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Reflection on Impacts of Climate Change on Fisheries and Aquaculture: Sub-Sahara Africa

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Abstract: Africa is being faced with issues of food security among others which is making it difficult when the future, vision 2030 is being thought of. As far as the African economy is concerned, fish production—both capture and aquaculture—are contributors, although due to the effects of climate change, the sectors are highly affected, hence increased issues of food security. This study therefore discusses the effects of climate change on fisheries and aquaculture, mitigation measures, and adaptation strategies in Africa according to the different available literatures reviewed. Different effects of climate change include rising sea level, rising water temperatures, rising water salinity, ocean acidification, changes in precipitation patterns, disease, and algal blooms. Some of the mitigation measures being restoration of mangroves at the coastal regions, corals, advocating for reduction in greenhouse gas emissions. On adaptation, both the fish and the fishing community have shown different adaptations. For instance, fish have shown migration habits to safe places as fishers have changed their fishing gears, increased fishing effort, and targeted different new species. However, some adaptations by the fisher community have been seen to be very harmful, hence not promising for the sustainability of the fishery. The study thus recommends that the fishing community be made aware of the importance of diversification in terms of their well-being and as a way to reduce food security, as well as the participation of resource beneficiaries in making policies that are in line with adaptation to the effects of climate change and flexibility of the fishery for sustainability.

Keywords: Climate change, Fisheries, Aquaculture, Adaptation, Mitigation, and Sub-Saharan Africa

1. INTRODUCTION

Fisheries and aquaculture play a vital role in food supply, income generation, nutrition as far as protein is concerned and therefore curbing food security issues both in the global and local scope (Cochrane et al., 2009). Aquaculture as a farming practice has an aim of attaining a sustainable production of aquatic products which is being spearheaded by the dwindling production catches experienced from capture fisheries. Therefore, aquaculture has been recognized as a big player in substituting capture fisheries and filling the gap in increased demand for aquatic products globally (AskarySary et al., 2012; FAO, 2020). Contribution of aquaculture to global fish production has been trending, going up to 82.1 million tons (46%) of the estimated 179 million tons of the total global production and is anticipated to rise to 53% in 2030 (FAO,2020). In spite of this, the question is to when the fisheries and aquaculture sector will remain sustainable enough to meet up the projected demand aggravated by a fast-growing human population, and the greatly changing climate. The greatest risk to global food production (Turyasingura & Chavula, 2022), quality, quantity of production and food security is now climate change effects (Beach and Viator, 2008; Hamdan et al., 2015; Myers et al., 2017; Kandu, 2017).

Climate changes may perhaps affect fisheries and aquaculture directly and/or indirectly (Handisyde et al., 2006; De Silva and Soto, 2009; Maulu, S., et al., 2021), directly by affecting stocks and the global supply of fish for consumption, or indirectly by affecting fish prices, goods and services required by fish farmers in their activities (Handisyde et al., 2006; De Silva and Soto, 2009; Freeman, 2017; Adhikari et al., 2018). Climate change therefore refers to changes occurring in distribution of weather over a period of time, on average decades to millions of years (Akinsanmi, 2009; UNFCCC, 2011: Yazdi and Shakouri, 2010; IPCC, 2014) and may be specific to a particular place or globally (Yazdi and Shakouri, 2010). Humans have however been linked directly to climate change drivers due to the different anthropogenic activities (e.g. use of fossil fuels for energy supply, deforestation and forest degradation) which are responsible for emission of Green House Gases in the atmosphere (Doubleday et al., 2013; Khaine and Woo, 2015; Riphah, 2015; Environmental Protection Agency, 2016; Gao et al., 2016; Barange et al., 2018; IPCC, 2019, Palmer and Stevens, 2019).

Effects of climate change on fisheries and aquaculture sector has been ignored in the past because the importance of the sector was devalued but the coastal and riparian communities are now experiencing the effects and is now difficult to be overlooked (Barange and Perry, 2010). The effect and its unpredictability on both inland and aquaculture production differ with some of the presently experienced and future predicted globally including increase in temperature, shifts in precipitation patterns and increased extreme weather events (Sileshi, A., 2013). Capture fisheries in particular has received more pressure from the effects of climate change together with overfishing, habitat degradation (Turyasingura, Ayiga, et al., 2022), pollution, introduction of new species (Brander, 2010). For instance, a report from FAO, 2009 on the global sustainable yields of the fishery resources show that 1% are recovering from previous depletion, 8% are depleted, 19% overexploited, 20% are moderately exploited and 52% fully exploited (FAO, 2009).

Africa is deemed a land of abundance with vast inland and marine water resources and also most susceptible continent to the effects of climate change (IPCC; Mohammed and Uraguch, 2013). In Sub Saharan Africa for instance, Nile River, River Zambezi, Lake Malawi, Lake Victoria and Lake Kariba are the major aquatic habitats together with many coastal estuarine, (Mohammed and Uraguch, 2013) deltas, floodplains, mangrove swamps and inland wetlands with diverse habitats (Turyasingura et al., 2022), and species that respond differently to changes in climate (Mohammed and Uraguch, 2013). Africa however has the least contribution of Green House Gas (GHG) emissions that are directly related to human activities that can cause climate change. In SSAGHG emissions is the least per capita of all the regions as at now (IPCC, 2022). In spite of that, Africa has by now experienced diverse human-induced climate change upshots. According to Callaghan et at., 2021, studies on the impacts of climate in Africa have paid attention on terrestrial ecosystems or water, with very little on marine ecosystems, agriculture, migration and health and well-being.

2. IMPACTS ON FISHERIES AND AQUACULTURE

2.1. Rising sea level

Globally, global warming has seen an envisaged rise of between 0-90 cm, with most ranging from 30-50cm in this 20th century which will lead to destructions of many coastal ecosystems included in being the mangrove and the salt marshes which are responsible of maintaining wild fish stocks and as source of seeds for aquaculture. Loss of mangroves results in emission of carbon back to the atmosphere. For instance, globally, the period between 2000- 2012, 2% mangrove carbon was lost because of deforestation and effects of climate change like sea level rises, and this equaled 317million tons of added CO_2 emissions (Hamilton and Friess, 2018). Changes in the salinity of the estuarine habitats, submerging wetlands, eradication or reduction of submerged vegetation negatively affect the species diversity, abundance and survival who are dependent on the coastal habitats for their well-being either reproduction, feeding which all result due to the sea level rise effect (Church et al., 2001; OECD, 2010; Hlohowskyjl et al., 1996; UNEP, 2006).

Mangrove and the other coastal vegetation for instance are responsible in cushioning the shore from the strong winds and waves that can end up damaging fish ponds, fishing facilities, research centers, storage facilities and other coastal infrastructure and this may go on and intensify under climate change (Ibe and Awosika, 1991; IPCC,2021). As a result, fish landings, marketing and processing facilities will impact negatively since the fishery production will reduce due to destruction of fish habitats and stress on the fish stock and all this because of sea level rise. For instance, in Nigeria, the 800 km low lying coastline makes the region susceptible to sea water disturbance into coastal freshwater resources which will impact negatively on inland and aquaculture which in turn has affected the coastal communities' livelihoods which are dependent on fishing (Urama and Ozor, 2010). Also, a rise in Abidjan is projected to inundate 562 km^2 along its coastline which is overshadowed by lowland marshes and lagoons. Moreover, a sea level rise of 0.3m in Mombasa, the East African coastal zone may possibly be responsible for submerging it making the area less productive due to salt stresses to fish and also loss of habitats (UN-HABITAT, 2008 report).

2.2. Ocean acidification

The ability of the ocean to soak up a good number of human induced CO_2 emissions is believed to high (Caldeirs and Wickett, 2003). The level of acidification in the oceans therefore, is high because the chemical reaction of water-soluble CO_2, which is converted to carbonic acid (Dupont and Thorndyke, 2009). However, the acidification is double sided with both positive impact (reducing the global warming rate) and negative impacts (affecting the ocean systems which react differently to the changes in pH). Conversely, studies on ocean acidification are still scarce and less done but slowly picking up such that there is no clear information that can support the fact that the acidification of the oceans has a great effect on marine fisheries (Dupont and Thorndyke, 2009; Le Quesne and Pinnegar, 2011).

Le Quesne and Pinnegar, 2011, stated that some of the express impacts on fisheries is the impact on growth of the whole organism: reduced growth and reproductive output hence less recruitments back in the system, alleviated predation and mortality, disturbances in food and feeding habits, high susceptibility to diseases and decrease in thermal tolerance. On the other side, the oblique effects: shift in presence of predator or prey profusion, effects on biogenic habitation (coral reefs) and drift in nutrient recycling. According to Painting, 2011, the most affected stages of fish in the case of alleviated CO_2 and low pH tolerance are the eggs and their larval stages which are the then responsible for stock recruitment. For instance, high CO_2 may sterilize the male gametes hence limiting fertilization which in turn will lead to no recruitment (Byrne et al., 2010). Thus, acidification reduces the growth of plankton and invertebrates which are the main producers in the food chain interrupting productivity of the fisheries.

In sub–Saharan Africa for instance, CC has caused a decline in the numbers of calcifying organism, mollusks, hence a drop in the earnings from mollusk exports, reduced employment opportunities by fishers directly involved in production of mollusks, mushroomed prices of the products hence increased gap between the poor and the rich (Yassin and Uraguchi, 2013). With regards to Cooley et al., 2011, most of the countries in Sub Saharan Africa are exposed to ocean acidification due to the characteristic's low adaptability, high dependence on mollusks and rapid population growths. In Mediterranean Sea for instance, Hilmi et al., (2009) predicted some of the potential direct and indirect effects of acidification; effects on calcifying organisms (mollusks, sea urchins and crustaceans) which can further lead to shell disbanding, lack of food to the finfish due to disturbance in the lower trophic levels (planktons) hence interruption in the food chain hence less production in the finfish sector. Likewise, in South Africa and Tanzania, ocean acidification has greatly impacted on fisheries and aquaculture with same impacts as those stated in Sub Saharan Africa in general and the Mediterranean Sea (Lingen and Hampton, 2018).

2.3. Rising Sea Temperature

Global warming has become a great concern and a threat to the whole world but Africa is the most affected due to its status of poverty (Juana et al., 2013; Rajesh et al., 2014). A prediction of a temperature rises between 0.7ºC to 2.5ºC by the year 2050 by the IPCC report in 2007 and a rise to about 2.5ºC from 1.5ºC will perhaps explain the important effect on ecosystem sustainability which as a result will lead to a meaningful reduction of fisheries production and productivity (Juana et al., 2013). Also, globally the high sea temperatures in the coral region leading to bleaching and damaging to reef ecosystems (IPCC, 2007). According to a report from The State of the climate in Africa 2021, Africa is said to have warmed at an average rate of nearly +3ºC per decade in a period between 1991 and 2021 which is quicker than +0.2º C/ decade that warmed between the period of 1961 to 1990, with 2021 being the third warmest month of all that was ever recorded.

Growth and development of aquatic animals is directly dependent on temperature (Ngoan, 2018). For instance, fish are poikilothermic and hence sensitive to certain temperature variations which may be a result of climate change (Sae-Lim et al., 2017; Adhikari et al., 2018). In regards to the predicted increase in temperature therefore, high mortality rates are expected to occur due to thermal stress especially to the cold species fish like salmon and cod and the intertidal shellfish (Hamdan et al., 2012; Gubbins et al., 2013). In aquaculture, fish metabolism and physiology, feeing and growth performance of shellfish and finfish is prone to the effects. Furthermore, due to chronic stress, neuroendocrine and osmoregulatory systems, and immune response of fishes will also be affected leading to mortalities (Akegbejo-Samsons, 2009; Brodie et al., 2014; Gazeau et al., 2014; Lemasson et al., 2018; Marcogliese, 2008; Paukert et al., 2016; Stévant et al., 2017; Stewart et al., 2019; Zhang et al., 2019). With an increase in ocean temperatures and ocean acidification, the ocean carbon sinking ability gets interfered with leading to emergence of red tides, shift in hydrology and hydrography of water systems which will lead to high management costs and declines in productivity hence impacting the sustainability of aquaculture economically and socially (Cochrane et al., 2009; Seggel et al., 2016). In addition, new species that are warm water species get a chance to be cultured hence making it possible for genetic improvements of aquatic organisms (Bueno and Soto, 2017; Gubbins et al., 2013).
South Africa for instance, is among the countries experiencing ocean temperature rise effects on the ecosystems (Jarre et al., 2015; Lingen and Hampton, 2018). Also, is the case in West African countries with both capture and aquaculture species being affected leading to changes in distribution, abundance and productivity of fish species hence loss of local species which in turn threatens lives of millions of people (Katikiro et al., 2010). Due to temperature rise in the ocean, with reference to western Indian Ocean, coral reefs have experienced very harsh bleaching and mortality. For instance, the El Nino of 1998 to 1999 bleached the corals and it happened again in 2005. In Seychelles, the inner reefs have shown acute ecological consequences leading to a drop from 27% to 3% with extinction of coral feeding species (Graham et al., 2006). Upwelling along the Gulf of Guinea caused by alleviated ocean temperature which makes the ocean waters unfit for fisheries hence a reduction or a complete fall down of fishing activities (African Action, 2007). In sub Saharan Africa, water stress is purported to amplify mostly in the areas that are fairly dry (International Dialogue on Water and Climate, 2004).

2.4. Increase in Water Salinity

As the water bodies in the tropics are rapidly turning out salty, those in the poles and closer to the poles are becoming fresher, hence the tropical lakes are prone to being affected with the issue of increasing water salinity. Like CO_2, changes in water salinity affect each aquatic organism differently depending on its levels of tolerance. According to IPCC 2001, freshwater body salinity is envisaged to increases with increase in anthropogenic activities. Changes in salinity affect zooplankton communities negatively, especially those of freshwater ecosystems. According to Schallenberg et al. (2003), those in low lying, coastal, tidal lake and wetlands gets highly affected to any slight change in salinity. If there is a change in abundance of zooplankton it therefore means there will be disturbance in the food chain as they are the primary producers hence a big effect to the fishery. Moreover, according to Turyasingura, Mwanjalolo, et al. (2022), changes in salinity in the estuarine ecosystems leads to destruction of habitats, breeding and nursery grounds of organisms in the estuary (Marshall and Elliot, 1998). However, there are euryhaline fish species in the estuaries but this only holds depending on the organism since each has their own level of tolerance (Blaber, 1997).

Senegal being a victim of effect of salinity where an increase in salinity has been a factor to destruction of 60 per cent of mangrove areas (IPCC, 2007). The salinity level in the Indian Ocean is reported to be rising but mostly on its upper layers (Bindoff et al., 2007).

2.5. Changes in rainfall patterns

Flooding (due to increased rainfall) and drought (reduced rainfall) are the two ways in which rainfall patterns can be changed by effects of climate change. Danger outcomes from drought are easily accounted for than the flooding impacts (e.g. drought dangers are elevated at 2^{o} C compared to when at 1.5ºC) (IPCC, 2018). Production threats will be increased in lowland areas due to increased rainfall (Bell et al., 2010). Rutkayova et al., 2017, flooding will lead to fish losses in aquaculture from ponds, invasive species or unwanted species in the ponds, management becomes expensive due to damage of ponds dykes and infillings which leads to water quality problems.

Also increased flooding may affect some macro algal which are primary producers in the food chain hence disrupting the food chain which in turn will have an effect on the fishery and will lead to nutrient loading when the macro algal die (Collins et al., 2020). Drought on the other hand leads to inadequacy of water and quality drop (Hambal et al., 1994). This will further lead to user conflicts of interest because the water body is serving a lot of people with different activities aquaculture, domestic use and industrial use (Barange et al., 2018; Handisyde et al., 2006).

Niang et al. (2014), stated that rainfall will possibly reduce by the end of the 21st century in Northern Africa. This is also in agreement with the UN Climate Change report of 2020, which states that the period between 2020 to 2024 will show reduced rainfall hence chances of drought cases mainly in North and Southern Africa but with increased rainfall over Sahel. Also, they indicated that in 2019, Southern Africa was faced with a drought in 2019 whereas there was a shift in the Greater Horn of Africa from very dry conditions in 2018 to early 2019 to heavy rainfall that brought about floods and landslides in the late 2019. Also, floods were experienced in the Sahel with its surrounding areas from May to October 2019. In South African east coast, effects of changes of rainfall patterns have been felt in estuarine and near shore areas in Mozambique and the United Republic of Tanzania where low rainfall has resulted in closure of estuaries which were breeding grounds for shrimps and small pelagic fishes which were responsible for small scale fisheries (Benkenstein, 2013). Furthermore, floods were experienced in South Sudan, Republic of Congo, DRC and Burundi in 2020-2021 while drought was faced in most parts of Northern Africa especially Tunisia, Morocco and Libya (The State of the Climate in Africa, 2022 report). In Lake Chilwa in Malawi, the shallow lake had high production and it supported a fish trade of about US$10M in a year. This was altered with the effect of rainfall fluctuations which then led to episodic drying out of the whole lake which affected production of fishery which is however dependent of water level. This made some farmers to broaden their horizons to farming, pastoralism and many other different occupations, with the able rich skilled fish farmers migrating to other lakes near the region for fish farming (Allison et al., 2007).

Decreased river flows in West Africa have been linked to drought caused by reduction in water level due to rainfall fluctuations and alleviated temperatures together with increased demand of water (Biao, 2017; Descried et al., 2018; Thompson et al., 2017). This is also the case with rivers in the Central Africa, for instance the Congo River. In return all these lead to reduced fish species abundance, destruction of fish habitats, breeding grounds hence no stock replacement at the end poor fishery production in the wild and poor species composition for selective breeding in aquaculture. All this change in rainfall /precipitation have been linked to climate change (Mahe et al., 2013; Alsdorf et al., 2016; von Lossow, 2017). Between 1971 and 1977, species of fish reduced from 40 to 15 in Lake Chad due to drought (Leveque, 1995). This was also the case in Lake Chilwa, but here the production of fish went to zero in 1996 (Allison et al. 2007; Njaya et al. 2011). Limnothrissa miodon in Lake Kariba, the catches reduced to 24metric tons of average per year in the period 1974 and 2003 due to variations in rainfall and water levels (Ndebele-Murisa et al. 2011).

2.6. Diseases and Harmful Algal Blooms

Fluctuations in temperature in aquaculture leads to different diseases which are bacterial, parasitic, viral and fungal (Collins et al., 2020). Thermal stresses both immediate and later affect finfish and shellfish depending on the susceptibility level of the organisms to the disease (Chiaramonte et al., 2016) and this explains why warm water disease outbreaks are on a rising trend in occurrence with more being predicted due to changes in climate (Sae-Lim et al., 2017). Temperature fluctuations is a main player in disease occurrence as it speeds up the rate of duplication, virulence, prolonged life cycle and spread of pathogens amid finfish and shellfish species ((Marcogliese, 2008).

Worldwide achievements in aquaculture production have been limited with the epidemic of epizootic diseases which in turn cause economic constraints in terms of controlling the diseases. Likewise, in cold water species, warm water pathogens (e.g., sea lice are a challenge to salmon culture and as the global warming continues and temperatures are rising more, the infections are exacerbated) (Collins et al., 2020; Maulu et al., 2019). This will therefore lead to poor profits accrued, which will then impact on the social and economic sustainability of the aquaculture production. On the contrary, some of the cold-water diseases for instance vibriosis and winter ulcers might at some point be wiped out because the environment will then not be favorable for their existence and multiplication hence reduced expenditure in disease treatment hence profit maximization (Sae-Lim et al., 2017).

Furthermore, algal bloom has been linked to climatic conditions (De Silva and Soto, 2009; Edwards and Richardson, 2004; Edwards et al., 2006; Lafferty, 2009; Moore et al., 2008; Trainer et al., 2019; Wasmund et al., 1998). For instance, flagellates and dinoflagelletes groups and other harmful species contain possible harmful toxins that can lead to stress and later fish kills (Basti et al., 2019; Gubbins et al., 2013; Hinder et al., 2012). Temperature variation has been reported to be responsible for widespread of harmful algae (Farrell et al. 2015). Lake Victoria for instance has been affected by frequent surge of Cyanobacteria that has led to huge deaths of fish and the bloom is being linked to eutrophication of nitrogen and phosphorus (Hecky et al., 1993; Mchau et al., 2019).

3. MITIGATION OF THE EFFECTS OF CLIMATE CHANGE

Climate change mitigation revolves around actions or activities that reduce global warming and its correlated effects. Greenhouse gases released by burning coal, oil and gas is the main game changer for climate issues (Olivier and Peters, 2020). Reducing greenhouse gases emitted from agriculture, reforestation, waste management are also ways of mitigating (IPCC, 2007). Aquaculture managers are also advised to use products or in their production processes (e.g., of food, they should use non-carbon emitting practices that are environment friendly like use of solar energy, appropriate feeding and ensure or encourage proper waste water management to reduce air and water pollution (IPCC, 2018). In Lake Kivu for instance, there is presence of a good amount of CO_2 that is reduced by degassing the lake water from the lower depths brought into the atmosphere at high heights back to the surface water of the lake with the aim of reducing its accumulation. Also, the methane gas in the lake is used to generate electricity (Morse et al., 2014)

Furthermore, different regions have done mangrove restoration projects along their coastal regions. Mangrove besides being living biomass, their soils are responsible for confiscating and accumulating carbon at vast depths. Mangroves normally occupy the smallest areas which is mainly along the coastal regions but they are able to requisite up to 3-4 more carbon than the terrestrial forests and their lifecycle is prolonged only if not distressed (Mcleod et al., 2011). For instance, the Kenyan coast, a lot of mangroves who are responsible for protecting the coastline from erosion and frequent storm surges, breeding and feeding grounds of fish and shellfish got destroyed. Above all they have been responsible for combating climate change effects by sequestering up to 22.8million tons of carbon each year by their roots, trunks (UNEP- https://news.un.org/en/story/2022/06/1121792). With this different organizations both communities based and government best at Mombasa that are actively engaging in planting more mangroves with the aim of restoration which kicked off in 2017 (https://africaclimatereports.org/2018/01/mangrove-restoration-in-kenya-a-source-of-livelihoods-that-is-a-fight-against-climate-change/).

Restoration of corals has also been advocated in different regions and with different organizations. For instance, NOAA developed a new type of coral nursery for coral restoration which is utilizing fully formed coral colonies and not small fragments (NOAA, 2019). Marine protected areas establishment and management of land-based pollution has been suggested as a way of controlling coral reefs destructions hence improving their resistance to disturbances (Anthony et al., 2017; McLeod et al., 2019a). Together with climate action and conservation and protection practices, predator control has also been vital in protecting and restoring reef ecosystems (Rinkevich 2019; Duarte et al. 2020). Worldwide at least 56 countries are putting into action efforts in coral reef restoration despite the fact that there is still inadequacy of skilled personnel for guidance on the same and the looming effects of climate change (Boström-Einarsson et al., 2020).

Issues related with harmful algal bloom have been stated to increase or occur more frequently in the water bodies. This is because all effects of climate change are responsible for increased blooms; increasing water temperatures (toxic blue-green algae), salinity changes (more droughts, freshwater saltier, invasion of freshwater by marine algae), higher CO_2 (algae require CO_2 for their survival mainly blue green algae), changes in precipitation (increased rains proceeded with drought increases algal blooms), sea level rise (result in creation of more shallow and stable coastal water which will enhance growth of algae) and coastal upwelling (EPA, 2022: https://www.epa.gov/nutrientpollution/climate-change-and-harmful-algal-blooms). Reducing therefore, all the effects of climate change will then definitely reduce the occurrence of algal blooms in the water bodies.

4. ADAPTATION TO CLIMATE CHANGE EFFECTS

Adaptation concentrates on creating resistance to the consequences, and the capacity to utilize arising opportunities sustainably and ethically (Bueno and Soto, 2017). Also, it is the changes in the natural or human systems which is a reaction to the anticipated effects of climate change to manage and regulate damages it will cause (IPCC, 2001). IPCC in their 2007 report stated that Africa as a continent is slow in matters Green House Gas emissions which would otherwise be difficult to tackle in the near future.

Freshwater fish species have shown adaptation to the effect of climatic change by adjusting their biological processes and phenology (Gao et al., 2011; Tao et al., 2018). Any change in temperature changes metabolic activities, physiological processes and the rate at which they grow which is the case for the ectotherms, which occupy the freshwater ecosystems the most (Gallo et al., 2017). For instance, a study on effects of temperature on Nile perch in Lake Victoria showed that temperature rises had a negative on the fish (Getabu et al., 2003; Goudswaard et al., 2011: Nyboer et al., 2020). Also, fish species are fond of migrating to habitats that are conducive for them that is with little or no stress at all in terms of temperature fluctuations, pH rises, salinity changes and food availability (James and Washington, 2013).

Fishers' communities around the world are on the move in adapting to a number of changes (Couthard, 2009) which can either be self-driven or planned and can also either be at individual level, community, national or regional level (Shelton, 2014; Muringai et al 2021). Income diversification has been a major move which gives the farmers different options to earn a living for their survival. For instance, in aquaculture, a farmer can decide to do integrated systems one way or in different water bodies (e.g. ponds for fish and lakes or sea for sea grasses, or fish and plants) (Maulu, 2021). Small scale fishers have also adopted some short-term plans which include shifting to new species, migrating to other places for fishing and aquaculture, changing fishing gears and some have gone far by relying on social networks for updates before they make a move (Musinguzi et al., 2016; Limuwa et al., 2018). In Lake Wamala, Uganda, fishers adjusted their fishing gears, extended fishing time, aimed at catching new species and decided to expand to source of living that is non-fishery related in the tackle of the effects of climate change (Musinguzi et al., 2016). In Lake Tanganyika, Mgana et al. (2019) hypothesized that fishers embraced the use of homemade Light Emitting Diodes (LEDs) to improve their catches of fish. Furthermore, others in the same Lake Tanganyika, have turned to using illegal fishing gears (i.e., mosquito nets which therefore means the ecology of the fish species in Lake is at stake because more of the young fish are captured which are the future stock) (McLean et al., 2014).

Regardless of fishers trying to adapt to the effects of climate change on productivity and distribution of fishes, some of their adaptations are destructive and they are on a short term with no future promising because the stocks are highly replenished with no replacement hence in the long term, issues of food security especially protein related will increase (Musinguzi et al., 2016). Hence therefore, slow but sure the lakes will be empty with some species going into extinction. In Lake Victoria for instance, the number of fishing vessels and illegal gears increased and it led to overexploitation of the existing species and capture of young immature fish (Njiru et al., 2008). At least 95% of the catches of Nile perch according to Njiru et al. (2008) was juvenile or young fish of length less than the stated maturity size. Bush et al. (2017) also found out that in Mida Greek, Kenya, mosquito nets are utilized in fishing by roughly half of the small-scale fishers, with the aim of catching prawns and juvenile fish. Musinguzi et al. (2016) found out that fishers in Lake Wamala, Uganda went ahead using non-selective mesh size drifting from a mesh size of 38.1mm from 88.9mm. Due to the use of illegal gears therefore, even the non-targeted species are caught which is more of exploitation on the stocks (Makwinja et al, 2021).

Organization and restriction among institutions or fishers themselves are the determinants of the adaptation process (Agrawal, 2010). In Tanzania for example, 85% of the fishery yield is contributed to by the inland fisheries, and fishing is referred to as a subdivision in water but the impacts on inland fisheries by climate change is not highlighted by the Tanzanian National Adaptation Plan of action. Also, the Fisheries Act of Tanzania authorized the formation of Beach Monitoring Units (BMUs) with the goal of conserving fishery resources to rejuvenate (Smucker et al., 2021). Lake Nyumba and other Lakes in Tanzania were imposed to a 6 month ban by BMUs which ended up impacting negatively to the wellbeing of the people dependent on the fishery (mainly those along the Lakes) for a living together with leading to food security issues. In Botswana fisheries sector is under the wildlife management approach which main concentration is on conservation and not on sustainability of the fishery (Mosepele and Kalawole, 2017). Role of institutions has also been considerable in Nyaminyami area in Kariba District in Zimbabwe in easing climate change adaptations by educating the fishers (Mubaya and Mafongwe, 2017) although the adaptations are slow due to expensive fishing licenses which is a challenge of affordability to the poor community's fishers.

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