A Seminar Paper
on
Climate Change and Its Impacts on Aquatic Environment

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on
Climate Change and Its Impacts on Aquatic Environment[1]
by
Md. Foysul Hossain[2]

Abstract

Climate is changing and it is continued by several human actions that increasing greenhouse gases in the atmosphere as well as accelerates greenhouse. This paper reviews the reasons that are responsible for climate change. Both terrestrial and aquatic environment are being affected by this climate change. Aquatic environment is much more sensitive rather than terrestrial environment because it has a limited ability to adapt to climate change. So this paper also reviews the possible impacts of climate change on aquatic environment. Sea level rising comes first. Average 3.3±0.4 mm/year Sea level rising is being occurred, by 2100 it will be half meter that enhance the list of extinct species. For temperature rising evaporation rate is being increased and shrinkage of freshwater aquatic environment is being accelerated. About 44% of the world region have had shortage of water. For rising of temperature as well as sea level normal functioning of ecosystem is being hampered and anomalies are being showed in terms of food production, larval survivality and metabolism. High level of CO_2 emission is decreasing ocean pH that is responsible for coral bleaching, kelp forest destruction and changes in the species composition of all aquatic ecosystems that has been already reported. Not only had this it also creates reduced habitat complexity that might lead aquatic species to be endangered, threatened and/or extinct. Climate change are being increased the prevalence of invasive species. Expansion of sea portion is responsible for salt water intrusion that has an immense negative impacts in coastal ecosystems. In respect of extreme climatic and other environmental changes are adversely affecting world edible aquatic animal's production from Open Ocean.

Key words: Climate change; greenhouse gases; aquatic environment; sea level rise; extreme weather.

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Chapter I

Introduction

Normally, the environment is in fine natural equilibrium. Natural equilibrium is maintained is there is no climate change. Climate simply refers a long term average weather condition of a region that is measured by evaluating the patterns of variation in temperature, humidity, air pressure, wind, precipitation, evaporation and other environmental variables of that particular region over long periods of time. Any change in any component of the environment makes it imbalance. Imbalance of environment is happening through instances of heavy disturbances of climate that is known climate change and it has an impact on world environment. Simply climate change refers to a change in average weather conditions or the variation of weather within the context of longer-term average conditions. Very frequently the term "climate change" is used to refer anthropogenic climate change that is also known as global warming. Anthropogenic climate change is direct result of human activity which is increasing in an uncontrolled manner that opposed to changes in climate that may have resulted as part of Earth's natural processes. In this sense, especially in the context of environmental policy, the term climate change has become synonymous with anthropogenic global warming. Over the last 100 years, it was observed that the earth is getting warmer and warmer which is unlike previous 8000 years when the temperatures have been relatively constant.

Average global surface temperatures are projected to increase by 1.5 to 5.8°C by 2100 (Houghton, 1996). The present temperature is 0.3 - 0.6 °C warmer than it was 100 years before (Melillo, 2014). There are lots of reasons that's why climate is changing day by day. There are a number of greenhouse gases (GHG) that is responsible for global warming. Carbon dioxide, one of the most prevalent greenhouse gases found in the atmosphere, has two major anthropogenic (human-caused) sources: the combustion of fossil fuels and changes in land use (Van den Bossche, 2017).

Scientists around the world now agree that the reasons of climatic changes occurring internationally are the result of human activity. Although responsibility for the origins of climate change primarily with the industrialized nations, the costs of climate change will be borne most directly by the poor. The effect of climate change is beggar description. Each and every component of environment is affected by climate change. Both terrestrial and aquatic environment are being affected by climate change in an indescribable manner. The aquatic environment can be defined as interacting system of resources such as water and biota and all of the communities of organisms that are dependent on each other and on their environment *l*ive in aquatic ecosystems. The world has a variety of lotic (moving water) and lentic (stagnant water) aquatic environments which are a major source of food to millions of millions people all across the planet. Aquatic environment is much more sensitive rather than terrestrial environment because it has a limited ability to adapt to climate change. All three ecosystems of aquatic environment that are critical components of the global environment are now facing a crucial moment. Being an essential contributor of biodiversity and ecological productivity, aquatic environment provides a variety of services for human populations. It provides water for drinking and irrigation, recreational opportunities, and habitat for economically important fisheries and so on (Scavia et al., 2002). Aquatic environment has been increasingly threatened, directly and indirectly by the impacts of climate change that can cause loss of aquatic biodiversity as well as area of it.

So it is high time to determine the degree of impacts of climate change on aquatic environment, of all form of its ecosystem. Not only this but also it should be identified what species are affected most and the variation of impacts on different aquatic ecosystem. Existence of life in this planet exclusively rely on its environment. If that environment is not congenial, then the existence of life will be collapsed. More over aquatic environment is so much important not only for water but also different animals and plants that it possesses. The most significant attributes of this environmental degradation is that it affects all mankind without regard to any particular country, region, creeds or race. The entire world is a stakeholder and this raises issues on who should do what to combat environmental degradation.

Objectives

After completing this article, readers will be able:

- To highlight the causes of climate change
- To review the impacts of climate change on aquatic environment

Chapter II

Materials and Methods

This seminar paper is completely a review paper and completely depends on the secondary data. Different published reports of different journals mainly supported in providing data in this paper. This paper is completely a review paper. Therefore, no specific method has been followed in preparing this paper. It has been prepared by browsing internet, studying comprehensively various articles published in different journals, books, proceedings, dissertation available in the libraries of BSMRAU and personal communication. The author would like to express her deepest sense of gratitude to her major professor and course instructors for their efficient and scholastic guidance, precious suggestions to write this manuscript from its embryonic stage. All the information collected from the secondary sources have been compiled systematically and chronologically to enrich this paper.

Chapter III

Review of Findings and Discussion

3.1 Causes of climate change

There are several reasons of climate change. But most of the studies have showed that greenhouse gasses, aerosols and changing of land use by human are considered main reasons of climate change.

3.1.1 Greenhouse gasses and greenhouse effect

Simply greenhouse gas refers a gas which is usually found in the atmosphere that absorbs and releases sunny energy within the thermal infrared range. This process is the fundamental cause of the greenhouse effect (Searchinger et al., 2008). The key greenhouse gases found in Earth's atmosphere are carbon dioxide, methane, nitrous oxide, and ozone. When sunlight reaches Earth’s surface, it can whichever be reflected back into space or absorbed by Earth. Once absorbed, the planet reliefs some of the energy back into the air as heat (also titled infrared radiation). Greenhouse gases such as carbon dioxide (CO_2) and methane (CH_4) absorb energy, slowing the loss of heat to space. In this system GHGs plays a role of blanket and making the Earth warmer than it would be. This phenomenon is commonly known as the “greenhouse effect” (Searchinger et al., 2008) (Fig. 1).

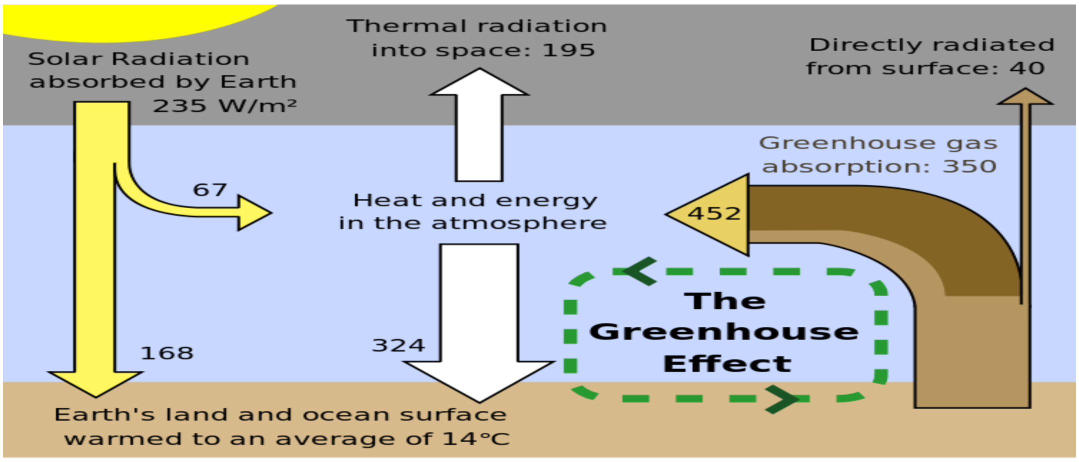


Fig.1. Schematic diagram of greenhouse effect.

(Source: Searchinger et al., 2008)

3.1.1.1 The main greenhouse gases

The most important GHGs directly emitted by humans are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and several others. Carbon dioxide is the main greenhouse gas that is contributing (62%) to recent climate change. Methane is produced through both natural and human actions and it is second highest. Human activities now release over 30 billion tons of CO_2 into the atmosphere every year (Masson-Delmotte et al., 2013). Methane is ampler in Earth's atmosphere now than at any time in at least the past 800,000 years. Nitrous oxide is another important gas that contribute 12% of total greenhouse gases. Carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) comprises 92% of total greenhouse gasses (Melillo, 2014) (Fig. 2).

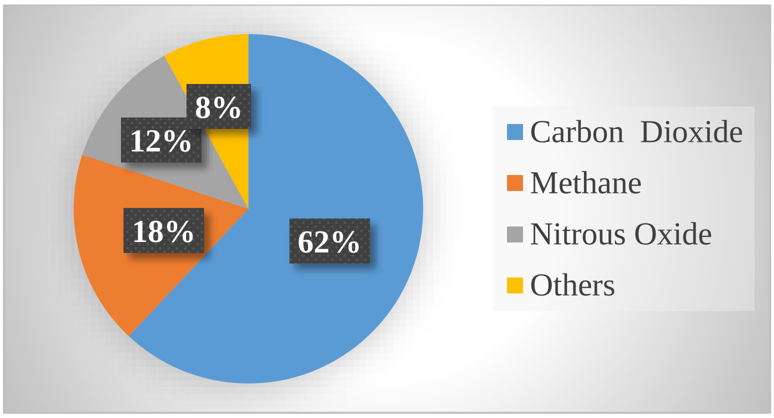


Fig. 2. Main greenhouse gasses.

(Source: Melillo, 2014)

Carbon dioxide (CO_2) in nature has increased by more than 40% since pre-industrial times, from approximately 280 parts per million by volume (ppmv) in the 18th century to over 400 ppmv in present. The current CO_2, CH_4 and N_2O level are higher than it has been in at least 2,000 years. The graph presented below shows the increase in key greenhouse gases (GHG) concentrations in the atmosphere over the last 2,000 years. (Masson-Delmotte et al., 2013) (Fig. 3.).

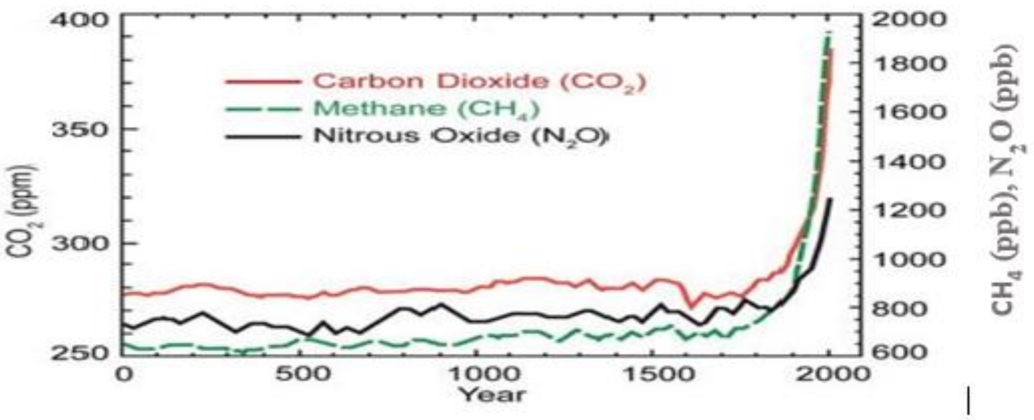


Fig. 3. Key greenhouse gases (GHG) concentrations in the atmosphere over the last 2,000 years.

(Source: Masson-Delmotte et al., 2013)

Because of human actions, concentrations of CH_4 amplified sharply during most of the 20th century and are now more than two-and-a-half time's pre-industrial levels. In recent decades, the rate of increase has slowed noticeably (Masson-Delmotte et al., 2013). Concentrations of N_2O have risen approximately 20% since the jolt of the Industrial Revolution, with a relatively rapid increase toward the end of the 20th century (Masson-Delmotte et al., 2013). Overall, N_2O concentrations have increased more rapidly during the past century than at any time in the past 22,000 years (Masson-Delmotte et al., 2013).

3.1.1.2 Other greenhouse gases

Water vapor is one of the abundant greenhouse gas and also the most important in terms of its contribution to the natural greenhouse effect, in spite of having a short atmospheric lifetime. Some human actions can influence local water vapor levels. However, on a worldwide scale, the concentration of water vapor is controlled by temperature, which impacts overall rates of evaporation and precipitation (Masson-Delmotte et al., 2013). Tropospheric ozone (O_3), which also has a little atmospheric lifetime, is a strong greenhouse gas. Chlorofluorocarbons (CFCs), hydro chlorofluorocarbons (HCFCs), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6), collected called F-gases are frequently used in coolants, foaming mediators, fire extinguishers, diluters, insecticides, and aerosol propellants.

3.1.1.3 Sources of greenhouse gases and their effectivity

There are some greenhouse gases that are naturally occurring in atmosphere. On the other hand, some are produced by human action. Certainly occurring greenhouse gases comprise carbon dioxide, methane, nitrous oxide, ozone and water vapor (table. 1). Concentrations of greenhouse gases are measured by the balance between sources (emissions of the gas from human activities and natural systems) and sinks (the removal of the gas from the atmosphere by conversion to a different chemical compound. Though Chlorofluorocarbons (CFCs) has high effectivity but of its abundance is lowest (0.00001). Value of CO_2 is standard and for its abundance it is main. Greenhouse factor of methane and nitrous oxide are higher than carbon dioxide. Some influential but not very abundant greenhouse gases that are not naturally occurring include hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6), which are created in a miscellany of industrial procedures.

Table.1 Greenhouse gases with their main source, green house factor and relative abundance

Gas	Main source	Green House factor	Relative Abundance
Carbon dioxide (CO_2)	Combustion of fossil fuel	1	0.036
Methane (CH_4)	Anerobic decay of organic matter	30	0.0017
Nitrous oxide (N_2O)	Artificial fertilizers	160	0.0003
Chlorofluorocarbons (CFCs)	Refrigerants and solvents	200000	0.00001
Water vapor (H_2O)	Evaporation of oceans and lakes	0.1	0.10

(Source: Masson-Delmotte et al., 2013)

Definite human activities, however, add to the intensities of most of these naturally occurring gases. (Melillo, 2014) (Fig.4). Carbon dioxide is released to the air when fossil fuels (oil, natural gas, and coal), solid waste, and wood and wood products are scorched. Methane is emitted during the production and transport of coal, natural gas, and oil. Nitrous oxide is produced during agricultural and industrial activities, as well as through combustion of solid waste and fossil fuels.

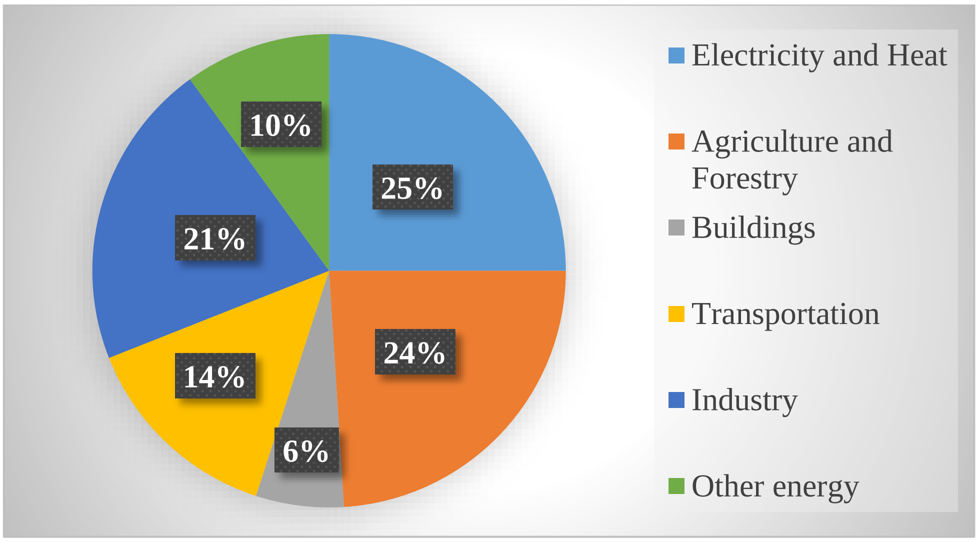


Fig. 4. Emission of Greenhouse gases by human action.

(Source: Melillo, 2014)

3.1.2 Aerosols

Generally, aerosols are less well-known than greenhouse gases. Aerosols are dust particles which are released into atmosphere in large quantities fossil fuels and when wood are burned. Some of those have a cooling effect on the climate, others have a warming effect. They are responsible for warming and heat retaining (Rahel and Olden, 2008). Given the immense capacity of oceans to absorb heat, it will take a long time to strike a new balance. Both natural and anthropogenic sources are responsible for atmospheric aerosols emission. But natural sources produce much higher than anthropogenic sources (table.2).

Table 2. Sources and estimates of global emissions of atmospheric aerosols

Source	**Amount [10^6 metric tons/yr.]**	
	Range	**Best Estimate**
Natural		
Soil dust	1000 - 3000	1500
Sea salt	1000 - 10000	1300
Botanical debris	26 - 80	50
Volcanic dust	4 - 10000	30
Forest fires	3 - 150	20
Gas-to-particle conversion	100 - 260	180
Photochemical	40 - 200	60
Total for natural sources	2200 - 24000	3100
Anthropogenic		
Direct emissions	50 - 160	120
Gas-to-particle conversion	260 - 460	330
Photochemical	5 - 25	10
Total for anthropogenic sources	320 - 640	460

(Source: Rahel and Olden, 2008)

3.1.3 Changing of land use by human

Land-use change, e.g., the clearing of forests for agricultural use can affect the concentration of greenhouse gases in the atmosphere by altering carbon flows out of the atmosphere into carbon sinks (Plaut and Canziani, 2007) (Fig. 5). Accounting for land-use change can be understood as an attempt to measure "net" emissions, i.e., gross emissions from all sources minus the removal of emissions from the atmosphere by carbon sinks (Banuri et al., 1996). Increasingly intensive agriculture where a great amount of fertilizers used that can be the great source methane and nitrous oxide. Not only this but also livestock farming is also increased. Cows and sheep produce large amounts of methane when they digest their food. There are substantial uncertainties in the measurement of net carbon emissions (Plaut and Canziani, 2007).

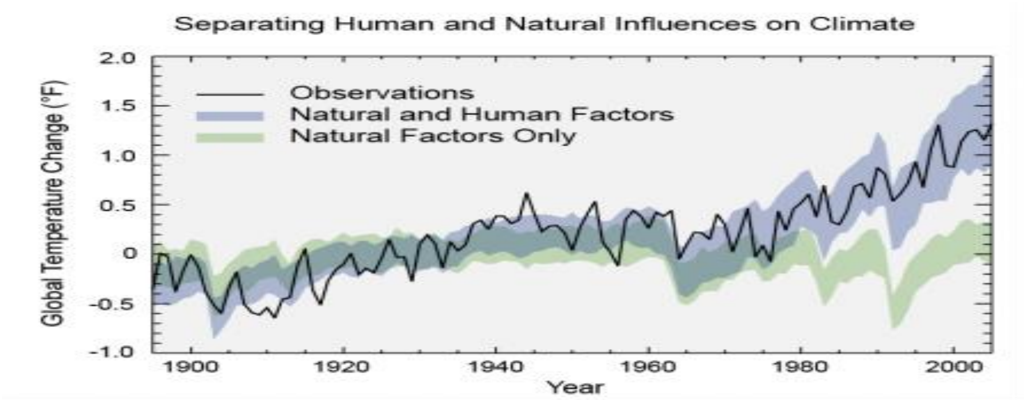


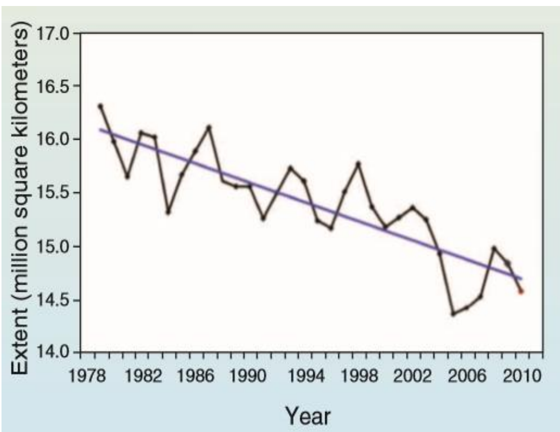
Fig. 5. Model that account both natural and human factors to explain global warming.
(Source: Plaut and Canziani, 2007)

3.2 Impacts on aquatic environment

Most of the studies have showed that sea level rise, shrinkage of aquatic environment, imbalance ecosystem function, thermal effects, abnormal ocean pH, reduced habitat complexity, invasive species supremacy, saltwater intrusion and decreasing open water production of aquatic environment is the ultimate result of climate change.

3.2.1 Sea level rise

Sea level is possible to rise for thermal expansion of marine water and faster melting of glaciers, average 3.3±0.4 mm/year and by about half a meter by 2100 (Carlson A.E. et al., 2008). This thermal expansion of the sea as well as increased meltwater and liquidated ice from terrestrial glaciers and ice block have increased ocean water volume and hence sea level (Rahmstorf et al., 2007) (Fig. 6, A and B).



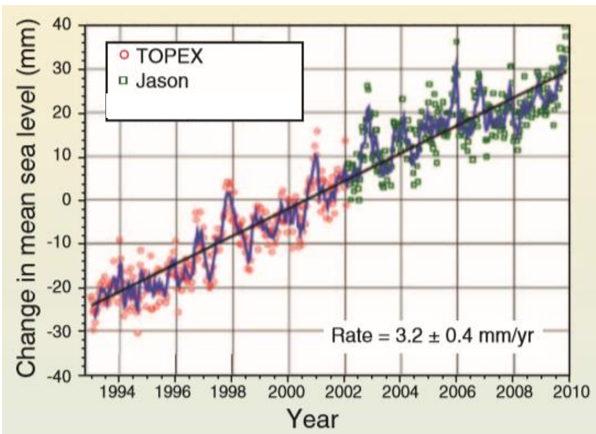


Fig. 6. (A) Extent of terrestrial glaciers and ice sheets. (B) Change in mean sea level.
(Source: Rahmstorf et al., 2007)

Warmer oceans also drive more intense storm systems (Knutson et al., 2010) and other changes to the hydrological cycle. General circulation models also predict that oxygen concentrations in the upper layers of the ocean are likely to decrease as a consequence of increasing stratification this is supported by recent observations. Some of the most striking impacts of global climate change have appeared in polar oceans, where temperatures and acidities are changing at more than twice the global average (Bindoff et al., 2007). A considerable number of aquatic species will be threatened with the continuous increase in sea level to a degree that some of them will be listed under the category of threatened or extinct species by the end of this century (Galbraith et al.,2002).Among the species that are vulnerable to such drastic effects, migratory fishes (mullet and eels), other aquatic species (turtles), coral reefs (red sea corals), some aquatic crustaceans and large number of aquatic birds (flamingo, aquatic warbler, pelicans and swan goose) (Newson et al., 2009). The threats are mainly due to destruction of spawning areas and nesting grounds for the above mentioned species (Galbraith et al., 2002; Newson et al., 2009).

3.2.2 Increased evaporation and shrinkage of aquatic environment

Increasing earth's temperature initiates subsequent episodes of water evaporation. This critical problem is due to the unregulated climate change human interference in the god gifted nature. At present, as much as 6 % of Earth's river runoff is evaporated as a consequence of climate change (Hicks et al., 2016) and it is increasing day by day. Last 35 years' average increment is 430 mm (table. 3).

Table. 3 Cumulative evaporation rate in delta

Time period	Evaporation rate (mm)
1980-1985	60
1985-1990	70
1990-1995	87
1995-2000	105
2000-2005	200
2005-2010	310
2010-1015	490

(Source: Hicks et al., 2016)

In vast areas around the globe, heavy rainfall may become heavier while semi-dry areas may receive less rainfall. There will be more common and more intense floods or droughts, especially in sub-tropical areas, which are liable to such events (Pew Research Center survey, 2016). Most of the scientists have started to link more intense droughts or shortage of water in water bodies to climate change. This is the result of more greenhouse gas is released into the air, causing air temperatures to increase, more moisture evaporates from land and lakes, rivers, and other bodies of water. So shrinkage of aquatic environment is occurring in a particular time of the year and it is highest in Africa and Latin America (table. 4)

Table .4 Water shortages area all over the world

Region	Water shortages or drought (%)	Severe Weather (flood or intense storm) (%)
Asia pacific	41	34
Latin America	59	21
U.S.A	50	16
Africa	59	18
Middle East	38	24
Europe	35	27
Global	44	25

(Source: Pew Research Center survey, 2016).

This isn't surprising given that much of the western US along with parts of Asia pacific, Latin America, Africa, Middle East, and Europe and around the world has battled devastating droughts in recent years (Pew Research Center survey, 2016). Severe weather such as floods and storms have the highest concern, with a global median of 25 percent, severe weather at 14 percent and rising sea levels at 6 percent.

3.2.3 Effects on ecosystem function

Climate change may result in sea level rise; water temperature increase; and deviations from present patterns of precipitation, wind, and water circulation (Scavia, et al., 2002). Estuaries may experience loss of breeding areas, disturbance of marine waters and associated organisms, changes in circulation models that affect maintenance of some native species, increased hypoxia and storm magnitude. Moderate increases in temperature increase metabolic rates, which ultimately determine life history traits, population growth, and ecosystem processes (O'Connor M. I. et al., 2007). In this regard, organisms tend to adapt to local environmental temperatures, with optimal physiological responses matching temperatures that are close to the environmental average. Organisms are able to acclimatize to arrange of temperatures around these optimal values (Hochachka and Somero, 2002). Beyond this range, however, acclimatization fails, mortality risk increases, fitness is reduced, and populations decline or are driven to local extinction (Hochachka and Somero, 2002). Variation in temperature canal so have impacts on key biological processes. For example, the distribution and abundance of phytoplankton communities throughout the world are being decreased with increased temperature but microbe's loads are being increased (Hochachka and Somero, 2002). The annual primary production of the world's oceans has decreased by at least 6% since the early 1980s, with nearly 70% of this decline occurring at higher latitudes (Gregg et al., 2001) and with large relative decreases occurring within Pacific and Indian ocean (Hoegh-Guldberg and Bruno, 2010) (Fig. 7.A to D).

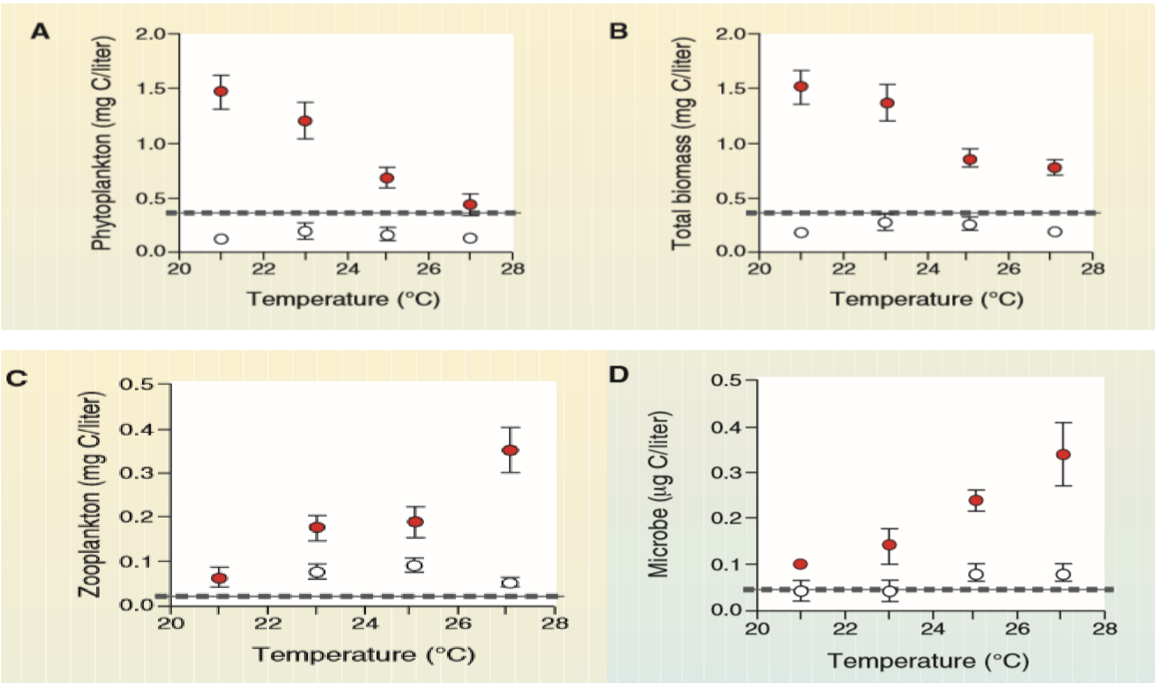


Fig. 7. Effects of climate change on biological processes in the ocean. (A to D) Experimental results demonstrating the effect of temperature on different food web properties. Solid symbols indicate nutrient addition; open symbols indicate ambient (low) nutrient concentration; dashed horizontal lines denote initial conditions; error bars denote SE; Black lines indicate changes Regression lines.

(Source: Hoegh-Guldberg and Bruno, 2010)

The anomalous conditions which that left a clear fingerprint on global ocean phytoplankton productivity and chlorophyll standing stocks (Behrenfeld et al., 2006). Respiration is also more sensitive than photosynthesis to changes in temperature (López-Urrutia et al., 2006) resulting in the caloric demands of consumers being potentially more strongly influenced by increased temperature when compared to the temperature response of primary production. Higher temperature has increased Picophytoplankton but reduced phytoplankton production. (Fig. 8. A to B).

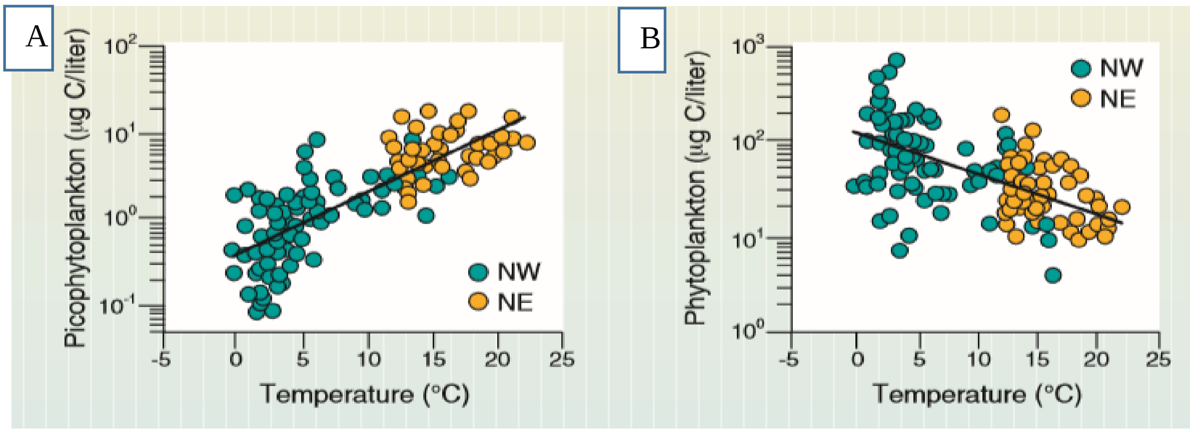


Fig. 8. (A) Relationship between temperature and abundance of small phytoplankton and (B) total phytoplankton biomass from large-scale field sampling of the North Atlantic. (NW= North West; NE= North East).

(Source: Hoegh-Guldberg and Bruno, 2010)

Animal metabolism is temperature-dependent (Hochachka and Somero, 2002), and consequently ecological processes such as predator-prey interactions are likely to be altered as warming occurs (Sanford E., 1999). These findings have implications for the ability of pelagic systems to capture and store carbon dioxide, with the potential for these critical ocean processes to decline as temperature increases (López-Urrutia et al., 2006). Warming has also been found to decrease the size of individual phytoplankton (Moran et al., 2010), further altering the functioning and biogeochemistry of shallow pelagic ecosystems and, in particular, reducing their potential for carbon sequestration. Changes to ocean conditions also have direct influences on the life history characteristics of marine organisms as varied as invertebrates and sea birds. Reduced developmental times may also result in phenological mismatches between developing larval organisms and the availability of suitable food (Durant et al., 2007), similar to phenological mismatches reported for terrestrial systems (Walther et al., 2002). When combined with changing patterns of primary productivity and metabolic rate, these fundamental influences have the potential to substantially modify ocean food web dynamics, from coastal to open-ocean ecosystems.

3.2.4 Thermal effects

The average air temperature near the earth's surface over the past century shows a lot of variability due to influences such as volcanic eruptions, variations in the heat from the sun and other natural phenomenal changes involving earth, seas, and air (Houghton, et al 1995). One major cause behind the ascending rise of world's temperature is the increased emissions of carbon dioxide gas. If carbon dioxide concentration increases during the 21st century to more than double of its pre-industrial value, then estimates show that global average temperature will rise by about 2.5ºC and. For this year after year global sea surface temperature is increasing (Van den Bossche, 2017) (Fig. 9).

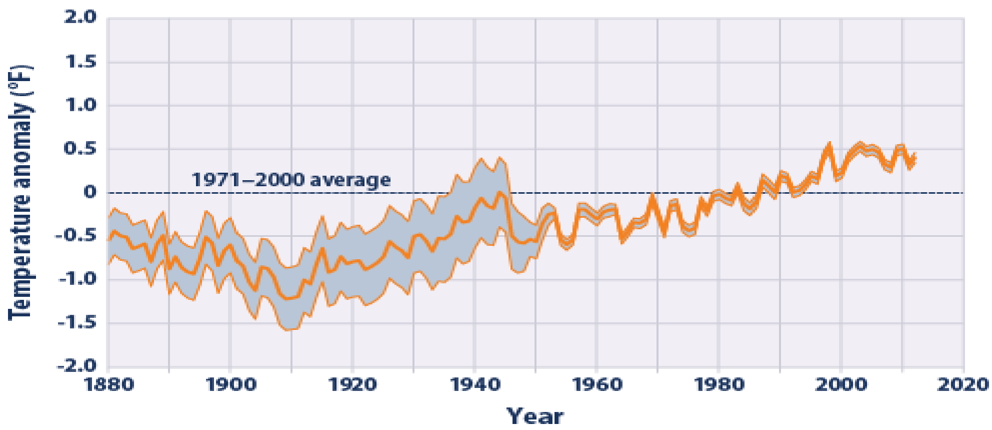


Fig. 9. Average global sea surface temperature.

(Source: Van den Bossche, 2017)

An important consequence of this thermal effect is the sex ratios change among animals.For example, many reptiles are reliant on temperature sex determination (Janzen et al., 1994) as are some birds (Göth and Booth, 2005) and fish. Temperatures of 29.2°C produce a 1:1 sex ratio in sea turtle populations; including the green turtle, hawksbill turtle, leatherback turtle, loggerhead turtle and the olive ridley turtle. Higher temperatures will lead to the feminization of populations (Hawkes et al., 2007) which will affect breeding success and ultimately will result in extinction of certain species. Temperature fluctuations during early fish development are another detrimental factor that may induce different prototypes of deformities including skeletal deformities. Primitive construction and remote location of fish hatcheries might expose the early developmental stages of fish to the sharp fluctuations in temperature and inappropriate hatching enclosure hydrodynamics. Such adverse climatic changes might disrupt vital developmental processes during early morphogenesis and might give rise to different types of deformities. The developmental rates of poikilotherms, where body temperatures vary with the environment, increase exponentially with temperature (O'Connor et al., 2007), with important consequences for a range of ecological attributes including larval dispersal, larval duration, local adaptation, and speciation (O'Connor et al., 2007) (Fig. 10, A to B).

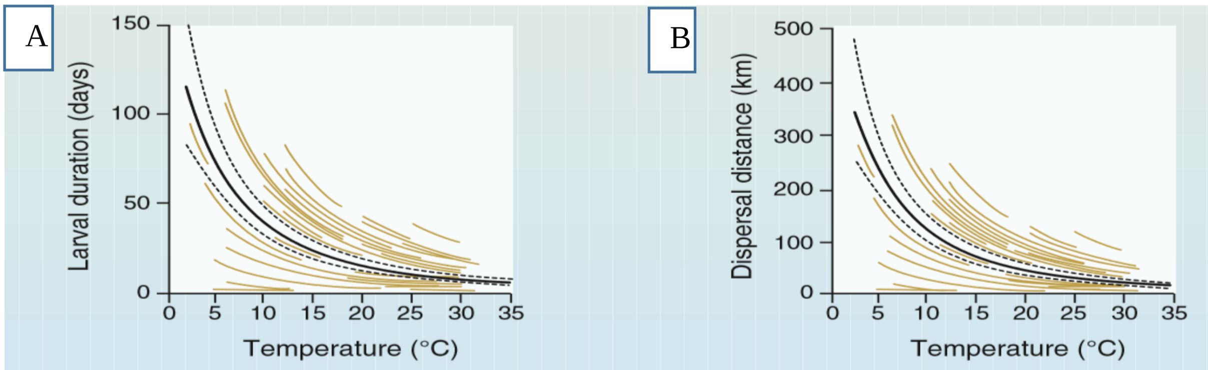


Fig. 10. (A) Relationship between water temperature and planktonic larval duration from published experimental laboratory studies of 72 species. (B) The predicted effects of temperature on larval survival. (Black lines represent the population-averaged responses; brown lines represent species specific trajectories).

(Source: O'Connor et al., 2007)

3.2.5 Gaseous emission and ocean pH

CO_2 is the primary molecule influencing the pH of oceans. Since the 1800's, oceans have absorbed 1/3 of anthropogenic CO_2 emissions (Sabine et al., 2014) and the average oceanic pH has dropped by 0.10 units, equivalent to a 30% decrease. If unmitigated, oceanic pH is likely to decrease by a further 0.4 units by 2100. Increases in atmospheric CO_2 are currently more rapid than at any point in the last 650,000 years (Sabine et al., 2014) (Fig. 11).

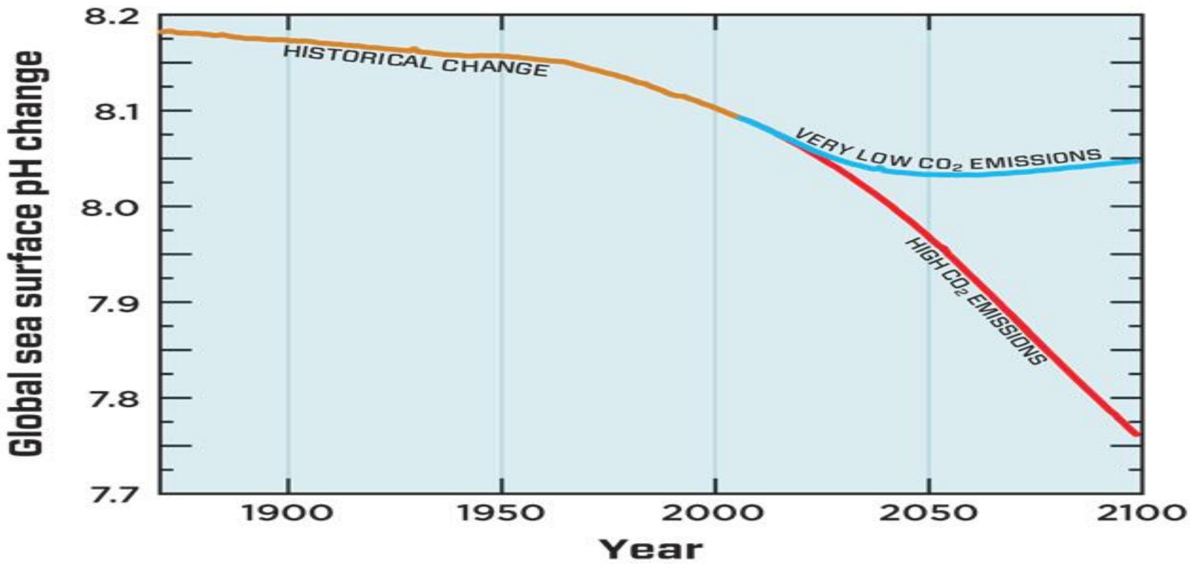


Fig. 11. Global sea surface P^H change over 2000 years.

(Source: Sabine et al., 2014)

Decreasing pH will have impacts on the whole oceanic system, with high latitude cold water oceans affected earlier and more harshly than warm water oceans. The fact that increased CO_2 affects species differentially means that it is likely to drive substantial changes in the species composition and dynamics of all terrestrial and aquatic ecosystems (Koch et al., 1996). Farming, livestock husbandry and the combustion of fossil fuels cause excess sulfur dioxide, ammonia, and nitrogen oxides to be released to the surrounding environment, where they are transformed into nitric acid and sulfuric acid. When nitrogen and sulfur compounds from the atmosphere are mixed into coastal waters, the change in water chemistry is as much as 10 to 50 percent of the total changes caused by acidification from carbon dioxide (Vitousek et al., 1997). Such new chemical mix changes the chemistry of seawater, with the increase in acidic compounds lowering the pH of the water while reducing the capacity of the upper ocean to store carbon. Further, the uprising increase in nitrogenous deposition into natural water systems can increase the dominance of non-native species (Burke and Grime, 2007).

3.2.6 Reduced habitat complexity

Among the clearest and profound influences of climate change on the world's oceans are its impacts on habitat-forming species such as corals, seagrass, mangroves, saltmarsh grasses and oysters. For example, mass coral bleaching, mortality and kelp forest destruction is the result of increasing temperatures, is already reducing the richness and density of coral reef fishes and other organisms. Coral ecosystems as well as kelp forests are declining because of warming ocean temperatures and driving a major contraction in the distribution of species (Hoegh-Guldberg et al., 2007) (Fig. 12).

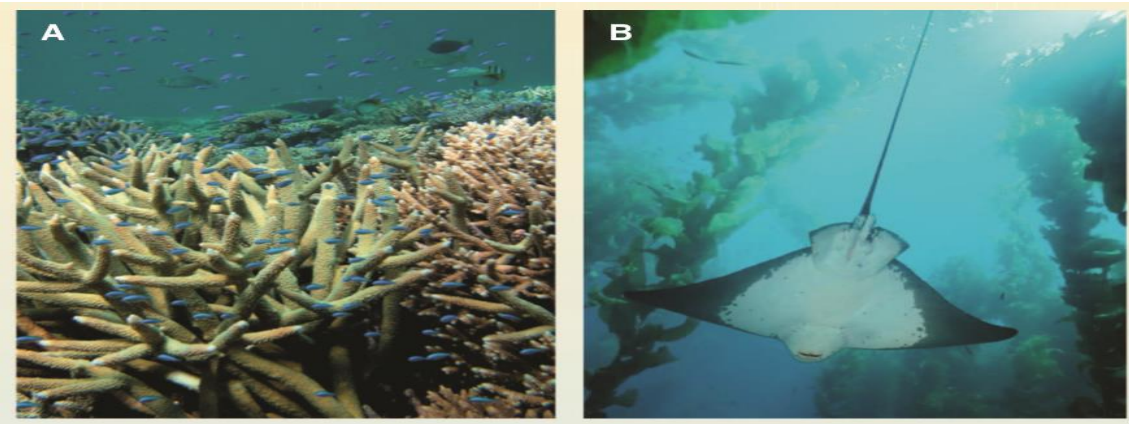


Fig. 12. (A) Heron Island, southern Great Barrier Reef. (B) Kelp forest California, USA. (Source: Hoegh-Guldberg et al., 2007)

Effects on kelp forests and mangrove habitats differ with site; areas with sharp coastal inclines or coastal human structure that limit landward migration are most at risk. Mangroves and kelp forest in many areas can adapt to sea level rise by landward migration, but these shifts threaten other coastal habitats such as saltmarsh, which have other important biogeochemical and ecological roles. The loss of sea ice is driving additional changes by reductions in food webs that are dependent on sea-ice algae which may describe the recent 75 ± 21% per decade decrease in krill (Atkinson et al., 2004).

3.2.7 Invasive species supremacy

In the past 3 decades, the continuous global surge in temperatures has positively favored the establishment, growth and supremacy of nonnative (invasive species) in its new environment (Wizen, 2008). A perfect example of such product on environmental impact of global climate changes is the freshwater red swamp crayfish (*Procambrus clarkii*) that is an invasive species and was unintentionally released into the Egyptian natural aquatic environment. Such invasive species have drastically dominated the vast majority of Nile River tributaries in Egypt with the induction of extreme environmental, economic, and/or human health harm (Fishar 2006). The abundance of red swamp crayfish (*Procambrus clarkii*) in Nile River are being increased at alarming rate since 1995 (table.5).

Table. 5 The abundance of red swamp crayfish (*Procambrus clarkii*) in the Nile River

Year	Red swamp crayfish (tones)	Native species (tones)
1995	32564	320560
1996	35067	285056
1997	39005	277089
1998	44046	260000
1999	52046	250707
2000	67765	234000
2001	69958	210245
2002	76005	188765
2003	83893	154569
2004	90430	145647
2005	110075	145637
2006	140060	125243

(Source: Wizen et al., 2008)

The degree of spread, environmental and economic damage is obviously related to the degree of local Egyptian and continental River Nile water chemistry changes (increased nitrogen deposition, eutrophication, increased acidification (carbonate, sulfate, and nitrates), and dissolved oxygen decline with continuous rise of water temperatures. In fact, only a small percentage of non-native species become invasive and cause ecological and/or economic damage. Available data indicate that invasive species can threaten the very existence of native species in the invaded environments (Wizen, 2008). Invasive species are a major cause of extinctions worldwide (25 percent of fish extinctions, 42 percent of reptile extinctions and 22 percent of bird extinctions).

3.2.8 Saltwater intrusion

Saltwater intrusion means a process by which sea water infiltrates coastal groundwater systems and mixing with the local freshwater. Groundwater is stored in the pores and fractures of rock beneath the surface, and the rock formations containing groundwater are referred to as aquifers (Barlow 2003). Sea level rise is likely to lead to increased risk of intrusion and well contamination **(**Figure 13**).**

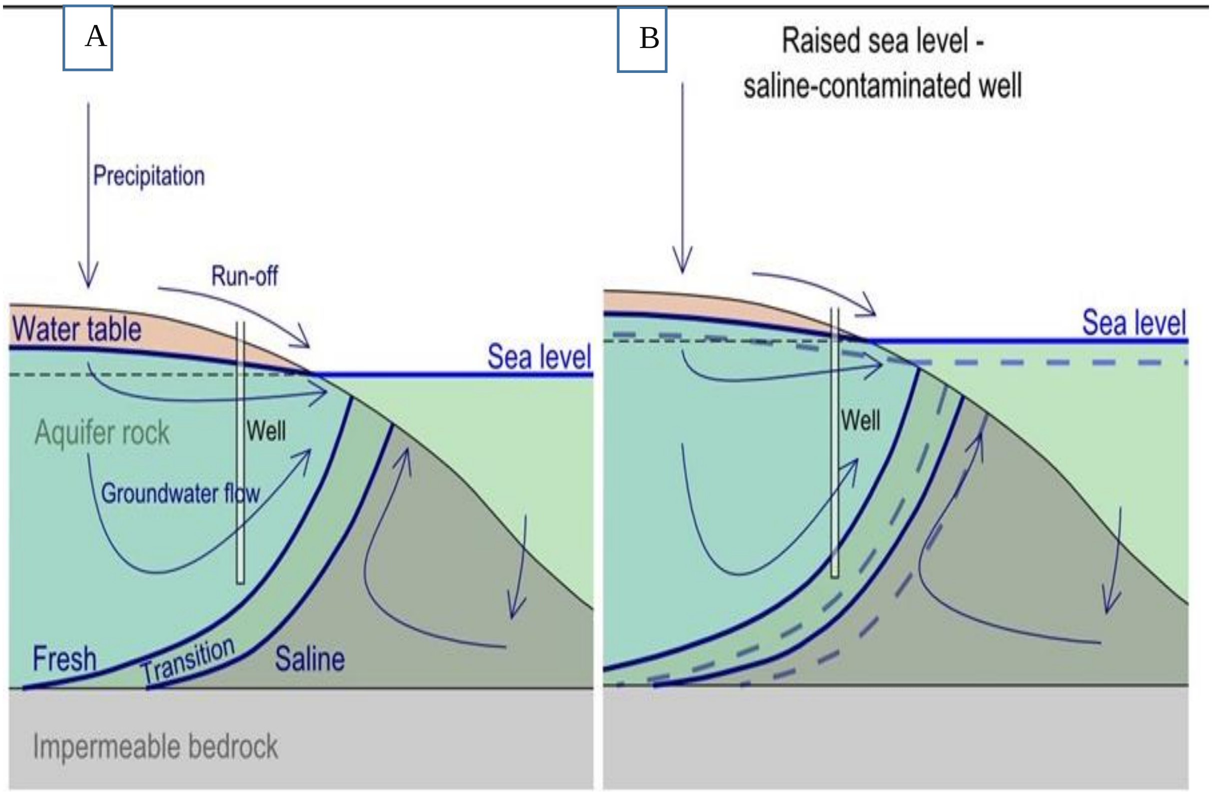


Fig. 13. Sea-level rise and saltwater intrusion. (A) saltwater-freshwater interface (B) Shifts landward under a scenario of sea-level rise.

(Source: Wada et al., 2010)

Bangladesh is a model country of salinity intrusion for the rising of sea level. It is estimated that 25,000 km^2 area of Bangladesh will go under water if sea level rise 1 m (table.6)

Table.6. Potential impact of sea level rise on Bangladesh (predicted)

Time period	Sea level rise (m)	Salt intruded area
2020	0.10	2% of land = 2500 km^2
2050	0.25	4% of land = 5000 km^2
2100	1	17.5% of land =25,000 km^2

(Source: Mac Kirby et al., 2014)

A study was carried out on Gorai river of Bangladesh. Usually the water is not usable for domestic purposes if salinity is higher than 1 ppt, though it is still favorable for crop and livestock agriculture unless salinity exceeds 2 ppt. Some freshwater aquaculture is still possible when the salinity is below 4 ppt. The southern and western part of the study region salinity is higher than 4 ppt at dry season which has intrigued brackish water shrimp farming in Khulna, Satkhira and Bagerhat districts (Mac Kirby et al., 2014). Increasing of salinity in river water (table. 7). It has a great negative impact on freshwater aquatic environment. Because only high salt tolerant fish will survive there. Normal fish production will be hampered.

Table. 7 Increasing salinity in river water

	2012	**2030(%of increase)**	**2050(%of increase)**
Salinity level (ppt)	Area km^2	Area km^2	Area km^2
>1	16720	17484 (5)	19075 (14)
>2	14831	15481 (4)	16806 (7)
>5	11272	11938 (6)	12062 (7)

(Source: Mac Kirby et al., 2014)

As the potential climate change will change the physiographic condition of the Sundarbans (habitat for plants and animals, nursery ground for fisheries and wildlife) will be greatly affected. A report by UNESCO (2007), "Case Studies on Climate Change and World Heritage" has stated that an anthropogenic 45-centimetre (18 in) rise in sea level (likely by the end of the 21st century, according to the Intergovernmental Panel on Climate Change could lead to the destruction of 75 percent of the Sundarbans mangroves.

A number of aquatic species are being considered to decline in the Sundarbans mangrove forest (table 8).

Table.8 A list of declined species in the Sundarbans

Species	Rate of deline
Northern river terrapins Butter fish Electric ray King crabs Finless porpoises	Low
Indo-Pacific humpback dolphins Ganges River dolphins Irrawady dolphins Estuarine crocodile Sea snakes	High

(Source: Ministry of Environment and Forests: Dhaka, Bangladesh, 2010)

3.2.9 Decreasing of open water production

Extreme weather events have severe consequences for aquatic environment. Studies have found that human activities have contributed to an increase in concentrations of atmospheric greenhouse gases contributing to intensification of heavy rainfall events in some area or no rainfall of some area at all. The increasing trend of extreme weather has great negative impact on breeding and gonadal development of fish species (Melillo, 2014). Not only this but also water depth and pH being fluctuated for extreme temperature. So fish production from open water bodies called capture fisheries is decreasing day by day. For fulfill the demand culture fisheries is taking that place in 1950 all fish comes from wild. From 1975 capture fisheries are decreasing and culture fisheries is increasing worldwide **(**Fig.14).

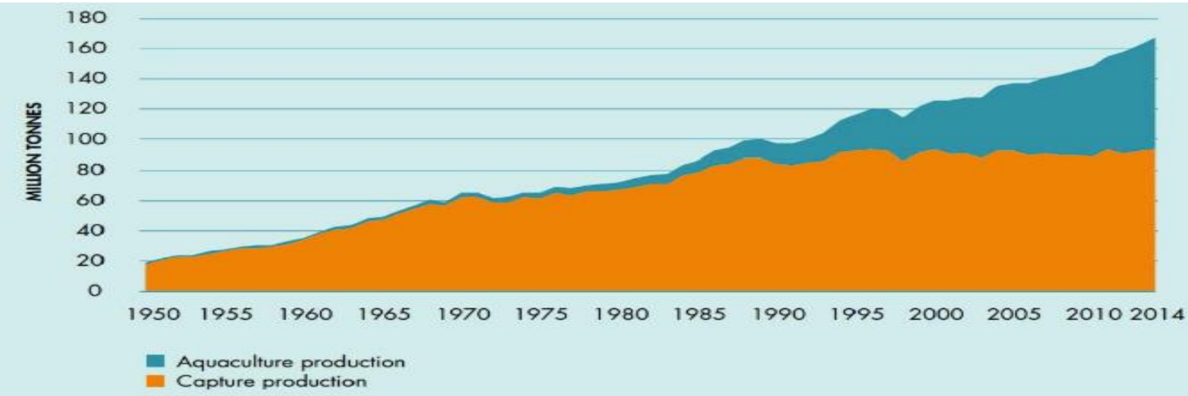


Fig.14. Contribution of Aquaculture production and capture production of global fish production since 1950 to 2014.

(Source: Melillo, J. M., 2014)

Chapter IV

Conclusion

- There are several reasons that why climate has been changed and this is continued. There are several greenhouse gases that are basically responsible for climate change resulted and "Greenhouse Effect". Manipulation of environment by human activities leading to establish several adverse climatic condition and alteration of different physical and biological cycle that is necessary for equilibrium of the environment. Aerosols and changing land use in addition with greenhouse gases are making this situation more severe.

- Climate change is predicted to have a wide range of impacts on aquatic animal populations and those who depend on them. Driving of so many aquatic species to be under the category of endangered, threatened or extinct species. Sea level rise with the subsequent coastal erosions is one major influential factor in the damage of breeding habitats of so many migratory aquatic species including fishes, shellfishes and birds. Increased ocean acidification is a detrimental factor for the predicted decline of large number of shellfishes due to the intense decalcifying effect of increased carbonic acid effects on calcium deposition in shell carrying animals. Another critical impact of global warming is the growing change in sex ratios among marine mammals, fishes, amphibians and aquatic birds and increase biological invaders. Environmental impacts on the production of aquatic food are diverse, complex and interactive. In respect to the possibility that climatic and other environmental changes could adversely affect world edible aquatic animal's production, there is a clear need to apply the precautionary principles such as taking presumptive action to minimize the future course of devastating environmentally damaging global climatic changes.

Chapter V

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