TEMPERATURE, LIGHT, DIRECTION OF CURRENTS AND SELECTED WATER QUALITY PARAMETERS AT CORAL REEF SITES WITHIN TALANG-SATANG MPA

Ng Chiew Tyiin

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Temperature, Light, Direction of Currents and Selected Water Quality Parameters at Coral Reef Sites within Talang-Satang MPA

Ng Chiew Tyiin

This dissertation is submitted in partial fulfillment of the requirements for the degree of Bachelor of Science with Honours

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Faculty of Resource Science and Technology
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DECLARATION

I, Ng Chiew Tyiin, final year student of Aquatic Resource Science and Management hereby declare that this thesis is my own work and effort with the guidance of my supervisor, Dr. Aazani Mujahid. No part of the thesis has previously been submitted for any other degree, university or institution of higher learning.

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(Ng Chiew Tyiin) Dated:

Aquatic Resource Science and Management
Faculty of Resource Science and Technology
Universiti Malaysia Sarawak
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List of Abbreviations

1. MPA – Marine Protected Area
2. PAR – Photosynthetically Active Radiation
3. SCUBA – Self Contained Underwater Breathing Apparatus
4. UVR – Ultraviolet Radiation
5. DO – Dissolved Oxygen
6. rpm – Rounds per Minute
7. BOD$_5$ – Biochemical Oxygen Demand in five days
8. USB – Universal Serial Bus
9. PSU – Practical Salinity Unit
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ABSTRACT

Coral reefs around the world are being increasingly threatened by the increase in sea water temperature. Therefore Temperature / Light logger and G Acceleration Logger were deployed to record temperature, light intensity and direction of current flow every twenty minutes for eight months at west of Pulau Talang Talang Besar, Sarawak. Other selected water quality parameters were also recorded at four stations within Talang-Satang MPA. Three regimes, Regime A, Regime B and Regime C each corresponding to the Southwest monsoon (May to September), intermonsoon (September to November) and Northeast monsoon (November to March) was distinguished based on the tidal cycle and large changes in direction of current during intermonsoon. Temperature and light intensity were found to decrease as the monsoon changes from Southwest monsoon to Northeast monsoon. The direction of current was found to have the highest variability during intermonsoon and the velocity of current was higher during monsoon seasons, corresponding to the larger change in hydrodynamics of the water column. It was also found that there was a positive correlation between light intensity and temperature throughout the eight months. Temperatures as high as 31.3°C were recorded during Southwest monsoon (July to September). High water temperatures from 30.8°C to 31.3°C were recorded for 23 days and change in 1.0°C of water temperature in a day was recorded during Northeast monsoon (November to March). The overall water quality of Talang-Satang MPA was found to be suitable for healthy coral reefs and there was no significant change in water quality between the two surveys (July 2011 and April 2012).

Key words: Temperature, light intensity, direction of current, coral reef, data logger.

ABSTRAK

Terumbu karang sedunia semakin terancam oleh peningkatan suhu air. Oleh itu, Pengelog Suhu / Keamatan Cahaya dan Pengelog G pecutan telah diempatkan untuk merekod suhu air, keamatan cahaya dan halatuju arus bagi setiap dua puluh minit selama lapan bulan di sebelah barat Pulau Talang Talang Besar, Sarawak. Parameter kualiti air juga telah dikaji di empat stesen dalam Kawasan Perlindungan Marin Pulau Talang-Satang. Tiga rejim, iaitu Rejim A, Rejim B dan Rejim C iaitu monsun barat daya (Mei hingga September), peralihan antara monsun (September hingga November) dan monsun timur laut (November hingga Mac) masing-masing telah ditentukan berdasarkan kitaran pasang surut dan perubahan besar halatuju arus semasa peralihan antara monsun. Suhu dan keamatan cahaya didapati berkurang dengan perubahan monsun daripada monsun barat hari (Julai hingga September) kepada monsun timur laut (November hingga Mac). Halatuju arus didapati mengalami perubahan terbesar semasa peralihan antara monsun dan hadaluju arus didapati lebih tinggi semasa monsun bersamaan dengan perubahan besar hidrodinamik turus air. Juga didapati terdapat korelasi positif antara keamatan cahaya dengan suhu air sepanjang musim suhu. Suhu air setinggi 31.3°C telah direkodkan semasa monsun barat hari. Perubahan suhu air yang tinggi dalam julat 30.8°C hingga 31.3°C telah direkodkan selama 23 hari dan perubahan suhu air sebanyak 1.0°C dalam sehari telah direkodkan semasa monsun timur laut. Kualiti air di kawasan Perlindungan Marin Pulau Talang-Satang secara keseluruhannya didapati bersesuaian dengan pertumbuhan terumbu karang yang sihat dan tiada perubahan keteran antara kualiti air kedua-dua pensampelan (Julai 2011 hingga April 2012).

Kata kunci: Suhu, keamatan cahaya, halatuju arus, terumbu karang, pengelog data.
1.0 Introduction

Coral reefs are calcareous formations found in warm waters with strong illumination and are composed of marine plants and animals, the most dominantly being scleractinian corals and crustose coralline algae (Fagerstrom, 1987), which are of highly productive algal component (Rogers & Salesky, 1981). Coral reefs support a diverse association of marine organisms, forming a distinctive ecosystem with ecological zonation, food chain relationships, trophic structure and mineral cycling. Hermatypic corals or Scleractinians are reef building corals, with optimal water temperature of 23°C to 25°C (Ho, 1992) and salinity of 25 to 42 PSU (Kleypas et al., 1999). Coral reefs around the world are being increasingly threatened by the increase in sea water temperature and other anthropogenic threats. Frequent temperature extremes increases bleaching and mortality of corals, disrupts the health and functions of reef and increases the vulnerability of corals towards other stresses (Clive & Robert, 1994). The problem statements for this proposed study is that Talang-Satang MPA is lacking present dataset on temperature, light availability, and water quality studies. There is also a lack of continuous datasets to study the relationship between temperature and light availability in Talang-Satang MPA and how it is affected by tides or monsoons. This is because no temperature and light data loggers have been set up in Talang-Satang MPA to collect these continuous datasets. Therefore the objectives of this study are:

1. To obtain temporal variability from continuous dataset of temperature, light intensity and direction of current for eight months at Pulau Talang Talang Besar West.

2. To determine the relationship between continuous dataset of temperature, light intensity and direction of current with the changes in tidal cycle.
3. To compare selected in situ water quality parameters at four coral reef sites within Talang-Satang MPA.

The Hypotheses for this research are as below.

1. $H_0 = \text{There are no variability in the continuous temperature and light intensity over eight months at Pulau Talang Talang Besar West}$
2. $H_0 = \text{There are no relationship between temperature, light intensity and current direction with tidal cycle.}$
3. $H_0 = \text{There are no variability in selected in situ water quality parameters at four coral reef sites within Talang-Satang MPA.}$

SCUBA diving is the main method for this research as diving is required to deploy the loggers at the chosen station. The loggers deployed recorded a continuous in situ dataset of temperature, light and direction of current flow. Water quality analyses were also done for all four selected study stations.

2.0 Literature Review

2.1 Relationship of Coral Reefs and Temperature

Coral reefs are vulnerable to slight change in temperature as corals live in the upper thermal tolerance limit. This can be seen in the increase in coral mortality and rate of coral disease during spatial patterns of greater than normal temperature anomalies (Selig 2008). On the other hand, research on global patterns of ocean temperature anomalies and the implications for coral reef health found that different coral reefs gave different responses to thermal stress (Selig et al., 2010). Another research on coral reefs in American Samoa by Smith and Birkeland (2003) showed that corals thought to be sensitive to high
temperatures, including *Acropora*, *Pocillopora* and *Millepora* spp. were able to survive in waters which varied in water temperature. It is suggested that water motion increases the resistance of corals towards high temperature, irradiance and hyperoxia stimulating the metabolism of zooxanthellae. However it does not stop the fact that rapid rise in temperature has negative effects on coral reefs. A research on coral and algae response to the 1998 El Niño Coral Bleaching and Mortality on Kenya’s Southern Reef Lagoons found that corals and their benthic community response in various ways. Quick recovery of coral cover and species composition, and change in coral dominancy occurs but there are also coral reefs that get overgrown by algae (McClanahan & Mangi, 2001).

### 2.2 Marine Protected Area (MPA)

MPAs in Peninsular Malaysia are established mainly to protect, conserve and manage selected marine ecosystems to remain undamaged for future generations, and to create public awareness and appreciation of Malaysia’s marine heritage (Yaman, 1993). Talang-Satang MPA is the only National park in Sarawak that is a designated coral reef MPA. Based on the Summary Report for Malaysia MPA (Reef Base, 2011), there are 83 MPAs in Malaysia and 51% are of coral reef MPAs, thus total of 43 Coral Reef MPAs in Malaysia. These MPAs are established primarily through Department of Marine Park (37 MPAs), Sabah Wildlife Department (5 MPAs) and through Forest Department Sarawak (1 MPA), with the total area of 14,167.634 km².

### 2.3 Data Loggers at Coral Reefs

Temperature loggers have been set up at many other coral reef sites overseas. In a coral reef monitoring programme in Chumbe Island Coral Park (East Africa) in May 2005 to October 2006, various temperature loggers were installed to provide the team with a
complete and continuous dataset. These dataset were then used to analyse the correlations between high temperatures and bleaching events or Crown of Thorns (COTS) outbreaks (Peters, 2006). Temperature loggers put out at three depths in Diego Gracia atoll, central Indian Ocean were used to validate the use of satellite-derived temperature data for planning of coral reef conservation areas. The results were that temperature plunges at the deeper water due to both tidal and unidentified internal waves which could not be traced by satellite-derived datasets (Sheppard, 2009). According to Smith (n.d.), temperature loggers were also deployed in the Island of Kosrae (Federated States of Micronesia) and Aldabra Atoll (Republic of Seychelles) to monitor the response of coral reefs to rising temperature, without other interference as mentioned in the application reports of HOBO compact data loggers. There is unpublished data on deployment of Temperature / Light Loggers at two depths in Tekek House Reef, Tioman (Personal Communication, Kee Alfian Abd Adzis 2011). The relationship between temperature and light can be observed in the graphs attached in Appendix 1. It can be observed that light intensity is directly proportional to water temperature and clear diurnal variability may be observed using the loggers.

3.0 Materials and Methods

Two sampling trips were done in order to complete this project which are referred to as Survey 1 and Survey 2. Survey 1 was conducted on 28th July 2011 while Survey 2 was conducted on 24th April 2012.

3.1 Selection of Study Site

The chosen study site for this research is in the region of Talang-Satang MPA Sarawak. This National Park was created mainly for marine turtle conservation and includes four islands which are Pulau Satang Besar, Pulau Satang Kecil, Pulau Talang
Talang Besar and Pulau Talang Talang Kecil. The study site was surveyed on the first dive and four study stations were chosen around Pulau Talang Talang for water quality analyses. Only one station was chosen as a pilot site for the deployment of the Temperature / Light and G Acceleration Data Loggers. The four selected stations are marked in Figure 1 and the GPS readings are provided in Table 1 below.
Table 1: Station numbers, names and GPS coordinates for each station.

<table>
<thead>
<tr>
<th>Station No.</th>
<th>Station Name</th>
<th>Coordinate</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Batu Penyu</td>
<td>N 01° 52' 41.0&quot; E 109°45' 35.3&quot;</td>
</tr>
<tr>
<td>2</td>
<td>Pulau Talang Talang Besar West</td>
<td>N 01° 54' 57.4&quot; E 109° 46' 27.9&quot;</td>
</tr>
<tr>
<td>3</td>
<td>Pulau Talang Talang Besar East</td>
<td>N 01° 55' 03.3&quot; E 109° 46' 47.8&quot;</td>
</tr>
<tr>
<td>4</td>
<td>Pulau Talang Talang Kecil</td>
<td>N 01° 53' 46.1&quot; E 109° 46' 01.2&quot;</td>
</tr>
</tbody>
</table>

3.2 Deployment of Loggers

Battery-operated Temperature / Light Logger (UA-00263 HOBO® Pendant Temp/Light 64K) and G Logger (UA-004-64 HOBO® Pendant G Acceleration Data Logger) were deployed at Station 2, West of Pulau Talang Talang Besar. The loggers were first calibrated and programmed using HOBOware Pro Mac/Win software before deployment. After programming and using the delayed start method for initiating logging, the loggers were deployed using SCUBA diving. The loggers were set up at a site where they can be easily relocated, protected from damage and prevented from dislodgement by wave action and fishes. Both loggers were set up at the same station and GPS (Global Positioning System) reading of the station was recorded using Garmin GPSMAP® Csx for easier relocation. The data loggers were programmed to record respective data continuously every 20 minutes. The data collected were in situ data trend of temperature, light intensity and acceleration of current flow according to X-axis and Y-axis. This provided a complete and continuous dataset for at least eight months of the loggers being deployed. During deployment, the Temperature / Light Logger was made sure to be mounted horizontally so that the light sensor faces upwards towards the sky as depicted in Figure 2. The G Logger was deployed with the y-axis facing North for easier alignment of data as seen in Figure 3.
Figure 2: (A) HOBO Temperature / Light Logger and location of light sensor on logger. (B) Direction of light sensor during deployment, facing up towards the sky as shown by the dotted arrow.

Figure 3: HOBO G Logger and direction of deployment with Y-axis facing North.
For this study, Temperature/Light logger and G Acceleration Logger were deployed twice to obtain a continuous dataset of eight months. The first deployment was from 28th July 2011 to 11 November 2011 while the second deployment continued from 11 November 2011 to April 24th 2012. However for G acceleration Logger, the logger was uplifted and dataset beginning March 1st 2012 was unable to be used, resulting in dataset of only seven months for the direction and velocity of current.

The loggers recorded data every 20 minutes and the data was mainly analysed using HOBOware while SPSS was used to determine if there were any significant difference among three Regimes that will be discussed further in the following sections.

3.3 Retrieval of Data From Temperature / Light and G Acceleration Data Logger

Loggers were retrieved using SCUBA Diving and the recorded data were uploaded into a laptop. The data were transferred into a laptop using HOBO Optic USB Base-U-1 Station and Coupler (example in Figure 4) along with the HOBOware software. The
battery level on the loggers (estimated to be one year for typical use) were checked before redeployment to continue collection of data.

![Logger diagram](image.png)

Figure 5: Logger connected to laptop through Base, Coupler and USB cable for retrieval of data.

### 3.4 Measurement of Water Quality Parameters

Other *in situ* water quality parameters were measured using EUTECH Multiparameter Series 600 for all four stations, of one being the same station as the loggers. Temperature, salinity, pH, conductivity, Biochemical Oxygen Demand in five days (BOD₅) and Dissolved Oxygen (DO) were taken in three replicates at the subsurface, middle and bottom by dividing the depth of the water body by three. GPS readings using Garmin GPSMAP® Csx and depth using SPEEDTECH Depth Sounder in meters of the study stations were recorded once the station was chosen for a more precise data. EUTECH Multiprobe was calibrated in the laboratory before being brought for sampling.

### 3.5 Calculation of Biological Oxygen Demand in Five Days (BOD₅)

BOD₅ water sample collection was done by bringing the glass bottle down to appropriate depths using SCUBA diving and then filling the bottles. BOD₅ glass bottles were firstly acid washed (Wilde, 2004) and brought to the study site to collect water samples. Dissolved oxygen (DO) of the water samples were recorded and the bottles were
then wrapped with aluminium foil to prevent further production of oxygen through
photosynthesis. The bottles were then labelled and kept for five days before taking the
reading. BOD$_5$ calculations were done after measuring the DO of water samples after 5
days, by using the following formula (APHA, 1998).

$$\text{BOD}_5 (\text{mg/L}) = \frac{D_1 - D_5}{V}$$

Where $D_1 =$ Initial in situ DO reading on day one 

$D_5 =$ Day five DO reading 

$V =$ Volume of water sample used (L)

3.6 Collection of Water Samples for Chlorophyll $a$ Analysis

Water samples were collected at the subsurface water, middle and at the bottom of
all four chosen stations using Van Dorn horizontal water sampler in three replicates, for the
calculation of primary productivity of the water column at coral reef sites. 1000 mL water
sample bottles were acid washed before being used for the collection of water samples.
Water samples were then labelled and stored in cooler box before being transported back
for laboratory analysis.

3.7 Chlorophyll $a$ Extraction

For relative primary productivity of the water column in coral reef area, chlorophyll
$a$ extraction was carried out using standard APHA (1998) method. This laboratory work
(as summarized in Figure 6) was carried out in subdued light or semi-darkened area to
prevent further photosynthesis to take place. Water samples collected were filtered through
glass fibre filter paper (GF/C 47mm diameter) placed in the pump water filtration system.
The filter paper was removed after filtration and grinded together with 90% aqueous
acetone and then put into refrigerator for 4 to 18 hours for complete extraction of pigments. The liquid extract was then centrifuged for 10 minutes under 3000 rpm using UNIVERSAL 32 Hettich Zentrifugen Hettich r type 1605. The supernatant was extracted and analysed using Spectrophotometer (HACH DR 2800). The extraction was measured at 750 mm, 664 mm, 647 mm and 630 mm wavelengths. Correction and calculation of chlorophyll \( a \) concentration was done using the standard APHA (1998) method as attached in Appendix 2.

![Figure 6: Chlorophyll \( a \) extraction method](image)

### 3.8 Data Analyses

Retrieval of data from the loggers were done using HOBOware software and related graphs were also plotted using the software by manipulating the data collected. The correlations between temperature, light intensity and current flow can be seen through the graphs in Figure 9, Figure 12 and Figure 13.
Direction of current in degree (°) was calculated from acceleration on X-axis and Y-axis using trigonometric functions and vectors as below (modified from Pond & Pikard, 2007).

\[
\text{Direction of currents, } \theta = \tan^{-1} \frac{Y}{X}
\]

with \(Y\) = acceleration on Y-axis and, \(X\) = acceleration on X-axis

Change in magnitude velocity of current direction was calculated using Pythagoras theorem, where \(x\) is the acceleration on X-axis and \(y\) is the acceleration on Y-axis, and acceleration is recorded at every burst of 1 second (modified from Pond & Pikard, 2007).

\[
R^2 = x^2 + y^2; \text{ Unit of acceleration, } g = (\text{m/s}^2)
\]

Velocity, \(R = (\text{m/s}^2) \times \text{s} = \text{ms}^{-1}\)

Water quality data were analysed using SPSS for One-way ANOVA (Analysis of Variance) to determine the significant difference of means among depths of each station. Tukey’s test was done to determine the significant difference of means between survey. Correction of salinity from conductivity was done for Survey 1 referring to the formula “Conductivity Ratio to Salinity Conversion” provided in UNESCO Technical Papers in Marine Science (Fotonoff & Millard, 1983).
4.0 Results and Discussion

Results from this study can be divided into two parts which are continuous data obtained from data loggers and \textit{in-situ} data obtained during two sampling trips.

4.1 Data from Loggers

Before elaborating on the temperature, light and direction of current, brief information on the changes in tidal cycles will first be discussed as the entire data logging period of eight months are divided into four regimes.

4.1.1 Changes in Tidal Cycle

In order to see how tidal cycles change with monsoon seasons, the graph of high tides and low tides during spring tidal cycle was plotted as in Figure 7. During Spring tides the tidal cycles face the largest hydrodynamic changes.

![Figure 7: High tides and lows tides during new and full moons.](image)

The Figure 7 above shows the means of high tide and low tide in a day during Spring tides. The dot-dash line is the first high and low tide of the day while the dotted line
is the second high tide and low tide of the day. From this graph, the total time frame is divided into five regimes which are Regime A, Regime B, Regime C, Regime D and Regime Z, based on the ranges in tide patterns. Regime A can be assumed to be the Southwest Monsoon (May to September), Regime B (September to November), D and Z (March to May) to be during the intermonsoon period and Regime C to be the Northeast Monsoon (November to March). The selection of Regimes periods were done referring to Monthly Weather Bulletin from Malaysian Meteorological Department (2012). The pattern displayed in this graph shows the difference in tidal levels during each regime. In Regime A and C which is during monsoons, it can be seen that the variation in low tides are much larger compared to Regime B which is during intermonsoon (September to November).

<table>
<thead>
<tr>
<th></th>
<th>Regime A (May-Sept)</th>
<th>Regime B (Sept-Nov)</th>
<th>Regime C (Nov-March)</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Tide (m)</td>
<td>3.8 ± 0.21</td>
<td>4.0 ± 0.25</td>
<td>3.9 ± 0.29</td>
</tr>
<tr>
<td>Low Tide (m)</td>
<td>1.1 ± 0.80</td>
<td>1.0 ± 0.44</td>
<td>1.1 ± 0.77</td>
</tr>
</tbody>
</table>

From the Table 3, the mean high tides in the three regimes where found to be significantly different at a significance level of 0.05 and the mean low tides were not significantly different. However the variation in low tides during monsoon seasons, Regime A and C, were very large as seen in the standard deviation from mean low tide in Regime A as ±0.80m and in Regime C as ±0.77, compared to in intermonsoon Regime B with the standard deviation of only ±0.44m from the mean low tide. This shows that the largest mean variation in low tide level ranges averagely from 0.3 meters to 1.9 meters in a day during monsoon, compared to 0.6 meters to 1.4 meters during intermonsoon.
Based on the tidal patterns seen in Figure 7, Regime A corresponds to Summer Solstice, Regime B corresponds to Autumnal Equinox, Regime C to Winter Solstice and Regime D and Z to Vernal Equinox as summarized in Table 4 below.

Table 4: Regimes corresponding to monsoons and seasons.

<table>
<thead>
<tr>
<th>Regime</th>
<th>Monsoon</th>
<th>Season</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Southwest</td>
<td>Summer Solstice</td>
</tr>
<tr>
<td>B</td>
<td>Intermonsoon</td>
<td>Autumnal Equinox</td>
</tr>
<tr>
<td>C</td>
<td>Northeast</td>
<td>Winter Solstice</td>
</tr>
<tr>
<td>D</td>
<td>Intermonsoon</td>
<td>Vernal Equinox</td>
</tr>
<tr>
<td>Z</td>
<td>Intermonsoon</td>
<td>Vernal Equinox</td>
</tr>
</tbody>
</table>

The changes in tide level during spring and neap tides are caused by the gravitational pull from the moon and sun while the variation of overall tidal level in Regime A and C are due to the inclination of Earth on its axis to the ecliptic plane of sun-earth system (Hicks, 2006). Due to the inclination of the Earth which is 23.452° to the ecliptic, there are four seasons experienced on Earth as in Figure 8 below (Hicks, 2006). During the Winter Solstice and Summer Solstice, the northern hemisphere and Southern hemisphere of the Earth respectively, has stronger tidal forces compared to during Vernal Equinox and Autumnal Equinox. This is because during Winter Solstice, the northern hemisphere of Earth is tipped directly toward the sun while during Summer Solstice the Southern Hemisphere is tipped directly to the sun. This causes asymmetrical tidal forces with respect to the equator, generated by the gravitational pull of the sun (Hicks, 2006). Therefore it can be seen in Figure 7 that the range in low tides are larger relatively in Regime A and C, corresponding to Summer Solstice and Winter Solstice, compared to in Regime B, corresponding to Autumnal Equinox and in Regime D and Z, corresponding to Vernal Equinox.