Nature Environment and Pollution Technology
An International Quarterly Scientific Journal | ISSN: 0972-6268 | Vol. 15 | No. 1 | pp. 297-300 | 2016

Original Research Paper

Estimation of Stress Levels of Coral Reefs Bleaching Using Night-time Satellite Data: A Case Study of Indonesian Tropical Waters

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Nat. Env. & Poll. Tech.
Website: www.neptjournal.com
Received: 31-05-2015
Accepted: 15-08-2015

Key Words:
Coral reef bleaching
Stress level
Satellite data
Sea surface temperature

ABSTRACT

Indonesia, the world's largest tropical archipelago, is composed of more than 17,000 islands with a total coastline of more than 81,000 km. Coral reefs are found along the coastlines of many islands. Although coral reefs are considered as important ecosystem, the impact of environment such as the increasing of sea surface temperature could bring the reefs under threat. The objective of this study was to forecast stress levels of coral reefs bleaching using night-time satellite data in Indonesia. The study used 50 km resolution composite images of NOAA-night-time sea surface temperature anomaly and NOAA-coral bleaching alert area for the period 2007 to 2012. In order to generate correlation between stress levels of coral reefs bleaching and sea surface temperature anomalies, we observed eight selected areas such as Tegal-Central Java Sea, West Bali National Park, Lamalera Sea, Wakatobi National Park, Tolo Bay, Seram Sea, Raja Ampat Marine Conservation Park and Kei Islands. The results of the study show that the stress level of coral reef bleaching varied from year to year. The study suggests that the stress levels of coral reef bleaching may be explained by sea surface temperature anomalies using the regression equation: Y = 1.1307X + 1.2158.

INTRODUCTION

Coral reefs have been known to serve as physical buffers for ocean currents and waves. Furthermore, coral reefs also provide significant contribution to the coastal marine ecosystem such as spawning and feeding grounds for fishes. On the other hand, coral reefs are one of the most sensitive ecosystem to climate change. Degradation of coral reef is caused by various anthropogenic and natural variations. A major natural threat to coral reefs come from high sea surface temperatures, which, if persisting for a long period can lead to a phenomenon known as coral reef bleaching (Bhandari & Sharma 2010). Coral reef bleaching is the potentially lethal condition where heterotrophic corals become white due to a heat stress induced decrease in the concentration of their zooxanthellae.

Recently, satellite remote sensing has been utilized as an important tool for obtaining synoptic measurements of the ocean (Saitoh et al. 2010, Semedi & Saitoh 2003). Many researches have developed a method of using satellite data to investigate the potential fishing zone (Semedi & Hadiyanto 2013). Mapping of ecological status of coral reefs has also been attempted using satellite data (Bahuguna et al. 2013). Although the coral reefs have been mapped at global level, the details in term of the relationship between stress level of coral reef bleaching and sea surface temperature anomaly variations are not available yet. The purpose of this study is to estimate stress levels of coral reefs bleaching using night-time satellite data in Indonesia.

MATERIALS AND METHODS

The study uses 50 km resolution monthly and annual composite images of NOAA-night-time sea surface temperature (SST) anomaly and NOAA-coral bleaching alert area for the period 2007 to 2012, provided by NOAA Satellite and Information Service. Data of SST anomaly images were downloaded from http://coralreefwatch.noaa.gov/satellite/current/products_ssta.html. Data of coral bleaching were downloaded from http://coralreefwatch.noaa.gov/satellite/baa/index.html.

The SST anomaly is the difference between today's temperature and the long-term average. The scale goes from -5 to +5°C. Positive number means that the temperature is warmer than average; negative means cooler than average. The bleaching stress levels are defined in Table 1.

This study observed eight sample areas (Fig. 1) in Indonesia, such as Tegal Central Java (area 1), West Bali National Park (area 2), Lamalera Sea (area 3), Wakatobi National Park (area 4), Tolo Bay (area 5), Seram Sea (area 6), Raja Ampat Marine Conservation Park (area 7) and Kei Islands (area 8). The flowcharts, as given in Fig. 2, show the processing steps for the data and map.

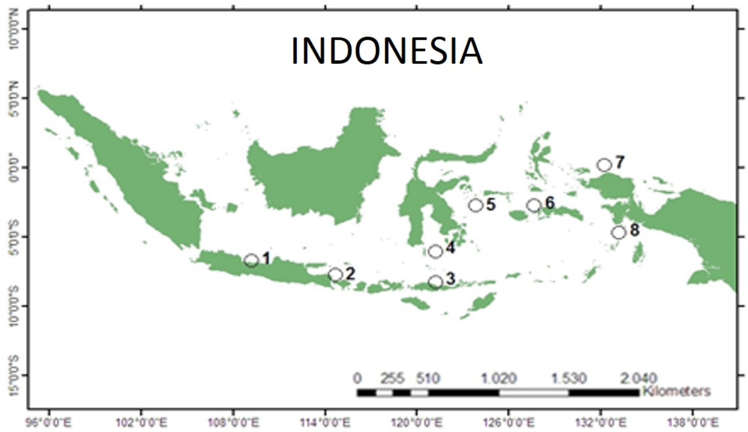

Fig. 1. Research area.

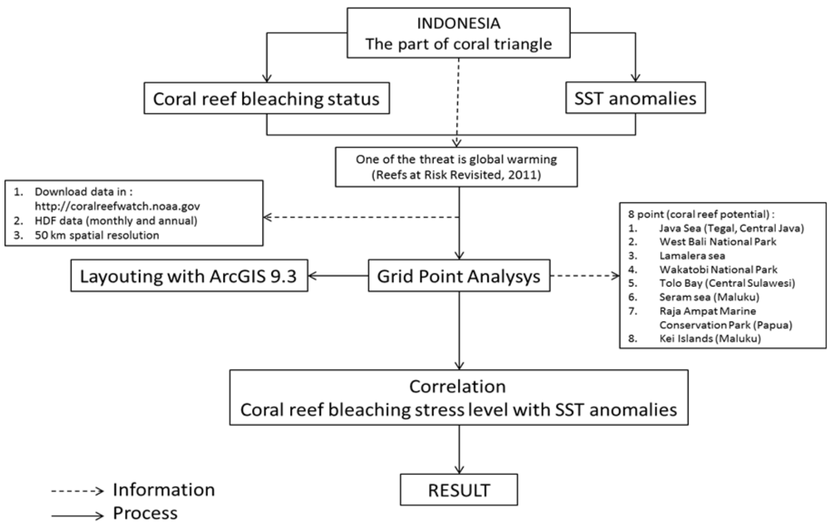

Fig. 2: Flowchart of data analysis.

RESULTS

In 2007, we observed SST anomalies distributed from -0.28°C to 1.80°C and stress level in all observed areas goes from 0.17 to 2.67. The mean SST was mostly warmer than average; in area 8 (Kei Islands), however, mean SST was cooler than average. Fig. 3 shows that the relatively higher SST anomaly and stress level occurred in Tegal-Central Java Sea (area 1). Furthermore, most of the increasing SST anomalies followed by the increasing stress level.

In 2008, we observed that SST anomalies are distributed from -0.07°C to 1.62°C and stress level in all observed areas goes from 0.25 to 1.92. Furthermore, Fig. 4 shows that the relatively higher SST anomaly and stress level occurred in Tegal-Central Java Sea (area 1). Furthermore, most of the increasing SST anomalies followed by the increasing stress level.

In 2009, we observed SST anomalies distributed from 0.20°C to 2.03°C and stress level in all observed areas goes from 0.33 to 2.58. The mean SST is mostly warmer than average; in area 4 (Wakatobi National Park), however, the mean SST was cooler than average. Fig. 5 shows that the relatively higher SST anomaly and stress level occurred in Tegal-Central Java Sea (area 1). Furthermore, most of the increasing SST anomalies followed by the increasing stress level.

In 2010, we observed SST anomalies distributed from 0.68°C to 2.54°C and stress level in all observed areas goes from 0.58 to 4.00. Fig. 6 shows that the relatively higher SST anomaly and stress level occurred in Tegal-Central Java Sea (area 1). Furthermore, most of the increasing SST anomalies followed by the increasing stress level.

In 2011, we observed that SST anomalies are distributed from 0.05°C to 1.64°C and stress level in all observed areas

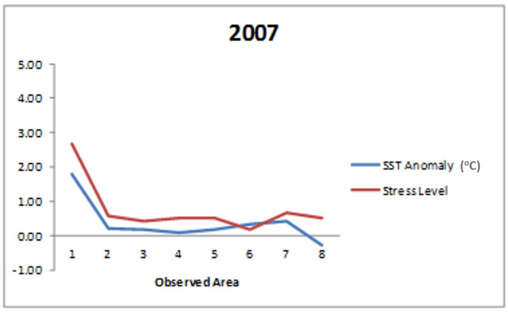

Fig. 3: Mean SST anomaly and stress level of coral reefs bleaching in 2007.

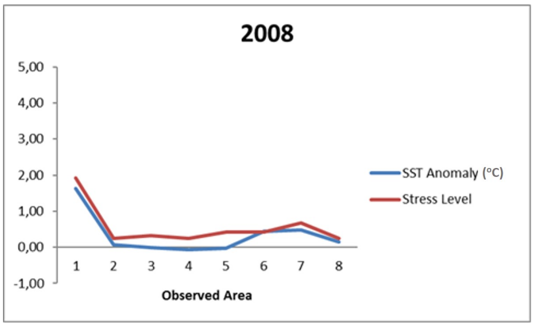

Fig. 4: Mean SST anomaly and stress level of coral reefs bleaching in 2008.

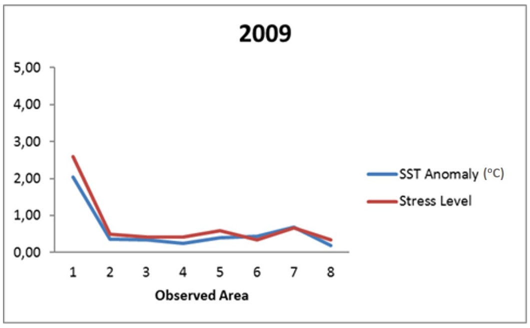

Fig. 5: Mean SST anomaly and stress level of coral reefs bleaching in 2009.

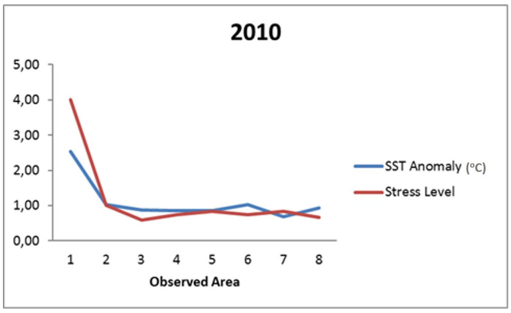

Fig. 6: Mean SST anomaly and stress level of coral reefs bleaching in 2010.

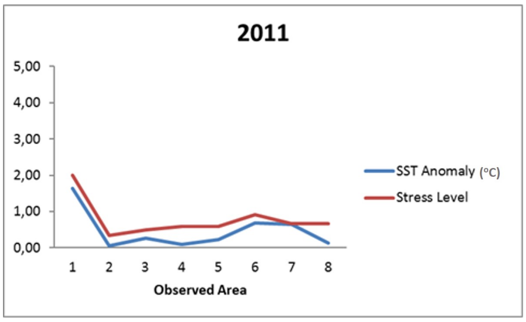

Fig. 7: Mean SST anomaly and stress level of coral reefs bleaching in 2011.

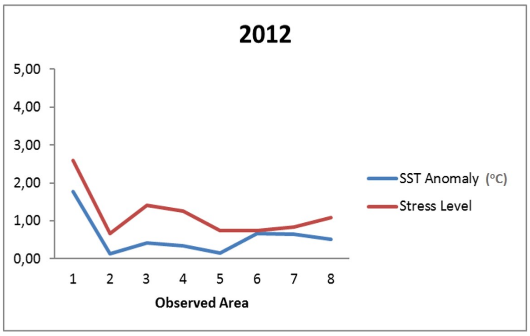

Fig. 8: Mean SST anomaly and stress level of coral reefs bleaching in 2012.

goes from 0.33 to 2.00. Fig. 7 shows that the relatively higher SST anomaly and stress level occurred in Tegal-Central Java Sea (area 1). Furthermore, most of the increasing SST anomalies followed by the increasing stress level.

In 2012, we observed that SST anomalies are distributed from 0.12°C to 1.78°C and stress level in all observed areas goes from 0.67 to 2.58. Fig. 8 shows that the relatively higher SST anomaly and stress level occurred in Tegal-Central Java Sea (area 1). Furthermore, most of the increasing SST anomalies followed by the increasing stress level.

DISCUSSION

The results of the study show that the stress level of coral reef bleaching was varied from year to year. Generally, SST anomalies had positive numbers during 2007-2012. However, in 2007 area 8 (Kei Islands) and in 2008 areas 3,4 and 5 (Lamarea Sea, Wakatobi National Park and Tolo Bay), the SST anomalies went to negative numbers. Based on the observation of six years mean SST anomaly (Fig. 9), we found that when SST anomalies increase, stress level of coral bleaching tend to rise. On the other hand, when SST anomalies decrease, the stress levels were also decreased.

Fig. 10 shows that a high stress level of 1.18 occurred in 2010 and in 2012 the stress level was 1.17. The lowest stress level of 0.56 occurred in 2008. The highest SST anomaly and stress level of coral bleaching occurred in 2010. This

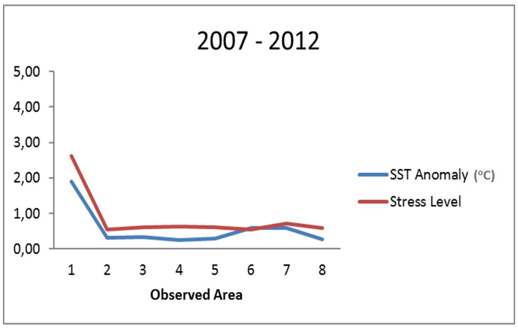

Fig. 9: Six year mean SST anomaly and stress level based on each area.

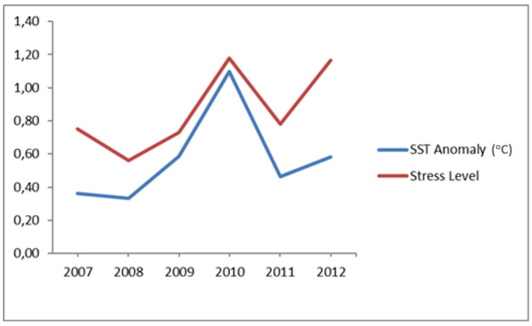

Fig. 10: Time-series of mean SST anomaly (Blue line) and stress level of coral reefs bleaching (Red line) from 2007 to 2012.

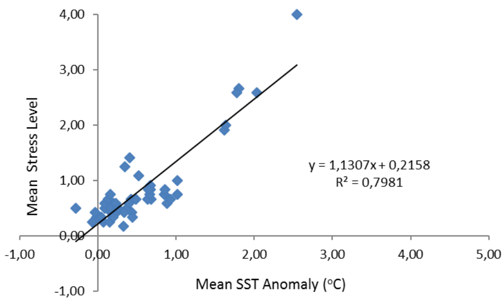

Fig. 11: Correlation between annually mean SST anomaly and stress level during 2007-2012.

condition likely corresponded to the El-Nino event detected in January 2010, during which the SST anomaly reached around 1.9°C. According to Tan & Heron (2011), along the northwestern coast of Peninsular Malaysia bleaching began in mid-May 2010, within three weeks, the reefs around the major islands along the east coast were bleached. This event followed the peak of the third strongest El Nino event in the past 50 years.

The regression equation, shown in Fig. 11, indicated that there was a high correlation ($R^2 = 0.7981$) between mean SST anomaly and stress level.

Table 1: Definition of stress level

Stress Level	Definition	Potential Bleaching Intensity
0	No Stress	No Bleaching
1	Bleaching Watch	No Bleaching
2	Bleaching Warning	Possible Bleaching
3	Bleaching Alert Level 1	Bleaching Likely
4	Bleaching Alert Level 2	Mortality Likely

Source:http://coralreefwatch.noaa.gov/satellite/bleaching5km/index_5km_baa_max_r07d.php

CONCLUSION

Time-series of SST anomaly and stress level of coral bleaching was relatively high. The high values of SST anomaly indicate that the sea surface temperature in Indonesia from 2007 to 2012 tends to be warmer than average. Global warming is possibly one of the answers to these conditions. This study suggests that in order to calculate the stress levels of coral bleaching in Indonesia, it could be forecasted using the equation $Y = 1.1307X + 1.2158$. Here, Y is the stress level of coral bleaching, while X points to value of SST anomaly, generated from 50 km resolution composite images of NOAA-night-time Sea surface temperature anomaly.

ACKNOWLEDGEMENT

The authors wish to acknowledge University of Brawijaya for support and facilities to carry out this study. Particularly, NOAA Satellite and Information Service is appreciated for providing the required satellite data.

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