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A Review on Impacts of Climate Change on Aquatic Biota, Ecosystem, Structure and Functions

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ABSTRACT

Climate change refers to an increase in average global temperatures. Natural and human activities are believed to contribute to increased average global temperatures. Other indicators of global warming include Arctic shrinkage and resulting to methane release, shrinkage of the world's rainforest (damaged by deforestation from logging and farming), increases in the intensity of extreme weather events, changes in agricultural yields, glacier retreat, species extinctions and changes in the ranges of disease vectors. Anthropogenic activities responsible for climate change are greenhouse effect, stratosphere, ozone layer depletion, acid rain, deforestation and among others. Climate change is projected to cause significant alterations to aquatic biogeochemical processes, aquatic food web structure, dynamics and biodiversity, primary and secondary production which affect the range, distribution and habitat quality/quantity of aquatic mammals and waterfowl. Global climate change disrupts community structure and increases native species loss and extinction. The magnitude, extent, and duration of the impacts and responses are location-dependent and difficult to separate from other environmental stressors. The options that are available as response to global warming: mitigation, adaptation and possible human suffering as consequences of what cannot be avoided by mitigation and adaptation are presented. An overview of the Nigerian environment, preparedness for the impact of global warming and related problems are also presented. The status of environmental data and the need for environmental baseline survey and the creation of a comprehensive database for the country driven by geographical information system were discussed.

Keywords: *Climate Change, Aquatic Organisms, Aquatic Environment, Structure, Functions, Anthropogenic activities*

INTRODUCTION

According to (1) climate change is defined as any change in the average daily weather pattern over an extended period of time (typically decades or longer) due to natural variability or as a result of human activity (2) and Intercontinental Panel of Climate Change (3) happening now, and is already affecting many natural systems around the world. Climate change is very likely to have both direct and indirect consequences on the biota. The effect of climate change manifests as increased average daily and annual temperatures, changes in precipitation patterns with heavy rain falls in some regions and drought in other area that were not erstwhile given to drought. Persistent droughts and flooding, off season rains and dry spells have sent crops growing seasons out in a country dependent on a rain fed agriculture.

Alarm bells are ringing as lakes dry up rivers experience a reduction in flow in the arid and semi arid regions. The result is less surface water supplies for use in agriculture, hydro power generation and other uses.

The magnitude and extent of the ecological consequences of climate change will depend largely on the rate and magnitude of change in three primary environmental drivers:

- Timing, magnitude, and duration of the runoff regime;
- Temperature and alterations in water chemistry such as nutrient levels, DOC, and particulate organic matter loadings (4).

The threats of climate change to human society and natural ecosystems have been elevated to a top priority since the release of the fourth

Assessment Report (3). While the importance of fisheries and aquaculture is often understated, the implications of climate change for these sectors and for coastal and riparian communities in general are difficult to ignore.

In Nigeria and Sub Sahara Africa (SSA) in general, fisheries are a source of employment for about 10 million people and the main or only source of animal protein for 20 per cent of the population. Thus, the sector plays a significant role in boosting the availability of food, by tackling risks to food security in several agrarian and highly food-insecure countries in the region. It can also earn the country substantial foreign exchange from its product export. In addition to creating employment through storage, transportation, marketing, facilities maintenance and food businesses, those who engage in fish production; fisheries education and consultancy; processing of fish and fishery products both for local consumption and export and marketing are in direct employment. Climate change is projected to impact broadly across ecosystems, societies and economies, increasing pressure on all livelihoods and food supplies, including those in the fisheries and aquaculture sector. Food quality will have a more pivotal role as food resources come under greater pressure and the availability and access to fish supplies will become an increasingly critical development issue. Climate change poses significant threats to fisheries on top of many other concurrent pressures such as overfishing, habitat degradation, pollution, introduction of new species and so on (5). Changes in biophysical characteristics of the aquatic setting and frequent occurrence of extreme events will have significant effects on the ecosystems that support fish. This will affect food security in multiple ways when there is no appropriate and effective mitigation and adaptation measures/ strategies. It is on this note that this paper seek to assess the impact of climate change on aquatic biota, ecosystem and its functions.

Indicators of Global Warming

Global warming produces increase in global temperature which impacts directly on human life and the natural environment. Increasing global temperature is having serious effects and consequences for the world, including rising sea levels, changes in climate patterns change in the amount and pattern of precipitation, and more severe weather including strong tropical storms, droughts, and heat waves. Other indicators of global warming include Arctic shrinkage and resulting to methane release, shrinkage of the world's rainforest (already very damaged by deforestation from logging and farming), increases in the intensity of extreme weather events, changes in agricultural yields, glacier retreat, species extinctions and changes in the ranges of disease vectors.

Causes of Climate Change

Climate change or global warming is attributed to the major anthropogenic activities leading to the accumulation of carbon dioxide in the air.

Greenhouse Effect

Greenhouse gases such as carbon dioxide (CO_2) absorb heat (infrared radiation) emitted from earth's surface. Increases in the atmospheric concentrations of these gases cause the earth to warm by trapping more of this heat. Human activities especially the burning of fossil fuels since the start of the Industrial Revolution have increased atmospheric CO_2 concentrations by about 40% with more than half the increase occurring since 1970. In 1900, the global average surface temperature increased by about 0.8 °C (1.4 °F). This has been accompanied by warming of the oceans, a rise in sea level, a strong decline in sea ice, and many other associated climate effects (Figures 1 and 2).

Stratosphere Ozone Layer Depletion

The stratosphere is an atmospheric layer of high concentration of ozone from an attitude of 16 – 181cm in polar latitude and 25km over the equator. Ozone is destroyed by its reaction with atomic oxygen, hydroxyl ions, oxides of nitrogen, chlorine, bromine, and fluorine and chloroflorocarbons (CFCs) which are products of industrialization (6). This makes the ultraviolet radiation from above to reach the earth thus increasing the global temperature resulting to global warming (Figures 1 and 2).

Acid Rain

Acid rain/acid precipitation occurs when the oxides of nitrogen and sulphur and hydrogen sulphide are photo chemically oxidized into nitric and sulphuric acids respectively in a humid atmosphere. This acid is capable of destroying the ozone layer resulting to global warming inducing climate change (Figure 1).

Deforestation Activity

Felling of trees in an area ends up exposing the area to changes. After deforestation, photosynthetic processes are altered or reduced leading to accumulation of carbon dioxide in the atmosphere which may end up in the destruction of the ozone layer and subsequent global warming. Also, deforestation in massive form exposes the earth to ultraviolet radiation (uvr) which leads to global warming (Figures 1 and 2).

Heat Island Effect

This could be regional or global. The high rate of industrial activities, transportation and domestic activities in the cities releases quantum of heat to the surrounding especially in the day time. At night the surface gives up absorbed heat contributing to global warming and consequently climate change (Figures 1 and 2).

Gas Flaring

Gases flared into the atmosphere also include greenhouse gases such as oxides of nitrogen, sulphur and carbon which are responsible for destruction of ozone layer thus increasing global warming (Figures 1 and 2).

Smog

This refers to a synthesis of smoke and fog. This is attributed to vast quantities of air pollutants emitted from industry, vehicle and domestic sources such as coal fires and incinerators during the periods when meteorological conditions fail to disperse the pollutants away from a city. This pollutants are build up and are trapped in moisture to form smog. Smog prevents outward reflection of heat absorbed by the earth's surface increasing local air temperature.

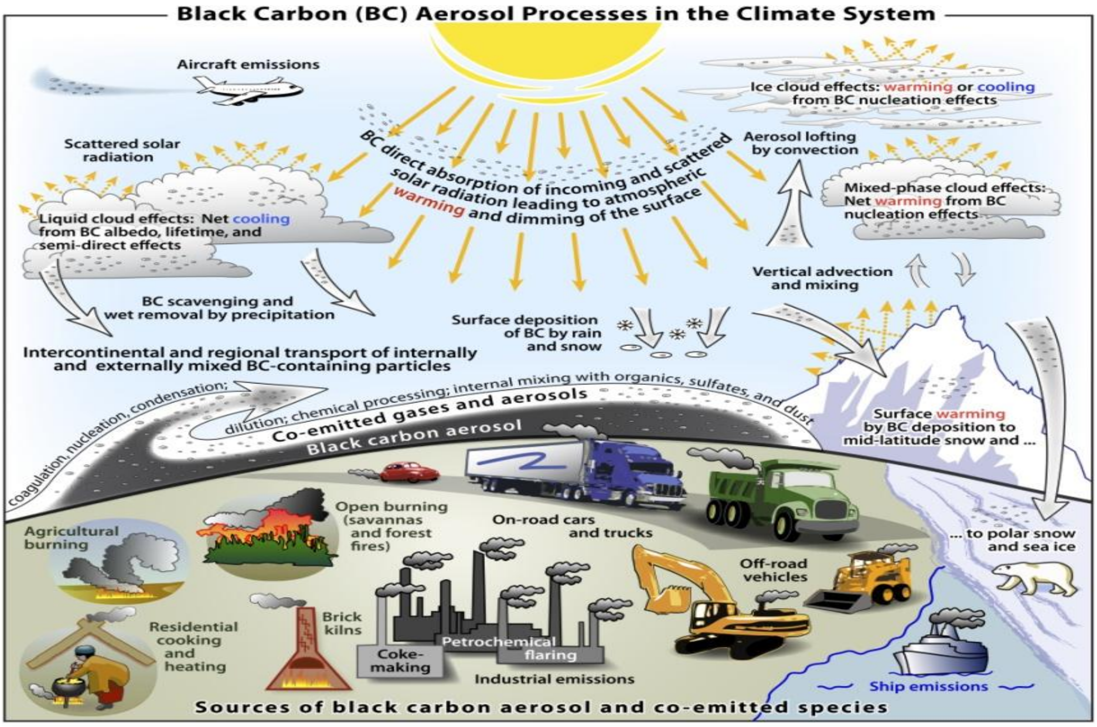

Figure1. *Representation of causes of climate change (Source:https://phys.org/news/2013-01-black-carbon-larger-climate-previously.html)*

Figure2. *One of the causes of climate change (Source: www.shutterstock.com/search/causes+of+ climate+ change)*

Effects of Climate Change

Nigerian Gross National Product includes contribution from the agricultural sector which comes mainly from the rural populace are employed in this sector. The dominant role of agriculture makes it obvious that even minor climate deteriorations can cause devastating socioeconomic consequences. Policies to curb the climate change by reducing the consumption of fossil fuels like oil, gas or carbon, have significant economic impacts on the producers or rather the suppliers of these fuels. Nigeria is the eighth largest oil supplier in the world and the ninth largest deposits of gas. The Nigerian national economy would be massively affected by a sustainable reduction of fossil energy consumption.

Nigeria is practically a monoculture: about 80% of the government income, 90-95% of the export earnings and more than 90% of the foreign exchange revenues evolve from the oil sector. The impact of the change will be difficult to handle and it will be potentially very long lasting.

There is already an increasing incidence of disease, declining agricultural productivity, and a rising number of heat waves. Declining rainfall in already desert-prone areas in northern Nigeria is causing increasing desertification, the former food basket in central Nigeria is now empty, and people in the coastal areas who used to depend on fishing have seen their livelihoods destroyed by the rising waters.

Effects on Biological Communities, Biodiversity and Adaptive Responses

Climate change will probably produce significant effects on the biodiversity of freshwater ecosystems and possibly initiate varying adaptive responses if changes are gradual. Global climate change disrupts community structure and increases native species loss and extinction. Biodiversity is related to, or affected by factors such as: the variability of regional and local climate; the availability of local resources (e.g., water, nutrients, trace elements, energy, substrate) affecting the productivity potential; the nature, timing, and duration of disturbance regimes in the area (e.g., floods, catastrophic water loss, fire); the original local and regional ‘‘stock’’ of species and their dispersal opportunities or barriers; the physiological capacity of individuals and populations to cope with new environmental conditions.

Many freshwater systems are exposed to multiple environmental stressors or perturbations including point and/or non point-source pollution (e.g., long-range aerial transport of contaminants); altered hydrologic regimes related to impoundments and diversions; water quality changes from landscape alterations (e.g., mining, oil and gas exploration); and biological resource exploitation (e.g., subsistence and commercial fisheries and harvesting of waterfowl and mammals; to name a few. These stressors, along with climate variability, can synergistically contribute to the degradation of biological diversity at the species, genetic, and/or habitat–ecosystem levels (7).

Effects on Food Web Structure and Dynamics

Recent studies of arctic systems have identified the structural and functional importance of the microbial freshwater food web. Work in this area has shown that the microbial food web can comprise a significant fraction of the total community biomass in rivers and lakes, and that energy flow is routed through a diverse trophic network of microbial species displaying a wide array of nutritional modes (heterotrophic bacteria, phototrophic bacteria, phagotrophic protozoa, and mixotrophic flagellates). Microbial food web is a significant source of energy to plankton, being largely responsible for recycling nutrients in the water column and thereby helping to sustain planktonic and benthic primary production and ultimately higher secondary and tertiary consumers in the food chain (8). Climate change cause increase in temperature dissolved organic and inorganic carbon affect the structural and functional dynamics of the microbial food web. Increasing temperature has the potential to alter the physiological (e.g., growth, respiration) and vital rates of individuals, and resulting dynamics of populations. According to (9), increasing temperature affect food chain length such that predator–prey system is destabilized at higher temperatures irrespective of the complexity of the food web (i.e., whether a two- or three-level food web was involved).

Primary/Secondary Production and Climate Change

Global Ocean

In general, observations and model outputs suggest that climate change is likely to lead to increased vertical stratification and water column stability in oceans and lakes, reducing nutrient availability to the euphotic zone and thus reducing primary (10) and secondary (11) production. The climate–plankton link in the ocean is found most strongly in the tropics and mid latitudes, where there is limited vertical mixing because the water column is stabilized by thermal stratification (when light, warm waters overlie dense, cold waters). In these areas, the typically low levels of surface nutrients limit phytoplankton growth. Climate warming further inhibits mixing, reducing the upward nutrient supply and lowering productivity (12).

Rise in Sea Level

Global warming leads to increase in temperature of the aquatic environment. This causes melting of ice and the general rise in water level leading to destruction of aquatic resources. All coastal ecosystems are vulnerable to sea level rise and more direct anthropogenic impacts, especially coral reefs and coastal wetlands (including salt marshes and mangroves).

Acidification and Other Chemical Properties

Roughly half the CO_2 released by human activities between 1800 and 1994 is stored in the ocean (13) and about 30 percent of modern CO_2 emissions are taken up by oceans today (14) Continued uptake of atmospheric CO_2 has decreased the pH of surface seawater by 0.1 units in the last two hundred years. Model estimates of further pH reduction in the surface ocean range from 0.3 to 0.5 units over the next hundred years and from 0.3 to 1.4 units over the next three hundred years, depending on the CO_2 emission scenario used (15). The impacts of these changes will be greater for some regions and ecosystems and will be most severe for shell-borne organisms, tropical coral reefs and cold water corals in the Southern Ocean (16). (17) reported that expected near-future levels of ocean acidification reduce sperm motility and fertilization success of the sea urchin (*Heliocidaris erythrogamma*) and suggest that other broadcast spawning marine species may be at similar risk.

Biological Impact of Climate Change on Fish Production

Direct effects of climate change impact the performance of individual organisms at various stages in their life history via changes in physiology, morphology and behavior. Climate impacts also occur at the population level via changes in transport processes that influence dispersal and recruitment. The combination of these proximate impacts results in emergent ecological responses such as alterations in species distributions, biodiversity, and productivity and micro evolutionary processes (18).

Spawning

The characteristics of spawning and successful reproduction of marine and freshwater organisms are largely under evolutionary control; organisms adapt to the prevailing conditions, and possibly the variability of these conditions, so that they can complete their life cycle and reproduce. Spawning times and locations have evolved to match prevailing physical (such as temperature, salinity, currents) and biological (such as food) conditions that maximize the chances for a larva to survive to become a reproducing adult; or at the very least to minimize potential disruptions caused by unpredictable climate events. Whereas evolution is responsible for the type of spawning, environmental features such as temperature have significant influences on specific characteristics of spawning. (19) Concluded that climate change is likely to induce strong selection on the date of spawning of Pacific salmon in the Columbia River system. Temperature has also been demonstrated toinfluence the age of sexual maturity, e.g. Atlantic salmon and Atlantic cod (20).

Fish Recruitment Processes and Climate Change

Many theories and processes have been proposed to explain the huge reduction in the numbers of most marine and aquatic species as they develop from egg to larva to juvenile and finally the adult (21). These hypotheses can be grouped into three general categories: starvation and predation, physical dispersal and synthesis processes.

One of the principal hypotheses proposed to relate the impact of starvation on recruitment, which has clear connections with climate variability and change is the match-mismatch hypothesis of Cushing (22). It recognizes that fish, particularly in the early stages, need food to survive and grow. It also recognizes that periods of strong food production in the ocean can be variable and are often under climate control (strength of winds, frequency of storms, amount of heating or fresh water supplied to the surface layers). The hypothesis proposes, therefore, that the timing match or mismatch between when food is available and when and where fish (particularly in the early stages) are able to encounter and consume this food which is a principle determinant of recruitment and the subsequent abundance of marine and freshwater species.

Inland Waters

As in oceanic environments, the impacts of global warming on biological production in inland waters depends strongly on the combination of contrasting processes such as ice cover, water flows, stratification and nitrification, with the additional impact of human water and land use. In high-latitude or high-altitude lakes, atmospheric warming has already led to reduced ice cover, warmer water temperatures, longer growing seasons and, as a consequence, increased algal abundance and productivity (23). There have been similar increases in the abundance of zooplankton, correlated with warmer water temperatures and longer growing seasons (24).

Abundance Changes

Change in the abundance and biomass of marine populations are due to changes in their recruitment and growth rates, and ultimately to the productive capacity of the region in which they live. For example, changes in temperature can have direct impacts on fish abundance and biomass by stressing the physiological systems of individuals causing them to change their locations or ultimately die. Temperature can also have indirect effects on fish abundance through its influences on growth and recruitment. Higher individual growth rates translate to greater productivity for the entire population, with the most productive stocks associated with higher bottom temperature and salinity conditions (25), although (26) found the growth performance of cod was optimal at 10 °C regardless of the latitudinal population investigated. This relatively simple picture becomes more complicated when food availability is also considered. (27) found that an index of plankton prey explained 48 percent of the variability of North Sea cod recruitment, with periods of good recruitment coinciding with higher abundances of its preferred prey.

Response to Global Warming

Knowing to manage the territory, protect the environment and evaluate the cultural heritage. The available options are: mitigation to reduce further emissions; adaptation to reduce their impact of global warming on the environment and human life as in Figure 3.

Mitigation

This means that measures must be taken by various nations to reduce rate and magnitude of global climate change caused by human activities. According to IPCC, the mitigation options includes reduction in burning of fossil fuels and reduction of greenhouse gases and soot from the energy sector; reduction of deforestation; increase in reforestation and afforestation; modification of agricultural practices to reduce emissions of greenhouse gases and build up soil carbon. Other mitigation options include: geo-engineering to reverse the effect of global warming by creating cooling effects which will offset greenhouse heating; and conceiving the development of technology for clean the greenhouse gases from the atmosphere. It has been estimated that at present the cost and benefit of mitigating global warming are approximately the same. In general, the IPCC concludes, without mitigation global warming will reach a point where it will be impossible for some natural systems such as ecosystem to cope and therefore may go into extinction. As for humans the cost of adaptation will be so prohibitive that many will not cope. It is therefore essential to do a little of mitigation and a little of adaptation.

Adaptation

Adaptation means that we should take measures to reduce the adverse impact of global warming on human life and the environment. Some of the options that are available include: changing the cropping patterns; stopping further development on wetlands, flood plains, and close to sea level; developing crops that are resistant to drought, heat and salt; strengthening public health and environmental engineering defense against diseases; designing and building new water projects for flood control and drought management; construction of dykes and storm surge barrier against sea level rise (28).

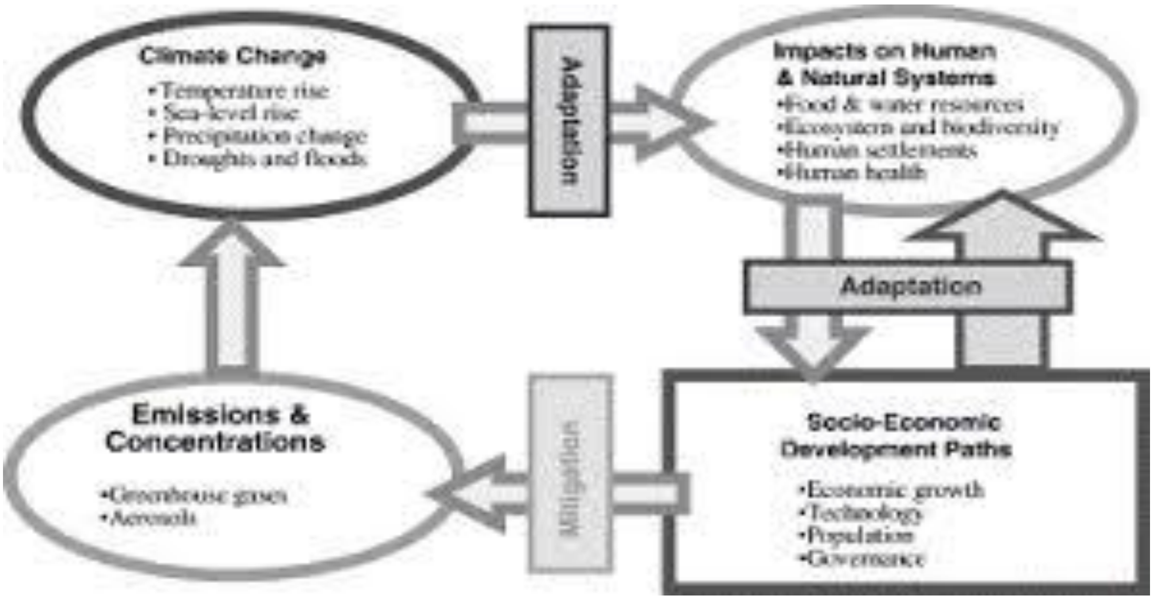

Figure3. *Representation of global climate change, adaptation and mitigation (Source: https://www.science direct.com)*

A good number of adaptation strategies to the impacts of climate change or global warming on fisheries and aquaculture and the fishing communities which depends on the resources for peoples livelihoods has been suggested (29). The countries capture fisheries which have experienced depletion through stress factors such as overfishing and pollution compounded by climate change should be well restocked to reduce vulnerability.

- There should be protection of the resilience of freshwater and coastal waters to avoid habitat destruction and pollution that could cause stress.
- There should be integration of fishing and aquaculture to diversify the economy and empower the communities to secure their source of livelihood
- There should be training opportunities and financial assistance to reduce vulnerability of the fishing communities.
- Development, adaptation and adoption of appropriate fish post harvest technology to reduce huge loss in the rural fishing communities should be emphasized.

Conclusion And Recommendation

Climate change is projected to cause significant alterations to aquatic biogeochemical processes, aquatic food web structure, dynamics and biodiversity, primary and secondary production and affect the range, distribution and habitat quality/quantity of aquatic mammals, waterfowl and others organisms. Climate change will also very likely affect the biodiversity of freshwater ecosystems. Global climate change disrupts community structure and increases native species loss and extinction. The magnitude, extent, and duration of the impacts and responses are location-dependent and difficult to separate from other environmental stressors. Concerted efforts should be made to control the various anthropogenic activities that contribute to climate change.

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