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Impacts of climate change on marine biodiversity

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Abstract
The Ocean climate change is defined as the changes in the statistics of average seawater temperature, average ocean water salinity, average sea level rise, average sea height, average water pH range etc. was reported changed over the decades, years or even centuries. Due to human activities over land such as the burning of fossil fuels, deforestation, agricultural activities etc. causes an increase in the greenhouse gases in an atmosphere and which ultimately causes human-induced climate change. Due to the increased temperature primary productivity production, the process is affected, which impacted on the recruitment process of the other marine biodiversity, this phenomenon called a match-mismatch theory. The increasing melting of glacial causes an increase in sea level and sea height, this also impacted on ocean water salinity. The increased temperature impacted increased metabolic rates of phytoplankton and if that coupled with eutrophication then it will cause as algal blooms in the ocean. The changing environment also causes the cyclones, which destroys the coastal breeding and feeding grounds of marine biodiversity. The increased level of CO2 in the atmosphere causes more diffusion in ocean water, where it changes the pH of water, the process called ocean acidification. The ocean acidification impacts on marine biota such as corals, molluscs species etc. So it can be concluded that the potential adverse effects of climate change have posed a serious threat not only to marine biodiversity but also for humans. So in future, it is necessary to take proper steps towards minimizing the human-induced climate change activities were required, for this purpose, detailed research and awareness are becoming necessary.

Keywords: Climate change, impact, marine biodiversity, ocean acidification

Introduction
Climate change is projected to cause enormous changes in the marine environment, which are on a scale unprecedented in the last 1,000 years. The causative factors of climate change are greenhouse gases, viz., carbon dioxide, methane, ozone, and Nitrous oxide. The most confident projections on the outcome of climate change are the amount of warming and changes in precipitation. The 20th century is the warmest century in 1,000 years, the 1990s the warmest decade, and 1998 and 2004 the warmest years. The comparatively steady warming in the 20th century increased the mean temperature by 0.6 ^{0}C. However, the projections from global warming models indicate that we may see nearly continuous warming of about 0.5 0C per decade for every decade of this century. Thus, each coming decade may successively add nearly as much warming as the entire 20th century. Considering the enormity of the problem and the need to address the issues connected with climate change and marine fisheries including seafood security and livelihood. Coastal marine systems are among the most ecologically and socio- economically vital on the planet. Marine habitats from the intertidal zone out to the continental shelf break are estimated to provide over US$14trillion worth of ecosystem goods (e.g. food and raw materials) and services (e.g. disturbance regulation and nutrient cycling) per year. Marine habitats from the intertidal zone out to the continental shelf break are estimated to provide over US$14 c. 43% of the global total [1].

Table 1: Range of Predicted Global Mean Temperature and Sea Level Rises For 2015 and 2050

Year	Global Temperature Change	Global Sea Level Rise
2015	0.20 - 0.70° C	0.04 - 0.06 m
2050	0.75 - 2.50° C	0.08 - 0.25 m

(***Source***: FAO, 2007)

2. Impacts on Marine Ecosystems and Biodiversity

Climate change and ocean acidification will increase rapidly due to human intervention on fisheries and marine ecosystems such as, environment degradation, over-fishing, invasive species, excess nutrients, pollution, and thermal effects arise both directly, through effects of high temperature and lower pH on individual organisms, and indirectly through changes to the ecosystems on which they depend and associated for food and habitat. Ocean acidification harmful for Bivalves (clam, mussel, oyster) and other aquatic plant and animal with surface and deep-water corals, marine plankton, pteropods (marine snails), molluscs and crustaceans like copepods, shrimp, crab, lobster, etc [2].Climate change also affects the ocean waters and patterns of ocean productivity. Small, photosynthetic organisms like phytoplankton's and marine plant grow in the well-illuminated upper ocean surface, planktons are playing an important role for the food web and food chain. Phytoplankton growth depends on the temperature, availability of nutrients like nitrogen, phosphorus, iron, and silicon. The oceanic productivity and distribution of phytoplankton's are determined by the circulation of the ocean and upwelling phenomenon, which are highest levels found along the Equator, intemperate, polar latitudes and along the western boundaries of continents. Climate change will likely affect the mixing of nutrients, which are lowering the biological productivity of the ocean and sea.

Phytoplankton declined in the tropics and subtropics during warm phases of the El Nino-Southern Oscillation (ENSO) marked by higher sea surface temperatures and ocean stratification. The abundance and distributions of individual plankton species are very sensitive to increasing sea surface temperature and changed ocean circulation that changed the total productivity. Fisheries ecosystems and fishing-based livelihoods are subject to a range of climate-related variability, from extreme weather events, floods and droughts, through changes in the marine ecosystem, productivity and to changing patterns and abundance of fish stocks [3].In Strong El Nino /Southern Oscillation, events have major impacts on phytoplankton, fisheries, marine mammal's birds and are prominent examples of climatic influences on ocean biology [4]. Rates of oceanic CO2 absorption vary regionally as a function of wind strength and temperature. Colder waters can accommodate more dissolved CO2 than warm waters and are, therefore, more prone to acidification [5]. Increasing oceanic temperature and shifts in seasonal temperature patterns will disrupt the predator-prey relationship, which will affect the survival of juvenile fish, which often hatch at a particular time of year and depend upon an immediate, abundant source of prey. Temperature changes will also alter the spread of diseases and parasites in both natural ecosystems and marine aquaculture. Ocean acidification and climate change will likely affect commercially important species of fisheries as well as tourism [6].

Changes in water temperature and precipitation affect the dynamics of ocean currents, the flow of rivers and the area covered by wetlands. This will have effects on ecosystem structure and function and on the distribution and production of fish stocks. Increased incidence of extreme events such as floods, droughts, and storms will affect the safety and efficiency of fishing operations and increase damage and disruption to coastal and riparian homes, services and infrastructure [3]. The different components of climate change are more likely to affect the various levels of marine biodiversity from organism to biome. At the level of biodiversity, climate change is able to decrease the genetic diversity of populations due to directional selection and rapid migration, which could, in turn, affect ecosystem [7].

3. Impacts on Life Cycle of Marine Organisms

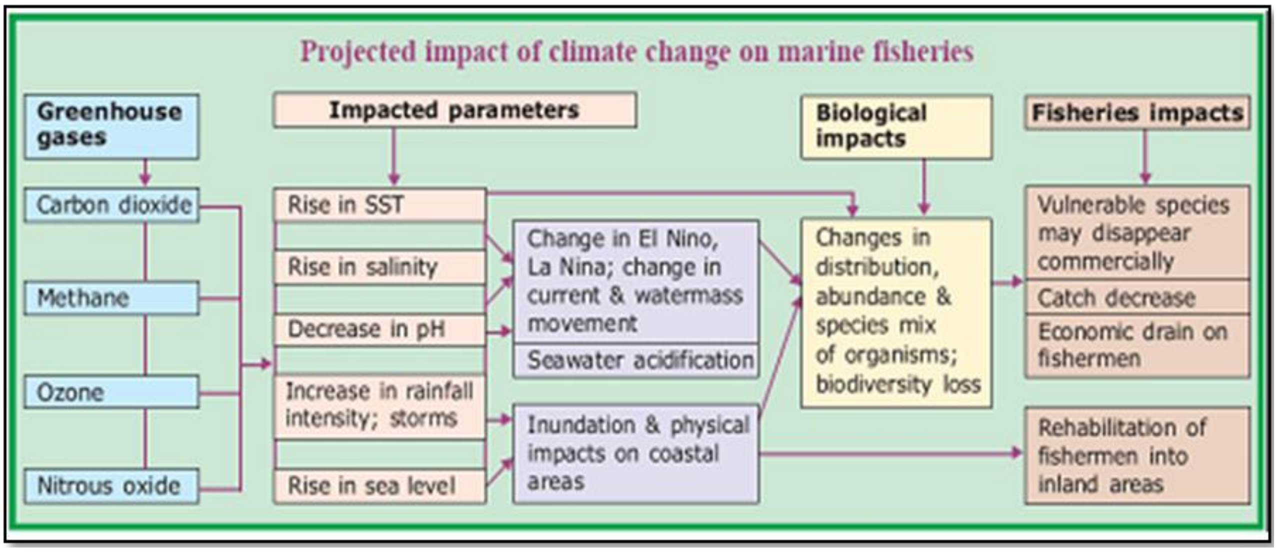
Marine organisms, which are found along the near coastal areas, will be impacted by degradation of near-shore nursery environments, such as mangrove forest, coral reef, sea grass, mud flats, marshes and estuaries, brackish water due to continuous rising sea-level, pollution and habitat destruction. Rainfall and river flow perturbations will change coastal freshwater currents, which will affect the transport of eggs and larvae of marine organisms. Some of the largest fisheries around the world, for example off Peru and the west coast of Africa, occur because of wind-driven coastal upwelling, which is susceptible to climate change. Increasing sea surface temperature will reduce gas solubility and thus increases the possibility of low oxygen or anoxia events already seen in some estuaries and coastal regions, such as off the Mississippi River in the Gulf of Mexico [6].

Migration of marine fishes, marine mammals, and seabirds all face very high risks due to continuous rising sea surface temperatures that causes high levels of mortalities, loss of breeding grounds and mass movements as species search for favourable environmental conditions [8]. Warming temperature is a factor which affects the marine organisms, survival, growth, hatching, and metabolic activity of embryo, and inducing oxidative stress on eggs of a keystone invertebrate, the squid *Loligo vulgaris* [9]. Pelagic and marine intertidal organisms also show complicated physiological responses to temperature stress, with likely negative effects on growth and maturity that lead to changes in population dynamics and ecosystem processes [10]. Metabolic activity in fish increases by 10% for every 1 ^{0}C increase in the temperature of the aquatic environment, i.e. fish need 10% more oxygen for every 1 ^{0}C rise in temperature [11].

4. Impacts on Indian Marine Fisheries

According to CMFRI 2006, the distribution of the oil sardine *Sardinella longiceps*, for instance, has responded markedly to increase in sea temperature. With the northern latitudes becoming warmer, the oil sardine, which is essentially a tropical species, is able to establish itself in the new territories and contribute to the fisheries along the northwest and northeast coasts of India. Some pelagic species such as the Indian mackerel *Rastrelliger Kanagurta* show shift in the depth of distribution and are now caught by bottom trawlers. Demersal species such as threadfin bream *Nemipterus japonicus* appear to shift the month of peak spawning toward colder months off Chennai. There are also indications, which show that copepod abundance is shifting toward colder months off Mangalore. These findings indicate that the adaptable species may be able to adjust to the immediate challenge of a rise in temperature for a shorter or longer duration. On the other hand, the vulnerable groups such as the corals are in peril. The distribution and migration of oceanic tunas, which are influenced by the thermocline, may be strongly influenced. The sex of sea turtles is critically determined by the soil temperature at which the embryo develops. Temperature above 28 0C produces only females. It is much more difficult to project how populations will behave under radically different conditions. Under these conditions, fisheries stock assessment, already difficult, may prove impossible. Fisheries management will likely become far more contentious because the abundance of fish populations and the composition of communities will change in unexpected ways [12].

Climate change increasing problem for the marine fishes some of the tropical fish species face regional extinction problems. Some of the other species may migrate towards higher latitudes. Coastal areas are more likely to be impacted through the through increasing sea surface temperature, sea level rise, extremes of nutrient enrichment (eutrophication) and invasive species. Most fish species have a narrow range of optimum temperatures for their growth, development for their basic metabolism and availability of food organisms. Even a variation of 1^0C temperature in seawater may affect their diversity, distribution and life cycle of marine species [13].



(***Source***: E. Vivekanandan, CMFRI, 2006)

Fig 1: Impact of Climate Change on Marine Fisheries

5. Changes in Species Composition and Community Structure

Climate change and ocean acidification cause pollution and environment degradation that reducing the diversity and abundance of various types of marine organisms and increasing the likelihood of local (and in some cases global) extinction. Although we know now present-day extinction of marine organisms is linked to pollution and climate change, extinction risk is now extremely high for some species such as the Mediterranean Mysid *Hemimysis speluncola* [14]. Even if species composition is not altered by climate change, the strength or sign of interspecific interactions might change. Because species respond individualistically to climate change [15]. Marine organisms may likely affect due to climate change that effects on distribution and abundance of marine species, changes in growth, survival, reproduction, or responses to changes at other trophic levels. The climate changes may have impacts on the environment and value of commercial and economical fisheries. Species-specific responses are likely to differ according to rates of population turnover [16]. Moderate increases in temperature increase metabolic activity, which eventually determine life history traits, population growth, and ecosystem processes. Organisms are able to adopt at a specific optimal temperature. Beyond this range, however, adaptation fails, the chance of mortality increases, growth & developments reduced, and populations decline or are driven to local extinction. Variation in temperature can also have impacts on key biological processes [17].

More research is needed into impacts of climate change at the levels of individual species and local fisheries and fishing communities, and investment is needed in the development of policies that will help reduce vulnerabilities and encourage people to take the actions needed to adapt to changed circumstances. People also need to be empowered to take those actions through increased access to appropriate financial services and opportunities for training [18].

6. Altered Pathways of Species Introductions

As per the research, the climate warms, the geographic areas with suitable temperatures for warm water aquaculture, tropical fish culture, and outdoor water gardens will expand. For example, optimal temperatures for aquaculture of catfish are projected to move 240 km northward in the south-eastern United States for every 1 0C increase in mean annual air temperature [19]. Although most studies of range expansion involve warm water species, climate warming could allow the expansion of invasive species into new areas. For example, native bull trout *Salvelinus confluentus* appear to have a competitive advantage over non-native brook trout *Salvelinus fontinalis* in the coldest streams in the Rocky Mountains. As these streams warm, brook trout are expected to achieve competitive superiority and thus displace native bull trout from one of their last remaining refuges from invasive species [20].

7. Coral Reef Bleaching

Coral reefs are among the most diverse and economically important ecosystems on Earth. They are threatened by a range of climate changes, due to increasing sea surface temperatures and raises sea levels as well as acidification of marine environment. Climate changes and increasing sea surface temperatures are results in coral bleaching. Warm temperature is not good for coral growth. Due to warm water, corals will expel the algae (zooxanthellae) living in their tissues causing the coral to turn completely white this is called coral bleaching (Fig.2).

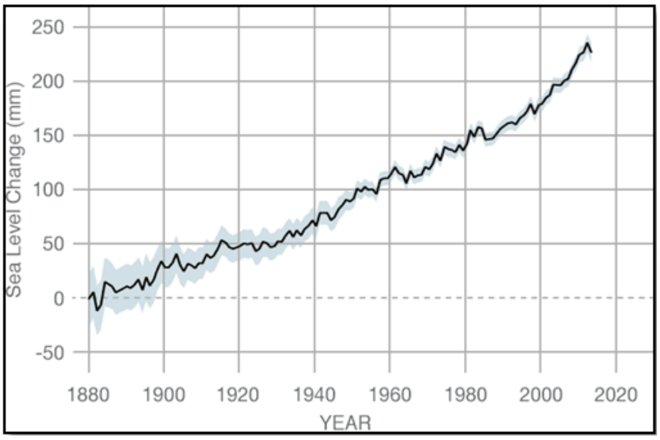
Fig 2: Bleached coral reef

It is set up that wide-ranging of coral bleaching occurred in Andaman & Nicobar, Gulf of Mannar and Lakshadweep Seas etc. when the Sea surface temperature was 31 ^{0}C or more in 1998 and 2002. The amount of bleaching was directly related to the number of days the higher temperature prevailed. When a coral bleaches, it is not dead. Corals can survive a bleaching event, but they are under more stress and are subject to mortality [21]. In the Indian water, coral reefs are found in the Gulf of Kutch, Gulf of Mannar, Palk Bay, Andaman Sea, and Lakshadweep Sea. By using the relationship between past temperatures and bleaching events, and the predicted SST for another 100 years, predicted that reefs should soon start to decline in terms of coral cover and appearance [22]. Coral bleaching because of the interacting negative effects of high temperature and light, bleaching has most commonly been associated with high irradiance environments experiencing unusually warm conditions (typically 1.0–1.5 ^{0}C above seasonal maximum mean temperatures) [23]. Reef-building corals and other numerous species of reef-dwelling cnidarians, molluscs, protists, polychaetes, and other taxa, are hosts to dinoflagellate symbionts in the genus symbiodinium. These symbionts commonly referred to as ‘‘zooxanthellae’’, are generally obligate for their hosts, contributing to their host’s energetic budgets through the provision of photosynthesis, as well as accelerating calcification in many skeleton-forming taxa [24]. Waters of the Great Barrier Reef are expected to warm by between 1 and 30C over the next 100 years, so the risk of high-temperature press events that could be fatal to corals is increasing [25]. Already, in the different region around the world such as the Palau, Seychelles, and Maldives, coral bleaching has effectively destroyed over 50% of reefs. Corals supply the ecological foundations that underpin enormous biodiversity and productivity and provide food and income to hundreds of millions of people throughout the tropical world [26].

7.1 Ecological Causes of Coral Bleaching
As coral reef bleaching is a general response to stress, it can be induced by different factors, alone or in combination. It is therefore difficult to unequivocally identify the causes for bleaching events. The following stressors have been implicated in coral reef bleaching events.

7.1.1 Temperature
Coral species live within a comparatively narrow temperature margin and anomalously low and high sea temperatures can induce coral bleaching. Bleaching events occur during sudden temperature drops accompanying intense upwelling episodes, (3^{0}C to 5^{0}C for 5-10 days), seasonal cold-air outbreaks. Bleaching is much more frequently reported from high seawater temperature. A small positive anomaly of 1-2 ^{0}C for 5-10 weeks during the summer season will usually induce bleaching solar ultraviolet radiation is potentially harmful to reef corals and their symbiotic. UV radiation can willingly go in clear seawater, and reef-building corals contain UV-absorbing compounds capable of blocking potentially damaging UV radiation. There is a possible interaction between temperature and UV, with a temperature significantly reducing zooxanthellae densities and also the concentration of UV absorbing compounds in a reef zooanthid, thus potentially increasing the exposure of the symbionts to the direct effects of UV radiation [27].

7.1.2 Increased Sea Levels
Increasing concentrations of greenhouse gases in Earth's atmosphere that increase the air as well as water temperature, which causes sea level to rise in two ways. First, warmer water expands, and this "thermal expansion" of the ocean has contributed about half of the 2.8 inches (7 cm) of global mean sea level rise. Second, melting land ice (Fig.3, 4) flows into the ocean, also increasing sea level across the globe. Global temperature influences water and ice volumes and, hence, sea level melting ice increase the depth of the ocean, affecting species like coral that rely on shallow water for photosynthesis. When sea levels rise rapidly, as they have been doing, even a small increase can have devastating effects on coastal habitats and cause destructive erosion, wetland flooding, agricultural soil contamination, and lost habitat for fish, birds, and plants. Cora reefs which are found near low-lying coastal areas, sea-level rise is possible to raise coastal erosion rates. This would deteriorate water quality due to reducing light penetration necessary for photosynthesis by zooxanthellae and increasing sedimentation that smothers and stresses coral animals [28]. Worldwide losses of 33 percent in coastal wetland areas are projected given a 36 cm rise in sea level from 2000 to 2080. The largest losses are likely to be on the Atlantic and Gulf of Mexico coasts of the Americas, the Mediterranean, the Baltic, and small island region [29]. Hawaiian monk seal, which inhabits islands for breeding and nursing their pups, have already lost 50 percent of their beaches due to rising sea levels [30]. While mitigation issues are valuable, the challenge of adaptation is both significant and potentially urgent. Policy support for adaptation involves supporting measures to reduce exposure of fishing people to climate-related risks, reducing the dependence of peoples’ livelihoods on climate-sensitive resources, and supporting people’s capacity to anticipate and cope with climate-related changes. The inherent inertia of the atmosphere and of our attempts to mitigate CO_2 emissions suggest that reef managers and coastal resource policies must first reduce the influence of local stressors such as declining water quality, coastal pollution, and over-exploitation of life functional groups such as herbivores. There may be opportunities for using coral restoration to reduce the risk that reefs will shift into a non-coral-dominated state, however, the efficacy of coral restoration methods to increase moistly and coral cover remains unclear, and further evaluation of methods is badly needed.



(***Source***: https://climate.nasa.gov/system/charts)

Fig 3: Sea level rises

Fig 4: Melting glacier

Table 2: Effects of Increased Atmospheric CO_2 on Coral Reefs (Source: Kennedy, 2002)

CO_2-related change	Mechanism	Effect on Coral Reefs
Seawater chemistry	Dissolution of CO_2 results in lowering of pH, lowering carbonate ion [CO_3^{2-}] concentrations	Reduced availability of carbonate ion [CO_3^{2-} causes reduction in calcification rates in reef building corals and algae.
Sea water temperature	Greenhouse effect increases to higher sea-surface temperatures.	Increase in annual maximum sea-surface temperature of 1–2°C causes coral bleaching.
Sea level	Global warming leads to melting of ice caps and glaciers, and thermal expansion of oceans, causing sea levels to rise.	Effects largely unknown; some reefs may benefit; others may suffer if coastal flooding causes an increase in nutrient or sediment inputs.
Storm frequency	Some climate models indicate an increase in storm frequency or intensity, or both, and a change in storm tracks	Effects largely unknown; some species may decline while others may benefit.
Dust deposition	Increased delivery of dust-borne iron may enhance phytoplankton and macro algal growth, transport of *Aspergillus* spp. fungus and possibly other pathogens.	Increased phytoplankton production decreases light penetration. Macro algae compete with corals and calcifying algae for space.

8. Conservation of Indian Coral Reefs

Conservation of Indian coral reefs is enforced under the Wild Life (Protection) Act (WLPA) 1972, Marine Fishing Regulation Act (MFRA) 1983, 2000 and the Coastal Regulation Zone (CRZ) Notification, 2011; under which coral reefs of India are protected by law. There are total 31 Marine Protected Areas (MPAs) in India among them five coral reef regions have been surveyed and identified for protection [31] 11 recommended halting all human intervention and malpractices that are responsible for mechanical damage and removal of corals and bringing numerous marine organisms except for scientific research. The resilience of coral reef ecosystems. Govt. of India, research institutes, universities, and non-government organizations (NGO). Implementation of robust laws, appropriate management approaches, pursue of conservation strategies, and sustainable exploitation of biological resources, modern technology, expert marine biologists and indispensable further scientific research are crucial in fulfilling this goal [32].

9. Conclusion

The major cause of global climate change is human-induced activities, therefore it becomes necessary to control this awareness among us it becomes a priority. Climate change is already affecting marine biodiversity, both through its own effects on marine ecosystems and through synergistic interactions with existing stressors, such as habitat destruction, overfishing, and marine pollution. These climate change impacts should become an important driver of improvements in ocean governance for coastal nations as part of an overall national climate adaptation strategy, spurring coastal nations to better protect their marine resources and the ecosystem services they provide, to reduce existing stressors to marine biodiversity, and to anticipate the future alterations that climate change will bring. Climate change is affecting biodiversity, altering the seasonality of natural events, the size, and ranges of populations, the composition of communities, and the functioning of ecosystems. Managing biodiversity will become far more contentious because the fauna and flora will change in unexpected ways. The ability to preserve marine biodiversity will rest on a mechanistic understanding of the interactions between global change events and localized disturbances. We need adaptation strategies to conserve biodiversity during climate change. However, to develop and implement such strategies we must address key areas of uncertainty with respect to the response of biodiversity to climate change. Critical requirements to be able to predict future trends include the need to study a much larger part of biodiversity, to overcome several major model limitations, to account for co- extinctions and other major drivers of biodiversity loss and to validate models by comparing projections with observations.

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