Coral Bleaching Alert System

Technical Document

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1. Introduction

The coral reefs are massive biological set up in the coastal seas and have taken several millenniums to attain current form. However, during last decade, worldwide coral reef ecosystems have been degrading largely that alarming the threat on the vital coral ecosystems. Coral bleaching has been one of the significant contributors to the increased deterioration of reef health.

Coral bleaching is a phenomenon that takes place when the symbiotic relationship between algae (*zooxanthellae*) and their host corals breaks down under certain environmental stresses. This result in the host expels their *zooxanthellae.* In the absence of symbiotic algae, the corals expose their white underlying calcium carbonate coral skeleton and the affected coral colony becomes pale in color. Coral bleaching can be activated and persisted during varied environmental stresses. It was observed a massive coral bleaching world wide due to increased anomalous warm waters during recent years. Coral bleaching can takes place even 1-2°C increase in ambient water temperature during summer months (Berkelmans and Willis, 1999; Reaser et al., 2000). Prolonged partial/total bleaching events on coral environs can cause the coral deaths. Stern bleaching events have striking long-term ecological and social impacts, which includes extinct of reef-building corals, changes in benthic habitat and in some cases even changes in fish populations. It can take several years for severely bleached reefs to recover even favorable conditions prevails thereafter the event.

There is a strong need for improved understanding, monitoring, and prediction of coral bleaching. The application of satellite remote sensing is the important tools to provide synoptic views of the global oceans in near-real-time and the ability to monitor global reef areas. Therefore to provide early warnings on the coral bleaching, the nocturnal Sea Surface Temperature (SST) is an important parameter to assess the thermal conditions and intensity of the bleaching. There are several remote sensing satellites revolving around the globe have an ability to provide SST information during day and night routinely. This facilitates in development of the coral reef bleaching warning system to generate early warning advisories/bulletins in near real-time. Earlier studies (Strong et al. 2004; Liu et al. 2005; Goreau and Hayes 1994 and Montgomery and Strong 1995) were reflecting the impact of thermal stress on coral reef, their monitoring and assessment over global synoptic view.

2. Objective

The objective of current study is to provide coral bleaching warning based on the thermal stress. The parameters SST climatology, bleaching HotSpot (HS) and Degree of Heating Week (DHW) were used for the study. These parameters generated using SST data with 5X5 km grid resolution retrieved from Advanced Very High Resolution Radiometer (AVHRR) sensor on-board National Oceanic and Atmospheric Administration (NOAA) satellites.

3. Study Area

The bleaching alerts/warnings were generated for the Indian coral environs (Figure 1). The individual geographic areas were selected based on the coral environs. These selected areas are coral environs from Andaman, Nicobar, Lakshadweep, Gulf of Kachchh (GOK), Gulf of Mannar (GOM) and Malvan.

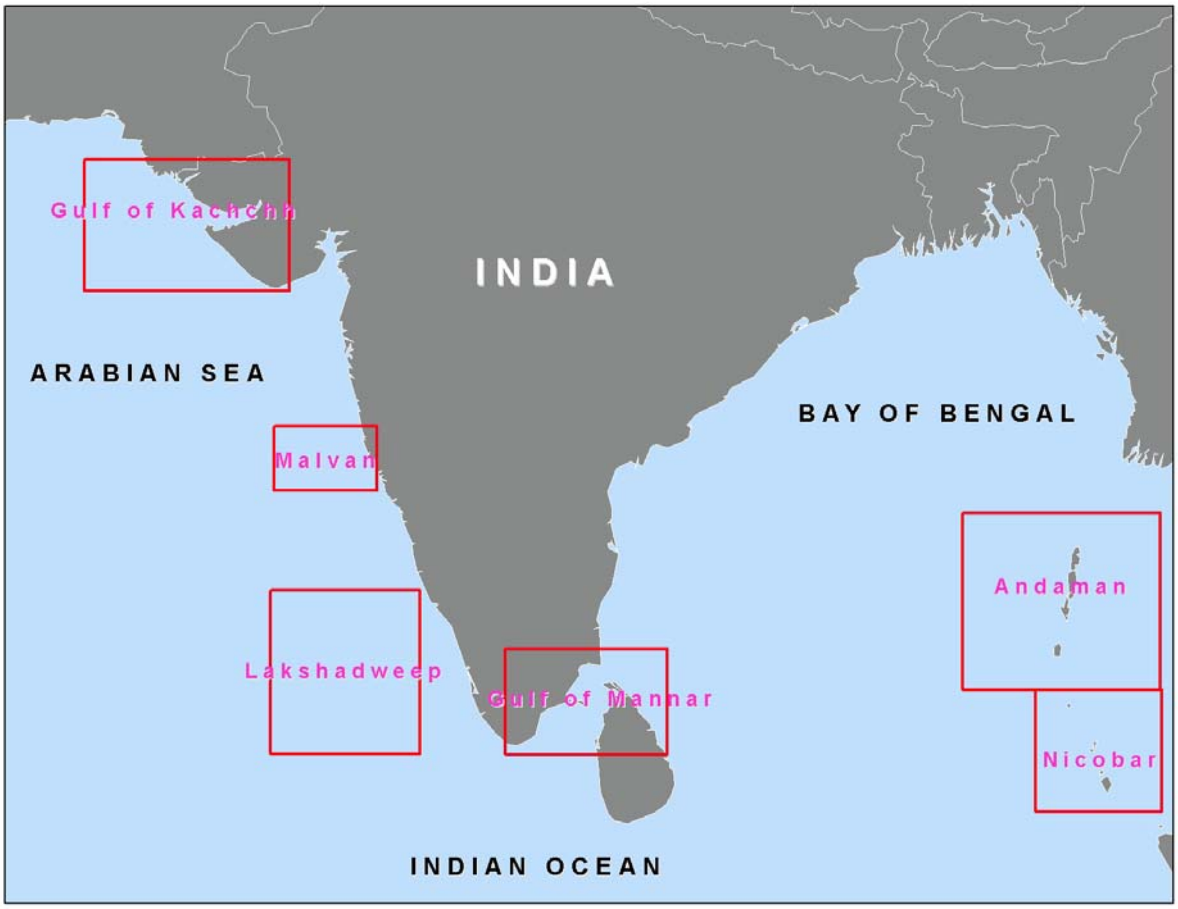

Fig. 1 Map showing the areas of the coral environs of India

4. Data Used

Sea Surface Temperature (SST) data from NOAA, AVHRR or data from the GHRSST was used in the current study.

5. Methods

The calculation of thermal stress similar to NOAA coral reef watch (URL: coralreefwatch.nooa.gov). According to Coral Reef Watch (CRW) the scheme of the coral reef bleaching warning levels presented in flow-chart (Fig. 2).

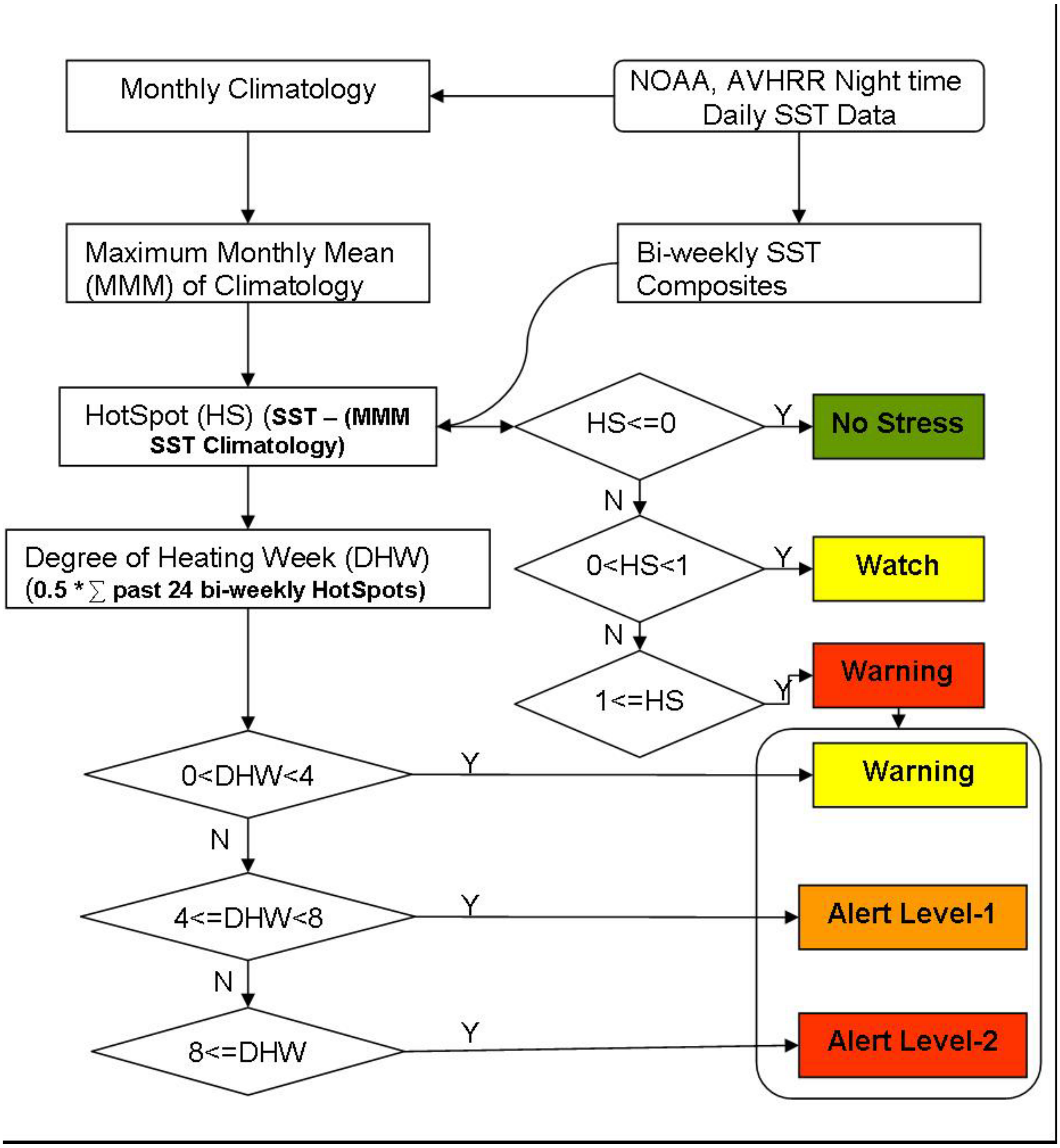

Fig. 2 Flow Chart depicting the methodology and the decision criteria for the coral bleaching status

5.1 Estimation of Monthly Maximum Mean of SST Climatology

The estimation of MMM of SST climatology using night time SST data retrieved using NOAA, AVHRR. The night time images are used because, to eliminate the effect of solar glare and reduce the variation in SST caused by the heating during day time. The daily night time SST data were used to generate monthly mean composites. Monthly SST climatology was calculated and Maximum Monthly Mean is defined as the warmest monthly mean value for each pixel around the area.

5.2 Coral Bleaching HotSpot (HS) Analysis

Corals are vulnerable to bleaching when the SST exceeds the temperatures they would normally experience in the hottest month. This reveal in the coral bleaching HS product, which highlights regions where the SST is currently warmer than the highest MMM of SST. The HS value lesser then or equal to zero were categorized as "No Stress" condition, the HS value with in the range of 0 to 1°C it categorized as "watch" and values above 1.0°C was a threshold for thermal stress leading to coral bleaching updated twice-weekly (Fig. 2).

Coral bleaching HS is a measure of the occurrence of thermal stress approaching conducive to coral bleaching for a location. The HS anomaly is based on the climatological mean SST of the hottest month (Liu et al., 2003; Liu et al., 2005; Skirving, 2006). The calculation of MMM SST climatology is simply the highest of the monthly mean SST climatology showed that temperatures exceeding 1°C above the usual summertime maximum are sufficient to cause stress on corals. Based on this study, MMM SST climatology was derived as a threshold for monitoring coral bleaching. The value of HS gives the difference between the measured near-real time SST and the MMM SST climatology as given in equation1.

$$\text{HotSpot } (^\circ\text{C}) = \text{SST} - (\text{MMM SST Climatology}) \qquad \ldots\ldots (1)$$

Only positive values are derived as the HS is designed to depict the incidence and distribution of thermal stress conducive to coral bleaching.

5.3 Calculation of Degree of Heating Week (DHW)

It was observed to be cause coral bleaching if the thermal stress persists for the prolonged duration. The DHW product that sums up HotSpots greater than 1°C recorded over past 12 weeks, this showing stressful condition prevails in corals environs for the previous three months. It is a cumulative measurement of the intensity and duration of thermal stress is expressed in the unit °C-weeks. The areas recorded DHWs up to 4°C-weeks depicts

“Warning” status which will cause stress on corals. DHWs 4-8°C-weeks depicts the “Alert Level-1” and these have been shown to cause significant coral bleaching. The DHWs above 8°C-weeks depict the “Alert Level-2” and this can cause widespread bleaching (Fig. 2). While the Coral Bleaching HotSpot provides an instantaneous measure of the thermal stress conducive to coral bleaching, there is evidence that corals are sensitive to an accumulation of thermal stress over time. In order to monitor this cumulative effect, a thermal stress index termed as Coral Bleaching Degree Heating Week (DHW) was developed by Liu et al., 2003; Liu et al., 2005. Glynn and D'Croz (1990) reported that temperatures exceeding 1°C above the usual summer time maximum are sufficient to cause stress on corals. This is commonly known as the temperature threshold for coral bleaching.

A half-week approach is used because near-real-time coral bleaching monitoring products are updated twice-weekly. With this approach, the DHWs are accumulated based on twice-weekly HotSpots using the following equation 2.

$$\text{DHWs (°C-week)} = 0.5 * \sum \text{preceding 24 bi-weekly HotSpots} \qquad ...... (2)$$

HS values more than or equal to 1.0°C-week required to be accumulated for the calculation of the DHW.

5.4 Assessment of Thermal Stress Levels

The coral bleaching warning status was estimated based on the thermal stress levels using the threshold HotSpot and DHW values (Fig. 2). The warning status categories “No Stress” and “Watch” were estimated using only HotSpot values zero or less and more than zero respectively. The categories Warning, Alert Level1 and Alert Level2 were estimated based on both HotSpot and DHW. The warning status will be assessed as “Warning” when the conditions of HotSpot => 1°C and 0<DHW<4°C-week were satisfied. The “Alert Level-1” was assessed when the conditions of HotSpot => 1°C and 4<=DHW<8°C-week were satisfied. Where as “Alert Level-2” was assessed when conditions of HotSpot => 1°C and DHW >=8°C-week was satisfied. A DHW accumulation of 4°C-weeks is triggers a significant bleaching which is Alert Level-1 and bleaching is expected at the site within a few weeks. An accumulation of 8°C-weeks triggers a strong bleaching with warning status Alert Level-2 causes widespread bleaching with likely coral mortality.

5.5 Warning status

The warning status has been assessed based on the criteria mentioned in the following table 1

Table 1. Criteria of the coral bleaching warning/alert

HotSpot (°C)	Degree of Heating Weeks(°C-week)	Alert Status
HS<=0	--	No Stress
0<HS<1	--	Watch
1<=HS	0<=DHW<4	Warning
	4<=DHW<8	Alert Level1
	8<=DHW	Alert Level2

No stress: No thermal stress on the corals
Watch: Low thermal stress on the corals
Warning: Thermal stress accumulated on corals
Alert Level1: Strong thermal stress on the corals, which may result in the partial bleaching
Alert Level2: Severe thermal stress on corals, which may result in widespread bleaching with likely coral mortality

5.6 Time series graphs

The time series graphs of the HS and Climatology from a virtual station from each coral environs as given in the Figure1

6. Deliverables

- ✓ Warning status
- ✓ HS composites
- ✓ DHW composites
- ✓ Time series graphs

References

Berkelmans R, Willis BL (1999) Seasonal and local spatial patterns in the upper thermal limits of corals on the inshore Central Great Barrier Reef. Coral Reefs 18:219-228.

Glynn, PW, D'Croz L (1990) Experimental evidence for high temperature stress as the cause of El Nino coincident coral mortality. Coral Reefs 8:181-191.

Goreau TJ, Hayes R (1994) Coral Bleaching and Ocean "Hot Spots". Ambio 23:176-180.

Liu G, Strong AE, Skirving W, Arzayus LF (2005) Overview of NOAA coral reef watch program's near-real time satellite global coral bleaching monitoring activities. Proc 10th Int Coral Reef Symp, Okinawa, Japan, 2004. 1:1783-1793.

Liu G, Strong AE, Skirving W (2003) Remote sensing of sea surface temperature during 2002 Barrier Reef coral bleaching. EOS 84(15):137-144.

Montgomery RS and Strong AE (1995) Coral bleaching threatens ocean, life, EOS, 75, 145- 147.

Reaser JK, Pomerance R, Thomas PO (2000) Coral bleaching and global climate change: Scientific findings and policy recommendations, Conservation Biology, 14, 1500-1511.

Skirving WJ, Strong AE, Liu G, Liu C, Arzayus F, Sapper J, Bayler E (2006) Extreme events and perturbations of coastal ecosystems: Sea surface temperature change and coral bleaching. Chapter 2 in Remote Sensing of Aquatic Coastal Ecosystem Processes, Richardson LL and LeDrew EF (Co-Eds), Kluwer publishers. January, 2006.

Strong AE, Liu G, Meyer J, Hendee JC, Sasko D (2004) Coral Reef Watch 2002. Bul of Mar Sci 75(2):259-268.

URL: coralreefwatch.nooa.gov, http://coralreefwatch.nooa.gov/satellite/methodology (assessed June 18, 2009)