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Ocean Acidification: A Serious Threat to Coral Reef

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ABSTRACT: Over the last few decades the amount of carbon-di-oxide has been increased day to day. The ocean acidification is the additional concern with global warming. The rate of ocean acidification in Atlantic Pacific and Indian Ocean has been increased in comparison to pre-industrial times to post industrial times. Reports and researches have showed that ocean acidification has a direct impact on coral reefs. This study reveals how tropical and cold water coral reefs reacts ocean acidification and what is risk factor for corals in different countries and how we can protect coral reefs.

Keywords: Coral Reef

1. INTRODUCTION:

Over the last 250 years the rate of anthropogenic carbon-di- oxide has been increased from 280ppmv at pre industrial age to 380ppmv in 2007(*Solomon et.al.2007*). Again in this year *Doney and Schimel, 2009* concluded that rapid deforestation and rapid fossil fuel combustion accelerates the rate of increasing carbon-di-oxide in the atmosphere. According to *Luthi* the current concentration of carbon di oxide is no longer experienced by earth over the past 800,000 years *(Luthi et.al.2008*).

Ocean acidification is the additional concern with the climate change and global warming and it is a predictable consequence of rising atmospheric carbon-di-oxide (*Feely, R.A., Doney, S.C., Cooley, S.R., 2009)*

2. WHAT IS OCEAN ACIDIFICATION?

Ocean acidification is the ongoing decrease of pH level in the ocean water. It is happened due to the uptake of carbon-di-oxide from the atmosphere to the global ocean water (*Feely, R.A., Doney, S.C., Cooley, S.R., 2009)*. As our ocean is a global carbon sink the acidification has been happened rapidly due to addition of carbon-di-oxide in the atmosphere during the last two decades (*Anthony KRN, Hoegh-Guldberg (2003)*. It has been estimated that 30-40% of carbon-di-oxide released at the atmosphere by the humans has been absorbed by the ocean (*http://ocean.si.edu/ocean-acidification, link from the NOAA official website, also cited in Balch WM, Drapeau D, Bowler B, Booth E. 2007)*. Ocean acidification is often called the ‘evil twin’ to climate change because both issues has been rooted in carbon-di-oxide emissions.*(NOAA, Ocean Portal*)

3. THE CARBONATE CYCLE:

In the context of chemical equilibrium in the earth there will be hardly any place remains void. An essential condition prevails in the equilibrium of pressure that there should be a flow from high pressure to low pressure condition (*Scott C.Doney, Victoria J. Fabry, Richard A. Feely, Joan A. Kelypas, 2009)*. Now simple thing is that the partial pressure of carbon-di -oxide in the atmosphere is always greater than that of ocean. As a result the carbon-di-oxide is coming from atmosphere to ocean. As soon as it is coming to the ocean it interacts with water and forms bi-carbonate ion. It again splits and forms the hydrogen ion and carbonate ion and ultimately deposits in the form of calcium-carbonate (*www.wilkipidia.org/*, also cited in *Jean-Pierre Gattuso and Robert W. Buddemeier*,2000*)*. Conversion of carbon-di-oxide has been happened in the ocean but in the atmosphere the conversion does not happen so the partial pressure of carbon-di-oxide in the atmosphere is always greater than the partial pressure of carbon-di-oxide in the ocean (*Scott C.Doney, Victoria J. Fabry, Richard A Feely, Joan A. Kelypas,2009)*. Now from the mechanism it is clear that if more and more carbon-di-oxide will be added in the atmosphere more and more hydrogen ion will form and that will result in the decrease in the pH level over the ocean water (*www.wilkipidia.org/*).

In the second phase of carbonate dissolution occurs and ultimately it results in the formation of bi-carbonate ion.

4. RATE OF OCEAN ACIDIFICATION:

From the year 1850 it has been noticed that the rate of dissolved carbon-di-oxide has been increased in a rapid manner. In the year 1950 the dissolved carbon- di- oxide has been reached almost 11Micromoles/Kg which was 10 Micromoles/Kg at 1850. Again after its ten years at the year 2000 the dissolved carbon-di-oxide almost reaches at 13 Micromoles/Kg. Now it has been projected that if this rate sustains the in the year 2100 the rate of dissolved carbon-di-oxide will stand at almost 21 Micromoles/Kg. Now if we observe the curve of average pH it also starts to decrease from the year 1850. If the rate of decrease of pH level sustains at this rate it will reach to 7.85 in the year 2100 (*www.wilkipidia.org/).*

According to Royal Society the ocean water pH has fallen approximately 0.1 units from approximately 8.21 to 8.10. The decrease of oceanic pH due to the uptake of carbon-di-oxide from the atmosphere is well verified by different models, hydrographic surveys and time series data (*Solomon et. al. 2007*). At the Hawaii Ocean Time Series (HOT) ALOHA the growth rates of surface water potential carbon-di-oxide and atmospheric carbon-di-oxide agree well (*Takahashi et. al.2006*). The NOAA ocean portal reports that ocean pH has dropped from 8.2 to 8.1 since the industrial revolution and is expected to by fall another 0.3 to 0.4 pH units by the end of this century (*Ocean portal, NOAA*). Takahashi explained that a drop in pH of 0.1 might not seem like a lot but the pH scale like the Richter scale measuring earthquakes is logarithmic. pH 4 is ten times more acidic than pH 5 and 100 times more acidic than pH 6 (*Ocean portal by NOAA*).

5. CALCIUM-CARBONATE SATURATION STATE:

In the warm tropical waters saturation states are highest. It is lowest in the cold high latitude regions. This factor reflects the increase in calcium carbonate solubility with decreasing temperature and increasing pressure (*Feely et. al.2004*). The *Indian and Pacific Ocean* comprises the shallower aragonite and calcite saturation horizons than that of the Atlantic Ocean due to the longer deep-water circulation pathways and thus accumulation of more DIC from respired carbon-di-oxide *(Broeker 2003, Bleize, 2007*)

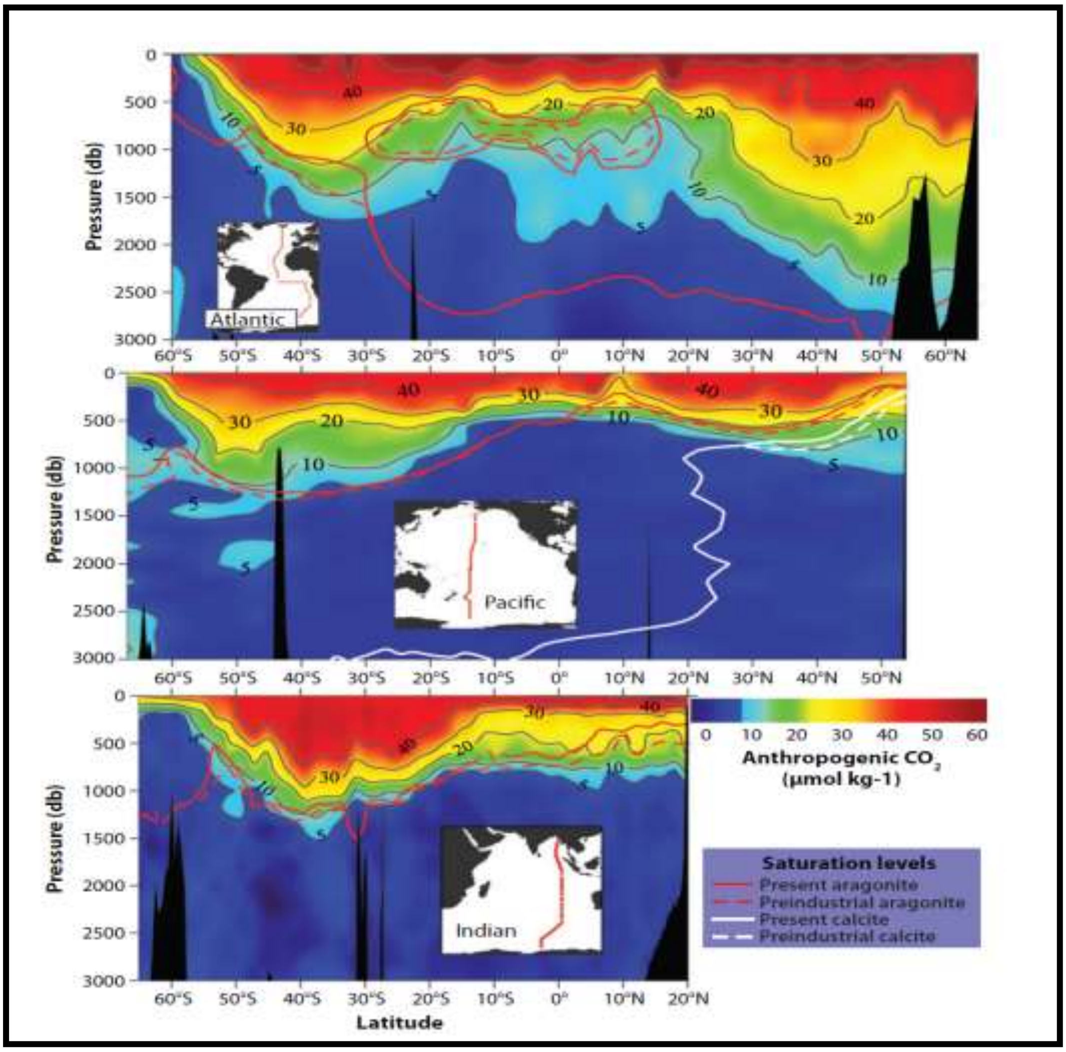


Fig 2: Aragonite and calcite condition in a) Atlantic b) Pacific and c) Indian Ocean respectively in comparison with those in pre-Industrial times(Feely et.al.2004)

6. OCEAN ACIDIFICATION AND CORAL REEF:

Zooxanthellae are the plant cells lives within the body of coral by forming symbiotic relationships. Zooxanthalle is a kind of algae which creates oxygen by their photosynthetic activities. This oxygen has been utilized by the corals in their respiration (*Feely RA, Byrne RH, Acker JG, Betzer PR, Chen CTA, et.al.1988)*. Whereas the corals in their respiration creates fats and sugars which are the essential elements for zooxanthellae for their photosynthetic activities (*Guillermo Diaz-Pulido, Kenneth R.N. Anthony, David .I. Kline ,Sophie Dove, Ove-Hoegh Guldberg,2012)*. The tight recycling of products between the polyp cells and zooxanthellae is the driving force between the growth and productivity of the coral reefs. Acidification spoils the coral's ability to make skeletons in their body (*Ben.I.Mecneil, Richard J. Matear,2006)*. The algae inside the coral die or the algae leave the coral due to acidification (*Nancy Knowlton,2001)*. The algae give coral its colour and without algae there is absolutely no colour and the white of the limestone shell shines through the transparent coral bodies. From about 1980's it has been noticed in India.

6.1. **Tropical Coral Reefs:** Tropical coral reefs can be found near the equator (30°-35˚ north south of equator) where the SST does not fall below 17°c. The total area of tropical coral reef is 284,300 sq. km (*Scott. C. Doney ,Natalie Mahowald, Ivan leema, Richard a. Feely, Fred. T. Mackinzie, Jean francois Lamarque and Phil.J Rash,2007, also cited in the report by NOAA,2009).*

Tropical coral reefs can grow 1cm to 150 cm per year. Tropical corals can form huge structure over a long period of time. And this makes them largest and oldest systems on the earth. Elevated a sea temperature of 1˚c above long term summer averages leads to bleaching i.e. the algae zooxanthallae leave the coral polyp cells. Thus bleaching happens. Ocean acidification makes dissolve the calcium carbonate cells and they get dissolved into the sea water (*N. Meskhidze, W. L. Chameides, A. Nenes, and G. Chen*,2003)

Tropical coral reefs form the basis of many complex ecosystems (*Gangjian wei, Malcom T.McCulloch,2009)*. Their soft polyps provide a ready food source for many other creatures while reef caves and crevices are first rate locations for breeding of predators (Andersson AJ, Bates NR, Mackenzie FT. 2007). Up to 4000 individual species can coexist in a single reef. These include the coral species themselves as well as algae, fish, dugongs, marine turtles, sea snakes, worms, crustaceans, mollusks, starfish, and many more (*Jordan. M. West and Rodney V. Salm, 2009*)

6.2. **Cold Water Coral Reefs:** Corals can also live in temperatures as low as 4°c. They are found in the regions of accelerated current flow (*Langdon C, Broecker WS, Hammond DE, Glenn E, Fitzsimmons K, et al. 2003*). They are found in deep sea areas as well as in the seamounts, mounds, ridges and pinnacles (*Hoegh-Guldberg O,2007)*. Deep sea corals made up of only a few coral species but they provide home for many other species i.e. starfish, brittle stars, sea urchins, crustaceans etc. cold-water coral reefs do attract large amounts of fish, serve as important spawning and nursery grounds(*Rost B, Riebesell U, Burkhardt S. 2003)*.

7.STATUS OF CORAL ECOSYSTEMS:

7.1.Status Of Caribian Coral Reefs After Acidification, Bleaching And Hurricans In 2005:

According to the report by NOAA at 2007, 2005 was the most damaging for coral reefs in the Caribbean. Abnormally high sea surface temperatures resulted in coral bleaching and mortality throughout the region. Record hurricane activity, including some particularly damaging storms affect the coral reef in caribian severely (*.Also cited in Status of coral reefs of the world,2008, edited by Clive Wilkinson*). *Clive Wilkinson and David Souter* identified several impacts of coral bleaching at this. They are as follows:

1. Rising sea-surface temperature.
2. Increasing concentrations of carbon-di-oxide in sea water.
3. Shifts of ocean currents.
4. Sea level rise.

7.2. Status Of Deep Coral Ecosystem In United State:

The NOAA report, 2009 suggests that the corals which live in 50-100 m deep in the ocean their rate of growth also tends to decline in the recent years *(Diaz-Pulido G, 2007*). Not only that the species diversity of deep sea coral are also tends to decreasing in number(also cited in *K. R. N. Anthony, D. I. Kline, G. Diaz-Pulido, S. Dove, and O. Hoegh-Guldberg,2008).*

7.3 Status Of Coral Reef Ecosystem In The Southeast Asia:

With more than 350 million people live in Southeast Asia for thousands of years. Coral reefs are important not only in culture of the local community, but also corals is also critical to the economic health of these nations.

Despite their worth corals are in the threat level from human activity. The unsustainable demand for corals in the Southeast Asia causes the degradation of corals. Not only that the rapid carbon-di-oxide released by the countries also affects ecology of corals in this region(*Bates NR.*

2002, also cited in Gangjian wei, Malcom T.McCulloch, Graham Mortimer,2009).

The overfishing activities as well as rapid industrialization of southeast and European countries causes the acidification of ocean water. Unplanned industrialization as well as the population explotion give birth the unplanned urbanization, urban slum, etc. and the poverty leads to the excessive dependence upon the marine resources in the southeast regions.

8. STATUS OF CORAL REEF ECOSYSTEM OF THE WORLD:

5th global report has been announced in 2008. The highlights are:

a) Overall 19% area of the coral reefs has been washed out. About 15% area or more are seriously affected in all over the world. Within next 20-40 years about 90% species will be seriously affected (cited in *Ocean Portal, NOAA).*

b) About 46% of the coral reefs are not in immediate threatening condition. But the unpredictable global climate change may affect these coral reef ecosystems as mentioned in the report by NOAA.

Recent evidence suggests that the evolutionary response to higher water temperatures may be possible (*Baker 2003*). As Baker suggests that mass bleaching events have been happened 1991-98 and 2000-02 (*Baker 2003*). However other studies indicate that many entire reefs are already at their thermal tolerance limits. But Donner has been concluded that the local evolutionary responses of coral are unlikely to mitigate the negative effects of future temperature rises and ocean acidification (also cited in *Langdon C, Broecker WS, Hammond DE, Glenn E, Fitzsimmons K, et al. 2003).*

9. THE FUTURE OF CORAL REEF:

Overexploitation and ocean acidification are the principle threats of degradation of coral reefs. Over the past two decades as a result of warmer baseline temperatures, increasingly severe temperature anomalies such as el-nino as well as global ocean acidification severely damaged coral habitats. Not only the habitat degradation but also habitat fragmentation force coral to die (*Ove Hoegh- Guldberg and John F. Bruno,2009*).

But the human efforts to increase the spatial resilience of coral reefs to bleaching through the creation and management of Marine Protected Area (MPA) networks (*West & Salm 2003*) should explicitly incorporate unusual and diverse habitats that maximize symbiont diversity into their design(*Richard E. Zeebe,2009)*. When coral reef hosts are assessed over their full range of systematic, ontogenetic, ecological, and biogeographic gradients, the existence of unusual symbionts normally found only in uncommon host taxa, larval stages, marginal environments, or at latitudinal extremes may prove critical in understanding the long-term resilience of coral reef ecosystems to environmental perturbation *(Morton, B & Blackmore,2001*). The NOAA has done tremendous job in prediction of coral reef shifting (*Archer D, 2005)*. On the reefs of the Papua New Guinea that are affected by natural carbon-di-oxide seeps big boulder colonies have taken over and delicately branching forms are disappeared probably because their thin branches are more susceptible to dissolving. This change is also likely to affect the thousands of organisms that live among the coral including those that people fish and eat in unpredictable ways. In addition acidification gets piled on all the other stresses that reefs has been suffering from such as warming water pollution and overfishing and as well as coral bleaching.(*NOAA, Ocean Portal*). In a report *status of coral reefs of the World, 2008* the detailed analyses have showed the following ponts:

a. Reefs all over the world are effectively lost.

b. About 15% of the coral reefs are at critical stage.

c. About 20% of coral reefs are at low risk condition.

d. In the next 20-40 years it is predicted that 40% corals will be under threat.

e. The report says that maximum coral reefs in have been damaged rpidly in the coast of java-sumatra Island due to tsunami in 26th December, 2004.

f. The report specifies the causes of threat to the world coral reefs. They are as follows:

Country	Threats
Kuwat	Fishing and recreational boating, oil pollution, discharge of ballast water.
Oman	Hazardous and solid waste, eutrophication, siltation due to coastal development.
Saudi Arabia	Discharge of sewage from vessels, illegal disposal of toxic waste, hazardous waste.
Iran	Temperature fluctuation, breakwater construction.
U.A.E.	Coastal development, oil spill, increasing of coral diseases.
Bahrin	Over fishing, sedimentation
Quatar	Local fishing boat anchors.

Source: Status of coral reefs of the world,2008 , edited by Clive Wilkinson

The experts have commented to take several steps to resist coral reef from deterioration:

a. Reduce the boat and anchor deterioration (*Ova Hoegh-Guldberg and John F. Bruno,2009*).

b. Solid waste clean-up project are necessary for every country.

c. Develop and expand local monitoring.(*Ben.I.Mecneil, Richard J. Matear,2006)*

10. RATE OF REEF ACCRETION:

The observation from the fields carbonate accretion on coral reefs approaches zero or becomes negative at aragonite saturation valuesof 3.3 in today's oceans which occurs when atmospheric carbon-di-oxide approaches 480 ppm and carbonate ion concentration s drop below 200mol/kg in most of the global ocean(*Yi Liu, Zcheng Pen, Renjun Jhou,Shaohua Song,Weiguo Liu, Chen feng you,Yen-po Lin, Kefu Yu, Chung-che yu,Gangjian Wei, Luhua Xie, George. S. Burr,Chuan- chou shen,2014)*. These findings by observation that reefs with net carbonate accretion today are restricted to waters where the aragonite saturation exceeds 3.39(*Maud c.o. Ferrari, Mark.I.Mccornick, Philip.L.Munday,Mark.G. Meekan, Danille.L.Dixon, Ooana Lonnstedt and Douglus E. Chivers,2011)*.

11. RESILIENCE:

Ecological resilience is a measure of the rate at which an ecosystem returns to a particular state (e.g. coral dominated communities) after a disturbance (e.g. hurricane impacts). Recent changes to the frequency and scale of disturbances such as mass coral bleaching coupled with decreased ability of corals to grow and compete are pushing reef ecosystems from coral algal-dominated states (*Coral reef under rapid climate change and ocean acidification, review paper by R.S. Stenek and C.M.Yakin, published in the magazine SCIENCE, online ISSN 1095-9203*).

At Caribbean reefs it is measured that the coral growth has been reduced to 20% noticed in the recent decades . Again a report about the resilience of coral reefs indicates that ocean acidification and temperature change are not only the one having an impact on the coral bleaching but also global fishing habit also creates a additional stress for the coral's growth. Here the resilience may be defined that capacity of reefs to absorb current disturbances and rebuild a new coral-dominated systems (*Jordan. M. West and Rodney,2009,also cited in Lorn Thomson, Isabel Casties, Christian Pansch, Arne Kortzinger and Frank Melzner,2012)*. An experiment over the Great Barrier Reef suggests that in the areas where fishes were abundant, abundance of algal activity remained low the coral abundance becomes almost doubled in the 3 year period and it has been noticed that within a no fishing reserve in the Great Barrier Reef coral abundances and diversity have been sharply reduced after bleaching happened in 1998(*Terence P. Hughes, Maria.J.Rodrigoes, David.R.Bellwood, 2007)*. Another experiment by K.R.N. Anthony, D.I.Cline, G. Diaz. Pulido, S.Dove and O-Hoegh.- Guldberg suggests that sensitive reef-building species such as CCA may be pushed beyond their thresholds for growth and survival within the next few decades whereas corals will show delayed and mixed responses (*K.R.N.Anthony, D.I.Cline, G.Diaz-Pulodo,S dove., o.Hoegh-guldberg , 2008).*

12. MANAGEMENT:

Several papers indicate several procedures to manage the coral reef degradation and deterioration (*Morton, B & Blackmore, G. South, 2001):*

1. First, we have to identify those people who are directly dependent upon the coralline resources in marine environment (UNEP 2009).
2. We have to determine the security, economic and cultural importance of coral (UNEP 2009).
3. We have to identify the species of coral that more flexible to change and which may encroach on habitats and survive in altered conditions and asses how these may affect ecosystems and food security (UNEP 2009).
4. Monitoring in a systematic way and use of high resolution measurements of potential carbon-di- oxide in surface water and atmosphere, carbonate, alkalinity, pH and provide proper guidelines and efficiency to understand and interpret the impact of acidification on ecosystems(*Scott C.Doney, Victoria J. Fabry, Richard A. Feely, Joan A. Kelypas,2009)*
5. Need more and more standardized protocol in case of calcification experiments(*Scott C.Doney, Victoria J. Fabry, Richard A. Feely, Joan A. Kelypas,2009)*
6. Need more and more accurate modeling to understand the ocean acidification process more precisely than and as well as to determine the effect of acidification on marine organisms.
7. Nested models of biogeochemical cycles and higher trophic-level responses are also needed (*Scott C.Doney, Victoria J. Fabry, Richard A. Feely, Joan A. Kelypas, 2009)*.
8. Need more and more sophisticated technology and require a new approach to mitigate the risk of ocean acidification (*Status of coral reef of the world, 2008*).
9. Global awareness about the emission of carbon-di-oxide to the atmosphere as addressed by UNFCC and they have arranged the Nirobi Work Program(NWP) to distribute improved knowledge and assessments of climate change impacts, vulnerability and adaptation and thus also could be a platform for the understanding and assessment of ocean acidification(ELLYCIA R. HARROULD-KOLIEB, DOROTHE´E HERR,2011).

10. Several countries (*Australia 2007*, *Indonesia 2007, Ireland 2007, and Japan 2009*) refer to ocean

acidification and its impacts in their planning process and strategies. However a more action-oriented developmental approach is needed to develop the ocean acidification (*Status of coral reefs, 2008*).

11. In the global report published at 2008, NOAA has been specifically mentioned some required steps as follows:

a. We have to combat with the global climate change.
b. Scale up the protected areas.
c. Include more reefs in Marine Protected Areas (MPA).
d. Maximize coral reef resilience.
e. Improve enforcement of MPA regulations.
f. Socio-economic and ecological monitoring is urgently needed to protect coral reefs(also cited in *DEFRA,2010, CLIMATE CHANGE PLAN 2010)*.

12. In case of protection of deep sea corals first of all we have to identify the deep sea corals (*Frances E. Hopkins, Suzanne M. Turner, Philip D. Nightingale, Michael Steinke, Dorothee Bakker, Peter S. Liss,, 2009).*

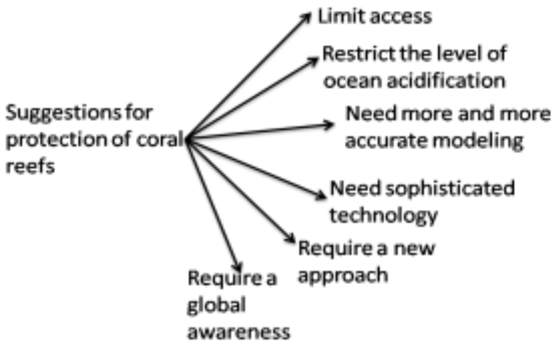
13. We have to develop some regional approaches and we have to reduce the interactions between the fishing gear and deep-sea corals and sponges (*Hans-o.Portner,2008)*.

14. We have to enhance the coordinated communication for public understanding about these ecosystems (*Emily C. Shaw, Ben I. Macneil, Bronte Tilbrook,2007)*.

15. As the mangroves are the sediment trapper so that growth of mangroves enhances the tropical reef building perspectives of coral (*Greg H. Rau,2008)*.

16. WWF has been active to protect coral and coralline resources since 1970s.The incorporation of cold water coral protection worldwide on the agendas of the International Coral Reef Initiative (ICRI) and UNEP's coral reef unit(UNEP 2009, *cited in Archer D. 2005*).

13. SUGGESTIONS FOR PROTECTION OF CORAL REEF:



14.CONCLUSION:

In science ideas and paradigms tend to evolve over time. New ideas and theories have been developed to combat against ocean acidification. But it must be frankly say that nature is our mother and man, may be only the modifier of the environment. But these modifications must be done sustainably. Human must check the carbon-di-oxide emission for their own interest. Otherwise their existence will be in danger. There are millions of people depends on the marine resources i.e. corals. So, if marine resources are lost due to ocean acidification it will affect the economy of the human communities. So, we should aware about the unplanned unresisting industrial pollutant that may cause the ocean acidification. Moreover planned treatment of sewage and industrial effluents are urgently necessary to combat against the ocean acidification and to recover the coral and coralline resources.

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