MONITORING OF SEA SURFACE TEMPERATURE IN SEMPORNA, SABAH, MALAYSIA BETWEEN 2015 AND 2016

WWF-MALAYSIA SEMPORNA MARINE PROGRAMME

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MONITORING OF SEA SURFACE TEMPERATURE IN SEMPORNA, SABAH, MALAYSIA BETWEEN 2015 and 2016

By

Cheo Seng Kong and Choo Poh Leem

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### Acronyms

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
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<tr>
<td>°C</td>
<td>Degree Celsius</td>
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<tr>
<td>CFS</td>
<td>Climate Forecast System</td>
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<tr>
<td>CTI</td>
<td>Coral Triangle Initiative</td>
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<tr>
<td>CTI-CFF</td>
<td>Coral Triangle Initiative on Coral Reefs, Fisheries and Food Security</td>
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<tr>
<td>DMPM</td>
<td>Department of Marine Parks Malaysia</td>
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<tr>
<td>ERP</td>
<td>Early Response Plan</td>
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<tr>
<td>GBRMPA</td>
<td>Great Barrier Reef Marine Park Authority</td>
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<tr>
<td>MSP</td>
<td>Marine Spatial Planning</td>
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<tr>
<td>MTEC</td>
<td>Ministry of Tourism, Environment &amp; Culture</td>
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<tr>
<td>NOAA</td>
<td>National Ocean &amp; Atmospheric Authority</td>
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<td>NRE</td>
<td>Ministry of National Resources and Environment</td>
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<tr>
<td>PCA</td>
<td>Priority Conservation Area</td>
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<td>RCM</td>
<td>Reef Check Malaysia</td>
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<td>SCUBA</td>
<td>Self-Contained Underwater Breathing Apparatus</td>
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<td>SIMP</td>
<td>Sipadan Island Marine Park</td>
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<td>SST</td>
<td>Sea Surface Temperature</td>
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<tr>
<td>TRACC</td>
<td>Tropical Research And Conservation Center</td>
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<td>TSMP</td>
<td>Tun Sakaran Marine Park</td>
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<tr>
<td>UMS</td>
<td>University Malaysia Sabah</td>
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<td>UMT</td>
<td>University Malaysia Terengganu</td>
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<tr>
<td>WWF-Malaysia</td>
<td>World Wide Fund for Nature Malaysia</td>
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Last but not least, high recognition to climate change researcher, Dr Ejria Salleh of University Malaysia Sabah, for reviewing the draft report.
Executive Summary

Semporna Priority Conservation Area (PCA), situated at the Apex of Coral Triangle, the center of marine biodiversity, harbours the most concentrated coral reefs in Malaysia. These reefs not only provide fishing ground for local fishermen, they also attract SCUBA divers from all over the world. In addition to the local threats, the rise of sea surface temperature is one of the most wide spread threat to coral reefs. Corals tend to bleach or turn white from the absence of zooxanthellae due to heat stress.

WWF-Malaysia recognises the impacts of climate change, in particular the rise of sea surface temperature on the coral reefs. This study was conducted to collect baseline data for sea surface temperature (SST) trends, with the aim to monitor the SST trend at reef sites in Semporna.

Underwater field trips were conducted every six months to retrieve temperature loggers at reefs site at 8-10 meter depth around Semporna waters. The study revealed that the months where SSTs exceed the bleaching threshold for more than two weeks were April to May 2016. There is an increment of 0.41°C in year 2016 (n=2196, mean SST=29.28±0.028°C) compared to the baseline of mean SST of 28.87 ±0.031 °C in year 2015 (n=1945). Bohey Dulang Island, located at the lagoon in Tun Sakaran Marine Park, had the highest mean SST compared to all sites for both years. Pom-pom Island, situated at the exposed northeast of Semporna PCA, had the lowest mean SST.

This study supported the development of a district level coral bleaching early response plan with the contribution from governmental agencies, private sectors, NGOs and local communities. A results sharing workshop was conducted and stakeholders are now aware of their role and responsibility for future bleaching events. Stakeholder cooperation is crucial to increase the resilience of coral reefs and to provide the optimum condition for corals to recover from mass coral bleaching.
Rumusan Eksekutif


WWF-Malaysia sedar bahawa kesan perubahan iklim terhadap batu karang dan kepentingan memulakan pemantauan suhu air laut untuk mengetahui trend suhu air laut di Kawasan Pemuliharaan Utama Semporna. Tujuan kajian ini adalah pemantauan kenaikan suhu air laut di Semporna, Sabah. Data suhu air laut yang direkodkan diguna untuk menganalisis corak tahunan suhu air laut dan mengenalpasti bulan-bulan tertentu yang lebih panas dan berisiko tinggi berlakunya perlunturan batu karang.

Kerja lapangan dijalankan setiap 6 bulan untuk pengumpulan data peranti suhu air laut. Sepuluh peranti suhu dipasang di kawasan batu karang dengan kedalaman air di antara 8-10m sekitar Semporna. Data yang terkumpul menunjukkan pertengahan April sampai May merupakan rekod suhu yang melebihi tahap kerentangan pelunturan karang. Purata suhu air laut di Semporna menunjukkan terdapat kenaikan suhu sebanyak 0.41°C dari 2015 sehingga 2016. Kawasan kajian merekodkan purata suhu air laut yang paling tinggi di Pulau Bohey Dulang yang mana terletak dalam Taman Laut Tun Sakaran. Pulau Pom-pom yang terletak di kawasan terbuka di bahagian Timur Laut merekodkan purata suhu air laut paling rendah.

Kajian ini menyumbang kepada penjanaan pelan tindakan awal perlunturan batu karang Daerah Semporna bersama agensi-agensi kerajaan, sektor swasta, badan bukan kerajaan dan komuniti tempatan. Pihak berkepentingan diberi kesedaran melalui ceramah pembentangan hasil kajian dan diamanahkan tanggungjawab masing-masing sekiranya perlunturan batu karang berlaku. Pihak berkepentingan bekerjasama dalam usaha melindungi terumbu karang dan memberi persekitaran yang optimum untuk batu karang memulih daripada perlunturan karang besar-besaran.
1. Introduction

1.1 Climate Change Impact to Coral Reefs

Climate change received global attention from coral experts in 1997-98 when mass coral bleaching threatened reefs globally due to the increase of Sea Surface Temperature (SST) associated with El Niño. Climate change might represent the single greatest threat to the global coral ecosystem (West & Salm, 2003). More reefs, reported bleached, received global attention in 1997-98 when climate change impacts from global warming and ocean acidification accelerated damage to the already fragile coral ecosystems around the world (Guest et al., 2012; Donner et al., 2005). Climate change refers to the drastic change of temperature, precipitation and other climate systems considered over long periods of time. Climate change is mainly caused by the rising concentrations of greenhouse gases in earth’s atmosphere. Greenhouse gases such as carbon dioxide play a vital role in heat insulation for the earth to ensure the continuity of life. However, man-made greenhouse gases, such as carbon monoxide and nitrous oxide act, similar to greenhouse gas and trap heat within the earth’s atmosphere. The increased concentration of greenhouse gases in the atmosphere can directly cause global warming. The rising temperature in the air contributes to rising sea surface temperature and affects coral reefs.

Increase in SST causes thermal stress to marine organisms, especially those living in shallow reefs. SST refer to the temperature of the first 20m of water column from the surface of the ocean. The reef building coral tends to face thermal stress when SST is 1°C warmer than the average temperature of the warmest month (Glynn and D’croz, 1990). Temperature-induced coral bleaching is one of the most studied subject after the El Niño event in 1998, which resulted in mass coral bleaching globally (Bruno et al., 2001). Thermal stress also suppresses the reef-building coral growth rate by reducing their calcification rate (De’ath et al, 2009; Cantin et al, 2010).

Coral bleaching is a phenomenon that occurs when coral polyps are stressed and they then expel their symbiotic algae, zooxanthellae, that lives within their body (Hoegh-Guldberg, 1999; Fitt et al., 2001; Carpenter et al., 2008). Zooxanthellae plays a vital role in the biology and survival of corals, as they provide most of the energy and limestone depositing ability (Goreau and Hayes, 1994; Moberg and Folke, 1999). However, during heat stress zooxanthellae produces harmful oxidants that can harm the coral polyps instead of producing energy (Fitt et al., 2001). This is why coral polyps expel the zooxanthellae to survive. This will render the corals to look white due to the transparent nature of coral polyps, which leave behind and reveal the white of the corals’ calcium carbonate skeletons. If the condition of the seawater stays unfavourable for the corals for an extended amount of time, the affected corals may die from starvation.
Prolonged mass coral bleaching is detrimental to the health of coral reefs and reduces live coral cover. With just an increase of 1-2 °C, the SST can trigger a mass bleaching event because the corals are already living close to their maximum thermal limit (Hoegh-Guldberg, 1999).

History shows that mass coral bleaching often occurs in the warmest period as recorded by in situ observations and NOAA records (Goreau et al., 1993; Goreau and Hayes, 1994). Studies had shown that severe and frequent bleaching events can be detrimental to the reproduction rate, growth rate, resistance and resilience of corals (Hoegh-Guldberg, 1999; Fitt et al., 2001; Donner et al., 2005). Bleached corals may have reduced immunity to pathogens, making them more susceptible to diseases (Harvell et al., 1999). Bleached corals infected by an unidentified disease outbreak were reported in islands in Peninsular Malaysia in 2010 (Tan and Heron, 2011).

Bleached corals might recover from bleaching naturally if the coral reefs are resilient. The resilience of coral reefs is their ability to maintain functions to absorb recurrent disturbance; in this case, an increase in sea surface temperature. Natural factors that increase the resilience of coral reefs against mass coral bleaching include cool water from upwelling or proximity to deep water, shading from cliffs or a mountain, and turbid condition in the water column. The immediate intervention to protect corals that are bleaching will be to reduce physical damage to the corals, and to control the water quality and fishing activities (Marshall & Schuttenberg, 2006). Reducing/elimination local stressors, such as pollutants and fishing pressure, are important factors in increasing coral survival and recovery (Hoegh-Guldberg, 1999).

The recovery of bleached coral reefs depend on the connectivity of the reefs to other reefs or refugia and favourable conditions for coral recruitment. Refugia serves as the seed bank to facilitate the recovery of reefs with lower natural resilience. Hence, it plays a crucial role in networks of protected areas designed to maximise the resilience of the whole ecosystem. We must identify areas that have corals that are resilient to thermal stress and need to protect them to ensure these corals can replenish other areas when mass bleaching occurs.
1.2 Coral Bleaching in Semporna, Malaysia

Semporna is a district located in the southeastern Sabah, Malaysia. The country has almost 4,000 km² of coral reefs and around 90% of these reefs are found within Sabah waters (Wilkinson, 2008). Semporna has the highest concentration of coral reefs in Malaysia, with 46 islands recognised by the local authority. Semporna Priority Conservation Area (PCA), is situated within the Sulu-Sulawesi Marine Ecoregion (SSME) at the Apex of Coral Triangle, the center of world marine biodiversity. Semporna was ranked globally significant because it contains a rich mix of habitats such as mangrove forests, seagrass beds and coral reefs. Within Semporna PCA’s 7.680km², coral reef geomorphology include a barrier reef, fringing reefs, patch reefs, a pre-atoll and an oceanic seamount.

Coral reefs in Semporna PCA can potentially be refugia for “re-seeding” other reefs areas that are damaged by mass coral bleaching due to its strategic location. There are no mass coral bleaching observed prior to 2010 in Malaysia, including the period of 1997/1998 global event (Tan and Heron, 2011, Wilkinson, 1998). Coral bleaching was reported at reefs in South China Sea, along the northwestern coast of Peninsular Malaysia, which lasted for 3 weeks from mid of May 2011 (Tan and Heron, 2011). Less than 10% of corals in East Malaysia, Sabah and Sarawak, were bleached (Reef Check Malaysia) because their waters are adjacent to the Pacific Ocean.

The coral reefs in Semporna play an important economic role for the local communities and Sabah due to the fisheries and tourism industries. Coastal communities highly depend on the productivity of coral reefs for their food and livelihood. The tourism sector is the fastest growing in East Malaysia, especially in Semporna, which has around 2,000 tourists going to the sea monthly. Unfortunately human activities have negatively impacted the coral reefs through destructive fishing techniques and unplanned coastal development as observed in Semporna PCA (Ho & Kassem, 2009).

The reef is Semporna is threaten by various local stressors that can reduce the resilience of coral reefs to climate change. A survey conducted by Ho and Kassem in Semporna in 2009 revealed that most reefs are either heavily impacted by exploitation of destructive fishing activities, such as blast fishing or boat and anchor damage. Live coral cover loss can immediately cause a reduction in the abundance and diversity of reef fishes due to loss of habitat and nursery opportunities (Jones et al., 2004; Graham et al., 2006; Bruno and Selig, 2007). To mitigate the effects of climate change, reef managers need to have a proactive management intervention for coral bleaching.
Coral bleaching may be unavoidable but we can improve reef resilience or provide a suitable environment for corals to recover. The world has already lost 27% of its coral reefs and if no steps are taken to counter the current situation, the world may lose another 60% of the world’s coral reefs (Cesar et al., 2003). A study by Selig and Bruno (2010) revealed that marine protected areas (MPAs) are effective in lessening and stopping loss of coral cover. However, past studies had shown that even high level protected areas with pristine conditions are still affected by severe heat stress and bleaching (Baker, et al. 2008; Hughes et al., 2010, 2017). Therefore, there is still a need for counter measures, such as a coral bleaching early response plan, within the management of any park authority.

The global warming phenomenon and other natural disasters cannot be avoided but it is possible to improve the chances for coral recovery in a bleaching event with an effective Coral bleaching Early Response Plan. The Great Barrier Reef Marine Park Authority (GBRMPA) developed an integrated framework known as the Coral Bleaching Response Plan (Great Barrier Reef Marine Park Authority, 2008). Department of Marine Parks Malaysia (DMPM) under the Ministry of National Resources and Environment (NRE) had developed a National Coral Bleaching Early Response Plan in respond to the 2010 bleaching event in Malaysia. These management actions contribute to the reduction or total elimination of local threats to improve the resilience of the corals towards climate change (Rahim et al., 2016). Effective communication is essential to pass accurate information to managers for decision making and also to the relevant stakeholders to garner effort to reduce the damage of coral bleaching (Maynard et al., 2009; Rahim et al., 2016).

Both of the study cases above are within MPAs, where coral bleaching early response plan is possible because coral reefs are under the jurisdiction of the management authorities. There are two marine parks that have been gazetted in Semporna under the jurisdiction of Sabah Parks; Sipadan Island Marine Park and Tun Sakaran Marine Park (TSMP). Sabah Parks, under the Ministry of Tourism, Environment and Culture (MTEC), is the managing authority and also decision maker for the Semporna Coral Bleaching Early Response Plan. Hence, Semporna District was able to develop its own customized coral bleaching early response plan that included all stakeholders; such as Sabah Parks, Department of Fisheries Sabah, dive and resort operators, local communities and local conservation NGOs.
2. Objectives

This study provides a baseline of sea surface temperature trend in Semporna from January 2015 to December 2016. The main reason to monitor SSTs is to identify coral reefs that are naturally resistant to temperature-related bleaching reefs and recommend a conservation policy for reef protection. Semporna PCA was chosen as the study site because the reefs there are made up of various reef structures, such as barrier reef, fringing reef, small patches of reef and a seamount known as Sipadan Island. We aim to monitor annual SST trend in Semporna to understand how global warming is affecting coral reefs at different sites in Semporna PCA.

The following are knowledge gaps that this study aims to rectify:

- What is the different in overall sea surface temperature for year 2015 to 2016 in Semporna waters? Is it increasing, decreasing or relatively stable?
- How many days and percentage of the time annually does the sea surface temperature exceed the bleaching threshold?
- What time of the year is the sea surface temperature prone to exceed the bleaching threshold continuously for more than two weeks?
- What are the potential reasons for differences between the sites?

This study will provide the necessary information for relevant authorities and decision makers on global warming and the rise of sea temperature. Results from this study will also contribute to produce a localized early warning system for Semporna’s reefs. The SST data for 2015 and 2016 will be shares with relevant stakeholders and marine resource users to facilitate the drafting of Semporna’s Coral Bleaching Early Response Plan, to ensure that reefs that are more resilient receive better attention and actions from managing authorities and resource users. The implementation of the plan will help coral reefs become more resilient towards thermal stresses from global warming.
3. Materials and methods

3.1 Study site

Semporna is a district located in the southeastern part of Sabah, Malaysia. There are 46 named islands as reported by the Semporna District Office. Semporna waters is part of the Sulu-Sulawesi Marine Ecoregion well known for its biodiversity, with a rich mix of habitats, such as mangrove forests, seagrass beds and coral reefs. There are two gazetted marine parks under the jurisdiction of Sabah Parks; namely, Sipadan Island Marine Park (SIMP) and Tun Sakaran Marine Park (TSMP). The Semporna Priority Conservation Area (PCA) is approximately 7,680 km² (Kassem and Ho, 2009) (Figure 2.1).

The ocean current in Semporna varies between seasons. During the warmer months from March to August, wave action comes from the northeast and moves towards the southwest as shown in Figure 2.2. However, during the cooler months, the direction of the waves changes and moves from the south and southwest towards the northeast as illustrated in Figure 2.2.
3.2 Materials used in this study

The underwater logger chosen for this study was the HOBO© Onset Water Temp Pro V2 U22-001 (Figure 2.3). The data had to be retrieved conveniently; hence, two waterproof shuttles, Hoboware U-DTW-1 (Figure 2.4), developed by Hoboware, were used as well.
The loggers were labelled and named according to sites before being launched using the Hoboware Pro Desktop software (Figure 2.5).

![Hoboware Pro Software](image)

Figure 2.5 The Hoboware Pro software used to access data from the loggers and shuttles.

The deployment and retrieval team have to dive using Self-Contained Underwater Breathing Apparatus (SCUBA) diving gears includes compressed air tanks, buoyancy control devices, wet suits, masks, diving fins, weights and weight belts.

### 3.3 Deployment of loggers

A workshop was organized on the impact of climate change to coral reefs by WWF-Malaysia in January 2015, to raise awareness of stakeholders on the impact of mass coral bleaching and gather support from Sabah Parks, dive operators and local communities to help monitor sea surface temperatures. One of the major outcomes of this workshop include the drafting of the first coral bleaching early response plan (ERP) for Semporna District. The participants learned to deploy underwater temperature loggers. Dive operators at Mabul, Pom-pom and Mataking islands agreed to assist in the deployment operations adjacent to their resorts.

The loggers were initially deployed at 10 different sites in Semporna PCA as shown in Figure 2.6. The sites at Larapan Island, Omadal Island, Singamata, Mataking Island, Timba-timba Island, Pom-pom Island, Mabul Island, Si Amil Island, Bohey Dulang Island and Sipadan Island were chosen based on:

i. The presence of stakeholders such as dive resorts and local communities.

ii. The availability of experienced dive masters at the logger deployment sites.
3.4 Data collection

Logger retrieval field trips were conducted every six months to ensure that the memory of each device did not fill up completely before collection. If the memory of a device reached full capacity, it would overwrite previous data and result in a loss of valuable sea surface temperature data. The measuring interval of the logger was set at 30 minutes. This meant the logger would constantly measure in situ temperature every 30 minutes until the next logger retrieval or until the internal memory had reached its limit.

The underwater loggers were collected and brought up to the surface, and Hoboware waterproof shuttles were connected to the loggers’ memory for data transfer to the shuttles. The loggers were then redeployed underwater for the next data over another six months.
3.5 Data analysis

A total of 48 data points collected each day were averaged to represent the daily sea surface temperature. The mean SSTs were compared between 2015 and 2016 with a confidence level of 0.95 (refer to footnote). The highest mean SST and the lowest mean SST of each year were compared based on study sites. Bar graphs of the mean SST with confidence interval versus study site/island were plotted to visualize the temperature difference for all sites according to the year.

A theoretical bleaching threshold of 30°C was used to compare the difference in SST distribution according to the sites. Previous research reported that the increase of 1°C of mean temperature in sea surface temperature would have a high possibility to trigger coral bleaching (Fitt et al., 2001). Daily mean SST that exceeds this would be recorded and the percentage would be calculated. The frequency distribution according to the SST were plotted in bar graphs to visualize the skewness in the data set.

In order to identify the period within a year that is prone to have higher SST, the mean daily SST for year 2015 and 2016 were plotted in line graphs according to the sites.

Footnote: 95% confidence interval means there is a 0.95 probability of containing the population mean.
4. Results

4.1 Sea surface temperature trend in 2015 and 2016 in Semporna

The mean temperature of Semporna’s waters in 2015 is 28.87 ±0.031 °C in year 2015 (n=1945). There is an increment of 0.41°C in year 2016, which means temperature is 29.28±0.028°C in year 2016 (n=2196). The highest mean temperature for all study sites is Bohey Dulang Island, with 29.33 ±0.077 °C in 2015 and 29.58 ±0.061 °C in 2016. Pom-pom Island has the lowest mean temperature of 28.53 ±0.062°C in 2015 and 28.94 ±0.072 °C in 2016 (Figure 4.1). All study sites showed higher mean sea surface temperature within a range of 0.250-0.522°C compared to the year before (Figure 4.1). Larapan Island showed the largest difference from year 2016 compared to 2015, while Bohey Dulang Island has the least difference in mean sea surface temperature. This indicates that Larapan’s reef experienced the largest increase in SST although the mean temperature of Bohey Dulang’s reef was higher.

Mataking Island, which is the closest to Pom-pom Island, has the second lowest mean temperature of 28.57±0.074°C in 2015 and 29.027±0.072°C in 2016. Both islands are in geographical proximity at the northeast of Semporna PCA and are more than 30 km away from the mainland. Sipadon Island, situated far south of Semporna PCA, is exposed compared to Pom-Pom and Mataking, with a higher mean temperature of 28.93±0.077°C in 2015 and 29.31±0.058°C.

Islands closer to the mainland, Omadal and Larapan, are community islands. The mean SST for Omadal Island is 28.79±0.069°C (2015) and 29.30±0.064°C (2016) respectively, whereas Larapan Island is 29.03±0.066°C (2015) and 29.55±0.055°C (2016). This might be due to the fact that the distance from Larapan Island (~9km) is closer to the mainland compared to Omadal Island (~17km). Furthermore, Larapan Island is sheltered by Timbum Mata Island (north), Tun Sakaran Marine Park (east), Bum Bum Island (south) and Mainland Semporna (west).
The mean SST for all the study sites in 2015 and 2016 with the error bar showed the confidence interval with a level of 0.95.

### 4.2 Percentage of days exceed the bleaching threshold

1,948 daily mean SST were recorded in year 2015 compared to 2,196 in 2016 for all 6 sites in this study. The start date for the loggers deployed at the reef sites are different. The logger in Mataking Island had a technical problem and the logger in Sipadan was unintentionally collected by a diver. The baseline of the daily mean SST in 2015 was 3.54% (n=1948) compared to 13.30% in 2016 (n=2196). There are 3.75 times more percentage of days in 2016 which the SST exceeded the bleaching threshold (>30°C) compared to the baseline 2015.

The frequency distribution of temperature provides the baseline of how the temperature varies annually. In 2015, all the study sites were negatively skewed in a range of -0.59 to -0.65 from the normal distribution (except for Mataking and Sipadan that were data deficient). For Pom-pom and Mataking, the skewness of temperature frequency distribution are -0.64 and -0.68 respectively in year 2016 (Figure 4.2a-b). The temperature distribution of Omadal and Sipadan were closer to normal distribution with a skewness of 0.03 to 0.17 respectively (Figure 4.2c-d). The skewness of temperature frequency distribution in Larapan Island significantly changed from negatively skewed (-0.61) in 2015 to positively skewed (0.32) in 2016. The frequency distribution of Bohey Dulang Island remained negative skewed from -0.65 in 2015 to -0.34 in 2016 (Figure 4.2 e-f).
Figure 4.2 (a) The frequency distribution of the daily averaged sea surface temperature in the year 2015 (n=325) and 2016 (n=366) for Pom-pom Island. Percentage of days exceed theoretical bleaching threshold is 0.0% for 2015 and 3.8% for 2016.

Figure 4.2 (b) The frequency distribution of the daily averaged sea surface temperature in the year 2015 (n=293) and 2016 (n=366) for Mataking Island. Percentage of days exceed theoretical bleaching threshold is 0.0% for 2015 and 5.2% for 2016.
Figure 4.2 (c) The frequency distribution of the daily averaged sea surface temperature in the year 2015 (n=282) and 2016 (n=366) for Sipadan Island. Percentage of days exceed theoretical bleaching threshold is 2.8% for 2015 and 14.8% for 2016.

Figure 4.2 (d) The frequency distribution of the daily averaged sea surface temperature in the year 2015 (n=351) and 2016 (n=366) for Omadal Island. Percentage of days exceed theoretical bleaching threshold is 0.0% for 2015 and 15.0% for 2016.
The frequency distribution of the daily averaged sea surface temperature in the year 2015 and 2016 (n=351) for Larapan Island. Percentage of days exceed theoretical bleaching threshold is 1.7% for 2015 and 19.4% for 2016.

The frequency distribution of the daily averaged sea surface temperature in the year 2015 (n=346) and 2016 (n=366) for Bohey Dulang Island. Percentage of days exceed theoretical bleaching threshold is 15.9% for 2015 and 21.6% for 2016.

### 4.3 Sea surface temperature trend according to island

The sea surface temperature trend for 2015 and 2016 are similar with two noticeable periods where water temperatures in 2016 were higher than 2015 (Figure 4.3 a-f). The first warmer period started in January 2016, and went back to the baseline in mid-February for all sites except for Bohey Dulang Island, which ended two weeks later. The potential reason might be due to the limitation of seawater circulation at the Bohey Dulang Lagoon.
The second warmer period for Pom-pom, Mataking and Bohey Dulang lasted for three months from July to September 2016. Omadal and Larapan started the warmer period as early as mid-April. The start date of the warmer period for Sipadan Island was not clear because a diver unintentionally collected a logger and sent it to Sabah Parks from 11 June to 15 Aug 2015. The second warmer period for all sites was at the end of September 2016. Data deficiency from 14 March to 8 May 2015 for Mataking Island was due to a technical problem with the logger (Fig. 4.3(b)).

Figure 4.3(a)  The sea surface temperature trends of Pom-pom Island for the year 2015 and 2016.

Figure 4.3(b)  The sea surface temperature trends of Mataking Island for the year 2015 and 2016.
Figure 4.3(c)  The sea surface temperature trends of Sipadan Island for the year 2015 and 2016.

Figure 4.3(d)  The sea surface temperature trends of Omadal Island for the year 2015 and 2016.
Figure 4.3(e)  The sea surface temperature trends of Larapan Island for the year 2015 and 2016.

Figure 4.3(f)  The sea surface temperature trends of Bohey Dulang Island for the year 2015 and 2016.
In 2015, the sea surface temperature for all study sites did not exceed the bleaching threshold for more than two weeks except for Bohey Dulang Island. The logger was deployed in relatively stagnant water at Bohey Dulang Bay, compared to other sites. For 15 days straight, the daily average temperature was more than 30°C from 27 April to 11 May recorded. The water cooled down for 5 days, and another warmer period of 17 days was recorded from 16 May to 1 June 2015.

For exposed islands at the northern Semporna PCA, Pom-pom and Mataking, the sea surface water temperature did not exceed the theoretical bleaching threshold (30°C) for a period of two weeks for 2016. For the exposed island at the southern barrier reefs, Sipadan, the water temperature exceeded the bleaching threshold for 27 days from 25 April to 21 May 2016.

In 2016, the daily average water temperature of Omadal, Larapan and Bohey Dulang, which are closer to the mainland, exceeded the bleaching threshold for more than two weeks. Omadal Island's water temperature exceeded 30°C for 26 days from 13 April to 8 May 2016, whereas Larapan Island also started on 13 April and lasted 12 days longer, ending on 20 May 2016. The warmest island, Bohey Dulang, experienced two warmer periods in 2016 from 17 April to 25 May for 39 days, and again from 6 September 2016 for 14 days.
5. Discussion

5.1 The sea surface temperature trend of Semporna

This study provided a baseline of sea surface temperature trend (SST) in Semporna for 2015 and 2016. It showed an alarming sign of rise in sea surface temperature for all study sites. However, the rise in temperature from 2015 to 2016 might be due to the occurrence of an El Nino event; a phenomenon that warms up the Pacific Ocean. NOAA recorded that 2016 was one of the warmest years since 1880 (Potter et al., 2016). The previous El Nino event in 1998 caused mass coral bleaching globally (Bruno et al., 2001). With the availability of only two years’ data, there is no concrete proof that there is a rising SST trend caused by global warming. The timeline for this study needs to be extended in order to analyse and produce a temperature trend that can represent the sea surface temperature in Semporna PCA.

Pom-pom and Mataking showed similar a SST trend for both years. Both exposed islands were found to have lower sea surface temperatures compared to other study sites. This may be due to both islands being close together (less than 10 km apart) and located at the northeast of Semporna. Other factors, such as ocean current and wave action, may also contribute to the lower sea surface temperature. These allow both islands further east to have access to the circulation of cooler water currents from the northeast and wave directions from the northeast from March (taken from Ocean Weather). Mataking Island and Pom-Pom are also low-lying islands with no geographical barrier such as hills, thereby exposing them to extreme weathers such as strong winds and hurricane that can increase water circulation and reduce the risk of bleaching.

The SST at Bohey Dulang Island was highest among all sites in 2015 despite the fact that it is 23 km away from Semporna. This might due to the logger location in the sheltered bay of Bohey Dulang Island. The shallow bay limits access to cooler waters from the deep. The 350 m Bohey Dulang Hill blocks winds from the north and east. Hence, the relatively stagnant waters in the bay get heated up by sunlight, thereby reducing reef resilience and increasing the risk of bleaching.

In 2016 the SSTs in Larapan and Bohey Dulang were the highest, probably due to the natural geographical factors and human activities, either from village settlements or tourism. Larapan Island is 9 km away from Semporna with more than 2,000 local inhabitants (Haji Buglayan, as per converse, 2017). Bohey Dulang is the most popular island for tourists because of the breath taking view from the peak of the Bohey Dulang Hill. Massive human disturbance and sewage pollution contribute to eutrophication at sea and higher sea surface temperature (Smith, et al. 1998).
5.2 Vulnerable reef areas to rising sea surface temperature

The rise in sea surface temperature that causes prolonged coral bleaching and leads to mass coral deaths must be prevented (Berkelmans et al., 2004; Heron et al., 2016; Rahim et al., 2016). Minor coral bleaching have been observed in the past in various shallow reefs around Semporna PCA, causing potential damage to the fragile reefs (Jolis and Salleh, 2015). Many other stressors, such as sedimentation, pollutants, bomb and cyanide fishing, changes in salinity and diseases on a local scale, may also cause corals to bleach (Marshall and Schuttenberg, 2006).

Apart from sea surface temperature, other factors that may cause coral bleaching include the proximity to Semporna town centre and related human activities, and the lack of access to cooler upwelling from deep waters. Further studies on ocean and surface currents are needed to understand the resilience of various coral reefs in Semporna PCA, in order to determine if coral reefs closer to deeper waters are more resilient to bleaching.

The resilience of coral reefs to heat stress that may cause bleaching depends on the connectivity, gene flow and species diversity (Hughes et al., 2003). The Coral Triangle, where Semporna PCA is situated, is well known for the biodiversity of coral species. Despite high sea surface temperatures with the risk of bleaching, there was no observation or report of major coral bleaching event. This could be due to the high biodiversity of coral species in Semporna PCA.

From results of this study, we know that the vulnerable reefs are in Bohey Dulang Island and Larapan Island. However, the difference in mean SST between year 2015 and 2016 in Larapan Island is twice that of Bohey Dulang Island. Bohey Dulang reef area normally has relatively high SST, so its reefs may be more resistant to thermal stress and less susceptible to coral bleaching. Reefs that are exposed to warmer temperature and thermal stress will be more susceptible to coral bleaching (Guest et al, 2012). Hence, we should prioritize efforts to monitor the Larapan and Bohey Dulang reefs during the warmer months.

The rise in sea surface temperature cannot be avoided but steps can be taken to improve the resilience of affected coral reefs. Semporna is the first district in Sabah to develop a coral bleaching early response plan. This early response plan plays a vital role by providing a framework of management actions and communication from various levels of stakeholders in response to future bleaching events. Semporna’s Coral Bleaching Early Response Plan is endorse by the Department of Fisheries Sabah and Sabah Parks with support from WWF-Malaysia. Posters for this Plan were distributed to relevant stakeholders for their action and awareness (Appendix III).
5.3  Reef resilience through Sustainable Marine Tourism

Responsible and sustainable operation of dive and other marine tourism can play an important role in helping corals combat climate change. Sustainable tourism operation includes proper sewage and solid water system; recycling facilities; composting stations; and re-using sullage water to maintain seawater quality for corals. “No contact” policy and environmental awareness should be conducted to deter tourist from touching or standing on corals. This is crucial because recreation activities like snorkelling, diving and boat anchoring can cause major damage to coral colonies, and increase the risk of the coral infection by disease and overgrowth by algae. Hence, sustainable marine tourism will enable a better chance for corals to combat and recover from heat stresses.

One of the platforms for sustainable marine tourism is through promoting Green Fins certification to dive operators. Green Fins has been providing free training and assessment for dive and marine tourism operators in Peninsular Malaysia since 2009. The operators are expected to follow the agreed code of conduct after Green Fins assessment. With the growing dive industry in Semporna, WWF-Malaysia encourages dive operators and resorts to engage Green Fins to ensure best practices for a sustainable dive tourism.

5.4  Challenges faced during study

Unforeseen obstacles and challenges, such as weather condition, human and technical errors, faced throughout this study greatly affected the study. As the logger retrieval field trips involved SCUBA diving, safety precautions had to be taken. Retrieval teams were required to go in pairs or groups, pre-dive safety briefings were conducted, and safety buoys were necessary for the divers. Bad weather was an obstacle to the logger retrieval teams, as retrieval activities ceased until the weather and sea conditions improved.

The main challenge is the loss of the temperature loggers due to theft, storms and other unforeseen causes. Lost loggers meant that valuable data was lost, which in turn reduced the accuracy of the data collected. The reliability and outcome of the study were compromised. Out of 10 loggers deployed, only 6 were still functioning and recording data during the last retrieval operations.

For monitoring of sea surface temperature in Semporna beyond the 2015-2016 study, a new batch of temperature loggers have been deployed with extra care in sites that were not subjected to strong currents to prevent damage by storms. This monitoring needs to be continuous to understand the impact of climate change to corals at different sites in order to prioritize conservation effort to areas that can potentially be the refugia.
6. Conclusion

This monitoring of sea surface temperature study was conducted from January 2015 to January 2017 by WWF-Malaysia in Semporna, Sabah. It gave a baseline of sea surface temperature trend in Semporna from 2015 to 2016. The study provided an overview of how Semporna reefs react to coral bleaching during warmer months when corals might bleach. Semporna PCA was chosen as the study site due to its location within the Coral Triangle, the world’s centre of marine biodiversity with the highest coral species, which makes it an ideal site for refugia from the impact of climate change.

From the 2015 and 2016 data, the warmest period in Semporna’s waters occurred between March to August. The mean sea surface temperature for each site in 2016 was 0.3 - 0.5°C higher than 2015. The sites with highest sea surface temperatures in 2016 were Bohey Dulang Island (29.57°C) and Larapan Island (29.55°C). The sites with low average temperature in 2016 were Pom-pom Island (28.94°C) and Mataking Island (29.03°C). The temperature difference may be caused by the distance of these islands to the cooler waters of the northeast of Semporna. The geographical attributes of the island may also be one of factors in temperature difference among the islands. With only the data sets collected from 2015 and 2016, there is no concrete evidence for the sea surface temperature trend in Semporna.

Despite the high temperatures in the 2015 and 2016, there were no occurrence of major bleaching in Semporna PCA. Ongoing monitoring of sea surface temperature is necessary to prepare for coral bleaching events in the future. A management framework known as Semporna’s Coral Bleaching Early Response Plan was developed with the active involvement of local stakeholders, such as government agencies, NGOs, local dive operators and fishing communities. This plan had been communicated and posters distributed to all parties involved during the Semporna Marine Eco Week held from 27 November to 2 December 2017.
References


Appendix

I. Map of temperature loggers for the island

Figure 8.1  Location of logger deployed in the waters of Pom-pom Island.

Figure 8.2  Location of logger deployed in the waters of Mataking Island.
Figure 8.3 Location of logger deployed in the waters of Sipadan Island. N 04° 07.089’ E 118° 38.081’

Figure 8.4 Location of the logger deployed in the water of Omadal Island.
Figure 8.5  Location of logger deployed in the waters of Larapan Island.

Figure 8.6  Location of logger deployed in the waters of Bohey Dulang Island.
II. Photo

(Top) A diver from WWF-Malaysia securing the logger on a underwater cliff in Sipadan Island.

(Bottom) The logger and the sign attached to the logger to announce the ongoing study.
(Top) The participants that attended the Semporna’s Coral Bleaching Early Response Plan Workshop 2016.
(Bottom Right) Lecturer from University Malaysia Terengganu giving a talk on corals and coral bleaching.
(Bottom Left) WWF-Malaysia Officer and one of the leaders from the local community discussing the details on the drafting of Semporna’s Coral Bleaching Early Response Plan.
The participants that attended the opening day of Semporna Marine Eco Week 2017.

**III. Poster for Semporna Coral Bleaching Early Response Plan**
<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
<th>Response Times</th>
<th>Organizations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Communication</td>
<td>- Regular updates on the status of the response plan</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Management Action</td>
<td>- Coordinate and communicate with stakeholders</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Early Warning System</td>
<td>- Monitor and report changes in reef conditions</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Green Canna</td>
<td>- Plant coral (WBC)</td>
<td></td>
<td>Women's Association of Coral Reef Development and Science</td>
</tr>
<tr>
<td>Rx-Marin</td>
<td>- Enhance reef resilience</td>
<td></td>
<td></td>
</tr>
<tr>
<td>[Other categories]</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
TOP 10 RULES FOR LOVING THE OCEAN

1. Do not touch corals, turtles and other marine organisms.
2. Control buoyancy and avoid stirring up sand and silt.
3. Do not place boat anchors on coral reefs.
4. Do not collect any marine organisms.
5. Improve knowledge on marine ecosystem.
6. Reduce the usage of chemical products (e.g. sunblock) and use products safe for the environment.
7. Turn off the flash on your device when recording marine animals.
8. Do not purchase products made from marine turtles, corals, shells and other endangered species.
9. Do support marine conservation activities.
10. Do not throw cigarette butts and other plastic materials into the ocean.
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.

WWF-Malaysia
1 Jalan PJS 5/28A
Petaling Jaya Commercial Centre (PJCC)
46150 Petaling Jaya
Selangor, Malaysia

Telephone No: +603 7450 3773
Fascimile No: +603 7450 3777
Email: contactus@wwf.org.my
wwf.org.my

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