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Warming Oceans, Rising Seas, Declining Fisheries: The Far -Reaching Impact Of Climate Change

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Abstract –

In the Cenozoic era, the one in which we are living in climate change is accelerating at a devasting speed and effecting almost every part of our biodiversity in one of the two ways. But the one that is alarming is global warming leading to warming of the oceans, melting of ice caps causing the ocean and sea rising. These changes disturbs the ecosystem present and also tremendously hazards to fishery industries throughout the world. Since the fisheries are directly affected by any change in the oceans or seas, climate change play a crucial role in fisheries and the livelihood of people having aquaculture. This paper seeks to dive through the theoretical and functional implications within the broad area of climate change with main emphasis on its influence on fisheries through effects on the acidification of oceans, changes in oxygen level, extreme weather events and analysis of temperature increase. Primary focus includes; changes in fish movement patterns, dwindling fish populations, and the disturbance of the food chain in the marine ecosystems, economic dependence on fisheries. Furthermore, the paper aims to understand and explore the after effects of increased sea level and ocean acidification , and how it worsen fisheries management and the pursuit of sustainability. It also explains measures that may include sustainable fishing, ecosystem approach to fisheries management, and international instruments are as major strategies as ways of coping with climate change in an effort to save world's fisheries. This research clarified those findings from the current data, case studies, researches done and underlined the need for international cooperation in combating climate change and the decline of fisheries.

KEYWORDS- global warming , ocean acidification , fisheries , sea rise , warming oceans, ice caps melts, mitigation, carbon sequestration**.**

1. INTRODUCTION –

Climate change is no more a future scenario that can be avoided; it is today's harsh reality that needs more attention. Though the effects of climate change can be seen on each organism at different stages of their life. The major setback that climate change is giving is the disturbance in our atmosphere which can be seen in the form of ocean warming, rising of sea levels and decline of fishes.

Taking note on the impact of climate change on fisheries is important because human depends on it extensively whether it is for the food, livelihood, cultural belief or global trade and economy. The role of fisheries is wide but the reason of its decline is connected with ocean warming and sea rising as it is their habitat. Any disturbance in their habitat has direct and indirect effect on the fish stocks. Direct effect can be seen on physiology, behavior.

It may seem that the rate of climate change is very slow but it is going very rapid in comparison with the previous natural changes. Warming of ecosystem is unequivocal. Its impact can be seen through changing temperature, regular and more frequent heat strokes during summer, floods, droughts, out of season rainfall and many more.

2. OCEAN WARMING

The oceans play a critical role in reducing global greenhouse gas emissions. It serves as a main component in mitigating climate change. Ocean ecosystem is vital for absorbing and storing carbon dioxide. Since oceans are the planets greatest carbon sink, it absorbs excess heat and energy released from emissions of GHGs which are trapped in our atmosphere. According to UN Climate Change Data Ocean has absorbed almost 90% of the heat generated without raising the temperature. It is also possible because oceans cover about 70% of the Earth's surface. This ability allows oceans to store and release heat over a long time. In addition clouds, water vapors and GHGs release the heat they have absorbed, with part of this heat transferring to the ocean bodies. Oceanic processes such as waves, tides, currents continuously mix the water and redistribute the heat from warm region to cooler region as well as deeper layers of ocean.

Though heat absorbed by the oceans keep being redistributed by the process of "Ocean Circulation" across the globe, also influencing the local climates. The major part of this is done by the Meridional overturning circulation (MOC). It carries the excess heat from the tropics to the middle and high latitudes. Though the heat is redistributed it doesn't disappear and eventually it re-enters the atmosphere by processes such as melting of ice caps, evaporation of water, or directly heating the atmosphere. It can be concluded that heat energy stored in the oceans can warm the planet for a decade or less. The increase in sea surface temperatures has already surpassed the typical range of natural seasonal fluctuation in sub tropical and the Arctic (Henson et al., 2017).

Traditionally, for measuring the ocean temperatures research scientists used ships lowering sensors or collectors into the oceans, which was a tedious and covered a very small portion of vast ocean. For being able to cover wide area scientists started using satellites that estimates ocean temperature by measuring the ocean surface heights, since water expands when it warms. At some point there was a need to dive deeper into oceans, in-situ instruments were used there. One of those was "AGRO FLOATS" a robotic which measures the temperature for oceans all over the globe. These floats drifts at different depths and rise to surface roughly every 10 day, recording temperature and salinity data, which they to scientist via satellite before descending again.

In the fresh water bodies, an increase in the temperature of the water can be seen, due to the increase in the temperature of the atmosphere. It can also be said that the temperature of water is highly affected by the variation in the atmosphere temperature. There are strong evidences that increasing water temperatures will cause shifts in the distribution of freshwater species and worsen existing water quality implications, mostly in ecosystem with high level of anthropogenic nutrient pollution.

2.1- **Impacts on Marine Ecosystem**

a) Coral Bleaching- The coral reefs are highly sensitive to the temperature variations in the ocean and can cause significant stress to coral species resulting in corals losing their vibrant color and turning white. This is known as coral bleaching. Corals are bright in color because of the microscopic algae (zooxanthellae). These algae lives within the coral in a symbiotic relationship, benefitting and helping each other survive. However if the ocean water gets too hot the coral expels the algae. Since the algae was the reason for corals color, with its depart corals loses its color and appears bleached. If the elevated temperature persists, corals will not be able to reabsorb the algae, which will ultimately lead to the corals death. This is concern worthy because once these corals die they rarely come back and with the very less species, they also struggle to reproduce. It should be noted that coral bleaching is not an isolated

phenomenon given that coral reefs supports most biodiversified ecosystems. Huge number of species rely on the for survival for example sea birds, fish, sea turtles, shrimps, starfish since they provide shelter, spawning grounds and protection. If we study more deeply we will find that corals not only supports the marine ecosystems but also human's livelihoods, food security and safety. Coral reefs works as natural barriers by absorbing the force of waves and storm surges, keeping coastal communities safe. If they go extinct we have to rely on manmade seawalls which are expensive, less environment friendly and even less effective. On the other side coral reefs tourisms brings in lots of money that supports thousands of job. Hence it is really necessary that we all take actions to conserve the by using less fertilizers, herbicides and pesticides.

b) Food Web Disturbance- Any ecosystems functioning is maintained by the flow of energy from bottom (primary producers) to the top (tertiary / top consumers) also the flow of nutrients through the same pathway. Disrupt or any variation in such habitats can alter energy flows to a smaller number of species , weakening resilience by discarding alternative feeding options in the food web. This can result in shifts in tropic network and even cause their destruction. These issues can impact many other disturbance such as habitat loss, overexploitation of species and invasive species. Warmer waters can cause some of the species to migrate to cooler waters, resulting in mismatch of predator and prey. The migration of fish populations directly impact global fisheries, making some species less accessible while others being overexploited. Though food web can be reconstructed but such alterations in the relation between the species from top to the bottom of the food pyramid can lead to changes in energy flow and shifts in biomass of the important species ultimately causing biodiversity loss.

c) Change in species habitat and behavior – Ocean warming and acidification are already impacting various dynamics that includes their physiology, behavior, life cycle, population dynamics and distributions. The elevated temperature increases the fish metabolism and respiratory demands, decreasing their ability to perform necessary activities such feeding, growth, reproduction and escaping the predators. Ocean warming also disrupts the timeline of breeding and spawning since the reproductive cycles of marine species are temperature dependent. Warmer temperatures also affect the availability of prey during critical feeding periods. It is also seen responsible for the spread of coral diseases contributing to reef degradation, increasing the vulnerability of fish species to parasites and infections. On the other side increase in the CO2 concentrations in the ocean declines the pH making it more acidic which leads to increase in the energy required for the process of calcification and acid – base regulation also disrupting the neural functions.

3. RISING SEA LEVELS

3.1 -Mechanism of the rising sea levels –

The rise in sea levels are primarily influenced by two main processes: the thermal expansion of sea water due to overheating and the melting of ice caps and glaciers. These process are mainly driven by the global warming, which is caused by the anthropogenic activities, and release of GHGs. Seawater tends to expand when it absorbs heat, this process is known as thermal expansion. Oceans acts as heat sinks and are known to have absorbed nearly 90% of the excess heat produced by all the human activities. The increased greenhouse gases trap more heat causing to even more increase of temperature. As the water wars it tends to expand, increasing the volume of water. It may seem that increase in temperature is quite small then how does it result it expanding volume, but the vast area of sea and ocean amplifies this effect, leading to a observable change. According to the data given by **Intergovernmental Panel on Climate Change (IPCC),** thermal expansion accounted to about 50% of the observed global sea level rise between 1971 to 2010.

The second key factor for the rising sea level is the melting of icecaps, land based glaciers. If we see the possibility – melting of the whole *The Greenland Ice Sheet* could raise the sea levels by approximately 7 meters whereas *The Antarctic Ice Sheet* the largest on the planet was to melt completely it could raise sea levels by 58 meters. The *Western Antarctic Ice Sheet* is mostly seen to be vulnerable and has been melting at an increasing rate. The period 1992 to 2017, Antarctica contributed to approximately 0.25 millimeters per year to sea level rise. Moreover, glaciers in the region of The Himalayas, Andes and Alps are also diminishing due to warming temperature. Whereas each and every glacier separately accounts a small amount of water and collectively they add considerable volume to the oceans.

If we study the melting of polar ice caps due to global warming, we will observe that it is additional freshwater into oceans. Though unlike ice sheets and glaciers these doesn't directly cause sea level rise when it melts, since it already distributes its volumes in the ocean. However , the loss of the reflective ice cover results in the feedback mechanism known as the albedo effect, where less amount of sunlight is reflected back into space and much more is absorbed by darker oceans, accelerating global warming and subsequently sea level rise.

Some of the human activities like extraction of groundwater and construction of dams also affect sea levels. Just like when groundwater is pumped out for agriculture or other industrial uses, it eventually flows back to the oceans contributing to the sea level rise. Shifts in the ocean currents, like weakening of the Gulf Stream, is responsible for the redistribution of water which can eventually lead to local sea level fluctuations.

3.2-Impact on the coastal ecosystems- The rise in the sea level and climate change are causing any degradation to coastal ecosystem for example mangroves, salt marshes and wetlands. These ecosystems are of high importance for biodiversity, protections from storms, flooding and also carbon storage. Their nature of resilience is being overexploited. Lets discuss these in a bit detail:

a) Mangroves forests are located mostly around tropics and sub tropical coastlines, and act as a major buffer between land and sea. They help in reducing the impact of storms, erosion, and serves as nurseries for numerous of marine species. Despite their resilience mangroves are primarily vulnerable to rapid sea level, human activities and changes in sediment supply. Due to increase in sea level the risk of flooding in the mangrove keeps growing and the flooding leads to water logging decrease in oxygen for the roots. The mangrove ecosystem depends majorly on the tidal movement because it helps in the nutrient exchange and also in keeping the soil steady. Since mangrove naturally have the ability to move to inland they can cope up with the rising sea levels till a point, but even that are being disturbed by the man-made structures like cities, farmland and infrastructures which confine their reach to higher grounds. This phenomenon is called “coastal squeeze”. This results in the mangroves being more in danger from the impacts of sea level rise, by being trapped between these barriers and rising seas. The growing risk of their loss can cost huge because they not only provide shelter and food to the marine species but also play a major role in *carbon sequestration* as they absorb and store notable amount of carbon in their biomass and soil, therefore contributing to the climate regulation.

b) Salt Marshes are known as the coastal wetlands that are frequently flooded by saltwater of the tides. They are commonly found in the intertidal zone, zone where land meets the ocean or estuaries. They have known to have salt tolerant plants which contribute in stabilization of soil. They also act as natural buffers, by reducing the storm surges, and coastal erosion. They can also filter pollutants, before it reaches the ocean, which tends to maintain the water quality. Along with all these crucial roles they also serve as the breeding ground for various fish, bird and invertebrates. Salt marshes rely on sediment deposition to maintain their elevation in comparison to the sea level. They need to accumulate more sediment to keep up with the rising however the dam constructions have reduced the availability of sediments, making the salt marshes even more vulnerable. The rising sea levels are drastically affecting these marshes as they face prolonged flooding, which prevent the adequate amount of sunlight and oxygen to reach these vegetation that can ultimately lead to their death and eventually the habitat degradation.

c) Coastal wetlands such as tidal flats, swamps, estuaries are crucial ecosystems that have high productivity and nurture wide range of species. They help in regulating the water quality, absorbing floodwaters also crucial for stopover points in the bird’s migration. They are mostly found in low lying areas along the coastline which makes then highly vulnerable to the rising sea levels. Due to water level rise in this area, land gets eroded and gradually washes away the lands this erosion reduces the area available for the wetland vegetation to grow and nourish. Due to lack of time given for the wetlands to Naturally adapt or change themselves, large area of these ecosystem get lost all together. This loss is not only the loss of a vegetation or land but also a crucial loss of Habitat for wildlife. The rise of sea level also cause the salt water from the ocean pushed further inland causing it to mix with the freshwater wetlands this process is also called the salt water intrusion which cause the changes in the salinity of this habitat. These changes in salinity of Habitat lead to species decline because they can't survive in hyper saline conditions. Usually wetland are known to move inland to escape the rising waters however in many areas this phenomenon is blocked by human development which include Road , Dam buildings agriculture land or by unsuitable Terrain like steep slopes.

3.3-Human vulnerability to the rise –

The rising sea levels are primary driven by the global warming climate change which is increasingly threatening the coastal areas across the globe. These communities are the most vulnerable because of their proximity to the show lines where the impact of elevation of sea is most noticeable. The socio economic repercussions of the rising sea level include displacement infrastructure damage and the increased frequency of coastal flooding. These effects are multi visited influencing not only the physical area but also including the social economic and cultural life of the people taking a shelter building their home in the coastal reason.

a)Displacement of coastal communities- One of the most significant outcome of the rising sea level on the humans are the force displacement of the people living in the low lying coastal areas as the sea level accelerate. The coastal erosion saltwater intrusion and compromises the availability of freshwater supplies making the area much more in habitable. These host migration causing the people to increasingly displace from the low line coastal area makes them climate refugees. As the displacement not only disrupt lives and livelihoods of the people and forcing them to leave their homes properties and the community is behind where also their might be a strain due to high population density.

The data from the United Nations estimates that by 2015 approximately 150 to 300 million people might be displace because of the rising sea levels and other related climate factors. The data also shows that countries such as Bangladesh, Philippines and Vietnam at high risk. In addition to the physical relocation there are social and cultural costs that are also related with displacement. Coastal communities often have great cultural ties with their land since it may hold historical and ancestral importance. Displacement not only causes these connections to severe but also leads to the loss of their tradition and their way of living. There are some indigenous and fishing communities whose culture and capital of living is highly affected due to this cultural dislocation.

b) Infrastructure damage- The threat poses by the rising of seas to the infrastructure including home, transportations, public services utilities in coastal areas are increasing. The densely populated coastal cities having large investment in their infrastructure also face huge economic damage resulting from the sea level rise. The most common damage due to sea level rise, storm surges is the damage of coastal homes and properties which affect many communities because housing is there primary asset which they have invested in with their earnings. The loss of homes can be devastating for financial as well as emotional aspect. These types of damages are so severe that it can take long time to recover which can lead to long term economic hardship. Beyond this the critical threat of damages being done to the transportation infrastructure including roads, bridges, railways, airports near the coastline is always at the peak for example many world major economical and happening cities like New York Tokyo Mumbai are settle near the coast areas having extensive infrastructure. Disruption or any damage to the transportation network can put threat on the public living there as well as the trade commuting and emergency response services. If we study some of the secondary impact we will find that public services and utilities are sometimes affected due to coastal flooding which threatens the services like water treatment facilities system and power plant which leads to water born diseases power out pages and interruption in the basic sanitation.

All these damages and disruption eventually have to be repaired which puts on additional financial burden for repairing and relocating this massive infrastructure. According to the data given by the World bank climate change related damages in the coastal cities cost more than one trillion dollar annually by 2015 if no further action is taken to reduce its effect. The economic stress is even greater for the countries which are still in their developing phase because they have limited financial resources to build climate resilient infrastructure or to relocate the affected population.

c) Increased coastal flooding- The first thing that comes to our mind if we say rising in sea level is the increased frequency and intensity of costal flooding because even a small rise in sea level can increase their risk of flooding especially during the high tides and storm. The storms can cause flooding in the low lying coastal area which is being more frequent and severe day by day due to the climate changes. Beyond this sunny day or nuisance flooding is being more common day by day these type of flooding are said to occur when high tides sea water on to the coastal areas and into their homes without a presence of storm. These events are seen to be already happening in cities like Miami and Charles stone where the sea water frequently floods the street during high tides. The increase frequency of coastal flooding enhances a direct risk to human life as well as people living on those flood prown areas. Moreover it also impacts the livelihood like tourism and Agriculture the coastal cities are of great. Tourism is of importance because it attracts tourist from all over the world so the frequent flooding cause a substantial economical loss. If we look from the prospective a food security and international sea food market these flooding drastically effect the fisheries production and stocks.

d) Unequal risk among socio-economic classes - Studying the socio and economic part of rising sea level we will find that the distribution is not equal vulnerable people including low income community indigenous people that are living in the developing countries often beard the most of these impacts. Since poorer communities have less resources for recovery and adaptation to flood insurance emergency Savings and their ability to relocate they face major fall back. Where as if we look to the developed country having wealthier economy we will see that they have resources to build he was restore natural barriers like wetlands vulnerable population. The lack of financial and institutional capacity to adapt to the climate changes worsen the vulnerability of these community making them more susceptible to the long term effects of sea level rise.

4. DECLINING FISHERIES-

The elevated sea and ocean temperature caused due to the climate change has intense impact on Marine ecosystem majorly in the behavior and the biology of fish species. As the temperature in the ocean keeps elevating fish migration, pattern, breeding cycle and nutrient availability are being significantly change which show the wide spread ecological and economic consequences.

4.1-Alternation in fish migration pattern- This receives is known to be highly sensitive to any changes in the water temperature which tends to affect their metabolism growth rate and habited preferences. Since there is temperature elevation in the ocean the fish species are increasingly migrating to the cooler wafers majorly towards the poles or dipper into the ocean. Fish species are traditionally known to inhabit in temperate water moving toward higher altitude

for example if we look Atlantic cod and haddock which were one abundant in mid-latitude waters are now migrating further North in search of cooler temperature. This behavior might seem normal but the migration disturbs the local ecosystems where predator prey relationship becomes unbalanced. This imbalance can lead to shifts on the new fishing ground while depleting traditional fisheries in their ancestral reason. Some of the species of fish that used to reside in deep water are now moving to Greater deaf due to the rising surface temperature of the oceans. These migrations tend to alter the structure of marine food web as the Predator may not be able to follow their prey to such depths.

4.2- Disruption of breeding cycles- Fishes being a water dependent species have their reproductive cycle linked with the changes in the water. It is seen that any minor fluctuation in the temperature of the water has significant effect on the reproductive cycle of the marine species. Even though many fish species are adapted to breed at a specific temperature range any changes can disturbed these perfectly tuned cycles. In species such as Salmon, temperature changes influence the spawning migration timing. It has been seen that warmer water can cause early spawning which can lead to the mismatch between the time young fish hatch and the availability of food resources like plankton for them. This phenomenon is known as phenological mismatch and it can reduce the survival rate of young fishes drastically. In some species like sea turtle the sex of the offspring is determined by the temperature during the incubation of the egg. It is seen that the warmer temperature leads to the production of more female which can deform the dynamics of population overtime and lead to future reproductive problems. Beyond that elevated temperature can reduce the reproductive success of some species by directly preventing the development of eggs and larva in the extreme cases prolong exposure to high temperature can lead to increase in the mortality rate among both adult fish as well as the offspring.

4.3-Nutrient Availability- The availability of nutrients is directly affected by the ocean warming which and turn affects the productivity of marine food web. The availability of nutrient is mostly connected to the ocean circulation pattern and upwelling of nutrient rich water from the ocean death. The Meridian Ocean circulation plays a major role as the surface water warms the mixing of ocean layer naturally becomes less efficient which tends to reduce the upwelling of nutrient that supports primary producer like phytoplankton and many more. Species like phytoplankton zooplankton are mainly present at the base of most marine food webs and on the nutrients upwelling in the ocean. Decline in the nutrient availability can lead to lower phytoplankton productivity which casket through the food chain reducing the population of zoo plankton and then small fishes and ultimately the large creators like shark, whale and human. In addiction to this ocean water warming and known to increase the stratification in the ocean which can be explained as there is less mixing between surface and deep water. This also prevents nutrient from reaching the surface where they are needed by most of the species such as phytoplankton for photosynthesis. The decline in the nutrients reaching the surface can lead to the overall decline in the productivity of marine ecosystem particularly in areas like Pacific Ocean where the upwelling of nutrients is very important for supporting the quality level fisheries. It can be said that the changes in nutrient distribution not only affect the productivity of ecosystem but also the quality and availability of which stock in commercial fishing.

4.4- Overfishing and Its Ecological Consequences- Overfishing is said to occur when the harvest a fish occurs at a faster rate than they can naturally reproduce leading to the decline in their population. This has been happening for over a while now many valuable species such as Atlantic cord, blue fin tuna have been overly exploited to the point of collapse. Overfishing has become a major environmental and ecological challenge globally which leads to significant decline in the population of fish species, disrupting the marine ecosystem, and also causing threat to the food security and livelihood of the people taken fishing as an occupation. Cascading effect of fishing which is being done excessively can be seen on the depletion of target species as well as sum of the non target species as their habitat and the marine ecosystem balance is lost. There is an urgent need of adopting sustainable fishing practices because of the crucial situation of continuous exploitation of marine resources at an unsustainable level of risk which is causing irreversible damage to Ocean biodiversity and livelihood of millions of people who depend on fishing. According to the data given by United Nations food and agriculture organization (FAO), as of 2022 approximately 34.2% of the world's fish talk were being fished at biologically non sustainable levels. This level of over exploitation disrupts the balance of the marine ecosystem as it tends to the removal of key species which can have a cascading effect on the food web. If we take example we will see that the overfishing of top predator species like shark or large tuna leads to increase in the population of their prey, which includes smaller fishes invertebrates that can then overgraze on alga or other organism that maintain habitat health. This is a phenomenon which is known as “tropic cascade” it is known to destabilize the entire marine ecosystem affecting biodiversity and the ecosystem services such as nutrient cycling and water quality issues. Beyond this sometimes some of the non targeted species get caught in accidental capture such as dolphin, sea turtle, sea birds which act as one more factor which contributes to more decline in the marine biodiversity.

a) Socio economic impact of overfishing- If we look at the social economic consequences will find that it is severe especially for the coastal community which rely on fisheries for their employment food security and development. According to the World Bank globally more than 120 million people depend on fishing as a main source of living

including small scale fisheries which provide about half of the world fish stocks. Since there is a decline in which population the fisherman are forced to travel further deep in the sea which also cause the expenditure of more fuel to catch fewer fish this makes fishing operations more unsustainable and even less profitable. In addition to all of these economic losses that comes from overfishing there has been major threat to the food security. Since fish provides essential nutrients and protein for billion of people that are particularly living in the developing countries fish is the staple food for them. The declining fish stocks leads to higher prices and reduced excess to the sea food that affects the population which have low income and rely on fish as their primary source of protein and nutrient. According to World health organization(WHO) It is estimated that more than three billion people rely on fish for their 20% of animal protein intake this highlights the critical importance of sustainable fisheries for regaining global food security.

b) Role of climate change in impacting overfishing- It can be said that climate change worsens the effect of overfishing by altering marine ecosystem, fish distribution patterns, ocean acidification that leads to disruption of fish habitats and their migratory rout. The species that are already under the stress from overfishing now also have to survive the ocean warming that disturbs their egg hatching, spawning and many more of their metabolic activities due to ocean temperature elevation and increase in the acidity of ocean water and salinity. It can be seen that not being able to survive in those conditions fish tends to migrate to cooler waters which can lead to Predator prey misbalance as well as put pressure on species which were previously less exploited now being under the radar of overfishing. If we study we will find that the link between over fishing and climate change creates a highly wishes cycle where declining fish stocks and shifting ecosystems lead to less number of fish harvest promoting fishermen to intensify their effort which again exacerbates the problem. This shows the urgent need for sustainable approach to manage fisheries that takes account of both human activities and the environmental changes it leads.

c) Strategies for promoting sustainable fishing practices- The urgency to address the increasing effects of overfishing shows the adoption of sustainable fishing practices is essential at this point of time. Sustainable fishing is a process in which there is a balance between the need for fishery resources with the health of marine ecosystem, while also taking care that fish population are maintained at healthy level. It should be also ensured that the broader environment of fisheries as well as whole Marine ecosystem is protected. Some of the strategies are mention that can be essential for promoting sustainable fisheries:

Implementation of science based quota- there should be implementation of limit based on scientific assessment done on fish population dynamics for preventing over fishing. Different quotes should be set that allow fish population to renourish themselves and they should be strictly followed to prevent any further over exploitation. The success of such implementation can result in recovery of certain fish stock.
Reduction of bycatch and habitat destruction - use of selective fishing method that minimize by catch are essential for reduction of the impact on non target its species beyond that protecting the sensitive habitat such as coral reef c grass bed, from these destructive fishing practices like bottom trawling is essential for maintaining Marine biodiversity and keeping it enriched with nutrients

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d) Establishment of marine protected areas: The establishment of these protected areas where fishing is restricted and strictly prohibited can ensure the safeguard of critical habitats and allow the overexploited species to renourish themselves. Some of the previous research done has shown that a well managed Marine protected area can lead to a significant increase in the diversity of marine life within their boundary as well as benefit to the surrounding areas.

e) Promoting consumption of sustainable sea food: Consumers should choose sustainably sourced seafood throw certification programs like Marine Stewardship council that can drive the increase in demand for sustainable fisheries. These programs create incentive for a responsible management.

f)International co-operation between countries - Species are known to migrate across the National boundary so the international corporation plays a crucial role for managing the shared fish stock. The regional fisheries management organization cooperates in regulating fishing of the international waters and insurance that sustainable measures are being implemented globally.

5.REGIONAL_CASE_STUDIES

The effect of climate change is seen across various regions around the globe in different ways. The detailed explanation of the Arctic Ocean, Pacific Island nation and global fisheries hotspot shows how climate change impact local system economies and community is shown.

5.1 - The Arctic Ocean:

The Arctic Ocean is experience in warming at rate that is nearly 3 times faster than the global average phenomenon called Arctic amplification. This rapid warming has caused dramatic loss of sea ice along with the Arctic losing around 13% of its sea ice cover per decade according to National snow and ice data centre 2020. This loss affects not only that area of ecosystem but also indigenous communities who depend on ice for hunting, fishing and transportation.

Intuit,a group of indigenous people in lived in harmony with the freezing environment for around thousand of year. But the shrinking of the eyes is disrupting there day to day lifestyle. They used to hunt for marine mammals such as seals whales which were the key to the diet and culture but now due to disappearance of ice it has been more difficult for them. As the sea ice disappears many of the organisms like polar bears seals are losing their habitats reducing the availability of these essential resources for indigenous communities (*Ford et al., 2012*). In addition to this the loss of ice also open up the Arctic to increase shipping and oil exploration even more which leads to endangering the regions precious ecosystem and traditional living. For example the melting of ice has open up the Northwest Passage for navigation in summer attracting many of the global ship roots which in turn increases pollution and risk of oil spill. These changes are forcing indigenous community to adapt to a new environment with different social and economic realities without a proper support. (AMAP, 2021)

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5.2- The Pacific Island Nations:

Some of the countries that are included in Pacific Island nation are Tuvalu, Kiribati, and the Marshall Islands. These are also the most vulnerable countries due to their low lying geography are drastically affected by the sea level rise. Many of these islands are very few meters above the sea level making them highly vulnerable to even the slightest increase of the sea water. That can cause a serious threat to their extinction. According to the data given by the Intergovernmental Panel of Climate Change, the rising global sea level are accelerating and are projected to increase by 0.43 m to 0.84 m till 2100 under a high emission scenario(IPCC, 2019).

The elevating threatens to submerge Maine low level coastal Island which leads to migration and the loss of entire nation. Moreover the salt water intrusion tends to contaminate freshwater supplies and farmland making these areas infertile for crop and less habitable system. The social cultural and economical impact of this are found as their cultural identity sovereignty and ancestral rents are at risk of being forgotten. These territories are becoming increasingly inhabitable turning them into climate refugees *(Connell, 2018).*

On the other hand coral reef degradation is major concerned considering they are crucial for protecting shorelines from erosion, supporting biodiversity, sustaining the tourism and fishing industry. The rising ocean temperature has led to significant coral bleaching during El Niño events. The Great Barrier Reef of Australia has experienced multiple mass bleaching events over the past two decades, resulting in the loss of nearly 50% of its coral reef. *(Hughes et al., 2017)*. The loss of coral reefs also determine that there is a disruption of food security and economic stability as many communities used to rely on reef fisheries for their livelihood.

5.3-Global Fisheries Hotspots-

In regions like South East Asia West Africa and gulf of Mexico are some of the global fisheries hotspot that are critical to both local economy as well as global food security therefore they are increasingly affected by the climate change. These areas where the impact of elevated temperature of the ocean, acidification of the ocean and overfishing are severely compromised tend to loss of marine ecosystem and fish populations.

South East Asia is known to have some of the most productive Mary ecosystem in the world that includes the coral triangle, with supports over 120 million people according to the WWF data 2020. However shift in fish migration pattern coral bleaching and habitat loss has been seen due to climate change. The decline in switched off severe economic impacts especially on the small scale fishers who solely relay on these resources for their livelihood. Moreover illegal, unreported and unregulated fishing practices with combination of climatic stress tends to further threaten fisheries sustainability in that reason *(Sumaila et al., 2020).*

West Africa tends to have a lot of climate change which results in disrupting of coastal ecosystem affecting both artisanal and industrial fisheries. The increasing sea temperature are causing the shift of fish population in deep waters and pushing them of shore beyond the reach of small scale fishers. This is extremely problematic for countries like Senegal and Mauritania, where fishing is the primary source of food and income. The combination of overfishing habitat loss rising of sea level, Ocean warming is leading to exaggerated decline in fisheries, which worsen the level of food insecurity and poverty in these regions (*Belhabib et al., 2016).*

The **Gulf of Mexico** is one of the critical fisheries regions mainly for shrimp, crab and oyster industries. But this region is also facing multiple climate threat including the increased frequency of hurricane, warming of ocean water, and expansion of the Gulf's dead zone it is an area of low oxygen caused by the run of nutrients from agriculture that is aggravated by warming of water *(Rabalais et al., 2010).* Dissolved oxygen being an important component for aquatic system its changes in concentration have major impacts on global carbon and nitrogen cycle. When a large area has its oxygen content very low they are known as oxygen minimum zone (OMZ) in open ocean. These changes in the environment are affecting the health of marriage which is drastically leading to reduced catches and major economic laws for the fisheries industry. Moreover the loss of coastal wetland which serves as nursery and shelter for many fish species are further endangered by the sustainability of gulf fisheries.

6. MITIGATION STRATEGIES-

6.1)Mitigating Ocean warming and sea level rise

Ocean warming and sea level rise at the consequences of climate change which are driven primarily by the increased accumulation of greenhouse gases in the atmosphere. Many international efforts to mitigate these effects have been done which focus on three main areas: reducing carbon emissions, conservation of marine ecosystem and advancing carbon capture technology.

6.2) Reduction of carbon emission-

This is one of the most effective ways to mitigate Ocean warming as this is the root cause. International agreements like the Paris agreement which has been adopted in 2015 under the United Nations Framework Convention on Climate Change UNFCCC , aims to limit global temperature rise to below 2 degree Celsius with many efforts to stay below 1.5 degree Celsius (UNFCCC, 2015). Switching to renewable energy resources can dramatically lower carbon emissions because the one of the largest source of carbon emission which are fossil fuels will be not be in use. These renewable energy sources generate electricity without emitting CO2 making them very crucial for achieving net zero carbon emission target. Moreover improving energy efficiency across residential commercial industrial and transportation sector can reduce amount of energy needed to perform same task resulting in less emissions. Improving fuel efficiency standard for vehicle and encouraging use of electric vehicles can also bring a major change in this. Nowadays carbon pricing mechanism such as carbon taxes or cap and Trade system also encourage business and consumer to reduce their carbon footprints by putting a price on the carbon emission. These economic ways make it more costly to emit carbon which leads to innovation and investment in low carbon technology and practices. Countries like Sweden and Canada are said to have successfully implemented carbon pricing to reduce its emission while parallel maintaining their economic growth. Innovative way to encourage people has been discovered as the born of The Bonn Challenge. This is a global initiative that aimed to restore about 350 million hectares of deforestated and degraded land by 2030. Its contribution to carbon sequestration is significant. In addition to that carbon capture and storage technology is seen as a necessary technology for the reduction of carbon emission in sectors where renewable energy alone may not be sufficient for example heavy industries and cement production industries. This technology aim to capture carbon emission from industries power plant before they are released into the atmosphere the captured carbon dioxide is stored underground in geological formation for use another industrial processes.

6.3) Marine conservation-

The protection of marine ecosystem play a crucial role in mitigating climate change effects. Since a healthy ocean can acts as carbon sink absorbing almost 90% of carbon dioxide from the atmosphere. Many initiative such as convention on biological diversity has been there that aim to conserve 10% of coastal and Marine ecosystem, by reducing the vulnerability of marine biodiversity to climatic impacts such as Ocean warming, acidification, increase in salinity level of water and maintaining the oceans ability to sequester carbon.

6.4)Restoration of ecosystem critical habitats-

For Marine conservation it is important to focus on the restoration of habitats like coral reefs, mangroves, sea grasses and salt masses which provide essential services to the ecosystem as well as the organism living there. Coral reef and mangroves protects coastline from storms, support fishes by giving them nutrients and area for spawning, these are also major biodiversity hotspots. Additionally mangroves and salt marshes act as a natural buffer against storm surges and sea level rise, whereas play a significant role in sequestering amount of carbon. Restoration, replanting of mangrove, coral gardening or creating artificial reefs to restore damaged habitat is essential these effort not only revive ecosystem but also the resilience of the coastal community.

6.5) Reducing pollution-

The Marine ecosystem are highly vulnerable to pollution that include plastic waste chemicals oil spills and agriculture fertilizers. To reduce the impact some measures and technology innovation is needed such as policy that band or limit use of single use plastic and clean up plastic waste in ocean. Reducing the use of harmful fertilizer that contains chemical which eventually flows into the rivers and ocean and switching to organic pesticides that does not harm the environment as well as is nutritious for agriculture. The harmful pesticides cause algal bloom and dead zone in the ocean which pollute the Marine ecosystem. Moreover the trade between countries of oil has been in trend, therefore strengthening the regulation on oil drilling and shipping can improve oil spill response techniques for minimizing these accident.

6.6)Marine spatial planning(MSP)- This is a process that manage the use of marine resources by balancing the ecological economical and social objective. It also involves mapping out Marine areas to provide spaces for various activities that involves fishing energy development shipping and conservation through which conflict minimize. This approach ensures that the health of marine ecosystems is maintained or improved while allowing for sustainable development. MSP helps in reducing conflicts between different sectors by allocating areas for specific activities, reducing overlap, and promoting efficient use of ocean space.

6.7) Adapting sustainable fisheries- This symbolizes balancing the ecological health of fishes with economic needs that fishing communities have. Some of the techniques such as Ecosystem Based Fishery Management (EBFM) consider the interdependency within the marine ecosystem and allowing more adaptive and responsive policies. (Pikitch et al., 2004). An international organization like Food and Agriculture Organization (FAO) promotes sustainable fishery that helps in reducing of overfishing with the help of selective fishing gear to minimize by catch. The policies of setting quota on the amount of fish that can be caught is necessary to prevent over fishing. There should also be a limit on the use of harmful fishing gears for example bottom trawling that can damage Marine habitats. There should be implementation of technique to reduce the capture of non target species such as the turtle's dolphin and sea bird in fishing net that are of no use for the community or the people hunting it. By adoption of these practices and many more fisheries can be conserved in the Marine biodiversity while parallellely providing economic benefits to the community that rely on it.

6.8)Protecting coastal areas-For the protection of marine biodiversity it is essential to protect the coastal areas from the effects of sea level rise increasing storm intensity to decrease the vulnerability of coastal population. For this sea walls and other forms of hard infrastructure structure are built that prevent from flooding and erosion. Though these provide effectiveness for a short term, these structures if left unattended consequences such as loss of beaches and natural habitats can be seen (Nicholls et al., 2011). Does they are often combined with more sustainable approaches like natural barriers.

6.9) Relocating vulnerable community - in many coastal areas thread of rising sea level is very severe. It is necessary for those vulnerable communities to be relocated in safer in land areas this approach is a termed as managed retreat it has been used in several postal areas. (Hino et al., 2017).

CONCLUSION –

The connection of increasing sea levels, shrinking fishery and warming of water highlights the enormous difficulty that climate change present. Marine ecosystem unparalleled stress is result of rising Ocean temperature which led in the changing dynamics of food web, reproductive cycle and species distribution. The final effect is not only a reduction in biodiversity but also disturbance in fisheries which provide food security and economic livelihood for millions of people . The deterioration of the coastal ecosystem such as mangrove, salt marshes and wetland which act as a natural barrier and spawning ground for marine life. These problems exaggerate due to rising of sea level CO2 concentration in atmosphere causing global warming and many more issues. Mainly the warming of ocean is because of the high concentration of CO2 that is being released by human activities as it absorbs and store most amount of CO2 the temperature and salinity of ocean get elevated due to it. These variations in the Marine ecosystem are causing coastal towns to become less resilient to climate change leaving them more susceptible to flooding, storm surges and habitat loss.

There is an urgent need for global coordinator action that cannot be overstated. The impacts of ocean warming and sea rising are accelerating at high rate and without any immediate and sustained mitigation effort these could become very toxic. To address this issue strong international agreement such as outlined in the Paris agreement regional and local initiative to reduce greenhouse gases is required. Establishment of marine protected areas for restoring and protecting the Marine ecosystem is crucial. Moreover adopting sustainable fisheries management, habitat restoration, reduction of pollution are equally important to maintain the integrity of ocean ecosystem and services they provide. While effects of these issues are known on a level, much more research is needed to understand how deeply it affects the organism as well as the environment. These researches can be done by investigating sustainable aquaculture,

alternative livelihood and community based conservation that could help develop more resilient food security for people. To ensure a long term resilience and adaptation it is important to invest in climate resilient infrastructure such as elevated building, sea walls, flood barrier that will safeguard the coastal community, moving to ecosystem based fisheries management. It is important to adapt method that does not harm the marine habitat which is already stressed. This includes setting catch limit , using sustainable fisheries gears , reducing bycatch and protecting critical habitats that support fish population. Scaling up the marine protected area is vital in conserving biodiversity, protecting endangered species and enhancing ecosystem resilience, it can also serve as refugee where marine life and recover from the impacts of climate change. It is important to integrate climate adaptation into National and international policy framework for coordinator action. It is important that government priorities policies that reduce emission, protect mangrove ecosystem and promote sustainable resources while addressing the social economic needs of affected communities. These all are the things that we came to know and studied about in this topic, but as much as other peoples are involved we are too so as a human being we should take responsibility and try on our level that how we can contribute to enhance our atmosphere and save our planet.

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