susceptible to or unable to cope with adverse effects of climate change, including climate variability and extremes" (Inter-Governmental Panel on Climate Change, 2013). It is also a means for assessing, measuring or characterising the Exposure, Sensitivity, and Adaptive Capacity of a natural or human system to disturbance. In order to understand and gather information on how climate change may affect certain systems in the management area, vulnerability assessments need to be conducted to determine the extent to which (if any) the area would suffer climate change impacts. The vulnerability assessment is conducted based on available information, local and traditional knowledge, expert opinions, understanding the hazards and associated impacts and development of realistic Adaptive Capacity and disaster hazards research (Kuriakose *et al.*, 2009). The primary goal of vulnerability assessments for climate change is to develop adaptation strategies that reduce the risk associated with climate change to the coastal communities and resources. In addition, the vulnerability assessment of management areas is important to identify the area's vulnerability, adaptability to climate change, and the need to prepare for its impacts.

Malaysia is one of the member parties involved in the CTI-CFF. With that, in accordance to the fourth goal, regional action 2 requires all participating countries to conduct vulnerability assessments and monitoring activities tailored to each country. To meet the goal in CTI-CFF, led by Universiti Malaysia Sabah (UMS) through the Borneo Marine Research Institute, the Coastal Integrity Vulnerability Assessment Tool (CIVAT) (Siringan *et al.*, 2013) was used to assess the vulnerability of Lahad Datu located at the east coast of Sabah, Malaysia. The Lahad Datu assessment was a continuation of a previous assessment conducted in Semporna Priority Conservation Area (PCA) in 2015 (Jolis & Saleh, 2015). The Lahad Datu assessment used the same tool that was used in the Semporna assessment for comparison purposes. This report will provide the necessary information regarding the level of vulnerability of selected sites within the Lahad Datu coastline along with propose adaptation strategies to reduce risks due to climate change.

# 2. Assessment Objectives and Geographic Scope

## 2.1 Assessment objectives

The aim of this assessment was to establish a climate change vulnerability assessment in Lahad Datu coastline.

The objectives of the assessment in Lahad Datu were to:

- Introduce and apply CIVAT in Lahad Datu as a tool to assess vulnerability to climate change;
- Determine the vulnerability of local communities to climate change, and
- Recommend adaptation options to climate change in Lahad Datu.

The assessment was conducted from April to May 2015. Part of the assessment was conducted during continuous imposed curfews by the Eastern Sabah Security Command (ESSCOM) as a result from the Lahad Datu standoff, which started in February 2013, and introduced limitations to the team. Furthermore, this assessment was part of the Silam Coastal Conservation Area Scientific Expedition 2015 led by the Sabah Foundation. The participation of both teams (UMS and WWF-Malaysia) in the expedition led to the expansion of assessed sites. This assessment was a continuation from a similar study in Semporna PCA (Jolis & Saleh, 2015).

The CIVAT tool was used to assess selected sites within the Lahad Datu coastline. The Lahad Datu assessment used the same tool that was applied in the Semporna assessment, and for that reason, further accurate comparison purposes between the two sites. CIVAT was developed to assess the vulnerability of coastal areas to erosion and inundation resulting from wave impacts and sea level rise according to the criteria under Exposure, Sensitivity and Adaptive Capacity.

## 2.2 Geographic scope

Lahad Datu is a district located in the east of Sabah, Malaysia (Figure 2.1). Its population was estimated to be around 199,830 (Department of Statistics, 2010). The ethnic demography of the local population is Idahan, Dusun Subpan, Dusun Bagahak, Suluk, Bajau, China, Kokos, Iranun, Bugis, Kadazan-Dusun, Timor, Tidong, Jawa, Sungai, and Kagayan (Department of Statistics, 2010). Some of the population in Lahad Datu can be categorised as coastal communities. The land area is largely surrounded by cocoa and oil palm plantations. The economy is mainly driven by the plantations and a few oil palm refineries can be found here with some of them close to the shore.

Lahad Datu has a coastline that is approximately 362km and only 56 km of that is part of Darvel bay with Sulawesi Sea in the East. Referring to Google Earth satellite images, the district has seven islands with Sakar Island as the largest populated island. The marine ecosystems that are present in Lahad Datu include coral reefs and mangrove forests. Due to the availability of these marine ecosystems and Lahad Datu being a coastal town, the economy is also driven by fisheries and aquaculture. Only one conservation area exists, which is the Silam Coast Conservation Area (SCCA) located South of the district. Some of the known tourism areas in Lahad Datu are Danum Valley and the Tabin Wildlife Park.

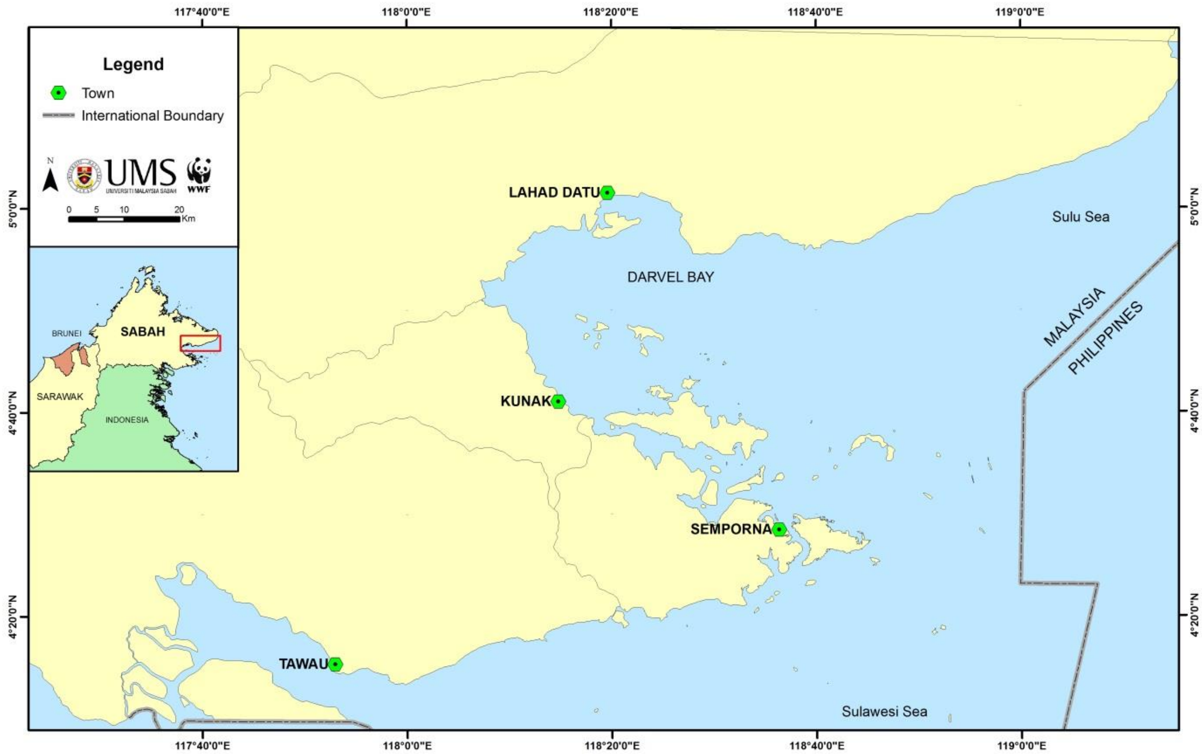


Figure 2.1: The location of Lahad Datu district at east Coast of Sabah

## 3. Literature Review

There are more research and studies conducted on the impacts of climate change on various systems; not only environmental, but social and economic impacts as well (McCarthy *et al.*, 2001; Füssel & Klein, 2005). Decision makers made up of Federal and State government bodies usually favour information regarding the vulnerability of coastal communities and resources over climate projections such as sea surface temperature rise (Tribbia & Moser, 2008). There are various vulnerability assessments tools that have been studied and developed in the past ten years (Füssel & Klein, 2005).

Created by the Coral Triangle Initiative (CTI) CCA Technical Working Group (TWG), the CIVAT has been used in the Philippines at the province of Batangas by the Provincial Government Environment and Natural Resources (PGENRO) in partnership with the Coral Triangle Support Partnership (CTSP). The result revealed that 29% of the total barangays in the province has coastal areas that are highly vulnerable to climate change (Conservation International, 2013).

Darvel Bay is among important semi-enclosed bay, located on the east coast of Sabah. As part of Malaysian Coral Triangle, the vulnerability assessment of the coastal area is important to determine the impact of climate change due to sea level rise or other extreme events. The outer parts of the bay coastal areas are mainly exposed to strong surface winds during the southwest and northeast monsoon periods from the Sulawesi Sea. However, presents of many islands such as Timbun Mata Island, Sakar Island and Tiga Island contributing to its unique marine environment (Saleh, *et al*, 2007). Most of those islands are fringing by mangroves, coral reefs or seagrass to form one of the most biologically diverse marine environment in the world.

Mangrove areas in Sabah account for 59% of the country's total and 7.6% of the global total (SFD, 2014). Mangroves are regarded as an important natural resource for the state and are legally protected under the Sabah Forest Enactment (1968) via the gazettement of forest reserves. However, many mangrove habitats outside the mangrove forest reserves have been degrading in the past decades because of direct conversion to urban and industrial spaces, aquaculture ponds, residential areas, ports, marinas, resorts, and oil palm development. In the Lahad Datu District, about 48.56 ha of Mangrove Forest Reserves (Class V) was gazetted in 2010 (SFD, 2014). Presence of mangrove forests surrounding the Darvel Bay and islands play an important role as shoreline protection.

Malaysia has almost 4000 km² of coral cover and over 500 coral species (Tan and Heron, 2011). The economic value of well-managed coral reefs in Malaysia is estimated to be RM 50 billion annually (Reef Check Malaysia, 2014). Coral reefs are vital as a healthy reef can be a sanctuary of biodiversity, provides protein source for sustenance and a major contributor to the diving tourism (Moberg and Folke, 1999; Graham *et al.*, 2006; Reef Check Malaysia, 2014). Coral reefs also play an important role as coastal defences or barriers against storms and other natural disasters (Moberg and Folke, 1999).

There are about 14 species of seagrass (Bujang, Zakaria and Arshad, 2006) that can be found in Malaysia. According to Bujang et al. (2006), it is reported that there are 78 seagrasse beds found scattered around East and West Malaysia. In Sabah, mixed-species seagrass beds can be found in the Western, Eastern and Southern coast. Seagrass ecosystems provide food to herbivores such as dugongs and green turtles, and as habitat and nursery for seahorses and other smaller crustaceans (Bujang, Zakaria and Arshad, 2006). Seagrass also provide other ecosystem services such as stabilising sediment with its roots.

Several studies were done using CIVAT as a tool to determine the vulnerability of coastal communities in Labuan, Sabah, and Sarawak. Athira *et al.* (2014) found that the Northeast parts of Labuan Island were more vulnerable to climate change as compared to other areas of the island. Ismail (2012) found that Kudat, located in the Northern part of Sabah, experienced medium to high vulnerability.

In the Southeast of Sabah, the Semporna PCA has vulnerabilities ranging from low to high with notes on small islands being highly vulnerable (Jolis & Saleh, 2015). Located Southwest of Sarawak, preliminary results of Semantan, Sampadi, Buntal, and Santubong coasts show medium to high vulnerability (Aazani & Mueller, 2015). Doweler (2015) expanded the study to more sites within Southwest Sarawak and found the sites to have its vulnerability range from low to high. All mentioned sites have a common reason for various vulnerability levels of high Sensitivity (facing the open sea) and lack of coastal habitats to serve as natural barriers and protection to possible storms or rising sea levels.

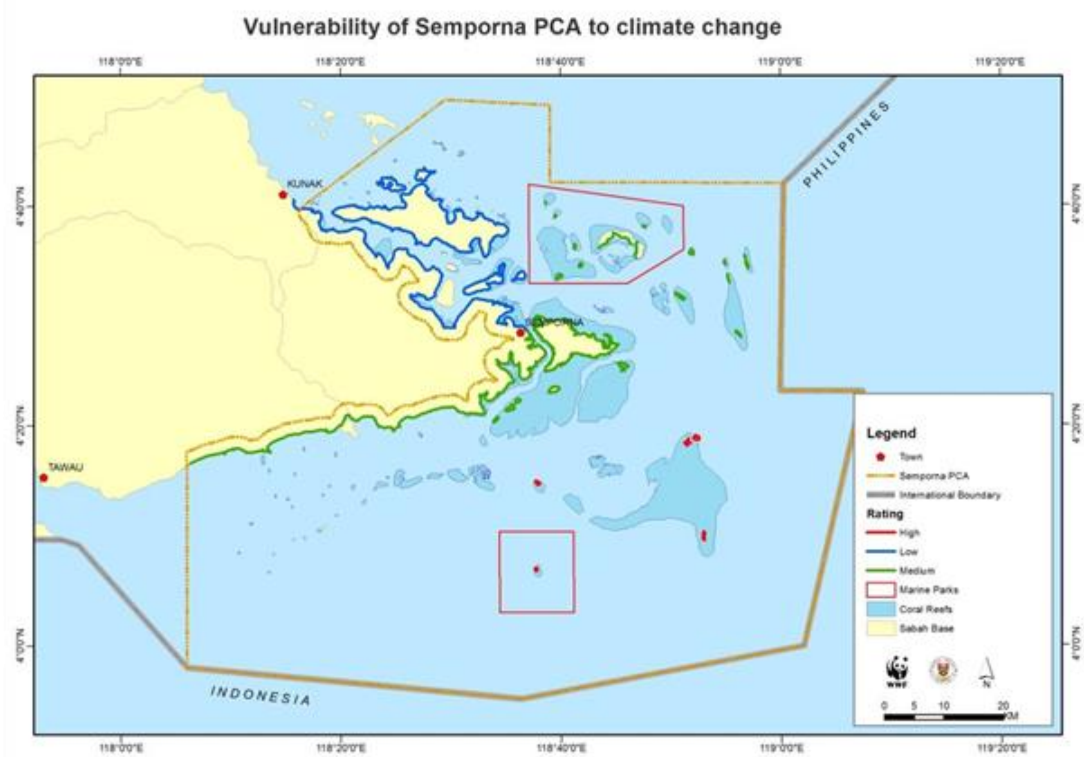


Figure 3.1: The vulnerability of Semporna PCA to climate change

# 4. Methods and Materials

The CIVAT tool assessed the vulnerability of the coastal area to erosion and inundation resulting from wave impact and sea level rise for Lahad Datu. This tool was designed for implementation by non-specialists such as coastal managers, to combine the coastal system's susceptibility to change with its natural ability to adapt to changing environment conditions; yielding a relative measure of the systems' natural vulnerability to the effects of sea-level rise and wave impacts.

CIVAT consists of three components in determining vulnerability which are; Exposure, Sensitivity, and Adaptive Capacity. Each component is defined as below:

- <u>Exposure:</u>
  Measures that quantify the intensity or severity of physical environmental conditions that drive changes in the state of the biophysical system (how much the coastal area is exposed to erosion and inundation);
- <u>Sensitivity:</u>
  Measures that describe the system's present state for specific properties that respond to Exposure factors arising from changes in climate (how sensitive the coastal area is to erosion and inundation results from sea level rise and wave exposure), and
- <u>Adaptive Capacity:</u>
  Measures that characterise the ability of the system to cope with impacts associated with changes in climate (how much the coastal zone has the ability to adapt to the changing environment).

These three components need to be taken into account in order to conduct the assessment of a coastal area to erosion and inundation resulting from wave exposure and sea level rise.

## 4.1 Selection of sites to be assessed

The selection of sites was done through a stakeholder's workshop in Lahad Datu by WWF-Malaysia and Universiti Malaysia Sabah (UMS) in April 2015. The purpose of the workshop was to introduce the assessment and gather information on the biological and social aspects of the district. The stakeholders actively participated in the fieldtrip site selection. Furthermore, this assessment was also part of the Silam Coastal Conservation Area Scientific Expedition 2015 led by the Sabah Foundation. The participation of both teams (UMS and WWF-Malaysia) in the expedition led to the expansion of the assessed sites in SCCA.


Figure 4.1: A group discussion to identify coastal areas for Vulnerability assessments

With that, the assessment for Lahad Datu was done in 11 sites. The sites selected were based on the outcome of the stakeholder's workshop in MyInn Hotel, Lahad Datu and site assessment during the Silam Coastal Conservation Area (SCCA) Scientific Expedition as well as availability of sandy beaches as indicators. During the stakeholder's workshop, the field site will be done at the Eastside of the Lahad Datu district which is located at outer part of Darvel Bay. The inner part of this Bay consists of fringing mangroves, including the Lahad Datu Town. However, to support the growing population and coastal development, the surrounding area was reclaimed for expansion of the town.

Three sites (Sites A to C) were on the further East of the district （Figure 4.1） while the remaining eight sites (Sites 1 to 8) were in SCCA (Southwest of the district) (Figure 4.2) Sites ranged from islands to shoreline at mainland of Lahad Datu District. Due to the geographical nature of the district and availability of road to assess the shoreline, most of the assessment sites were located along sandy beaches. The total length of the selected sites' coastline (exclude islands for SCCA) is shown in Tables 4.1 & 4.2.

Table 4.1: Sites on the East of the Lahad Datu district

| Site | Coordinates (N/E) | Location | Length of beach (km) |
|---|---|---|---|
| A | 4° 58’ 47.81”/ 118° 47’ 37.43” | Parapat | 9.21 |
| B | 4° 59' 58.68”/ 118° 52' 3.35" | Nala Village | 11.96 |
| C | 4° 58' 32.44" / 118° 20' 36.36" | Sakar Island | 32.50 |

The villagers residing in Parapat Village, Nala Village, and Sakar Island are mostly made up of fishermen living on lands that had been passed down from one generation to another. The sites chosen have mangrove forests that are close to coral reefs.

Table 4.2: Sites in the Silam Coastal Conservation Area (SCCA)

| Site | Coordinates (N/E) | Location | Length of beach (km) |
|---|---|---|---|
| 1 | 4° 52' 49.5"/ 118° 9' 27" | Bangkaruan Mangrove Forest Reserve | 0.23 |
| 2 | 4° 53' 7.4" / 118° 9' 27.9" | Bangkaruan Beach | 0.42 |
| 3 | 4° 54’4.6” / 118° 10’ 17.4” | Malampayau Island | 1.92 |
| 4 | 4° 54' 48.6" / 118° 10' 24.3” | Jetty Bay | 0.39 |
| 5 | 4° 54' 43.4" / 118° 10' 28.6" | Silam SCCA Beach | 0.14 |
| 6 | 4° 55' 04.4"/ 118° 11' 06.6" | Pandanus Beach | 0.15 |
| 7 | 4° 55' 59.6"/ 118° 11' 02.6" | Tumunong Forest Reserve | 0.27 |
| 8 | 4° 55' 50.2" / 118° 12' 02.5" | Tabun Island | 1.25 |

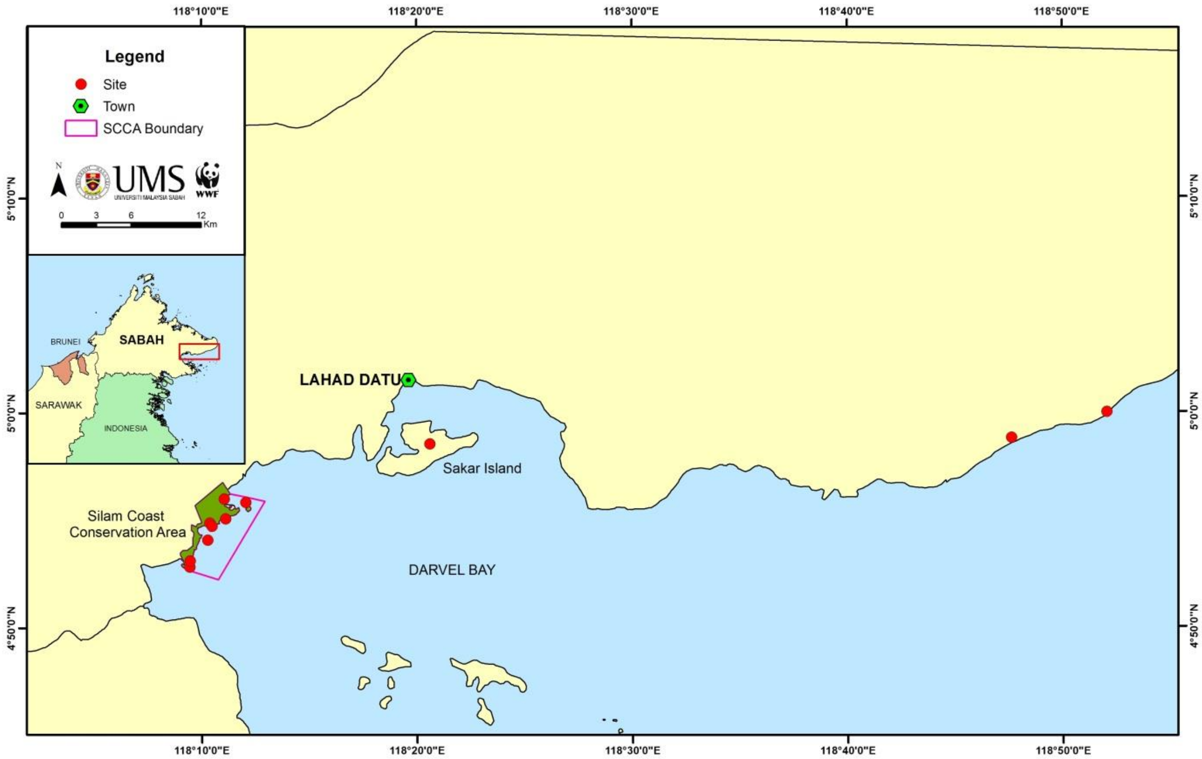


Figure 4.2: Map of the assessment sites

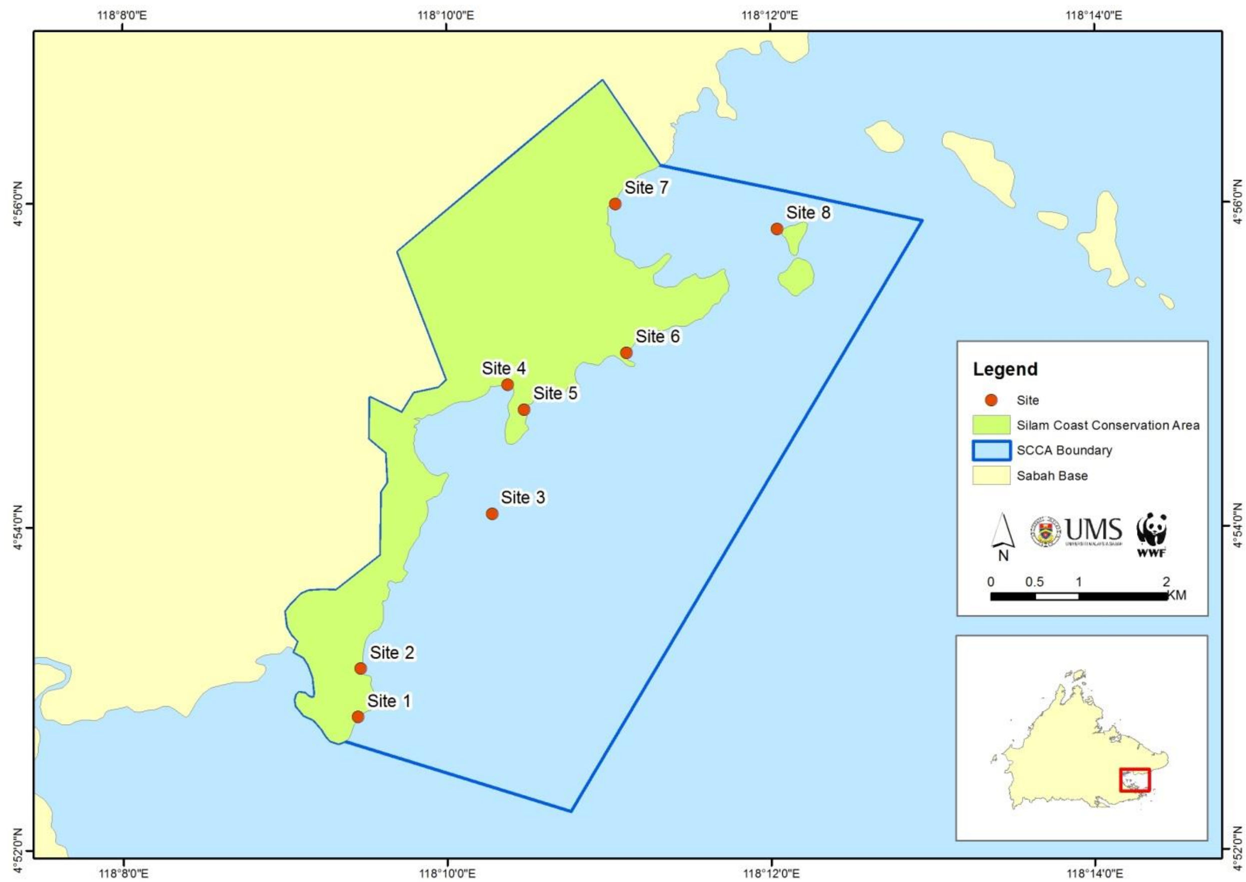


Figure 4.3: Map of the assessment sites in SCCA

### 4.2 Assessment of sites according to criteria

Each site was assessed according to the variables under the Exposure, Sensitivity, and Adaptive Capacity components based upon available information (Table 4.3).

Table 4.3: The CIVAT variables of Exposure, Sensitivity, and Adaptive Capacity components

| EXPOSURE | SENSITIVITY | ADAPTIVE CAPACITY |
|---|---|---|
| 1. Rates of relative sea level change (RSLC: cm/year)<br>2. Wave exposure during monsoons<br>3. Wave exposure during typhoons<br>4. Tidal range (m) | Intrinsic:<br>1. Geomorphology/Lithology<br>2. Seasonal shoreline trend<br>3. Slope from the shoreline to 20 metres elevation (landward slope)<br>4. Width of reef flat or shore platform<br>5. Beach forest and vegetation<br>6. Lateral continuity of reef flat or shore platform<br>7. Presence or absence of natural habitat<br><br>Extrinsic:<br>1. Beach and offshore mining<br>2. Structures on the foreshore | 1. Long term shoreline trends<br>2. Continuity of sediment supply<br>3. Guidelines on setback/easement<br>4. Guideline on coastal structures<br>5. Type of coastal development |

### 4.3 Scoring of sites

Each variable is assigned a relative score between 1 and 5, corresponding to Low (L) (1-2 points), Medium (M) (3-4 points), and High (H) (5 points); based on the magnitude of their contribution to physical changes on the coast in relation to waves and sea level change.

The exposure criterion is to assess physical processes affecting the sites and adjacent area such as sea level change, wave exposure during monsoon, and tidal range. Detailed information of low, medium, and high criteria is shown in Appendices.

After an Exposure assessment is completed, a Sensitivity assessment of each site was done based on criteria consist of intrinsic and extrinsic factors. Intrinsic factors are ecological, physiological, or behavioural response of the study site to climate change; which includes coastal landform and rock type, seasonal shoreline trend, slope from shoreline to 20m elevation, width of reef flat or shore platform, beach forest or vegetation, lateral continuity of reef flat or shore platform, and coastal habitats. Extrinsic factors are the existence of barriers to habitat migration; examples are coastal and offshore mining (includes removal of fossilised corals on the fringing reef and beach) and structures on the foreshore. Details on the criteria assessed are shown in Appendices

Adaptive Capacity components are defined as the ability of a system to adjust to climate change impacts and to reduce potential damages, take advantage of opportunities or cope with the consequences. Adaptive capacity was assessed by five criteria such as long term shoreline trends, continuity of sediment supply, guidelines on coastal structures, type of coastal development, and coastal habitat.

Scores for each criterion in Exposure, Sensitivity, and Adaptive Capacity were aggregated and re-scaled into Low (L), Medium (M), and High (H). The range of scores for rescaling is dependent on the difference between the highest and lowest scores possible.

The scores given were based on the primary and secondary data obtained. Various ways were done to collate information in order to obtain the necessary data to set score to the assessment sites. In this study, workshops and field observations were conducted to gain more insight on the local marine resources for livelihood to the local communities. Unstructured interview to the villages were done to get the historical change of the area due to natural phenomenon or human activities. Other than that, supporting data from literature reviews, maps, and recognised peer review journal articles were referred to. Field observations on coastal landform and rock types, types of the beach vegetation, structures on the foreshore, and type of coastal development in the study sites were done between April to May 2015. During the trips, random informal interviews with coastal communities (fishermen, etc.) were conducted in order to support several criteria that have little or no available data.

## 4.4 Vulnerability computation of study sites

Once all data related to Exposure and Sensitivity components of the study area were collected, the two components (Exposure and Sensitivity) were cross-tabulated, which corresponded to a certain degree of Potential Impact as shown in Table 4.4.

Table 4.4: Potential Impact as a function of Sensitivity and Exposure

| **Potential Impact** | | | | |
|---|---|---|---|---|
| | **Sensitivity** | | | |
| **Exposure** | | **L** | **M** | **H** |
| | **L** | **L** | **L** | **M** |
| | **M** | **L** | **M** | **H** |
| | **H** | **M** | **H** | **H** |

Then, the results of Potential Impact were cross-tabulated with Adaptive Capacity to infer the degree of vulnerability (Table 4.5).

Table 4.5: Vulnerability as a function of Potential Impact and Adaptive Capacity

| **Vulnerability** | | | | |
|---|---|---|---|---|
| | **Adaptive Capacity** | | | |
| **Potential Impact** | | **L** | **M** | **H** |
| | **L** | **M** | **L** | **L** |
| | **M** | **H** | **M** | **L** |
| | **H** | **H** | **H** | **M** |

In summary, vulnerability was calculated in two stages whereby:

i. Exposure x Sensitivity = Potential Impact
ii. Potential Impact x Adaptive Capacity = Vulnerability

Where, Exposure and Sensitivity was first cross-tabulated to get the value for Potential Impact. The Potential Impact was then cross-tabulated with the Adaptive Capacity of each station to assess Vulnerability. Details information of this method can refer Siringan, *et al,* (2012).

# 5. Results

## 5.1 Vulnerability in East Lahad Datu

The first component – Exposure; was assessed during the trip according to the criteria of the components, relative sea level for all stations and were given a score of 3. This score is based on the sea level rise study conducted by Awang & Hamid (2013), where the projected mean sea level rise for Lahad Datu is 0.413 (cm/year). The wave exposure for Station A scored a 3 (moderate), 4 (moderate) for Station B, and 2 (low) for Station C. Tidal range for all stations were at 3 (moderate) with reference to the Lahad Datu tide table (Royal Malaysian Navy, 2015). Overall, Station 1 and 2 have medium Exposure, while Station 3 has low Exposure to climate change (Table 5.1).

The wave exposure variable considered the fair-weather and storm wave conditions. Wave exposure of each location was scored based on the geographical location surroundings of the study area. Station A has a long coastline area, small islands seen in front of the coastal area, and scored a 3 for wave exposure as the area was predicted to receive weak wave actions due to its geographical location. Station B scored a 4 as the coastal area is an open coastline without any offshore obstructions such as islands in front of the shoreline. The score was also based on an informal interview with the villagers experiencing bad erosion, living near the coastal areas. In Station C, the length of the shoreline area is short and sheltered by the presence of mangrove trees along the shoreline, thus scoring a 3. In summary, all sites scored medium Exposure except for Station C.

Table 5.1: Score for Exposure components in all sites

| Exposure Criteria | | Source | Site Scores | | |
|---|---|---|---|---|---|
| | | | A | B | C |
| 1 | Rates of relative sea level change (RSLC) (cm/year) | Awang & Abd Hamid (2013) | 3 | 3 | 3 |
| 2 | Wave exposure | Marine chart: Darvel Bay | 3 | 4 | 2 |
| 3 | Tidal range (m) | Royal Malaysian Navy, 2015 | 3 | 3 | 3 |
| **TOTAL** | | | 9 | 10 | 8 |
| **RATING** | | | **M** | **M** | **L** |

The Sensitivity components of each station were collected based on intrinsic and extrinsic factors. Intrinsic factor refers to the biology and ecological factors of the area while extrinsic refers to the physical factors of the surrounding area that would be considered in the vulnerability assessment.

For extrinsic factors, all sites were given a low score as there were no coastal or offshore mining activities observed during the assessment. In addition, there was also no structure built on the foreshore, which protects the coastal areas from the impacts of wave action and weather (Table 5.2).

The Sensitivity component of each site was slightly different; where there was Medium Sensitivity in Site A, Site B and C had High and Low Sensitivity, respectively.

Table 5.2: Score for Sensitivity components for all sites

| **Sensitivity Criteria** | | | **Source** | **Site Scores** | | |
|---|---|---|---|---|---|---|
| | | | | **A** | **B** | **C** |
| 1 | INTRINSIC | Coastal landform and rocky type | Field observation/Google Earth | 5 | 5 | 3 |
| 2 | | Seasonal beach recovery | Field observation/ Informal interview | 4 | 5 | 3 |
| 3 | | Slope from the shoreline to 20m elevation (landward slope) | Field observation/Lahad Datu topographic map | 5 | 5 | 1 |
| 4 | | Width of reef flat or shore platform (m) | Field observation/ Google earth | 1 | 4 | 1 |
| 5 | | Beach forest/vegetation | Field observation | 3 | 3 | 1 |
| 6 | | Lateral continuity of reef flat or shore platform | Google earth | 2 | 5 | 2 |
| 7 | | Coastal habitats | Field observation/ Informal interview | 3 | 3 | 2 |
| 8 | EXTRINSIC | Coastal and offshore mining (includes removal fossilised corals on the fringing reef and beach) | Field observation/ Informal interview | 1 | 1 | 1 |
| 9 | | Structure on the foreshore | Field observation | 1 | 1 | 1 |
| **TOTAL** | | | | 25 | 32 | 15 |
| **RATING** | | | | **M** | **H** | **L** |

Adaptive Capacity components showed that all scores were medium (Table 5.3). Site B and C scored high for the type of coastal development due to the presence of houses and agriculture activities. Site B had a stabilised rate for sediment supply.

Table 5.3: Score for Adaptive Capacity for all sites

| Adaptive Capacity criteria | | Source | Site Scores | | |
|---|---|---|---|---|---|
| | | | A | B | C |
| 1 | Long-term shoreline trends (m/year) | NAHRIM (2010) | 2 | 1 | 3 |
| 2 | Continuity of sediment supply | Field observation/ topographic map | 5 | 5 | 5 |
| 3 | Guidelines regarding to easement (setback zone) | Field observation/ Informal interview | 1 | 1 | 1 |
| 4 | Guidelines on coastal structures | Informal interview/ Chew *et al.* (2005) | 1 | 1 | 1 |
| 5 | Type of coastal development | Field observation, informal interview | 3 | 5 | 4 |
| 6 | Viability of coral reefs as sediment source | Field observation | 5 | 1 | 4 |
| 7 | Viability of seagrass as sediment source | Informal interview | 5 | 5 | 5 |
| 8 | Viability of mangrove as sediment trap | Field observation | 5 | 5 | 1 |
| 9 | Viability of mangrove as wave buffer | Field observation | 1 | 1 | 4 |
| **TOTAL** | | | 28 | 25 | 28 |
| **RANKING** | | | **M** | **M** | **M** |

Based on the Exposure and Sensitivity results obtained (Tables 5.1, 5.2 & 5.3), scores were aggregated and re-scaled into low, medium, and high to obtain the Potential Impact (Table 5.4) of each site. Site A scored a medium, Site B a high, while Site C had low Potential Impact. The Potential Impacts were then cross-tabulated with Adaptive Capacity components to assess its vulnerability. The vulnerability of these sites ranged from low to high. Site A scored a medium, Site B a high, and Site C a low.

Table 5.4: Summary of the Vulnerability assessment results in the East of Lahad Datu

| Sites | Exposure | Sensitivity | Potential Impact (Exposure x Sensitivity) | Adaptive Capacity | Vulnerability (Adaptive Capacity x Potential Impact) |
|---|---|---|---|---|---|
| A | M | M | M | M | M |
| B | M | H | H | M | H |
| C | L | L | L | M | L |

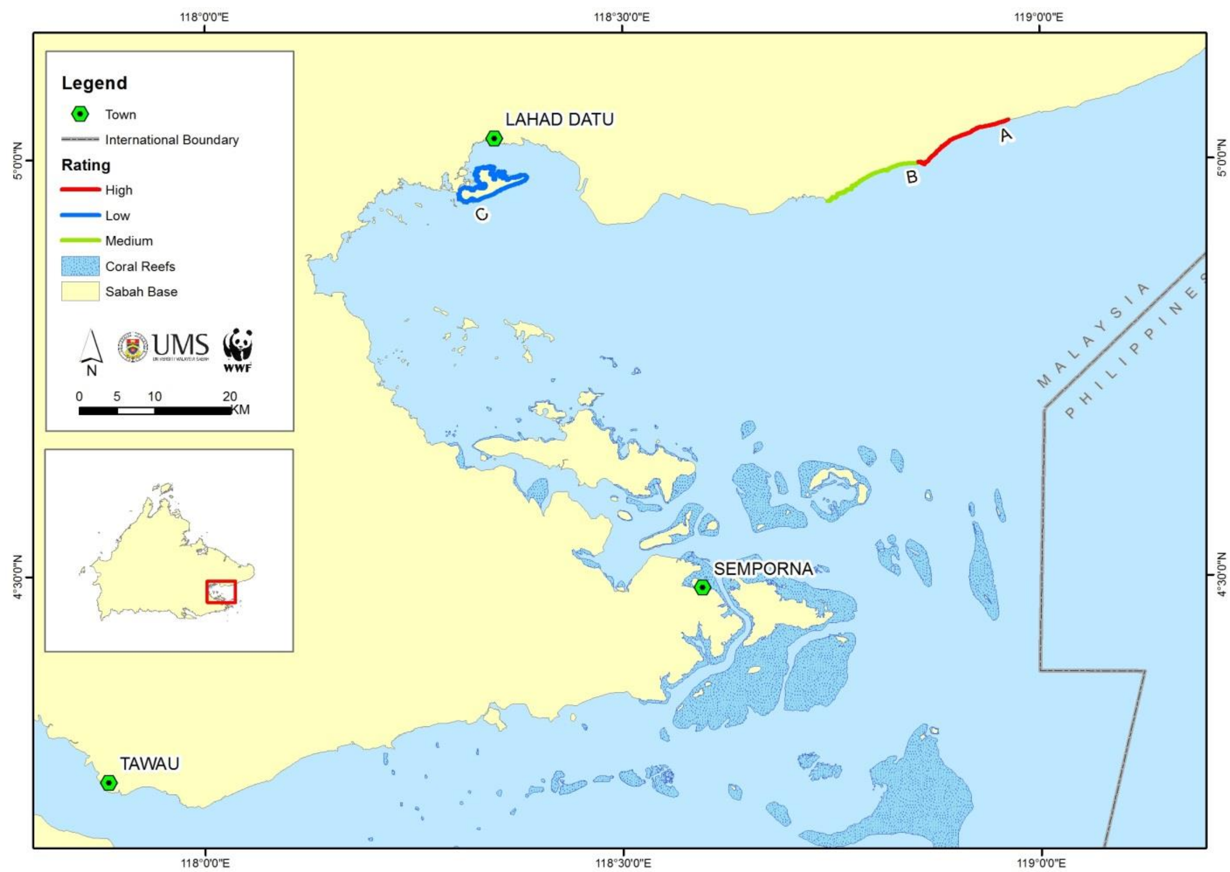


Figure 5.1: The vulnerability of East Lahad Datu coastal area to climate change

## 5.2 Vulnerability in the Silam Coastal Conservation Area (SCCA)

Exposure components show that all sites in SCCA experience low to medium Exposure to climate change. All sites are considered to have low wave exposure during monsoons and typhoons. The relative sea level change is 0.413 (cm/year) (Awang & Hamid, 2013). The rate of sea level change in each site is assumed to be the same, as the size of the area is small (Table 5.5.).

Table 5.5: Score for Exposure components in SCCA

| Exposure Criteria | | Source | Site Scores | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 1 | Rates of relative sea level change (cm/year) | Awang & Hamid (2013) | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| 2 | Wave exposure during monsoons | Malaysian Meteorological Department (2013) | 2 | 2 | 2 | 1 | 1 | 1 | 1 | 1 |
| 3 | Wave exposure during typhoons | Malaysian Meteorological Department (2013) | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 4 | Tidal range (m) | Royal Malaysian Navy (2015) | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| **TOTAL** | | | 9 | 9 | 9 | 8 | 8 | 8 | 8 | 8 |
| **RANKING** | | | **L** | **L** | **L** | **L** | **L** | **L** | **L** | **L** |

Sensitivity components show that all eight sites in SCCA are low in Sensitivity to both intrinsic and extrinsic factors. All sites have no mining activities, including removal of fossilised corals on the fringing reefs and beaches. There were also no structures in the foreshore at all sites. The Sensitivity criteria for coastal habitats at all sites were given low scores due to the presence of coral reefs or mangrove ecosystems. Most sites had a mixture of these ecosystems (Tables 5.6 & 5.7). Assessing further with the coastal habitat variables, the sites were observed to have coral reefs and mangroves while seagrass were not found in these sites.

Table 5.6: Score of Sensitivity components in SCCA

| Sensitivity Criteria | | | Source | Site Scores | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 1 | Intrinsic | Coastal landform and rock type | Field observation | 1 | 5 | 5 | 3 | 5 | 5 | 3 | 3 |
| 2 | Intrinsic | Seasonal beach recovery | Field observation, interview | 4 | 4 | 4 | 3 | 4 | 4 | 3 | 3 |
| 3 | Intrinsic | Slope from the shoreline to 20m elevation 4(landward | Google Earth/Field observation/Topographic map: Lahad Datu | 1 | 1 | 1 | 4 | 2 | 2 | 4 | 1 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | slope) | | | | | | | | | |
| 4 | | Width of reef flat or shore platform (m²) | Marine chart map Darvel Bay/ Environment Protection Department (2013) | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 5 | | Beach forest/vegetation | Field observation | 2 | 3 | 2 | 1 | 3 | 4 | 1 | 4 |
| 6 | | Lateral continuity of reef flat or shore platform | Marine chart | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| 7 | | Coastal habitats | Field observation, interview | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| 8 | Extrinsic | Coastal and offshore mining (includes removal of fossilised corals on the fringing reef and beach) | Field observation, interview | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 9 | | Structures on the foreshore | Field observation | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **TOTAL** | | | | 15 | 20 | 19 | 18 | 21 | 22 | 18 | 18 |

Table 5.7: Sensitivity scores for coastal habitat components in SCCA (* = Data not available)

| **Sensitivity Criteria** | | | **Source** | **Site Scores** | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** |
| 1 | Coral sediment source | Living coral cover | Marine chart, interview | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| 2 | | Coral community growth form in the shallow reef | Interview | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| 3 | Seagrass bed as sediment source and stabiliser | Areal extant relative to reef flat | Marine chart, interview | * | * | * | * | * | * | * | * |
| 4 | | Capacity to withstand storm removal and wave impact | interview | * | * | * | * | * | * | * | * |
| 5 | | Seagrass meadow type | Interview | * | * | * | * | * | * | * | * |
| 6 | Mangroves as sediment trap | Forest type | Field observation, marine chart | 5 | 5 | 4 | 1 | 4 | 5 | 1 | 3 |
| | | Mangrove | Field | 5 | 5 | 4 | 1 | 4 | 5 | 1 | 3 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | zonation | observation, interview | | | | | | | | |
| 7 | | Capacity to trap sediment | Field observation, interview | 1 | 1 | 1 | 3 | 1 | 1 | 3 | 4 |
| 8 | Mangroves as wave buffer | Forest type | Field observation, marine chart & interview | 5 | 5 | 4 | 1 | 4 | 5 | 1 | 3 |
| 8 | | Present vs historical mangrove extent | Interview, Google Earth | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 10 | | Mangrove zonation | Field observation | 5 | 5 | 4 | 1 | 4 | 5 | 1 | 3 |
| 11 | | Mangrove canopy cover | Field Observation | 5 | 5 | 5 | 1 | 5 | 5 | 1 | 3 |
| 12 | | Mangrove basal area | Field Observation | 5 | 5 | 4 | 1 | 5 | 5 | 1 | 2 |
| **TOTAL** | | | | 37 | 37 | 32 | 15 | 33 | 37 | 15 | 27 |
| **RANKING** | | | | **M** | **M** | **M** | **L** | **M** | **M** | **L** | **M** |

Adaptive Capacity components showed that most scores ranged from medium to high (Table 5.8). Sites 4 and 7 scored a high in their variability of mangroves as wave buffers. All sites also have imposed guidelines regarding the easement as well as for coastal structures.

Table 5.8: Score of Adaptive Capacity components in SCCA (* = Data not available)

| **Adaptive Capacity criteria** | | | **Source** | **Site Scores** | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** |
| 1 | Long-term shoreline trends (m/ year) | | Interview | 2 | 1 | 1 | 4 | 2 | 2 | 4 | 3 |
| 2 | Continuity of sediment supply | | Field observation, interview | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| 3 | Guidelines regarding the easement (setback zone) | | Chew *et al.* (2005) | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| 4 | Guidelines on coastal structures | | Chew *et al.* (2005) | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| 5 | Type of coastal development | | Field observation | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| 6 | Viability of coral reef as sediment source | Living coral cover | Marine chart, interview | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| 7 | Viability of | Capacity to | Interview | * | * | * | * | * | * | * | * |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | seagrasses as sediment source | recover from storm blow-outs | | | | | | | | | |
| 8 | Viability of mangroves as sediment trap | Capacity to trap sediments | Field observation, interview | 5 | 4 | 4 | 1 | 4 | 4 | 1 | 3 |
| 9 | Viability of mangroves as wave buffer | Mangrove canopy cover | Field observation, marine chart | 1 | 1 | 2 | 5 | 2 | 1 | 5 | 3 |
| | | Mangrove basal area | Google Earth | 1 | 1 | 2 | 5 | 2 | 1 | 5 | 3 |
| **TOTAL** | | | | 32 | 30 | 32 | 38 | 33 | 31 | 38 | 35 |
| **RANKING** | | | | **M** | **M** | **M** | **H** | **M** | **M** | **H** | **M** |

Based on the Exposure and Sensitivity results obtained (Tables 5.6 & 5.7), scores were aggregated and re-scaled into low, medium, and high to obtain the Potential Impact (Table 5.9) of each site. All sites were found to have low Potential Impact. The Potential Impacts were then cross-tabulated with Adaptive Capacity components to assess their vulnerability. The vulnerability of these sites was low (Table 5.9).

Table 5.9: Summary of the Vulnerability assessment results in SCCA.

| **Sites** | **Exposure** | **Sensitivity** | **Potential Impact (Exposure x Sensitivity)** | **Adaptive Capacity** | **Vulnerability (Adaptive Capacity x Potential Impact)** |
|---|---|---|---|---|---|
| 1 | L | L | L | M | L |
| 2 | L | L | L | M | L |
| 3 | L | L | L | M | L |
| 4 | L | L | L | H | L |
| 5 | L | L | L | M | L |
| 6 | L | L | L | M | L |
| 7 | L | L | L | H | L |
| 8 | L | L | L | M | L |

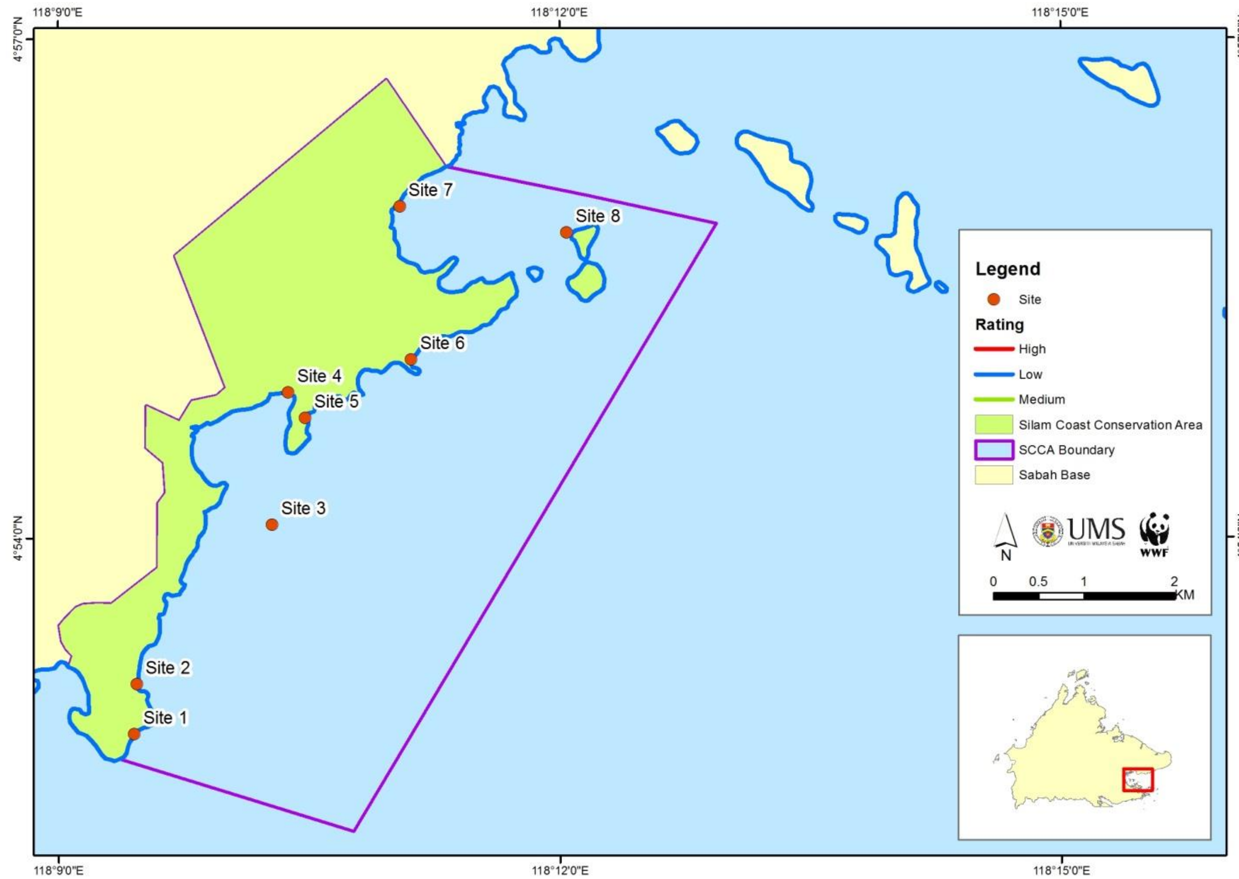


Figure 5.2: The vulnerability of SCCA to climate change

## 6. Discussion

The Vulnerability results provides a baseline that helps determine the level of vulnerability at the sites, followed by the determining adaptation options for remedial action in order to reduce both the short-term and long-term impacts of climate change (Kelly & Adger, 2000). Darvel Bay is part of the Sulawesi Sea and one of the most important fishing grounds in the Malaysian Coral Triangle areas. It is typically hot and humid all year round (CIA, 2008). Its sea temperature is within 31°C and annual rainfall can be up to 6,000 mm/year (Kleypas *et al.,* 2008; Hoegh-Guldberg, 2009). Generally, the sea temperature trend reveals that large parts of the Coral Triangle are increasing at ~0.4°C per decade (Hoegh-Guldberg, 2009). Annual oscillations of rainfall are influenced by the seasonal monsoon, while the Indonesian throughflow in the Sulawesi Sea play an important role in balancing the temperature and salinity between the Pacific Ocean and the Indian Ocean (Murray & Ariel, 1988; Gordon & Fine, 1996; Gordon *et al.*, 1999). Rapid changes in the Earth's climate have altered weather patterns, contributing to increased flood risks at low land areas, landslides, and severe storms in some parts of the coastal area. Rising sea levels are putting pressure to marine ecosystems and the livelihood of the coastal communities, through storm surges and inundation of fresh water supplies. Damage of coral reefs, seagrass, and mangrove ecosystems by storms and anthropogenic activities are breaking-down barriers of shoreline and are contributing to beach erosion. The combination of local and global stresses puts enormous pressure on ecosystems at coastal area (Hoegh-Guldberg, 2009).

The relative sea level changes of Lahad Datu are 0.413 cm/year and falls under moderate (3-4 points). Based on the known range of Vulnerabilities (Siringan *et al.*, 2012) of coastal systems to sea level rise, coastal areas experiencing sea level rise in excess of 1.5 cm/year is considered highly vulnerable to inundation. This shows that the rate of sea level change in all study sites is not significantly high as it falls under moderate and scored a 3. In Malaysia, the rate of sea level rise in 30 stations have been studied and analysed. In Sabah, the projected sea level rise for the year 2100 is 0.69 to 1.06 metres with the maximum value occurring in low-lying areas, river mouths, and estuaries in the East Coast of Sabah (Nor Aslinda and Mohd Radzi, 2013).

Wave exposure is also one of the criteria that need to be considered for Exposure. The range for wave exposure in Lahad Datu is between low to medium, which may differ during monsoon and typhoons. The third Exposure variable considered in this study is tidal range; where the tidal range of Lahad Datu is 0.02 m to 1.5 m. The differences between the highest and lowest tide is 1.48 metres and falls under moderate Exposure (1.0 to 2.0 metres); rank given for tidal range in all sites is a 3 - ranked medium potential for inundation. Tidal range influences both permanent and episodic inundation hazards (Aazani and Mueller, 2015).

## 6.1 Vulnerability in East Lahad Datu

The Vulnerability assessment in East of Lahad Datu showed a medium, high, and low Vulnerability at site A, B, and C respectively. Medium Vulnerability in Site A was due to medium Exposure, Sensitivity and Adaptive Capacity of the area. Site B was identified to have high vulnerability to climate change due to the fact that this area has been exposed to open sea, and experienced severe beach erosion on the shoreline. This is similar to certain sites in Kudat and Semporna where there was high vulnerability due to the site being exposed to the open sea (Ismail, 2012). The assessed site near Site B did not have neighbouring islands in near proximity. However, it may also be highly vulnerable as seen at some islands in Semporna PCA (Jolis & Saleh, 2015). It is likely that the site was much exposed to wave action especially during monsoon seasons. The lack of vegetation and trees made the area more sensitive to the effects. The vegetation and trees were deliberately removed, unlike in Site A, which faced nearly the amount of exposure; however, the local villagers retained the existing trees and vegetation. For Site C, it had low vulnerability. From observation, Site C was not exposed to the strong waves as there were a few islands as barriers in front of the area, thus reducing its exposure. Coastal area within the Site C (inner pat of Darvel Bay, including Lahad Datu town is also considered as low exposure and sensitivity with high adaptive capacity.

The Sensitivity assessment of all three sites excluded a few criteria due to lack of data as no underwater assessments were conducted. The reason for not conducting underwater surveys was due to safety reasons during the curfew period. In the shoreline area, a few coral fragments were seen on the beach especially in Site A. There was still a lack of information on coral reef abundance and distribution at all study sites, but informal interviews with local communities were conducted to gather more information of the area. Habitats that were assessed for all sites were mangroves (most were *Rhizophora spp.*) and coastal vegetation (coconut tree, palm tree) where both Site A and Site B had patchy trees;while in Site C, the vegetation were continuous along the beach. There were many mangrove trees observed along the shoreline, where the presence of mangroves and other vegetation reduced all sites to medium Sensitivity, as these vegetation are able to protect the shoreline area from events such typhoons.

Most sites have the same medium Adaptive Capacity. All sites scored high (5) on the continuity of sediment supply which meant that the sites had the ability to restore their sand. Although it is at a medium, it is crucial to increase Adaptive Capacity at all sites, especially in Sites A and B, as there were many infrastructures such as schools, shop lots, and houses.

## 6.2 Vulnerability in the Silam Coastal Conservation Area (SCCA)

The coastal area of SCCA face low Exposure to waves during monsoons and typhoons due to its geographical location at the inner part of Darvel Bay (Figure 4.1) and the presence of many offshore islands, sand bars, and complex bathymetry within Darvel Bay (Adenan and Mansor, 2013; Environment Protection Department, 2013). Furthermore, most of the offshore islands of SCCA are surrounded by coral reefs or fringing mangroves. The Environment Protection Department (2013) reported that the maximum astronomical tidal in the Silam area is less than 1.2 millimetres and the nearest tidal station (Lahad Datu) recorded a tidal range in Darvel bay of less than 1.5 metres (Royal Malaysian Navy, 2015). Complex bathymetry by the island and reefs reduce wave's sensitivity. Overall stations at SCCA are under low exposure. Presence of coral reef, continued sediment supply from mainland, and efficient natural sediment trap from roots of fringing mangroves contribute to high Adaptive Capacity.

The headland of the SCCA is mainly formed by rocky beaches. Its shelter area is occupied by fringing mangroves (Bangkuruan and Tumunong Mangrove Forest Reserve), while thick vegetation forms behind the sandy beaches. The natural habitats are dominated by *Rhizophora* sp.; however, *Sonneratia* sp. and *Avicennia* sp. could still be spotted in certain areas of the shoreline. Field observations indicated that almost 80% of the shoreline is mangrove or coastal vegetation, with variables species. Most of the mangrove fringing areas were in good condition and plays an important role to protect the shoreline. Mangroves play an important role as sediment trap. The mangrove forests were the riverine fringing type, with no clear mangrove zoning. Generally, coastal areas are dominated by species with prop the root system. Coral reefs were scattered along the seafront, except next to the mangrove forest reserve areas. Reckless fishing methods in the past have damaged the coral reef. However, good water clarity and scattered corals can still be seen from the surface. At least half of the new healthy massive hemisphere shaped corals were observed to be growing on the coral rubbles parallel to the shoreline. Field observations indicated that the short and narrow beaches or rocky areas were followed by steep hill inland. Almost all marine water areas had lateral continuity of reef flat or shore platform behind a front of scattered mangroves. No human activities (e.g. beach mining or hard structure) were observed at the foreshore, except portable fishing gears and abandoned seaweed farm (Site 1) were observed during field trip.

Assessment of Potential Impacts and Adaptive Capacity were mainly based on the field observations of each station due to lack of available primary data and publications related to the SCCA area. Medium shoreline trends were chosen as there were no indications of severe erosion during the fieldtrip. Murky waters were observed along the Southern part of SCCA (Site 2). It was probably contributed by freshwater from the mainland and provided continuous sediment supply from the mainland to nearby beaches. Another source of beach sediment was coral fragmentation as coral fragments of different sizes can be found. The SCCA shoreline was located between Sites 1 to 3 and Site 7 had a large coastal plan (< 20 metre elevation), where more than 200 metres of low land areas were found inland. Almost all coastal areas were less than the 20 metre elevation formed by green belt. Absence of coastal development and sea mining activities contributed to low Sensitivity on structures in the foreshore of SCCA. Detailed findings of the Vulnerability assessment using this method have been submitted to Sabah Foundation as part of the SCCA scientific expedition output.

SCCA can be considered ideal for conservation with conditional tourism development. The advantages are low risk of tsunami threats with maximum water level increase of up to 1 metre in a worst case scenario (Environment Protection Department, 2013). Proposed tourism activities in SCCA under the Tourism Area Concept Plan for Darvel Bay, where Malampayau Island has been reserved as Low or Medium density tourism development (Jakobsen *et al.*, 2007). Other islands in the SCCA cluster have been reserved for Environmental Protection and Conservation. The lack of human activities nearby the shoreline can lead to less erosion. Activities such as sand mining can lead to erosion and it is worth noting that for protected areas such as SCCA, such activities are not allowed. The impact of human activities towards shoreline can be seen in Sarawak where selected sites in Southwest Sarawak are facing erosion due to sand mining and the oil palm industry (Aazani *et al.*, 2015; Doweler, 2015).

### 6.3 Result comparison of Lahad Datu and Semporna Priority Conservation Area (PCA) assessments

The Lahad Datu assessments were only done at selected sites of the district's shoreline, whereas the Semporna PCA assessments were done predominately throughout the shoreline. It is through Universiti Malaysia Sabah (UMS) and WWF-Malaysia's initiative to map the vulnerability of both districts to climate change; for the purpose of this report, a few coasts that were not assessed in the Lahad Datu assessment will be discussed in term of its vulnerability.

The Vulnerability of Lahad Datu and Semporna can be quite different due to its geographical location. Lahad Datu is situated in a bay (Darvel Bay) which is protected from the effects of extreme weather and strong wave action; thus, increasing its Adaptive Capacity and in turn, decreasing its vulnerability to climate change. However, the more exposed area located East of Lahad Datu showed medium to high Vulnerability. On the other hand, Semporna is slightly more exposed geographically; like a cape. Therefore, its vulnerability to climate change is slightly riskier than Lahad Datu and scored a medium vulnerability to the effects of climate change. Certain islands that were located away from the mainland, such as, Ligitan Island, Denawan Island, Si-Amil, and Sipadan Island were highly vulnerable; as they are small islands that were neither protected geographically by other land mass, nor had strong natural barriers around the tiny islands.

In the Lahad Datu assessment, the Vulnerability at the Southwest of the district was observed to be low (as seen through the results in Site C and the sites in SCCA). Site C (alongside with sites in SSCA) have low Vulnerability, mostly due to the relatively protected location (low exposure and low sensitivity) and little human activities (high Adaptive Capacity). This may also be applied to the other remaining sites in the Southwest of the district that were not assessed, assuming that the Variable results would be similar to the ones assessed in Site C and SCCA. Thus, the Southwest of the Lahad Datu district is low in Vulnerability alongside with the sites in Site C and SSCA. This similar Vulnerability result due to similar result of Variables was also seen in the mainland of the Semporna PCA, particularly at the North mainland of the district (Jolis & Saleh, 2015). The mainland of the Semporna PCA was identified as low in Vulnerability and seen to be relatively protected within the bay and various islands off coast.

By combining both assessments to map the Vulnerability of both districts, the result suggests that the Vulnerability is higher in sites where it is exposed to the open sea (e.g. Site B of Lahad Datu, and Sipadan, Mabul, Denawan, Si Amil of Semporna PCA) and lower in the inner parts of Darvel Bay (e.g. Site C and SCCA of Lahad Datu, and North mainland of Semporna PCA) as it is protected by the bay (Figure 6.1).

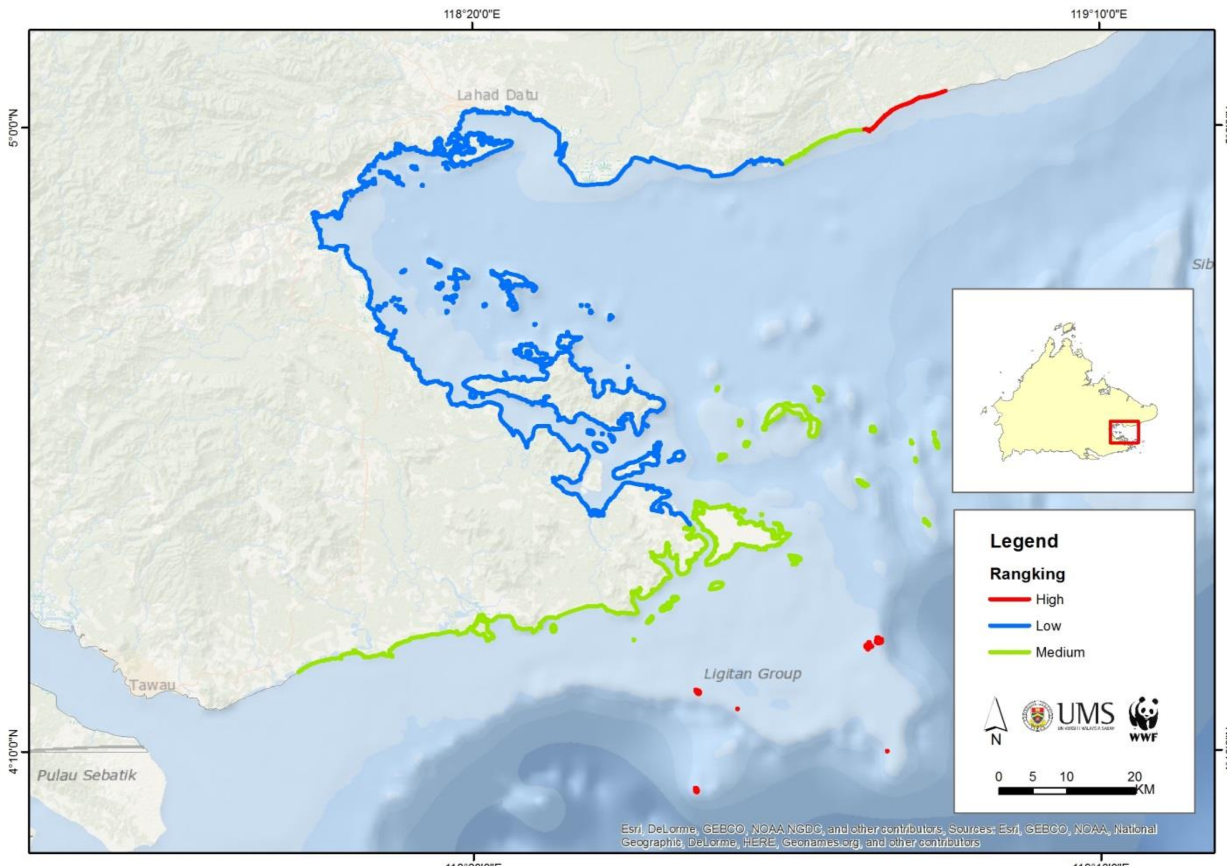


Figure 6.1: The Vulnerability of Semporna and Lahad Datu districts to climate change

## 6.4 Recommended adaptation options

The scores of each site determined prioritising the needed adaptations, especially for sites that revealed to have high Vulnerability. Aside from the assessment results, a stakeholder's workshop in Lahad Datu on April 2017 was conducted with the purpose to share the results as well as to discuss adaptation options most feasible in the sites (Figures 6.2-3).

The recommended adaptation options are as follows:

- As coral reefs, mangroves, and various natural coastal habitats play a vital role as natural coastal barriers, it is recommended that coastal habitats, especially in Site B, are to be maintained and if possible, restored. In addition, it was shared during the stakeholder's workshop that fish bombing by fishermen was reported to be a common threat to the waters near the SCCA, as recorded by the Malaysian Maritime Enforcement Agency (MMEA) (Jessica, 2017). Thus, aside from Site B, protection of coral reefs is also needed in SCCA despite it being presently low in vulnerability.
- A sustainable coastal development local plan for the villages in all sites that takes the Vulnerability results into account. The suggested plan will recommend adhering to guidelines on developing infrastructure (such as homes, roads, schools, etc.) not close to the coasts.
- In areas that are highly vulnerable to climate change such as Site B, there is possibility asses place in relocating the community to a safer location particularly during strong wind that may contribute to storm surge in the low land area. Further engagement with the village head from Nala Village revealed that the local community is reluctant to move to another area. The reason to this was that their ancestral lands are the root of their culture and lifestyle in their village. The village head proposed instead have seawalls and barriers to reduce the incoming impacts of erosion and sea level rise. Nonetheless, the former suggestion is the final option to be used, as most communities are less likely to relocate from their ancestral grounds that are filled with their culture and lifestyle. This may also be the most expensive strategy to implement and can only be employed when the coastal area is too risky for the community to reside in.

Figure 6.2: A presentation during a stakeholder’s workshop on the result assessments in Lahad Datu

Figure 6.3: Participants of a stakeholder workshop in April 2017.

## 7. Limitations

Parts of the assessment were conducted during the imposed curfew by the Eastern Sabah Security Command (ESSCOM) as a result from the Lahad Datu standoff which started in February 2013. This introduced limitations to the team in conducting the assessment as below:

| Limitations | Suggestions to improve |
|---|---|
| Lack of baseline data on communities and resources. We depended primarily on data from communities through informal interviews<br><br>Lack of published geological and ecological data of the Lahad Datu coasts and SCCA<br><br>Limitation of land infrastructure (road) to access some part of Lahad Datu shoreline<br><br>Lack of published data particularly at SCCA. | Apply different methods to obtain primary data<br><br>Desktop research but depends on existing published data. |
| Underwater observation (same part of Lahad Datu) through diving was not possible due to the unsuitable conditions of waters, currents, and tide in the area | Desktop research but depends on existing published data.<br><br>Obtain information of underwater situations by interviewing fishermen |
| Assessment was not conducted at the Northeast of the Lahad Datu district due to safety and security issues | Conduct assessments with escort from military personnel |

In the interest of not jeopardising the safety of the team and the need to abide with the imposed curfew rule; recognising the limitations affecting the assessment, the assessment activities depended largely on existing literatures and visual images taken during field trips by the team.

## 8. Conclusion

A Vulnerability assessment on climate change was conducted collaboratively by Universiti Malaysia Sabah (UMS) and WWF-Malaysia between April and May 2015 in Lahad Datu, Sabah. The aim of the assessment was to establish a Climate Change Vulnerability Assessment along the Lahad Datu coastline.

The objectives of the assessment were to introduce and apply Coastal Integrity Vulnerability Assessment Tool (CIVAT) in Lahad Datu as a tool to assess vulnerability to climate change, determine the vulnerability of local communities to climate change, followed by recommend adaptation options to climate change in Lahad Datu.

The assessment was done at Lahad Datu as part of a continuous vulnerability study, previously done in Semporna, along the East coast of Sabah. Selected sites in Lahad Datu were assessed; i.e. three sites along the East of the district and eight sites in the Silam Coast Conservation Area (SCCA). The CIVAT was used to conduct the assessment.

In East Lahad Datu, low and medium vulnerability were identified at Site C and Site A respectively. Site C had low vulnerability due to the low exposure to waves as there were a few barriers present, a lot of mangroves and other trees could be found along the beach. High vulnerability to climate change were identified in Site B due to the high Sensitivity in terms of sand recovery and the presence of coastal habitats (such as coral reefs and seagrass), which meant that Site B needs to be monitored to prevent asset loss.

In SCCA is located at inner part of Darvel Bay, the presence of many offshore islands contribute to  low current flow, and complex bathymetry have reduced exposure of the SCCA shoreline to climate change factors, making all eight sites to score a low in Vulnerability.

The recommended adaptation options for the sites include maintaining or restoring coastal habitats especially in Site B, implementation of a sustainable coastal development local plan for the villages in all sites that takes the Vulnerability result into account, and possible relocation of villages to safer areas.

The study on the Vulnerability of coastal areas in Lahad Datu using CIVAT determined that the current situation of communities living in highly vulnerable areas need to be prepared or at least consider finding another settlement before situations worsen due to climate change, especially for the residents of Nala Village. However, due to objections from the local community, other adaptive measures need to be looked into. Other than that, the results can be used by higher authorities, coastal engineers, or policy makers to provide relevant recommendations and plans for the type of development that can be done in order to prevent and reduce the impact of climate change; such as seawall constructions or replanting mangroves as natural coastal barriers. For the local communities, this study was also important to understand the risks that they are facing while living at the coastal areas.

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# 10. Appendices

## 10.1 CIVAT calculation

### Calculation for rating Exposure:

Criteria : 3
Maximum Score: 4 x 3 = 12
Minimum Score: 2 x 3 = 6
Max score possible: 12 – 6 = 6
Interval: 6/3 (criteria) = 2

| Rating | Range |
|---|---|
| Low (L) | (6– 8) |
| Medium (M) | (9 - 11 ) |
| High (H) | (12) |

### Calculation for Sensitivity:

Criteria : 9
Maximum Score: 5 x 9 = 45
Minimum Score: 1 x 9 = 9
Max score possible: 45 – 9 =36
Interval: 36/3 (ranking) = 12

| Rating | Range |
|---|---|
| Low (L) | (9 –21 ) |
| Medium (M) | (22 - 31) |
| High (H) | (32 – 45) |

### Calculation for Adaptive Capacity:

Criteria : 9
Maximum Score: 5 x 9 = 45
Minimum Score: 1 x 9 = 9
Max score possible: 45 – 9 = 36
Interval: 36/3 (ranking) = 12

| Rating | Range |
|---|---|
| Low (L) | (9 – 21) |
| Medium (M) | (22 - 34) |
| High (H) | (35- 45) |

## 10.2 CIVAT rubric

(A) CIVAT Exposure rubric

| Exposure variable | Low (1-2) | Medium (3-4) | High (5) |
|---|---|---|---|
| Rates of relative sea level change (cm/yr) | ≤ 0.2 | 0.2-1.5 | >1.5 |
| Wave exposure during monsoons | From Oceanography Group | | |
| Wave exposure during typhoon | From Oceanography Group | | |
| Tidal range (m) | ≤ 1 | (1 to 2) | ≥ 2 |

(B) CIVAT Sensitivity rubric

| Sensitivity variable | | Low (1-2) | Medium (3-4) | High (5) |
|---|---|---|---|---|
| Intrinsic factors | Coastal landform and rock type | Rocky, cliffed coast; beach rock | Low cliff (<5m high); Cobble/gravel beaches; alluvial plains; fringed by mangroves | Sandy beaches; deltas; mud/sandflat |
| | Seasonal beach recovery | Net Accretion | Stable | Net Erosion |
| | Slope from the shoreline to 20-m elevation (landward slope) | greater than 1:50 | 1:50-1:200 | less than 1:200 |
| | Width of reef flat or shore platform ($m^2$) | greater than 100 | (50, 100) | less than 50 |
| | Beach forest/vegetation | Continuous and thick with many creeping variety | Continuous and thin with few creeping variety | Very patchy to none |
| | Lateral continuity of reef flat or shore platform | greater than 50% | (10-50) | less than 10% |
| | Coastal habitats | Coral reef, mangroves and seagrasses or coral reef and mangroves are present | Either coral reef or mangrove is present | None |
| Extrinsic | Coastal and offshore mining (includes removal of fossilised corals on the fringing reef and beach) | None to negligible amount of sediments being removed (i.e., sand and pebbles as souvenir items) | Consumption for household use | Commercial scale |
| | Structures on the foreshore | None; one or two short groins (i.e., <5m long) and/or few properties on the easement with no apparent shoreline modification | Short groins & short solid-based pier (5 to 10m long); seawalls and properties with aggregate length of less than 10% of the shoreline length of the barangay | Groins and solid-based pier > 10m long; seawalls and other properties with aggregate length of more than 10% of the shoreline length of the barangay |

(C) CIVAT Sensitivity rubric for coastal habitats

| Sensitivity variable | | Low (1-2) | Medium (3-4) | High (5) |
|---|---|---|---|---|
| Coral as sediment source | Living coral cover | Over 50% | Between 25 to 50% | Less than 25% |
| | Coral community growth form in the shallow reef | At least half of the corals are hemispherical/ massive and encrusting | At least half of the corals are tabulate | At least half of the corals are branching and foliose |
| Seagarass bed as sediment source and stabiliser | Areal extant relative to reef flat | Seagrasses cover more than half of the reef flat | Seagrasses cover more than 1/8 to 1/2 of the reef flat | Seagrasses cover less 1/8 of the reef flat |
| | Capacity to withstand storm removal and wave impact | Root system extensive; *Enhalus acoroides* and *Thalassia hemprichii* dominated | *Thalassia* - *Cymodocea*- *Halodule* beds | Small sized species, i.e. *Halophila* – *Halodule* meadows |
| | Seagrass meadow type | Mixed bed with over 5 species | 2 to 4 species | Monospecific bed |
| Mangroves as sediment trap | Forest type | Riverine-basin-fringing type; basin-fringing type | Riverine-fringing type; fringing | No mangrove; scrub type |
| | Mangrove zonation | 3 to 4 mangrove zones (*Avicennia*-*Sonneratia; Rhizophora; Ceriops- Bruguiera Xylocarpus*; Nypa zones) | 2 mangrove zones | Only 1 mangrove zone present |
| | Capacity to trap sediment | At least half of the mangrove area is *Avicennia*-*Sonneratia* dominated | At least half of the mangrove area are dominated by species with pneumatophore (*Avicennia, Sonneratia*) and knee root (*Bruguiera, Ceriops tagal*) system | Area is dominated by species with prop(*Rhizophora*) or buttress/ plank (*Xylocarpus granatum, Heritiera littoralis*)type |
| Mangroves as wave | Forest type | Riverine-basin-fringing type | Riverine-fringing type | Scrub-fringing type |

| | | | | |
|---|---|---|---|---|
| buffer | Present vs historical mangrove extent | 0 to 25% of original mangrove area loss; at least 75% of seaward zone remaining | 26 to 50% of original mangrove area loss | over 50% of original mangrove area loss |
| | Mangrove zonation | 3 to 4 mangrove zones (*Avicennia-Sonneratia;Rhizophora; Ceriops-Bruguiera-Xylocarpus; Nypa zones*) | 2 mangrove zones | Only 1 mangrove zone present |
| | Mangrove canopy cover | Mangrove area with over 50% canopy cover | Mangrove area with canopy cover that is between 25% to 50% | Mangrove area with less than 25% canopy cover |
| | Mangrove basal area | More than 50 $m^2$ per ha | Between 25 to 50 $m^2$ per ha | Less than 25 $m^2$ per ha |

(D) CIVAT Adaptive rubric

| Adaptive Capacity criteria | Low (1-2) | Medium (3-4) | High (5) |
|---|---|---|---|
| Long-term shoreline trends (m/ year) | ≤-1 (eroding) | (-1,0) | >0 (accreting) |
| Continuity of sediment supply | if interruption in sediment supply is regional | if interruption in sediment supply is localised | If sediment supply is uninterrupted |
| Guidelines regarding the easement (setback zone) | No provision for easement (setback zone) in the CLUP and zoning guidelines | Setback policy is clearly stated in the CLUP and zoning guidelines; with <50% implementation | Implementation of setback policy is at least 50% |
| Guidelines on coastal structures | CLUP and zoning guidelines promote the construction of permanent and solid | Clearly states the preference for semi-permanent or temporary structures to be built along the coast(e.g., made of light materials and on stilts) is in the CLUP and zoning | Implementation of setback policy is at least 50% |

| | | | | |
|---|---|---|---|---|
| | | based structures along the coast | guidelines | |
| Type of coastal development | | Industrial, commercial, highways, large institutional facility | Residential | Agricultural, open space, greenbelt |
| Viability of coral reef as sediment source | Living coral cover | less than 25% | between 25 to 50% | over 50% |
| Viability of seagrasses as sediment source | Capacity to recover from storm blow-outs | *Enhalus-Thalassia* dominated | *Thalassia-Cymodocea-Halodule* dominated | *Halophila - Halodule* dominated |
| Viability of mangroves as sediment trap | Capacity to trap sediments | area is dominated by species with prop (*Rhizophora*) or buttress/ plank (*Xylocarpus granatum, Heritiera littoralis*) type of root system | at least half of the mangrove area are dominated by species with pneumatophore (*Avicennia, Sonneratia*)and knee root (*Bruguiera, Ceriops tagal*) system | at least half of the mangrove area are *Avicennia-Sonneratia* dominated |
| Viability of mangroves as wave buffer | Mangrove canopy cover | mangrove area with less than 25% canopy cover | mangrove area with canopy cover that is between 25% to50% | mangrove area with over 50% canopy cover |
| | Mangrove basal area | less than 25 $m^2$ per ha | between 25 to 50 $m^2$ per ha | more than 50 $m^2$ per ha |

| | | | | |
|---|---|---|---|---|
| Mangroves as wave buffer | Forest type | Riverine-basin-fringing type | Riverine-fringing type | Scrub-fringing type |
| | Present vs historical mangrove extent | 0 to 25% of original mangrove area loss; at least 75% of seaward zone remaining | 26 to 50% of original mangrove area loss | over 50% of original mangrove area loss |
| | Mangrove zonation | 3 to 4 mangrove zones (*Avicennia-Sonneratia;Rhizophora; Ceriops-Bruguiera-Xylocarpus; Nypa* zones) | 2 mangrove zones | Only 1 mangrove zone present |
| | Mangrove canopy cover | Mangrove area with over 50% canopy cover | Mangrove area with canopy cover that is between 25% to 50% | Mangrove area with less than 25% canopy cover |
| | Mangrove basal area | More than 50 m² per ha | Between 25 to 50 m² per ha | Less than 25 m² per ha |

## 10.3 Pictures taken at East Lahad Datu

| | |
|---|---|
|  Coral fragments and seashells along Site A (Parapat) show that there is a coral reef in front of the beach. |  A sandy shore with fine and medium sized sand at Site A. |
|  The community experienced beach erosions at Site B (Nala Village) and as seen, a few trees have fallen down on the beach. It is also expected that the erosion is higher compared to its sediment recovery. |  The study area on Sakar Island is near a mangrove and community settlement. |

## 10.4 Pictures taken at the Silam Coast Conservation Area (SCCA)

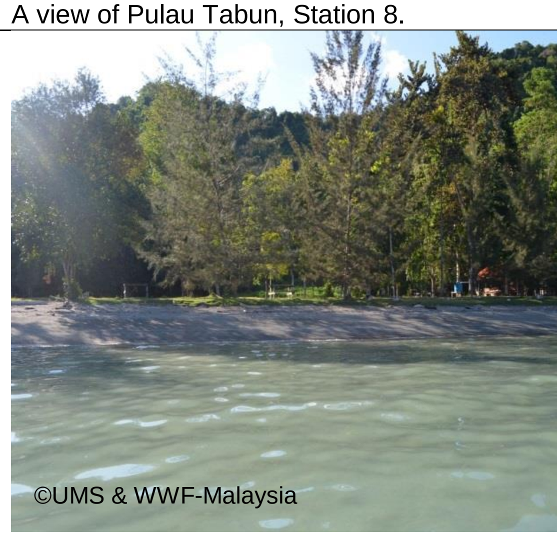

The rock beaches found in Pulau Malampayau as Station 3.


Station 2 is Pantai Bangkuruan, form a bay nearest to the Bangkuruan Mangrove Forest Reserve.


The mangrove habitat in Station 4, the Jetty Bay


A view of Pulau Tabun, Station 8.


The sandy beaches view above at Station 5, also the basecamp for this expedition.




Station 6, Pantai Pandanus which is the longest beach in SCCA.

**About WWF-Malaysia**
WWF-Malaysia (World Wide Fund for Nature-Malaysia) was established in Malaysia in 1972. It currently runs more than 90 projects, covering a diverse range of environmental conservation and protection work, from saving endangered species such as tigers and turtles, to protecting our highland forests, rivers and seas. The national conservation organisation also undertakes environmental education and advocacy work to achieve its conservation goals. Its mission is to stop the degradation of the earth's natural environment and to build a future in which humans live in harmony with nature, by conserving the nation's biological diversity, ensuring that the use of renewable natural resources is sustainable, and promoting the reduction of pollution and wasteful consumption.

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WWF

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To stop the degradation of the planet's natural environment and to build a future in which humans live in harmony with nature.

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