DETECTING THE CORAL BLEACHING AT THE CORAL REEFS OF SON TRA PENINSULA AND CU LAO CHAM ISLAND IN THE SOUTH CENTRAL COAST REGION OF VIETNAM

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Abstract - Coral bleaching events are of concern globally because of their adverse effect on the coral reef ecosystem. However, there is a lack of observed bleaching in many coral reefs in Vietnam, leading to difficulty in implementing the suitable management and protection solutions. The study aims to provide general information about coral bleaching in ST and CLC basing on bleaching alerts of NOAA Coral Reef Watch in 2019. Field data was collected by a photographic method for analyzing and classifying bleached coral. The results showed that coral reefs experienced low bleaching by an average of 8.86% and 9.09% in ST and CLC, respectively. In addition, the study broadly identified the relationship of sea surface temperature and Degree Heating Weeks to coral bleaching in the study area.

Key words - Coral bleaching; NOAA; sea surface temperature

1. Introduction

Coral reefs are the most species-rich marine ecosystem, occurring approximately 32% of all named marine species and 13% of not named marine ones. However, they cover less than 0.1% of the ocean floor [1]. Coral reefs provide ecosystem services, goods, marine protection, and fisheries home [1-3]. Unfortunately, coral reefs had lost 50% since the 1980s by the increasing levels of pollution, the unsustainable coastal development, overfishing, outbreaks of coral predators like the Crown of Thorns Starfish, and anthropogenic ocean acidification and global warming [1, 3, 4]. Coral bleaching is widely known as a significant contribution to the global loss of coral reefs [5]; The event involves breaking the symbiosis between the coral host and photosynthetic zooxanthellae. The reduced abundance of zooxanthellae makes the coral appear pale or ‘bleached’, resulting in subsequent mortality [6]. Rising sea surface temperature (SST) is the primary cause of coral bleaching; the temperature increases of only 1–2ºC above the average maximum for a region can trigger mass bleaching events. Coral reefs can recover from bleaching if the anomalous conditions do not persist too long [1, 6]. However, coral reefs exposed to high temperatures for significant time periods result in increased coral bleaching and mortality [1, 3, 7]. Furthermore, various stressors such as diseases, sedimentation, cyanide fishing, contaminants, and salinity variations can cause corals to bleach on a local scale [8].

Coral bleaching at a small scale was described nearly 100 years ago [7], but until mid - 1980s it had become a profound concern worldwide because coral reefs experience bleaching at regional and global scales from 1982 - 1983. Although coral bleaching patterns vary spatially and temporally, the highest probability of coral bleaching occurred at tropical mid-latitude sites (15–20 degrees north and south of the Equator) [9]. To date, all five severe global bleaching events (1983, 1987, 1998, 2010, 2014-2017) had happened during or shortly after a moderate or major El Nino year, with the two most severe bleaching events occurring in 1998 and a three years (2014–2017) [10, 11]. The Indian Ocean was the most harshly impacted region in the 1998 coral bleaching event, with roughly 90% of coral death; the event was linked to an increase in SST (> 1ºC) over the typical maximum summertime level [7, 12]. A three-year global coral bleaching event (2014–2017) represented the first multi-year global scale of coral bleaching and caused bleaching and mortality two or more times than normal [11]. During the event, more than 70% of global coral reef locations were exposed to bleaching-level stress [13].

After being initially discovered in 1998 in Phu Quoc Island, coral bleaching has become a major concern in Vietnam. Since then, bleaching events had been discovered in Con Dao, Binh Thuan, Nha Trang Bay, Ninh Thun, and Phu Quoc [14-16]. After obtaining alerted bleaching for the Pacific region of NOAA Coral Reef Watch in 2019, Hoang et al. [15] verified bleached coral cover ranging from 7.3% to 39.4% of hard coral in Nha Trang Bay, Ninh Thuan, Con Dao, and Phu Quoc Islands during June and July 2019. However, the problem had not been widely studied, resulting in a paucity of information for coral reef management.

The paper publishes coral bleaching survey results in the Son Tra peninsula and Cu Lao Cham Island. The photographic method was conducted after NOAA Coral Reef Watch alerted bleaching for the Pacific region from June – September 2019 [17]. Thus, it is the first bleaching coral survey in the study area in recent years.

2. Locations and Methods

The study areas consist of Son Tra Peninsula (Danang City) and Cu Lao Cham Island of Hoi An city (Quang Nam Province), located at the South-central coast region of Vietnam (Figure 1), where coral diversity was estimated to be higher than in other locations [18]. Son Tra Peninsula is bordered by Danang bay at the Northwest, East sea at the east and Southeast, and land at the West, covering the Son Tra national nature reserve, a hotspot of diverse wildlife species. Cu Lao Cham Island, also known as Tan Hiep

Commune, is a small group of islands located approximately 19 km offshore from Hoi An Old Town and around 30 km from Son Tra peninsula toward the South-east. Cu Lao Cham Island possesses biodiversity in both terrestrial and marine ecosystems and, hence designated as a world biosphere reserve by UNESCO in 2009. The climate in the study area is the typical tropical monsoon, and two seasons consist of the dry season (from January to July) with average monthly temperatures of about 30°C, and a rainy season (from August to December) with occurring of storms, typhoons.

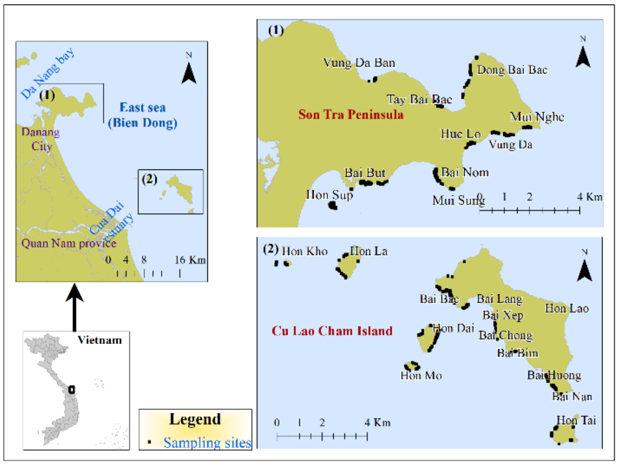

Figure 1. *Location of the study area*

The bottom types were collected using the photos of 25, 1.0 x 1.0 m cells within the 5.0 x 5.0 m grid [19]. These photographs were obtained by local divers using the underwater camera of GOPRO 6. Besides, the grids were distributed parallel to the shoreline and increased by depth from the near shoreline to an area with little or no coral. A total of 3103 photos were taken for the whole study to identify coral bleaching. The images were then classified into bottom types using twenty simple random points in Coral Point Count with Excel Extensions (CPCe) software [19, 20].

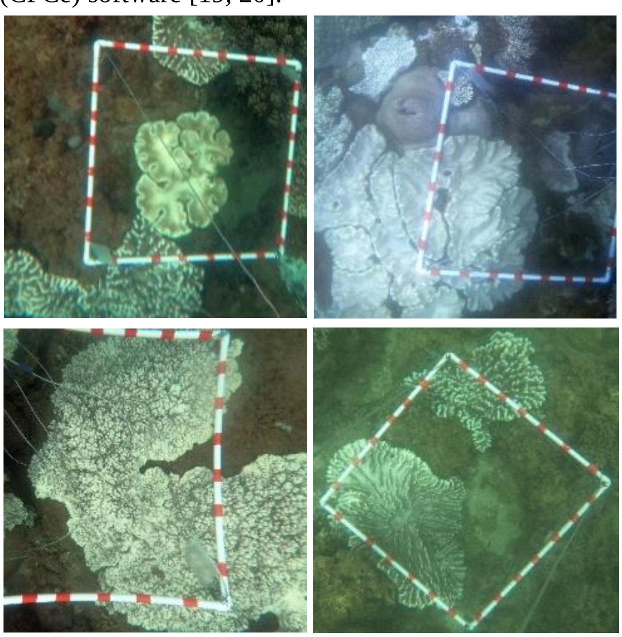

Figure 2. *Identifying bleached coral (white color)*

The feature directly under each point was classified as healthy living coral, coral bleaching (CB), sand, or hard bottom (rock, rubble, or dead coral) (Figure 2), and the percentage bottom feature composition was calculated. The bleaching cover of corals was calculated by dividing the proportion of bleached coral by the overall proportion of live coral in 5 x 5 grids. Bleaching severity was categorized by using indices developed by a Global Protocol for Assessment and Monitoring of Coral Bleaching [8] that are shown in Table 1.

Table 1. *Recording the proportion of corals affected by bleaching*

Category	% bleached coral	Description	Visual Assessment
0	< 1	No bleaching	No bleaching observed, or only very occasional, scattered bleached colonies (one or two per dive).
1	1 – 10	Low bleaching	Conspicuous bleached colonies seen occasionally, but vast majority of colonies not bleached.
2	10 – 50	Moderate bleaching	Bleached colonies frequent but constitute less than half of all colonies.
3	50 – 90	High bleaching	Bleaching very frequent and conspicuous, most corals bleached.
4	> 90	Extreme bleaching	Bleaching dominates the landscape, unbleached colonies not common. The whole reef looks white.

3. Result and discussion

CLC, with a range of 1.7 to 35.31% bleached coral, although mean bleaching categories were at low levels, with 8.86% and 9.09% in ST and CLC, respectively. The bleaching of ST and CLC was substantially lower in this study's simultaneous survey than an estimated coverage in Nha Trang, Ninh Thuan, and Con Dao, where recorded CB cover varying from 25% to 39.5% of hard coral, but the level was similar to the coral reef in Phu Quoc Island.

The spatial distribution shows vast differences in the bleaching level of coral reefs in each study area. In ST, most coral reefs occurred the bleached coral excepting Vung Da Ban in the North ST and Hon Sup in the South. With a proportion of bleaching ranging from 13.88% to 35.31%, the moderate level of bleaching accounted for half of the examined coral reefs, including Tay Bai Bac in the North, Mui Nghe, Vung Da, and Huc Lo in the Southeast of ST. Tay Bai Bac and Vung Da obtained a high percentage of coral bleaching, 24.31%, and 35.31%, respectively. The rest of coral reefs were classified by low bleaching, with a proportion of bleached coral from 1.7% to 7.18%. Significant bleaching appears to occur in regions of coral reef that are less shielded by ocean dynamics such as currents and surface waves. Unlike ST, CLC bleaching was observed at all coral reefs, with a modest bleaching (5.37% - 9.01%) and a moderate categorization (10.54% to 20.49%). The bleaching is prominent from the center to the South of the CLC, encompassing Bai Xep to Bai Nan in the main island and Hon Tai and Hon Mo in the small islands. At the same time, the majority of low bleaching is reported to the north of CLC.

Table 2. *Coral bleaching categories in ST and CLC*

Study area	Coral reefs	% Bleaching	Bleaching categories
Son Tra Peninsula	Vung Da Ban	0	Non
	Tay Bai Bac	24.31	Moderate
	Dong Bai Bac	1.7	Low
	Mui Nghe	18.96	Moderate
	Vung Da	35.31	Moderate
	Huc Lo	13.88	Moderate
	Bai Nom	5.84	Low
	Bai But	7.17	Low
	Hon Sup	0	Non
	Mean	**8.86**	**Low**
Cu Lao Cham Island	Hon Kho	10.54	Moderate
	Hon La	6.44	Low
	Bai Bac	5.37	Low
	Bai Ong	9.01	Low
	Bai Xep – Bai Bim	20.49	Moderate
	Bai Huong – Bai Nan	18.81	Moderate
	Hon Tai	14.5	Moderate
	Hon Mo	11.16	Moderate
	Hon Dai	7.71	Low
	Mean	**9.09**	**Low**

Heat stress on coral reefs is believed to be the cause of bleaching, and it is often manifested by an increase in SST and Degree Heating Weeks (DHW) [1, 4, 9]. Rising SST was linked to substantial bleaching in ST and CLC. The SST of Southern Vietnam is typically around 30°C, according to NOAA Coral Reef Watch, yet the research area witnessed above-average SST anomalies, ranging from 1°C to 2°C, between April and June 2019 (Figure 3). Although DHW was under the bleaching threshold in 2018, the coral reef accumulated severe heat stress, which demonstrated at 4°C -weeks and over 8°C -weeks in DHW (Figure 3), reflecting significant and severe widespread bleaching [21]. As a result of thermal stress, the coral reefs in ST and CLC were at Alert level 2 of bleaching risk in latter August 2019. Our research matched the widespread bleaching predictions of NOAA Coral Reef Watch at the same time (Figure 4). However, the difference of bleaching category in the study area may regard local stress such as variability local heat stress within reefs, vertical mixing temperature in the water column [11, 22]. Besides, the heat-tolerant coral species presence also contributes bleaching risk of these coral reefs [11, 15].

The study revealed the bleaching in ST and CLC only at a specific time; it is limited by observing frequency that should be required different approaches initially, during, and after the event to better understand coral reef resilience. Moreover, some in-situ measures such as local temperature and local anthropogenic stress should be conducted concurrently to identify bleaching by coral species to examine synergistic interaction between local stress in terms of the coral bleaching response.

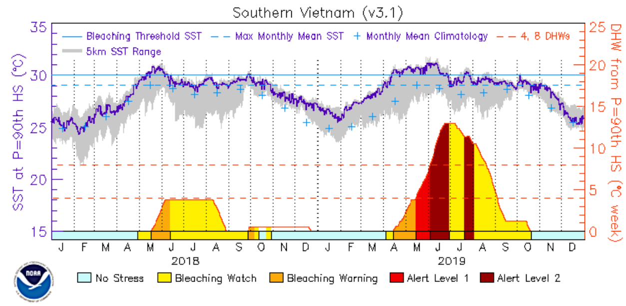

Figure 3. *NOAA Coral Reef Watch 2018-2019 two-year time series graph for the Virtual Station at southern Vietnam*

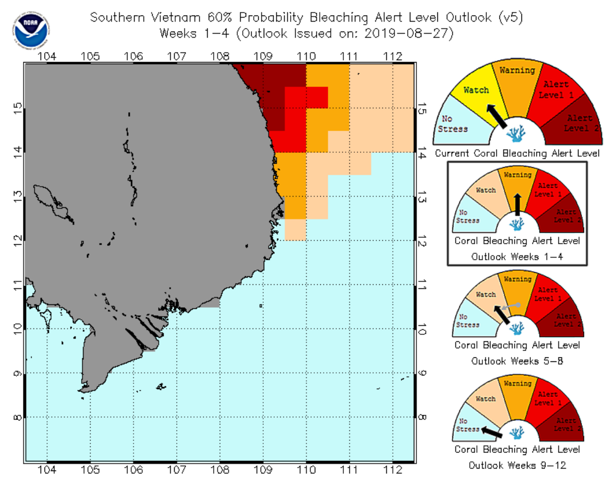

Figure 4. *Bleaching alert level in south Vietnam on 27/8/2019*

4. Conclusion

From analysis results of 3103 photos obtained from the field survey, coral bleaching occurred in most coral reefs in ST and CLC. Accordingly, individual coral reef bleaching was categorized as non-bleaching, low bleaching, moderate bleaching in ST, and low to moderate bleaching in CLC. However, mean bleaching was low in both study areas, with 8.86% and 9.09% of bleached corals. In addition, the study found a 1–2°C increase in average SST in the summer and a high DHW in 2019, resulting in widespread bleaching.

Because the current study has not frequently investigated some local stress and identified only the coral species' bleaching, there is a dearth of records to verify the heterogeneous bleaching in the study area. Future research should address these constraints to get a better understanding of coral reef resiliency.

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