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Global climate change and its effects on biodiversity

Paulami Maiti

Department of Zoology, Lady Brabourne College, Kolkata P1/2 Suhrawardy Avenue, Park Circus, Kolkata 700017 India; e-mail: paulamim262@gmail.com

ABSTRACT Unprecedented rise in greenhouse gas due to undue anthropogenic activities has induced global warming. It has been speculated that about 1.4–5.8 °C temperature is likely to increase by 2100 for which every species and their habitat are at risk. Some species have already perished while others are on the face of decline. This review work discusses the threats of global warming and the response of diverse biota to the global climatic shift.

KEY WORDS Climate change; biodiversity; anthropogenic activities; global climate.

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INTRODUCTION

Summers were never so severe, erratic rains never disturbed us while cyclones and storms never frequented so often in this part of the continent. Unpredictable climatic conditions, unnatural disturbances are rampant throughout the globe. Global climate has become unpredictable and undergone drastic change that is inversely affecting every life form on this earth.

Global warming is the gradual increase in the average temperature of the Earth's atmosphere and its oceans that have induced a gradual change in the Earth's climatic pattern. Global temperature has already risen by 5 °C since the last ice age whereas mean temperatures of the earth have risen by about 0.6 °C since the last century. However, more than half of this increase has happened in the last 25 years. It has been speculated that 1.4–5.8 °C temperature is likely to increase by 2100 (Millennium Ecosystem Assessment, 2005).

Although global warming is a natural phenomenon induced by volcanic eruptions, shifts in the tectonic plates, striking of meteors on the earth's surface and altered solar outputs yet it can be mainly attributed to anthropogenic causes (Lovejoy & Hannah, 2005).

Urbanization, population growth, economic development, change in life style, fossil fuel consumption, depletion of forest and altered land use pattern have induced unpredictable change in the climatic pattern round the world.

Global warming and cooling are primarily controlled by cyclical variations in the sun's energy. The short wavelength solar radiation is readily transmitted by the atmosphere to heat the surface of the earth. However energy absorbed by the earth's surface is reflected back in the form of long wavelength infrared rays that are absorbed by clouds, aerosols and greenhouse gases which remain as a blanket over the earth's surface. These gases absorb and emit radiation within the thermal infrared range and trap heat the way glass does in a greenhouse , preventing it to radiate back into the space. As a result the energy that is unable to disperse, builds up in the atmosphere culminating to temperature rise (Maiti & Maiti, 2011).

The potential environmental implications of climate change are many. Temperature rise not only alters the climatic conditions but also intensely affects every single species and their habitat. Moreover, animal behavior, reproduction, population size, species richness and their distributions are also affected. However different ecosystems are impacted differently. Inhabitants of coastal, montane regions, high-latitude or polar zones and tropical belts are maximally at risk. About 43% of the world's endemic species, 25% of the biodiversity hotspots around the world, covering a total area of 1.4% of the earth's surface, nursing 44% plants, 35% vertebrates are seriously threatened (IUCN, 2000). It has disrupted ecosystem stability with unprecedented loss of biodiversity.

GREENHOUSE GASES

These are natural or anthropogenic gases that absorb or re-emit infra red radiation contributing to global warming.

Carbon Dioxide (CO_2) is a potent, natural greenhouse gas. Every year about 6.5 billion tones of carbondioxide are released in the atmosphere by anthropogenic sources such as burning of fossil fuels (oil, natural gas, and coal), solid waste, wood products, vehicular emissions and industrial release. Global Warming Potential (GWP) of carbondioxide is 1 and it has a variable atmospheric lifetime, contributing 9–26% to the global temperature rise. Human economy is run by carbon so progress in economic development releases more of carbondioxide and since 1980 carbondioxide in troposphere has been recorded to have increased to 380 ppm. It has been speculated that an average rise of 550 ppm of carbondioxide can increase the global temperature by 4.5 ^{o}C in the near future. With the advent of Industrial Revolution carbondioxide concentration has risen by 31% and will double within the next 50 to 100 years (Cunningham & Cunningham, 2007).

Methane (CH_4): Marsh gas contributes only 4–9% to the global temperature rise. It has an atmospheric lifetime of around 12 years with a lower GWP value. It degrades gradually in nature and is emitted from decay and bacterial fermentation of organic and municipal landfills, solid waste, livestock manure, paddy stubbles and sewage plants. Besides cattle belching or transport of coal, natural gas and oil also release considerable amount of gas. Bogs, fens of Polar Regions besides gas hydrates under the sea sediments and polar permafrost trap million tones of methane inside them (Maiti & Maiti, 2011).

Nitrous Oxide (N_2O) and Nitrogen dioxide is emitted from vehicular emission, agricultural and industrial activities, as well as during combustion of fossil fuels and decomposition of solid waste. The gas has an atmospheric lifetime of 114 years with a GWP of 289 over 20 years. Nitrogen dioxide is a common component of smog that induces respiratory ailment and acid rain. The latter has devastating effects on vegetations and human properties.

Chlorofluorocarbons (CFCs) or Freons are chlorine and bromine containing compounds that have led to the depletion of stratospheric ozone layer. These were commercially manufactured during the 1930s for use in refrigerants and other cooling systems. Depending on the chemical nature, the atmospheric lifetime of the gas is 23 to 270 years. In 1987 , the Montreal Protocol appealed to reduce the production of CFC gases. In 1990 an amendment was passed that totally banned the production of these chemicals.

Stratospheric ozone layer occurs naturally which blocks the harmful UV radiation from the sun. Atmospheric pollutants such as CFC gases, halon and even the activities of the supersonic air craft induce ozone holes, which is actually thinning of the stratospheric ozone layer. This allows uninhibited ultraviolet radiations from the sun on the earth's surface that induces DNA mutation and related disease such as skin cancer, burns, melanoma, leukemia, breast cancer, lung cancer, cataracts and photokeratitis. Further, it is injurious to plants as induce lesion and deplete chlorophyll reducing crop productivity (Cunningham & Cunningham, 2007).

Ground level ozone or troposheric ozone is formed through a series of complex reaction involving hydrocarbons and nitrogen oxides in the presence of sunlight. It is highly reactive and an active component of photochemical smog that contributes to 3–7% of global warming.

Fluorinated gases like perfluorocarbons, and sulfur hexafluoride are synthetically formed greenhouse gases, emitted mostly as an industrial by-

product. These potent greenhouse gases are recently used as substitutes for CFCs, HCFCs, and halons and are often referred as High Global Warming Potential gases.

Volatile organic compounds (VOC's) are ozone-destroying chemicals that form smog and are released when fuel is burned. Moreover, certain aerosols are also effective pollutants.

Interestingly, water vapour is one of the most potent greenhouse gas contributing to about 36–72% of the total global warming. It absorbs and traps enormous amount of radiant infrared rays reflected from earth's surface. Warm air holds more water vapor per unit volume so warming associated with increased level of the other greenhouse gases actually increase the concentration of water vapor that further add to temperature rise. Cirrus or high thin clouds increase surface temperature by trapping solar infrared rays but low thick clouds reflect incoming solar ray and reflect a cooling effect (Asthana & Asthana, 2009).

EFFECTS OF GLOBAL WARMING

The most drastic effect of global warming are the receding snowcaps of mountains and melting of polar ice besides rising of average summer temperatures, intense rain, overflooding of coastal zones and expansion of deserts in the interior of the continent. The third Assessment Report of the Intergovernment Panel on Climate Change on Biodiversity discussed the impact of climate change on biodiversity. This has a profound negative effect on crop fields, forests, coastal wetlands and various biodiversity rich ecosystems.

Effects on the Polar and Montane Environment

Following global warming polar ice caps and glaciers over mountains have started melting significantly. With retreating of Gomukh glacier that feeds the river Ganges significant drying up of the latter has been observed with profound change in the climatic conditions of the Indo Gangetic belt. Glaciers in Scandinavia, Central Europe, Africa, and South America have already retreated upwards. As a result watercourses depending on them are also in the face of challenge. Moreover, huge amounts of methane have been released from loss of Arctic and Antarctic permafrost and also from bogs and fens of sub arctic Siberia and Alaska that have further added to the agony of temperature rise (Sanyal, 2006).

With the disappearance of polar ice, many endemic species such as polar bears, arctic fox, seals and penguins, have lost their habitat and have no place to live and forage. Melting of sea ice in the Arctic has led to decline in the abundance of algae that thrive in nutrient-rich pockets of the ice. These have temperature optima above the ambient water temperatures at which they reside, and are therefore likely to respond to moderate increase in temperature. These algae are consumed by zooplanktons, which are in turn eaten by Arctic cod, an important food source for many marine mammals, including seals. Seals are food for polar bears. Hence, decline in algal population can contribute to the decline in the apex predators disrupting the entire food chain.

Increased warming has changed the composition of the biotic communities and shifted the vegetation zones more towards the poles or higher latitudes. With only 1°C rise in temperature a shift in 100–160 km towards the higher latitudes has been observed by more than 5 km per year. Alaska's boreal forests have been shifted northwards by 100 kilometers. Plant species native to the mountain region of Alps, have been also shifting upwards by one to four meters per decade. Biotic communities have also started shifting towards the higher latitudes or higher altitudes and if this continues then those in the higher range would finally disappear. Many species may perish with rising temperature, as they would retreat from their historic range, to face new competitors in the new habitat. Species sensitive to warmer climates such as butterflies, dragonflies, moths, beetles and other insects have started shifting to higher latitudes or altitudes especially in the northern hemisphere. This has induced increased territorial aggression and fight for natural resources. Thus climate optima will be observed which means that animals would withdraw from their unsuitable native localities and shift to relatively cooler region while those adapted to higher altitudes or polar zones would find nowhere to disperse. Red fox has been already observed to be heading northwards. Species with small population size inhabiting in restricted ranges, with limited ability of dispersal or

migration are declining at a steady state (Dobson & Rubenstein, 1989).

Observations reveal that in the Antartican region, Emperor penguins, dependent on sea ice, have declined from 300 breeding pairs to 9 in the Western Antarctic Peninsula. Adelie penguins have declined by 70 percent on Anvers Island along the Antarctic Peninsula but are thriving at more southerly Ross Island. Rock hopper penguins have also suffered.

In the Himalayas, range adjustment has been observed in the Red Panda and Monal Pheasant. These have migrated to the higher altitudes within Singhalilla National Park, leaving their earlier territory at the lower reaches of Senchal Sanctuary, (Darjeeling). Similarly the snow leopards of alpine Himalayan ranges have migrated to the higher altitudes. However, amphibians are at greater risk as many species, including the tiny golden frog living in the misty Monteverde Cloud forest of Costa Rica and Emerald frogs, are on the edge of extinction due to increased dryness. There has been a large shift in the reproductive seasons of many species especially the egg laying ones and some are reproducing earlier. In the mountain forests of Central America, the Harlequin frogs are falling prey to global warming. About 67% of 110 endemic species have become extinct in just two decades. Similarly, lizards inhabiting the higher altitudes especially at the Western Ghats of India and the Himalayan range are decreasing in population for which the entire food chain is being threatened. As reptiles tolerate only narrow temperature range therefore fall prey to abrupt climatic fluctuations (Lovejoy & Hannah, 2005).

Besides, the picas of the highland areas of West USA are already extinct. It has been speculated that 15 to 37% fauna will be wiped out in the next 50 years if global temperature continues to increase. Global temperature has threatened Beater's Opossum of Victoria, Hairy-nosed wombat of South Australia and Koala of Queensland in Australia and many others.

Problem of Sea level rise

Melting of polar ice caps and glaciers would make the sea level rise by 4–35 inches at the end of this century culminating to extensive floods throughout the low lying coastal regions of the world. Hence, people in the coastal areas of Bangladesh, Southern Asia and Egypt will be highly affected. An UN Environmental Programme (UNEP, 2002) report suggests that 40% of the world's total populations that live in coastal zones are at higher risk. Besides, melting of ice adds significant amount of freshwater to the sea reducing its salinity that subsequently slows down the thermohaline circulation (Wood et al., 1999).

Sea level rise with consequent overflooding of the coastal zones can cause saline water to seep into the coastal aquifers, estuaries or freshwater bodies making freshwater and brackish water system unsuitable for both animals and human use. As a consequence, loss of plant productivity, depletion of biodiversity, destruction of wetlands, coral reefs or mangrove forests is foreseen. Coastal settlements, low-lying islands and coral islands that rely on underground fresh water have been also affected. In the estuarine areas, seawater intrusion is largely affecting the stenohaline animals.

In India, sea level rise has pushed the mangroves of the Sunderbans further north, with considerable shrinking of the ecosystem. The prevailing salinity of creek waters has increased, due to transgressions of sea which have affected population of Water Buffalo *Bubalus bubalis* (Linnaeus, 1758), Swamp deer *Rucervus duvaucelii duvaucelii* (G. Cuvier, 1823), Great One-Horned Rhino *Rhinoceros unicornis* (Linnaeus, 1758), Indian muntjak *Muntiacus muntjak* Zimmermann, 1780, Gharial *Gavialis gangeticus* (Gmelin, 1789), Finless porpoise *Neophocaena phocaeniodes* (Cuvier, 1829), Small Clawed Otter *Aonyx cinerea* Illiger, 1815, and the Fishing Cat *Prionailurus viverrinus* (Bennet, 1833). At the Gulf of Mannar, damage of the sea grass, Halodula or Dugong grass due to sea level rise has consequently affected the population of dugong (Sanya, 2006).

Temperature rise of sea water

This has induced negative impact on the migratory routes of birds and fishes. Species composition and dominance of a community seems to be changing while sensitive species are going extinct. Warmer seas could lead to some turtle species becoming entirely female, as water temperature strongly affects the sex ratio of hatchlings. Frequent floods and marine surges have destroyed the

nesting sites for sea turtles and wading birds. Increased storminess has damaged the breeding colonies of albatross. Hundreds of thousands of seabirds have already failed to breed. The breeding grounds of Flamingo and Lesser Florican at the Rann of Kutch, Gujarat have been already destroyed. Decrease in precipitation has led to the extinction of Aldabra banded snails and rockfish crustaceans.

Corals reefs are showing signs of stress with water temperature rise. A rise of 2° to 3°C expels most of the symbiotic algae zooxanthelae leading to coral bleaching. Major bleaching event was observed between 1998 and 2002 at the Great Barrier Marine Parks, Australia. However, reef ecosystem is resilient to severe stress and can recover after major setback. Recently Fungia and Brain corals are observed to have been affected mostly in the Andaman and Nicobar islands. In the region of the Bering Sea disrupting climate change has reduced productivity and phytoplankton productions negatively affecting the survival of large mammals. Change in water temperature induces migration of lobsters to colder climates (Venkataraman et al., 2003).

Changes in the Terrestrial system

Temperature change is felt greater over land than over sea. With El Nino conditions developing, there have been large changes in the redistribution of heat and moisture that caused droughts and floods in the various parts of the world. Intense summer, low precipitation in the tropical regions and semi-arid low-latitude countries have increased the risk of forest fires and depletion of soil moisture. This is inducing crops and livestock to perish. With progressive clearance of evergreen forest, increased summer temperature and water stress have brought to periods of drought. There has been a trend towards desertification. Arid lands have started losing their fringe region resulting in expansion of deserts. The Sahara desert in Africa has also shifted northwards. Some parts of Europe, Central Asia, Africa, Australia New Zealand and Mediterranean regions, are receiving less rainfall. This has culminated into the crisis of safe drinking water besides loss of food crop production. Heat waves and drought interfering with plant growth have further reduced carbondioxide uptake. With intense summer heat, thousands of temperature sensitive fruit bats have also perished in 1998. Unpredictable droughts and floods, food crisis and heat stress have maximally affected the third world countries. Besides, the biota in this region is slowly moving towards a threshold limit of tolerance to this increased temperature (Maiti & Maiti, 2011).

According to climate models, some regions of high temperature range would experience prolonged heat waves, higher precipitation and consequently increased incidence of floods that will inflict greater damage to crops. Plants will suffer due to water logging and other heat related stress. Moreover, increased outbreaks of pests and pathogens will be observed as warm climate and wet soil would allow microbes to grow. Enhanced soil erosion, and contamination of groundwater from seepage of pollutants are among the other problems that would linger. Higher precipitation is also predicted for polar and sub polar region (Lovejoy & Hannah, 2005).

In places of higher precipitation associated with warm climatic conditions algae and weeds will dominate the water bodies leading to eutropication. Intense precipitation will increase flood, erosion and increased flow of surface water runoff dumping more pollutants and sediments in the water bodies. Isolated freshwater ecosystem supporting rare and endemic population will be also highly stressed due to ecosystem alteration, unexpected rise in temperature and change in precipitation pattern. Wetland inhabitants such as shorebirds, wading birds and waterfowls will be highly impacted for changes in hydrological cycles. Many species of plant and animals, highly vulnerable to climate change, will fail to adapt falling prey to the global warming. With loss of suitable habitat, cold water fish are also at risk while warm-water fish have been observed to expand their ranges (Lovejoy & Hannah, 2005).

There has been marked change in the breeding season of birds especially in the colder parts of the world, such as Europe, North America, Latin America and United Kingdom following shift in seasonal patterns. Shifts in migratory patterns of several species of birds have been observed and long distant migratory birds are at greater risk due to habitat alteration of their wintering grounds. Growing water scarcity in many regions has further

destroyed the wetlands on which migrating waterfowls depend.

Observations reveal that bird's migratory route and timings have drastically changed. There has been an advanced spring time arrivals and birds are departing later in the autumn with subsequent change in the breeding activities by an average of 1.9 to 4.8 days per decade over a time frame of 30–60 years. This has resulted in increased territorial aggression. European and the western Palearctic birds have been shown to lay eggs earlier. Migration have also failed due to unforeseen weather consequences while some birds may have even starved to death.

Effects on Ocean diversity

Oceans are important carbon sink. The amount of carbon absorbed in ocean is determined by the solubility pump and the biological pump. The former is primarily a function of differential atmospheric CO_2 dissolving in sea water that induces thermohaline circulation. The biological pump on the hand consists of the phytoplanktons, shelled animals (mollusca, protozoas), calcifying organisms (coccolithophores, foraminiferans) and pteropods that absorb atmospheric carbondioxide to form carbonate shells. The biological pump thus transports organic and inorganic carbon from the euphotic zone to other parts of the ocean. With the death of these animals a part of this assimilated organic carbon remains buried in the seabed, that contribute to the forming of fossil fuels.

In the past two hundred years, acidity of sea water has increased by 1 unit and likely to rise further by 0.5 units in the future. Increased ocean acidification due to rise in atmospheric CO_2 would affect the biological pump negatively that would endanger corals, molluscs and others organisms. As these form calcium carbonate shells they would have difficulty in growing their exoskeleton. With decrease in their population the ability of the ocean water to absorb more carbondioxide will also decrease. The concerted effects of these factors will actually increase the global build up of this greenhouse gas (Jeffries, 1997).

Rise in ocean temperature and alteration of patterns in circulation of currents have also affected the nutrient delivery system. As cold waters are more productive than warm waters, warming of the oceans may disrupt marine food chain threatening the heat sensitive under water species.

The system of currents supplies the deeper parts of the water with oxygen and nutrients from the deep are transported to the surface that helps the phytoplankton to flourish. Rise in temperature of water disrupts the upwelling of cold, nutrient-rich waters leading to loss of planktonic populations. This in turn affects the population of krill which feeds on these planktons. Reducing the population of krills has largely threatened whales, larger fish and seabirds which feed on these creatures. Several species of whales such as beluga, narwhal, bowhead, right whales are threatened with changes in ocean currents and food shortage.

Consequently, decrease in phytoplanktons would reduce the uptake of carbon dioxide from the oceans. All these factors have affected the rich food web in the continental shelf areas on which global marine biodiversity thrives.

The '2005 Millennium Ecosystem Assessment' estimated that by the end of 21st century, climate change will be instrumental for most of the global biodiversity loss. Worldwide, 25% of all mammals and 12% of birds are already at significant risk. With prolonged summers in warmer parts of the world and the shortened winters in the colder regions, the overall shift in the global climate has profound effect on the world's biotic communities (Sanyal, 2006).

When temperature rises, it may drive some plants and animal species to go extinct as their range shrinks or are forced to compete with invasive species and pathogens moving into their territory. About 1250 Indian plant species are already extinct from the wild.

Effects on Human Health

Since there is an optimal temperature specified for each organism, climate shift has already led to low crop, dairy and meat production.

Small shifts in temperature can extend the range of mosquitos increasing the occurrence of malaria, yellow fever and other vector borne diseases. According to a study by WHO (2002), almost 150,000 people die every year from the ill effects of heat stress, malaria and malnutrition. The number could almost become double by 2020. Risk of damage to people and properties, decrease in food production,

respiratory troubles, skin problems and spread of infectious tropical diseases and metabolic disorders are the other problems on the card. Moreover, decrease in agriculture, crisis of food and potable water would challenge the poorer sectors of the third world countries. This has resulted in increased cases of environmental refugees.

Reducing Global Warming

Global warming can be reduced either by lowering the release of greenhouse gases or by removal of greenhouse gas from the environment. This can be done by adoption of afforestation programs including social forestry and plantation outside the range of forested areas. Automobile or factory emissions, tilling soil, addition of fertilizers and construction of cemented structures release huge amount of carbondioxide. So minimizing soil disturbance, recovering degraded soil, besides restoring grasslands, water bodies and other natural habitats would help in the process of carbon sequestration. Reduction in the use of fossil fuels, burning of plant materials and adoption of energy efficient biofuels can effectively mitigate global warming. Greenhouse gases can be effectively removed from the atmosphere by various physical and chemical processes. Moreover, solar energy, biomass energy, wind, wave or tidal power and other renewable energy has to be harnessed as an alternative to fossil fuels. Reduction of power generation in the urban sectors, use of energy saving bulbs, change in lifestyle, alteration in the pattern of trade or communication, adoption of modern sail design in shipping and aviation can also brings positive results.

According to the Intergovernmental Panel on Climate Change "*a sustainable forest management strategy aims at maintaining or increasing forest carbon stocks, while producing an annual sustained yield of timber, fiber or energy from the forest, and this will generate the largest sustained mitigation benefit*". Carbon offset programs have been implemented for planting millions of fast-growing trees per year to reforest tropical lands.

The blame of global warming goes on man's misdeed that limits the survival of other species. For his endeavor to conquer nature the air is over burdened with pollutants, natural system has been replaced by manmade structures with thousands of species losing their life and habitat. There has been a pervasive change in the global landscapes that have modified the ecological background on which species evolve. Most species are now suffering from the indirect and subtle changes of global climatic shift. Exploding rise in human populations along with the need and greed of man has impoverished the rich biodiversity on which his own existence is depended. So, global climatic shift might be a revenge on nature's part. If this is allowed to continue it is certain that man's existence will be at stake in the very near future.

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