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CORAL REEFS AMIDST CLIMATE CRISIS - A REVIEW ON STRENUOUS STRUGGLES BY THE SYMBIOTIC SCLERACTINIANS TOWARDS MULTIFOLD CHALLENGES

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ABSTRACT

The coral reef is an ecosystem where various elements of the marine realm are intervened for multiple dependencies through food webs, shelter needs or a vital breeding platform. Apart from the grandeur, ethical values and tourism regimes, it is highly crucial to discern the complexity of dynamism and long term trends in order to get insight to the ecosystem response towards the acute and chronic stressors such as climate change, ocean acidification, over exploitation etc. Survival of an ecosystem amidst the dynamic marine environment reflects the tremendous ecological potential of the community to overcome the natural and anthropogenic challenges. Moreover, due to the coastal orientation, ecosystems like Coral reefs and Mangroves have to confront various threats of both oceanic and terrestrial origin in nature. In addition to that, climate change has shaken the basis of survival of all ecosystems including corals and coral reefs. Hence, understating the current state of climatic threat and coral resilience can invigorate the research to pave the possible ways of conservation for such a productive ecosystem.

Keywords: Coral reef, climate change, ocean acidification

INTRODUCTION

The Coral reefs exhibit one of the oldest ecosystems on earth with remarkable functional and structural evolutionary trajectory. Biologically, scleractinian corals constitute the key biodiversity on reef whereas geologically they characterize the major framework contributor. However, current trends of natural and anthropogenic changes have threatened such an ancient ecosystem on multiple fronts. In fact, any change in physico -chemical parameters of the ambient environment of corals will cause alteration in their growth, reproduction and survival. Apart from corals, the reef supports 25% of all marine species and makes the ecosystem unique in terms of biological diversity and productivity. The climate change threatens coral reef ecosystems through synergistic effects of various chronic and acute stresses. There are marine habitats which get affected by different climatic parameter differently i.e., sandy beach habitats are susceptible to storms, pelagic habitats are significantly affected by sea-surface temperature whereas continental shelf habitats are vulnerable to sea-level changes primarily. Moreover, coastal ecosystems like coral reefs, salt marshes/Mangroves as well estuaries are susceptible to more than one factors i.e., Sea level changes, coastal storms, temperature and CO_2 rise. The major consequences imposed by Climate change on corals and coral reefs have been discussed with refrence to the affecting climatic parameter:

Coral bleaching

Coral bleaching is the expulsion of symbiotic algae zooxanthellae from the coral tissue resulting in white or pale appearance of the coral colony. The phenomenon of bleaching is a general stress response that can be induced by a number of environmental factors i.e., extremes of temperature (heat shock and cold shock), high irradiance, prolonged darkness, heavy metals (especially copper and cadmium) and pathogenic micro-organisms (Hoegh-Guldberg, 1999; Brown, 2000). However, the increasing sea surface temperature is considered as a major factor to bring about coral bleaching events (Stone et al., 1999).

The temperature threshold for bleaching is relative to other environmental variables (especially light) and to the duration and severity of the departure from the normal temperature conditions of a reef (Liu *et al.,* 2003). Therefore, it can be said that the bleaching due to thermal stress is not limited to areas of normally high water temperature. However, regions where higher temperatures are the norm seem likely to be more vulnerable to increased physiological bleaching (Fitt *et al.,* 2001). It has been observed that branching coral species that exhibit higher growth rates and thin tissue veneer are more prone to bleaching, and heavy bleaching events may be fatal for them. The coral species with slow growth rate but thick tissue are less susceptible in case of bleaching (Hughes *et al.,* 2003).

In India, evidences of mass coral bleaching ranging from 25.8% to 76.5% bleached corals were recorded from different reef areas i.e., Palk bay during the month of April and May, 2010, at Andaman and Nicobar reefs, Lakshadweep during May and June (Ravindran et al., 2012; Krishnan et al., 2011). Coral bleaching evidences were also recorded by researchers from Gulf of Kachchh (Joshi et al., 2014, www.wti.org.in).

Fig. 1 Coral bleaching observed - Reef view

Reduced Calcification Potential

The oceans currently absorb about a third of the anthropogenic CO_2 inputs to the atmosphere, resulting in significant changes in seawater chemistry which in turn effects the calcification of the marine organism (Houghton *et al*., 2001). Photosynthesis and respiration by marine organisms also affect seawater CO_2 concentration, but several studies have predicted a reduction in ocean pH and a lowering of the saturation state of seawater with respect to the calcium carbonate minerals such as calcite and/or aragonite as a consequence of the increased CO_2 concentrations in atmosphere (Caldeira and Wickett, 2005; Harvey, 2003; Orr *et al*., 2005). The predicted elevation in the Carbon dioxide level may result in considerable lowering of ocean pH which was never evident in the past geologic time (Caldeira and Wickett, 2003).

When CO_2 dissolves in seawater, it forms carbonic acid (H_2CO_3):

$$H_2O + CO_2 \rightarrow H_2CO_3$$

H_2CO_3 is a weak acid that can lose H^+ ion to form bicarbonate (HCO_3^-):

$$H_2CO_3 \rightarrow H^+ + HCO_3^-$$

or

Further remove the remaining hydrogen ion to form carbonate (CO_3^{2-}):

$$HCO_3^- \leftrightarrow H^+ + CO_3^{2-}$$

Thus, carbon can occur simultaneously in several forms: CO_2 (dissolved CO_2 and carbonic acid), HCO_3^-, and CO_3^{2-}. Increasing atmospheric CO_2 drives more CO_2 into the ocean, lowering the pH (making the ocean more acidic) and changing the relative proportions of the three forms of carbon. This reduction in ocean pH has some direct effect on marine organisms (Seibel and Walsh, 2001; Ishimatsu *et al*., 2005).

The differences in preindustrial and industrial levels of CO_2 consequently alters the concentration of carbonate ion i.e., the CO_2 (280 ppm) remains 85% and carbonate ions 15% at preindustrial levels but the industrialization at elevated the CO_2 to 90% in sea water and free carbonate ions to 10%. Calcifying organisms combine calcium and carbonate ions to build their skeletons ($Ca_2^+ + CO_3^{2-} \rightarrow CaCO_3$), so a reduction in carbonate ion concentration slows the calcification process and making it more difficult for calcifying marine organisms to form their shells and skeletons(Feely et al., 2004; Orr *et al.,* 2005).

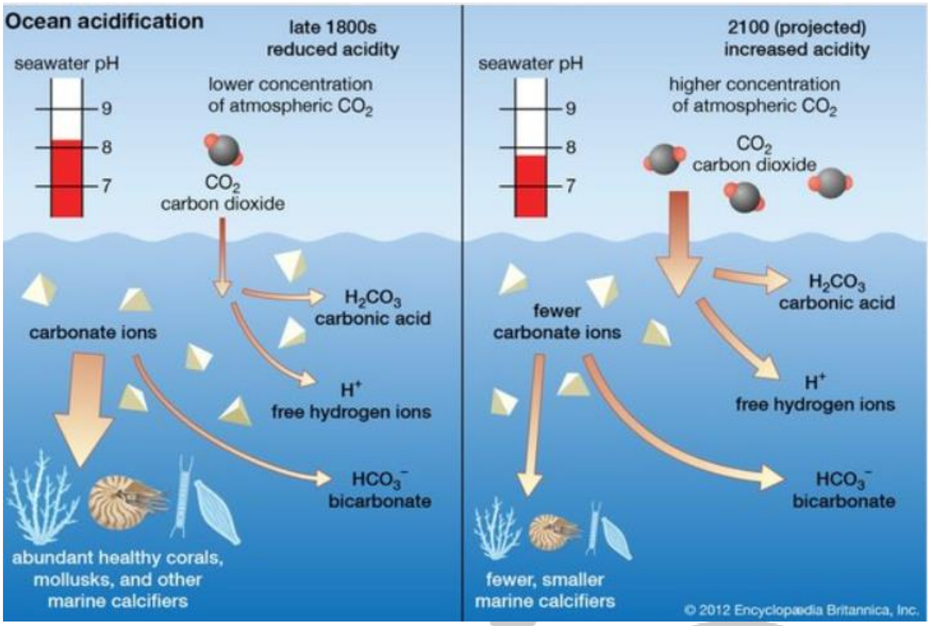

Fig. 2 Impact of ocean acidification on Calcification Potential of marine organisms

The effect of reduction in the available carbonate ions has been most studied in coral, which form their skeletons from aragonite, a metastable form of calcium carbonate (Kleypas *et al.*, 1999; Langdon *et al.,* 2003).

Reef-building coral occurs where calcium carbonate precipitation exceeds its removal. The structural components of reefs (skeletons of corals and calcareous algae) are glued together and made more resistant to physical breakdown by calcium carbonate cements that precipitate within the reef framework, and by the overgrowth of thin layers of calcareous algae. A reduction in CaCO3 precipitation by either mortality of reef organisms, lowered calcification rates, or lowered cementation rates reduces a reef's ability to grow and to withstand erosion (Kleypas *et al.*, 2001). Some slow-growing or weakly cemented reefs may stop accumulating or shrink as carbonate deposition declines and/or erosion increases. Such effects have been observed in the Galapagos (Eakin, 1996; Reaka-Kudla *et al.*, 1996).

Future changes in seawater chemistry will not only lead to decrease in calcification rates, but also to increase in $CaCO_3$ dissolution. Field experiments by Halley and Yates (2000) indicated that the dissolution rate could equal the calcification rate once atmospheric CO_2 concentrations reach double the preindustrial levels. This indicates the slow-down or reversal of reef-building and the potential loss of reef structures in the future.

Sea level alteration

Eustatic transgression remains one of the key concerns of IPCC reports due to its inheritable consequences on low lying areas and marine ecosystems. Sea level has remained fairly stable for the last few thousand years, and many reefs have grown up to the sea surface, with restricted water circulation and little or no potential for upward growth. A minor rise in the sea-level would therefore be beneficial to such reefs. Though such a slight sea-level rise might "drown" the reefs that are near to their lower depth limits by decreasing the light availability, the projected rate and magnitude of sea-level rise are well within the ability of most reefs to keep up (Smith and Buddemeier, 1992). A more likely source of stress from sea-level rise would be sedimentation due to increased erosion of shorelines. Houghton *et al.,* 2001) predicted that the rise of sea level due to the combined effects of thermal expansion of ocean water and the addition of water from melting icecaps and glaciers will be between 0.1 and 0.9 meter (4-36 inches) by the end of this century.

Studies on Eustatic changes of Indian coasts have revealed that it will rise from 2- 8 mm/year at various coasts. It is predicted to lead submergence of the bio-protectors of the coasts- the mangrove ecosystem and consequently increasing coastal erosion and unpredictable inundation. This implies the prior damage to coral reef ecosystem, too; as the projections of mean sea level rise are also made with reference to Okha and Kandala of Gujarat state (Chowdhury and Behera, 2015).

Coral Reef Distribution

Globally, the distribution of reef-building corals is limited by annual minimum temperatures of ~18°C (64°F) (Veron, 1995; Kleypas *et al*., 1999). Although global warming might extend the range of corals into areas that are now too cold (Precht and Aronson, 2003), the new area made available by warming will be small and the countervailing effects of other changes suggest that any geographic expansion of coral reefs will be very minor. At present, coral reefs are limited to the tropics and occur only in waters where temperature remains warmer than 18°C (64°F). A 2°C (4°F) warming of the oceans will expand the range by a few degrees latitude. Locations within this region that have suitable depth, substrate, and other environmental conditions could potentially support new coral reefs at the higher temperatures. Only Southern China, Japan, Australia, and Southern Africa present geographically realistic opportunities for reef expansion. Additionally, sea-surface temperature (SST) gradients are very steep in the vicinity of 18°C (the annual minimum temperature threshold for coral reef growth), and ocean model projections suggest that SST warming associated with doubled CO_2 will only move the 18°C contour by a few hundred kilometers, especially in the critical western boundary areas (Kleypas *et al.,* 2001). Whereas the west coasts of North and South America, Europe, Africa and southeastern United States and near the Amazon River, reef expansion along the coast is blocked due to the flow of cool water towards the equator and are thus "upstream" from potential sources, causing restricted distributions of coral reefs in the former while muddy coastal shelves, river deltas, and turbid water for the latter.

El Niño- Southern Oscillation (ENSO)

Mass bleaching of corals has been clearly linked to El Niño events in the past two decades *(Hoegh-Guldberg, 1999; Glynn, 2000)*. The widespread bleaching events took place during the El Niños of 1982-83, 1987-88, and 1997-98. A region of unusually warm water develops throughout the Pacific and Indian Oceans during a typical El Niño event. When the seasonal maximum water temperatures coincide with the warm water anomalies, coral bleaching event takes place. In the western Pacific, the Mean sea level decreases during an El Niño event, which can expose shallow reefs, and lead to mass mortalities (Eakin and Glynn, 1996; Eakin, 2001). Coral bleaching also takes place in regions that tend to have warmer-than-normal SSTs during the La Niña i.e. the cold phase of ENSO (e.g., South Pacific Convergence Zone; New Britain during 1998-99).

El Niño events have increased in frequency, severity, and duration since the 1970s (Stahle *et al.*, 1998; Mann *et al.*, 2000). The severity of bleaching events during El Niño years of the last two decades presents a "worst case scenario" in predicting the future of coral reef ecosystems, particularly when added to a background of warming sea-surface temperatures.

Other marine Biodiversity

Marine habitats are highly biodiverse, however the climate change has not left any species/habitat unaffected. It has been observed that the species composition and diversity found at tropical region has exacerbated; whereas the marine species occurring at temperate region have exhibited range shift due to the migration from lower latitudes. The example of North Sea species richness reflects the climatic influence clearly i.e., the species diversity of North Sea has doubled in 21 years (1985-2006). This was a result of species range shift by the average northward shift of 2.2 km per year (Worm et al., 2021). Scientists have also studied distribution range shifts for marine biodiversity which averages 30.6 (±5.2 km) km/decade species displacement (Worm et al., 2021). Apart from thermal threshold, marine species also confront ocean circulation changes, pelagic bio-physical changes, over exploitation and pollution.

The above discussions imply that Coral reef conservation or even continual survival demands for global scale strategic planning however, the implementation needs local efforts. The local factors in addition to the global threats may still deteriorate the reef associates towards the climate crisis. Hence, along with controlled GHG emissions which is thought to be one of the leading factor of temperature rise, many local practices such as eco-friendly fishing and traveling practices, reduced fertilizers and industrial run-off, reduced trash at coastal area, awareness generation for coral conservation, reef restoration/coral transplantation programs etc. may play significant role towards strengthening Corals to combat climate crisis.

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