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Review Article

Fisheries and Climate Change in Tropical Rivers: Challenges and Adaptation Strategies: A Review

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ABSTRACT

Every ecosystem is affected by climate change day by day. The decline in fish catch in tropical rivers, changes in species distribution, spawning time, mortality, and loss of habitat, as well as falls in productivity in developing countries, is an alarming phenomenon that needs quick intervention. Tropical species are amassed differently across the various region, they also possess diverse life history physiologies and ecological communities. Thus, in contrast to polar and temperate regions, different responses to climate change might be exhibited by tropical species and their communities. This review provides a critical summary of the effect of climate change on fisheries in tropical regions and the current state of knowledge on the challenges faced. It discusses research priorities to understand better the ways of adapting to such challenges by browsing how species and ecological communities are acclimatizing to climate change in the most biodiverse places in such regions. Other strategies for managing climate change were also considered to be of relatively much importance. This paper suggests other important strategies for mitigating the effects of climate change, considering the social and economic outlays.

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INTRODUCTION

Tropical water bodies represent one of the multifarious marine and freshwater ecosystems in the world which is most likely affected by climate change and anthropological activities (Smith *et al.*, 2010). Tropical Rivers are more exposed to higher water temperatures and solar radiation with lower inter-annual and inter-seasonal climatic variations (Taniwaki *et al.*, 2017). This climate change will impact on biogeochemical factors such as, impairment of water bodies (such as eutrophication) and water unavailability, increase climatic complexity leading to phenomena such as extreme rain events which will consequently result in changes in species composition, distribution, and habitats (Hamdan *et al.*, 2014). These factors as well as the predicted high temperature which is manifested in some regions of the world (Pachauri *et al.*, 2014), will directly affect tropical rivers as well as life in them.

Tropical rivers have recently documented decrease productivity and fish catch as well as the loss of biodiversity. Fisheries in tropical rivers may be threatened by increasing dam construction, pollution, water abstraction, overfishing, warming, and change in water flows. These factors make it difficult to separate the effect of climate change. The challenges of climate change on fisheries and aquaculture have been studied mostly in temperate ecosystems, and their effects, management, and mitigation approach on a broad range of scales have been outlined. However, little knowledge is available on the challenges and possible adoption of mitigating factors in the tropical ecosystem, which might lead to difficulty in the integration of modern practices to mitigate climate change (Taniwaki *et al.*, 2017). This may result in a nonproductive aquatic ecosystem with risks to freshwater aquaculture practices and lead to an economic loss (Pour and Hashim, 2016). This calls for the need to critically examine and evaluate the interaction between fisheries and climate change in tropical rivers.

Adaptation to climate change is no longer a secondary and long-term response to be considered as a last alternative. Adaptation to climate change is now rambling and overbearing, especially to the vulnerable communities (Cooper *et al.*, 2013). Despite the rich research that is

carried out in the aspect of fisheries and climate change in water bodies, a gap exists in the aspect of tropical rivers. This paper provides a conceptual explanation of the state of fishery in tropical rivers and the impact of climate change. It also provides adaptation strategies that germane the impacts. Measuring success in terms of impact on the ground at the local level is the key approach to mitigation. This paper argues that improved pliability of communities in the tropical areas most susceptible to the impacts of climate change on fisheries is the proof of effective climate change adaptation.

Adaptation strategies for climate change

Adaptation is the act of predicting the multifarious effects of climate change and providing appropriate action to prevent or minimize the damage they can cause, or taking advantage of opportunities that may arise. It has been shown that well planned, early adaptation action saves money and lives later (Commission, 2020). These Adaptation strategies are needed at the local, regional, national, and also the international level (EPA, 2017).

The adaptation strategy on local communities is essential and priority in other to provide effective measures from the grassroots or the most vulnerable group of individuals. Adaptation strategy on local communities include; prioritizing adaptation efforts in vulnerable communities, building projected climate change-related trends in today's risk, vulnerability assessment based on current climate variability, integrating full adaptation into longer-term national and local sustainable development. These can be supported through poverty reduction strategies, prioritizing the strengthening of existing capacities – among local authorities, civil society organizations, and the private sector. There is also a need for developing robust resource mobilization mechanisms for adaptation, as well as controlling the opportunities in disaster prevention and response (IFRC, 2009).

The climate adaptation strategies include efficient utilization of scarce water resources (this is crucial for achieving food security and improving rural and periurban livelihoods), mitigating extreme weather by building codes, raising dykes' levels, and building flood defenses which will help in achieving food security and poverty reduction, growing drought-tolerant crops and mitigating species by setting aside land corridors. These adaptations are a more or less general approach; climate change needs to be observed in terms of effects on tropical rivers and how it considerably affects fisheries and its activities. Several researchers have recommended several strategies for the adaptation of climate change. Asiedu *et al.* (2017) highlight that good adaptation strategies involve extension education in aquaculture, construction of river embankment to check for flood, adjusting fish stocking time, construction of boreholes, water management, and setting farms close to water bodies. Climate change can also be adapted by enabling fishermen to learn alternative skills such as systematic information management; periodical assessment, access to credit managed retreat; accommodation, and protection (Shaffril *et al.,* 2017*)*. Likewise, Strengthening the knowledge and information related to climate change among fishermen such as El Nino and La Nina, hurricane, frequency of rain, and others which related to the disaster of Mother Nature, Mangrove replanting and artificial reef, as well as expansion of sustainable marine aquaculture (Muhammad *et al.,* 2016), will help to adapt to new and effective practices of fisheries in tropical rivers. The tropical region's capture fisheries which have suffered depletion through stress factors such as overfishing and pollution, and now being compounded by changes in climate, should be on continuous well-planned restocking programs to reduce their vulnerability (Magawata and Ipinjolu, 2014). Other approaches include; periodical adaptive assessment, training, and adaptive capacity building, participatory action research, access to climate technology, information, and skills that should be further strengthened. These approaches can be strengthened through the establishment of agencies that will ensure mobilization and implementation of the action plans as well as ensure supervision. Early education and public awareness programs, research information sharing and information dissemination programs should be intensified; diversify fishermen alternative skills (Samah *et al.,* 2013).

Adaptation toward climate change at the local level can also be achieved by addressing drivers of vulnerability (through diversifying sources of household income, participate in income stabilization programs, introduce social protection initiatives, promote community-based risk management measures to face production failure and price of the product, develop innovative risk financing instruments and insurance schemes to reduce climate-related risks), building response capacity (by Conservation of genetic resources, Implement co-management systems), managing climate risk (by Disaster risk reduction, Disaster risk management) (Olawale, 2016). The government can also enforce strategies of adaptation empowering and strengthening relevant institutions to support locals and work together in enforcing laws to minimize polluting of water bodies and providing training on modern techniques of fishing. There is also a need for the provision of assistance through credit/loan and increase to stakeholders through empowerment (Freeman, 2013). Although, despite these adaptation strategies recommended by several authors, and the effective implementation road map is not provided to achieve the suggested approach with the fact that tropical rivers are affected by climate change at an alarming rate, which needs quick intervention.

Contemporary climate change in the tropics

Increasing fossil fuel burning and land-use changes have emitted greenhouse gases in increasing quantities into the Earth's atmosphere. Due to the rise in greenhouse gases (CO_2, CH_4, and N_2O), heat from sunlight that will normally be radiated back into space is withheld in the atmosphere which ultimately led to the greenhouse effect, resulting in climate change (NASA, 2020). Climate change is mainly characterized by increases in mean annual global temperature (global warming); rises in ocean temperatures; fluctuations in cloud cover and precipitation particularly over land and ocean acidity (as a result of seawater absorbing heat and carbon dioxide from the atmosphere); melting of ice caps and glaciers and reduced snow cover (UNFCCC, 2017).

The tropics are experiencing tremendous climate change lately as it is in the rest of the world (IPCC, 2014). In the previous years, tropical residents have little experience of climate change due to the fact that the

progressive rise in greenhouse gases is less obvious because they are overlain by considerable natural variability (such as high temperature, drought, and flooding). Many tropical areas are now significantly experiencing a high amount of rainfall and drought in some areas than they were a century ago, with highly noticeable fluctuations. The low day-to-day variability of tropical temperatures shows that fluctuation in mean annual global temperature is certain to bring temperature extremes higher than any that occur today (Hulme and David, 1998).

Water pollution problems increase with an increase in temperature. Increases in water temperatures are expected to result in the following: Lower levels of dissolved oxygen due to the inverse relationship that exists between dissolved oxygen and temperature. Many aquatic habitats will be negatively affected by an increase in water temperatures resulting from an increase in the air temperature. As the temperature of the water increases, dissolved oxygen levels decrease; Increase in algal blooms; Loss of aquatic species whose survival and breeding are temperature dependent; Increases in pathogens, nutrients, and invasive species. Increases in concentrations of some pollutants such as ammonia and pentachlorophenol due to their chemical response to warmer temperatures (Ficke *et al.,* 2007). Increased rates of evapotranspiration from water bodies, resulting in the shrinking of some water bodies such as the Great Lakes. Climate change also affects water availability by decreasing groundwater and surface water supply in some areas. Increased water demand due to higher temperatures. High temperature is also related to high evaporation, which may in turn increase the amount of cloud cover, precipitation, and intensity. It also affects water quality by increasing runoff resulting in erosion and sedimentation as well as overwhelmed water infrastructure due to flooding.

An increase in temperature has a direct effect on the amount of evaporation and intensity of rainfall. In recent years, an increase in the amount of heat as a result of global warming has affected the amount of rainfall in various regions of tropics. Reports have shown that countries like Sudan have experienced a tremendous amount of rainfall in 3 days that is equivalent to an entire year rainfall. Other countries like Nigeria, Uganda, Somalia, Chad, Mali, Cameroon, and Niger have experience more widespread rainfall than usual, leading to flooding and land degradation in the regions (NOAA, 2020).

Sudan has been greatly affected by flooding with more than 0.5 million people affected, over 100,000 houses have been demolished and about 100 people have lost their lives. 17 states have been affected with a higher magnitude than that of 1988 and 1946. In South-Sudan, the United Nations has reported the displacement of over 600,000 people from their settlements. Four countries along the white Nile have been affected since 2020 as a result of heavy rainfall which causes flooding of water across embankments, dykes, and banks which ultimately overflood settlement and habitants (IFRC, 2020).

Increased tropical storm intensities will have negative effects on water resources. More intense tropical storms can damage infrastructure, cause increased flooding, which can overwhelm water infrastructure, and cause pollutants to directly enter waterways and contaminate water supplies.

Fisheries responses to climate change

Freshwater biodiversity has declined faster than either terrestrial or marine biodiversity over the past 30 years and is likely to be further reduced by warming temperatures, reduced precipitation, and increased water withdrawal for agriculture and other human uses (Alcamo *et al.,* 2003). Xenopoulos *et al.,* (2005) studied scenarios of freshwater fish extinctions from climate change using General Climate Models and proposed that by 2070 tropical rivers were predicted to lose more than 10% of their fish species. The effect of climate change (the combination of increased evapotranspiration and reduced precipitation in river basins) was the most important driver of freshwater fish loss, with water consumption (the fraction of water withdrawn from a river for various anthropogenic uses, but not returned to the river) contributing much less to species loss.

Brander (2010) studied the effects of climate change on ecosystems, fish, and fisheries. At the individual level, climate change impacts the performance of different life-history stages through changes in physiology, morphology, growth, reproductive capacity, mortality, distribution, and behavior, while at the population level climate change influences dispersal and recruitment. Climate change may bring about community-level changes through effects on species interactions, namely competition, and predation. Climate change can indirectly bring about changes in productivity, structure, and composition of marine ecosystems. According to Barange and Perry (2009) marine species are strongly influenced by temperature, with optimal conditions for growth at the mid-range of the distributional temperature limits. Species adapted to colder waters may have difficulty in providing enough oxygen to tissues as water temperature increases and along with its metabolic demands, larger individuals generally reaching their thermal aerobic limits sooner than smaller fish. Temperature effects may be compounded by interactions with other factors such as PH and oxygen. For this reason, the Dynamic Bioclimate Envelope Model (DBEM) approach has been used to model the effects of climate change on distribution and abundance (Cheung *et al.,* 2009). Climate Change can also strongly influence spawning and reproduction, given that species have adapted spawning times and locations to particular physical (e.g. temperature, salinity) conditions and biological (e.g. food) conditions that maximize reproductive success (Barange and Perry, 2009). Several hypotheses linking climate change and changes to recruitment and abundance of marine fishes have been proposed. That recruitment is maximized under average, or "optimal" conditions, and therefore any deviation from these conditions due to short-term climate change or long-term climate change might lead to less successful recruitment. Since conditions at the extremes of the distributional range of a species are usually less optimal, the hypothesis predicts that recruitment will generally be less successful at the distributional limits.

On the other hand, climate change can have an indirect effect on fishing activities. This can be socio-economic effects, ecological effects, and direct effect. The ecological effect may lead to change in the yield of fish, change in species distribution, increase the variability of catches, and change in seasonality of production. Direct effects are impacts on infrastructure which include damaged

gears, loss/gain of navigation routes, and flooding of fishing communities. The socio-economic effect causes an influx of migrant fishers, increasing fuel costs, reduced health due to disease, the relative profitability of other sectors, resources available for management, and reduced security funds for adaptation.

Adaptation strategies for the impact of climate change on fisheries

In many cases, adaptation can help in decreasing the effect of the significant adverse impact of climate change, hence, it is essential. On one hand, uncertainties in the predictions for future climates favor 'low regrets' strategies that provide benefits under current climate conditions as well as a range of future climates. On the other hand, these uncertainties threatened the aquatic biodiversity and the possible prospective such as Robust Decision Making (RDM) and Predictive Biological models (PBM) in developing efficient and effective fisheries practices. Some of these measures are essentially attractive due to the fact that they produce benefits both fishery practices and co-benefits for other development goals (Fig. 1).

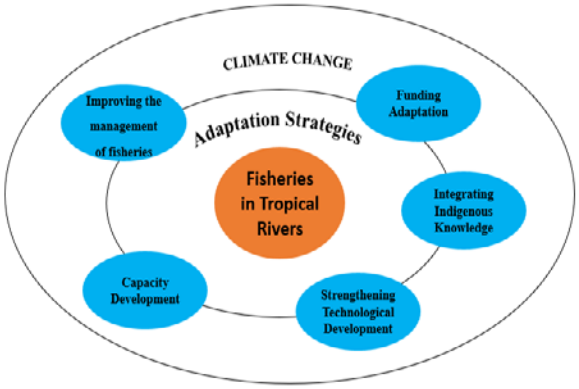

Fig. 1: Adaptation strategies of the impact of climate change on fisheries

Adapting to climate change will entail regulations and changes at every level ranging from community to national and international. Appropriate technologies must be put in place in conjunction with most of the traditional knowledge, and diversifying livelihoods to cope with current and future climate stress. Local coping strategies and traditional knowledge need to be used in synergy with government and local interventions. The choice of adaptation interventions depends on national circumstances such as characteristics of the community, the nature of the intervention, and the local factors that are driving climate and non-climatic risks. To enable workable and effective adaptation measures, ministries and governments, as well as institutions and non-government organizations, must consider integrating climate change in their planning and budgeting in all levels of decision making (Birkmann *et al.*, 2010).

Improving the management of fisheries

Several management strategies should be adapted such as, the region's capture fisheries which have suffered depletion through stress factors like overfishing and pollution. These have now been compounded by changes in climate. Therefore, there should be a continuous well-planned restocking program to reduce their vulnerability (Magawata and Ipinjolu, 2014). Protecting the resilience of the freshwater and coastal waters, by avoiding habitat destruction and pollution that could further aggravate stress on the systems. De-silting of the natural water bodies, (rivers, lakes, creeks, and reservoirs) to prevent drying-up has already manifested in zones across the country. Control of fishing effort and limiting the quantity of fish caught to reduce overfishing as ways of protecting the water bodies and the resource for poor fishermen. Integration of fishing with agriculture to diversify the economy and empower the communities to secure their means of livelihoods. Promote the culture of planktonophagous and herbivorous fishes that feed at the lower level of the food chain and others such as seaweed and shellfish which, according to (FAO, 2018) could help to sequester carbon. The adaptation of these strategies will go a long way in minimizing the vulnerability of fisheries to climate change.

Capacity development

Capacity development emphasizes the need to build on what exists, to utilize and strengthen existing capacities, rather than arbitrarily thinking of starting from scratch. Capacity development to adapt to climate change in the tropics is about complex processes of changing people's mindsets and behavior and introducing more efficient technologies and systems. In the aspect of fisheries, new technologies are required to complement existing local techniques of fishing. Local fishermen should be enlightened to welcome changes through practical awareness. Just as capacity is not static but requires continuous renewal, so capacity development is a continual process of improvement within an individual, organization, or institution, not a one-time event. It is essentially an internal process, which only may be enhanced or accelerated by outside assistance, for instance by donors. This has two important implications. First, capacity development takes a long time and requires a long-term commitment from all involved. Second, the success of capacity development efforts should not be measured in terms of disbursements or outputs with little attention to sustainability. The need for capacity development in developing countries on the issue of adaptation to climate change requires: scientific and research capacity, strengthening the most vulnerable communities, sector-specific capacity building, National policy level capacities, and public awareness.

Strengthening Technological Development

Low cost and appropriate technologies should be used in enhancing existing traditional technologies better than investing in new technology. For example, deepening existing wells in a river floodplain, and adopting simple rainwater harvesting technologies showed good results indicating that good scientific information and low-cost technology can provide appropriate adaptation that can also increase the level of resources management. The development and testing of these varieties should not be restricted to controlled experimental farms but should be tested in real-world situations with local farmers (Magawata and Ipinjolu, 2014). It is also recognized that investments in fishery research (especially in genetic modification to cope

with the change in water environment due to high climate variability) which need a constant involvement of the public sector (through policy actions and investments) could increase productivity.

Integrating Indigenous Knowledge

The high climate variability that characterizes the tropical region presupposes that people have developed successful indigenous adaptation strategies. Indigenous knowledge refers to the skills and expertise realized by combining local and traditional knowledge held by the native people of a particular place (Berkes, 2012). For example, bump head parrotfish (Bolbometopon muricate and) was observed by indigenous people of the Western Solomon Islands that it undergoes a population change and they provided conservation strategies (Ban *et al.,* 2017). Change in the relative abundance of several fish species after the construction of a local dam was observed by local fishermen in the Brazilian Amazon, this is consistent with subsequent scientific surveys (Hallwass *et al.,* 2013).

There are also documented successful traditional farming techniques to conserve biodiversity while managing freshwater bodies so that water and water resources relationship is maintained. These traditional practices include agroforestry, intercropping, crop rotation, cover cropping, traditional organic composting, and integrated crop-animal farming which have the potentials for enhancing crop productivity and mitigating climate change (Singh and Singh, 2017). It has been pointed out the fact that traditional adaptation strategies are hindered by widespread poverty and the recurrence of droughts. It is advocated that formal climate change mitigation and adaptation strategies should be integrated with indigenous knowledge should. The first step is to acknowledge that well scrutinized indigenous knowledge has guided local people with the competence of dealing with changes in vulnerabilities to climatic extremes and other stresses in the past and present (Fauzi *et al.,* 2010). Second, local participation most be encouraged by adopting the bottom-up participatory approach to achieve the highest level input (Butler *et al.,* 2012). This is essential because (i) it provides important insight into how communities and households interact and share ideas, and (ii) it allows the intended beneficiaries to exhibit their skills and innovations to sustain the projects (Nyong *et al.,* 2007). Third, the local communities should be seen as equal partners in the development process. It is an internal process, which only may be enhanced by outside assistance. Local agencies should be in charge while other external partners should back their efforts to assume greater responsibility for their development.

Funding adaptation

While several adaptation funds have been set up to assist developing countries to adapt to climate change (Isabella, 2020), the mechanism for drawing these funds is still vague and continent like Africa is yet to benefit from such funds. It is therefore important that such funds are made operational and easily accessible. Underprivileged small-scale fishermen are highly vulnerable to the impacts of climate change. Thus, improving their access to credit can help them to adapt and expedite recovery processes (Shaffril *et al.,* 2013).

CONCLUSION

Climate change is a global prodigy that affect the natural environment. Climate change is a serious challenge for tropical rivers. The impact of climate change causes limited sustainable production of fisheries and aquatic life. Several studies have proven that climate change increases continuously which introduces several symptoms such as an increase in temperature, an increase in water pollution, increased tropical storm, loss of aquatic life, extreme rainfall, wind speed, and so on. All of these 'symptoms' are found to significantly affect the natural environment of the tropical rivers which ultimately affects fish and fishing activities. Fisheries are affected by changes in physiology, morphology, growth, reproductive capacity, mortality, distribution, and behavior of fishes as well as damage to infrastructure and gears.

Six strategies are suggested to intensify adaptation of climate change; (1) Improving the management of fisheries (2) Capacity Development (3) Strengthening Technological Development (4) Integrating Indigenous Knowledge (5) Funding Adaptation. Therefore, it is important to ensure the implementation of these adaptations in response to climate change by local fishermen as well as stakeholders to safeguard sustainable fish production and food security improvement.

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