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### RESEARCH ARTICLE

## SEA SURFACE TEMPERATURE INFLUENCED CORAL BLEACHING IN THE SALTWATER ISLAND OF GULF OF MANNAR, EASTERN SEA BOARD OF INDIA.

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### Abstract

The Corals are symbiotic organisms which are very sensitive to different environmental variables and can tolerate up to their optimal limits. However SST is a key factor in terms of coral bleaching which can result in the mortality of the corals thereby retarding their growth in coral environments. Based on the available cloud free satellite data, the health of the corals during 2000-2009 was assessed in coral environs of the Gulf of Mannar (GoM). Landsat Thematic Mapper (TM) and Enhanced Thematic Mapper plus (ETM+) data were used for identification and mapping of coral reefs, and National Oceanic and Atmospheric Administration (NOAA) Advance Very High Resolution Radiometer (AVHRR) derived SST data was used to assess the thermal stress and its induced bleaching. This study is concerned about the bleaching of coral reefs in response to SST. The average of monthly AVHRR SST data of ~5km radius on saltwater island out of 21 islands was taken in order to find out the time series data for saltwater island which was considered as virtual station of respective islands. Then variation of Sea Surface Temperature (SST) data was correlated with health of coral environment. The results suggested that during 2002 and 2005 coral reef bleaching might have been induced due to elevated SST.

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### Introduction:-

Gandhiji had rightly observed that the India lived in villages. Comprehensive development of rural area supported by economic upsurge has been the central point in the thought of planners who really steered India through hard time. If we look into the economic activities of small Islands bedecked with Coral reefs and coral islands, it becomes pertinent that the economic development of the villages of these coastal areas are heavily dependent on the corals. Coral islands have become attractions of tourists who flock to these areas to feel the beauty of corals. In additions to that, corals maintain such a biodiversity that fish mass feed on the nutrients and grow their numbers which ultimately leads the fishermen to earn their bread in form of fish catching. However, a twist is seen in the existence of corals who are dwindling due to rise in SST and heavy sedimentation around them.

The coral reef crisis is certainly a complex interaction between change in SST and human activity. Coral bleaching is the whiteness of corals due to stress or death of symbiotic algae "Zooxanthellae". The Coral Reefs are very

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sensitive to different environmental factors such as salinity, suspended sediment, DO, Kd490, SST and other pollutants. It can survive up to a certain threshold limit by above factors. However SST is a key factor in terms of coral bleaching which can affect the mortality and growth rate of coral environs (Mahendra et al. 2013; Krishnan et al. 2011). In recent days, their dwindling numbers shall definitely have negative impact on the economic activity of the rural mass leading to a negative growth of rural development. Earth observation satellites are felt to be essential for protecting coral reefs because their tonal variation can be seen in the satellite imagery. The current study aims at the impact of Sea Surface temperature (SST) in the study area through digital image processing technique. SST data, derived from the NOAA, AVHRR were used to assess the Spatio-temporal changes in the surface temperatures. The surface of the sea heats up by direct insulation, causing stress to corals and other shallow water organisms. Satellites directly measure the skin temperature of the sea, providing their maps and coral bleaching product for early warning. The bleaching thermal stress outlook is based on SST forecasts generated by NOAA. In this research paper such a case study has been undertaken to indicate that a few parameters are responsible for the decreasing number of corals and methods are devised to detect the causes and accordingly protection measures are put forth to put a stop on the menace.

### Study area

The present study area shown in Fig.1 consists of the coral environs of the Gulf of Mannar, which extends from Tuticorin to Rameshwaram Island in the SE-NE direction. The geographical extension of the study area are  $78^{\circ} 5'$  to  $79^{\circ} 30'$  E longitude and  $8^{\circ} 47'$  &  $9^{\circ} 15'$  N latitudes with a total length of about 140 km. There are 21 islands situated at an average distance of about 8 km from the coast and running almost parallel to the coastal line. These areas are largely covered with sea grass, mangroves, seaweeds and coral reefs. The area comes under the spell of both southwest and northeast monsoons. The ocean currents in Gulf of Mannar area are swift. The sea is rough between April and August and calm during September; during June to August it is very stormy. Tidal amplitude in the area is about half a meter. For this study, the work has been carried out only in one island. This study is concerned about the current status of coral reefs in the Gulf of Mannar and how coral reef bleaching might have been attenuated due to elevated SST.

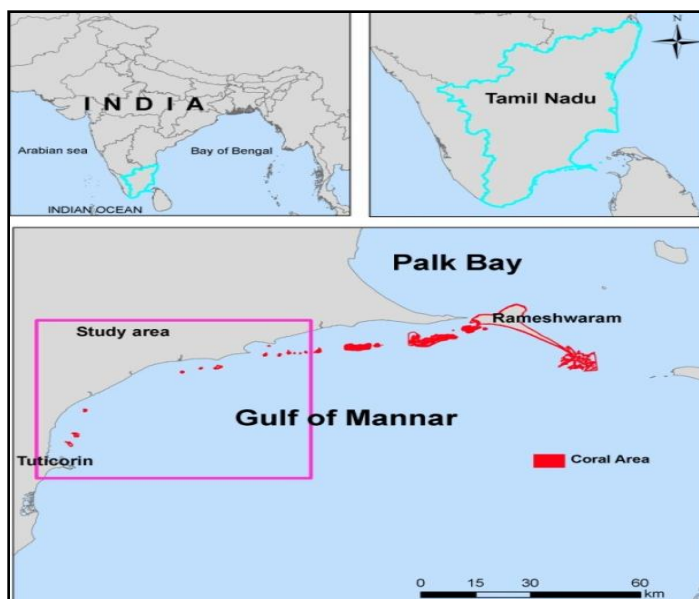


Fig. 1:-Location map depict of the Gulf of Mannar

### Methodology:-

For the present study the open source Landsat satellite data were collected as per availability from <http://www.earthexplorer.usgs.gov> site and has been analyzed to fulfill above objectives. The orthorectified satellite data were acquired from National Aeronautics and space Administration (NASA) and were downloaded from United States Geological Survey (<http://www.earthexplorer.usgs.gov>) site. The satellite image used for this study (Table 1) was acquired by the sensor Landsat TM and ETM+ on board of Landsat 7. The study area is falling

under path row of 143/54 & 142/54. Further processing was done using Arc GIS 9.3, ERDAS Imagine 9.1 and ENVI 7 software. According to satellite acquisition date, SST monthly data were plotted each island wise. Sea Surface Temperature data was retrieved from the NOAA. Monthly five kilometer spatial resolution of Advance Very High Resolution Radiometer (AVHRR) data were downloaded and analyzed for change in coral environment during the period of 2000 to 2009. Then variation of SST data was correlated with the health of coral environment. If SST rises for a period of as little as 1°C higher than the usual average monthly SST during the hottest months of the year, this could result in a bleaching event (Glynn, 1996). The temperature range for coral environment is 20-29°C. If temperature fluctuates beyond these ranges, the coral suffer from a bleaching event.

**Table. 1:-**Satellite data used for the study

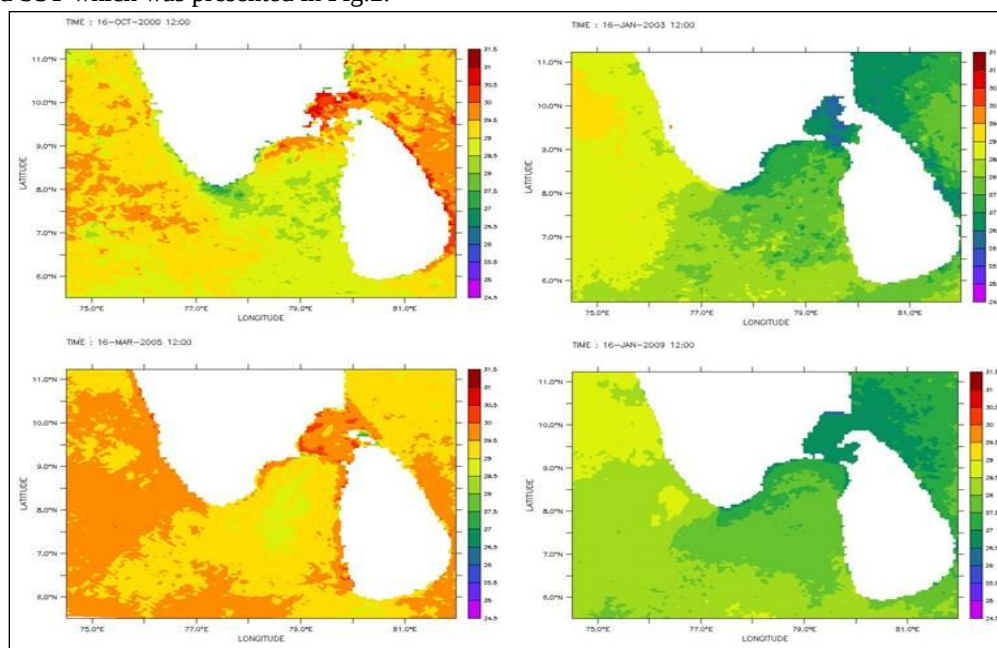
| Satellite/Sensor | Band             | Date of pass | Spatial Resolution |
|------------------|------------------|--------------|--------------------|
| Landsat TM       | 7 Band           | 19.10.2000   | 30 m               |
| Landsat ETM+     | 7 Band+ Pan Band | 26.01.2003   | 30 m + Pan 15m     |
| Landsat TM       | 7 Band           | 16.03.2005   | 30 m               |
| Landsat TM       | 7 Band           | 21.01.2009   | 30 m               |

The corals thrive in a shallow marine environment under a thin water column. The overlaying water column was not uniform along the morphological zonation of coral throughout the area. Hence, it was necessary to apply water column correction / water column normalization. For this purpose Lyzenga Algorithm method was applied (Bayu Prayudha et al., 2010). To generate the Depth Invariant Index (DII) of bottom types within a pair of bands, the following formula is used.

$$\text{Depth-invariant band } ij = \ln(li) - \left[ \left( \frac{ki}{kj} \right) \cdot \ln(lj) \right]$$

### Sea Surface Temperature

Sea Surface Temperature (SST) is a key factor in terms of coral bleaching which can affect the mortality and growth rate of coral environments. Therefore as per availability of data, the comparison has been assessed between the rate of change of SST and quantification of coral classes to study the health of coral Reef during the study period. It also shows that due to ElNiño, the coral bleaching event in 1998 caused a significant decline in the cover of healthy coral in most of the areas (Wafar, 1999; Arthur, 2000). According to reef research Team (RRT) of Suganthi Devadason Marine Research Institute (SDMRI), there was no coral bleaching found in the year 2011, in the entire GoM. Coral Reef area in GoM at 0.5-4.5 m depth has an SST of an average of around 29°C throughout the year. During summer, the temperature varied between 31°C and 33.5°C and due to elevated SST, coral bleaching has been observed during summer in GoM since 2005 (The New India Express, 23 May, 2011). Before 2005, there was a sparse bleaching event in 2002. Bleaching of extensive areas was recorded during 2002 in Palk Bay, Gulf of Mannar and the Andaman Island (Kumara guru et al., 2003). As per SDMRI, the average percentage of bleaching in 2005 was 14.6 %. The AVHRR data from 2000 to 2009 shown in Fig. 2 were collected from NOAA and analyzed for change in coral environment. The result suggested that 2002 and 2005 bleaching may have been induced due to elevated SST which was presented in Fig.2.



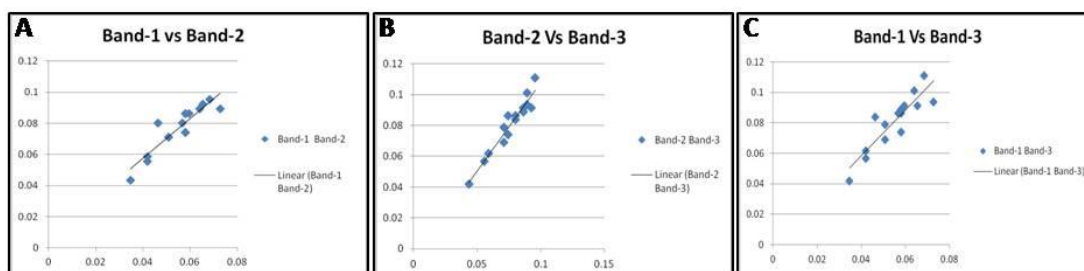
**Fig.2:-**Sea Surface Temperature (SST) composites of the study area during Oct.2000 (UL), Jan.2003 (UR), Jan.2009 (LL) and Mar.2005 (LR)

## Result and discussion:-

### Water Column correction

On the scatter plot, most of the pixel values of band 2 and band 3 are falling on a straight line (Fig.3), however this is less in case of band 1 Vs band 2 and band 1 Vs band 3. This might be attributed to larger light attenuation in band 3. Based on this result, for the classification, only pair of band 2 and band 3 was used. The ratios of attenuation coefficient were calculated using the equation 1, 2, 3 and 4. The results are shown in the table 2.

**Fig. 3:-**Linear graph object pixel sample of Sand in the pair of spectrum bands, A) Band-1 and Band-2, B) Band-2 and Band-3, C) Band-1 and Band-3

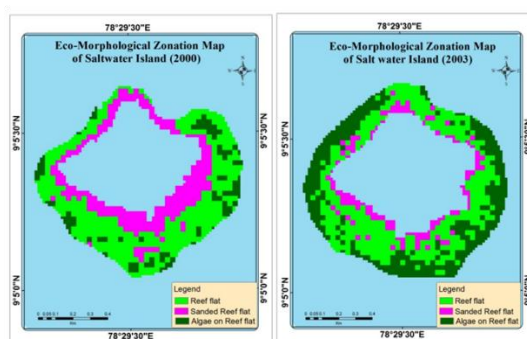


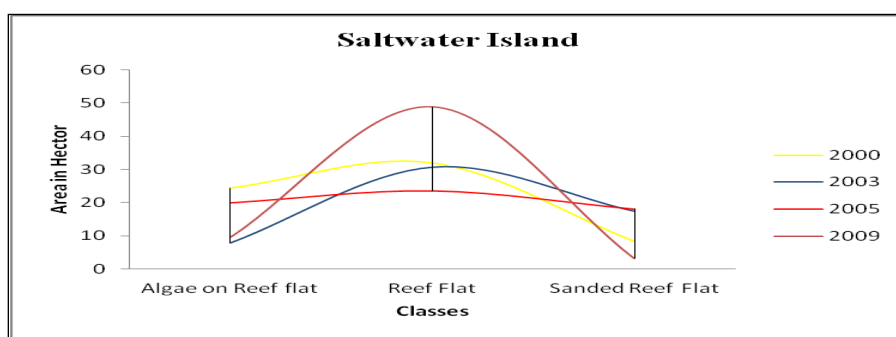
**Table. 2:-**Calculate the ratio of attenuation co-efficient between band2 and band 3

| Parameter       | Values     |
|-----------------|------------|
| Variance band 2 | 0.00006    |
| Variance band 3 | 0.00010    |
| Co-variance     | 0.000056   |
| a (b-2 and b-3) | -0.3874456 |
| $k_i/k_j$       | 0.6849881  |

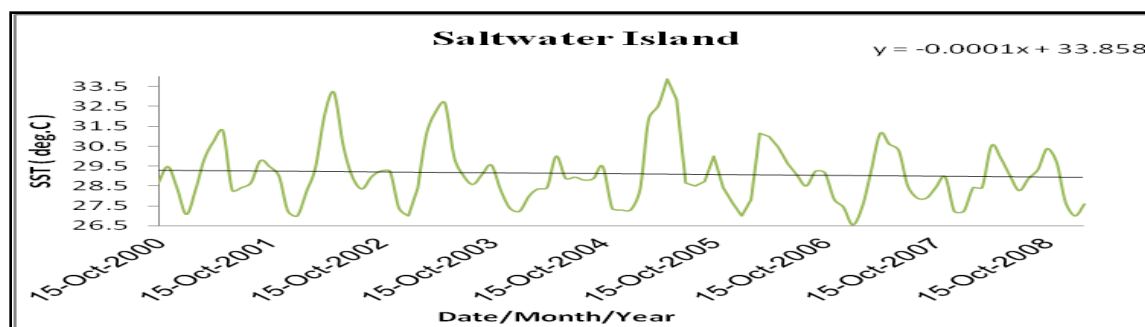
### Eco-morphological zonation mapping

The coral reef zonation maps of focus Island are shown in Fig.4 and Fig. 5. These maps show the spatial distribution and zonation of coral in each category. After DII classification, the area of reef flats, sanded reef flat, algae on reef flat and sand patches were calculated for further analysis. The reef flats, displayed in green color and deep green color show algae on reef flat. The other two colors pink and yellow show sanded reef flat and sand patch respectively. The Eco-morphological map illustrates the status of the reefs in a particular year during the study period. The total area of the island shown in Table 3 is 29.94ha and is located 8km from Vembar beach. It is a big sandy Island with plenty of coral cover all over the island. There are few trees, tall bushes, one lagoon and grasses present in this island (ICMAM report). Table.5 indicates the area of various geomorphic units in different periods. A close observation proves that from the year 2000 to 2009, the reef flats and algae on reef flat reduced in 2003 as compared to 2000 because of increased value of SST which may be due to the Tsunami of Dec. 2004.



**Fig.4:-**Eco-morphological map of Saltwater Island 2000, 2003, 2005 and 2009.**Fig.5:-**Area comparison of eco-marphological classes of coral reef during the study period around Saltwater Island**Table.3:-**Area comparison of Eco-morphological classes of coral reef

| Class              | Change in area (Hectares) |           |           |
|--------------------|---------------------------|-----------|-----------|
|                    | 2000-2003                 | 2003-2005 | 2005-2009 |
| Algae on reef flat | -16.56                    | 12.15     | -10.33    |
| Reef flat          | -1.21                     | -7.24     | 25.35     |
| Sanded reef flat   | 9.0                       | 0.72      | -14.94    |

**Fig. 6:-**Temporal variation of SST from Oct. 2000 to Feb. 2009

### Sea Surface Temperature

The linear graph of SST (Fig.6) shows that, SST reduced by  $0.00020^{\circ}\text{C}$  / month from Oct. 2000 to Feb. 2003. But in 2002, due bleaching event (Kumara guru et al., 2003) some corals degraded when the temperature was  $33.02^{\circ}\text{C}$ .

Similarly the linear graph of SST from Jan 2003 to May 2005 shows that, SST increase by  $0.0002^{\circ}\text{C}$ / month. In this period, the temperature rose up to  $34^{\circ}\text{C}$  particularly in the summer season. After 2005, the SST reduced at a rate of  $0.001^{\circ}\text{C}$ / month year wise. If we compare the values from 2002 to 2009, the SST of Saltwater Island fell off at a rate of  $0.00010^{\circ}\text{C}$ /month

### Conclusion:-

Indian coral reefs have faced 29 widespread bleaching events since 1989 ([www.reefbase.org](http://www.reefbase.org)), but intense bleaching occurred during 1998 and 2002 (Kumara guru et al., 2003). After 2002, Tsunami again affected Indian reef in Dec.2004. Bleaching events are most commonly linked to high SST, but other stressors also affect coral bleaching. River runoff into ocean during summer monsoon periods means corals and other reef builders can be simultaneously exposed to SST and pollution. The few field and laboratory studies have so far shown that combination of SST and pollution like sediments, sewage nutrients (Nagelkerken 2006), metal (Nystrom et al. 2001) and nitrate (Nordemar et al.2003; Wooldridge 2009) affect coral more severely than thermal stress (Negri et al. 2011).The present study adds further evidence of affect of high SST on coral reefs. If the bleaching phenomenon continues at the present rate, very soon all the corals in this marine ecosystem will break down thus affecting heavily on the number of fish catch by the local villagers. The corals not only give livelihood to the locals but also give opportunity to use the corals in jewelery and preparation of various types of medicines. In this way the, the whole economy of the area will suffer due to bleaching and perishing of corals. Therefore, the local administration must be vigilant not to allow any sort of anthropogenic polluting activity, which will otherwise lead to perishing of corals. This information generated in the present study become vital for the coastal resource managers, researchers and academicians for understanding the current and recent past status of the coral environs.

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