FUDMA Journal of Earth and Environmental Sciences (FUDJEES), Vol. 3, No. 1, 2026
Print ISSN: 1595-9686
EISSN: 1595-9708

# EFFECTS OF CLIMATE CHANGE ON THE COMPOSITION OF FISH SPECIES AND FISHING ACTIVITIES ALONG THE JAMA'ARE RIVER, NIGERIA

**[1]Dahuwa, A. A., [2]Shehu, K., [1]Auwal, I. N., [1]Muhammad, B. A., [2]Muazu, A. and [2]Abdulhamed, A. I.**
[1]Department of Geography, Aminu Saleh College of Education, Azare, Bauchi State, Nigeria
[2]Department of Environmental Sciences, Federal University Dutse, Jigawa State, Nigeria

Correspondence: Kabiru Shehu (email: kasaaga36.ks@gmail.com)
https://doi.org/10/3303/jees.2026.0301/037

***ABSTRACT***
*This study examines the effects of climate change on fish species composition and fishing activities along the Jama'are River, Nigeria. The study was conducted along a section of the Jama'are River between latitudes of 12.00°N and 12.30°N and longitudes 9.00°E to 11.00°E. Data were collected from five fishing communities (Zigau, Disina, Jama'are, Walai, and Sakwa) located along the Jama'are River Valley. In the selection of fishing communities, a probability random sampling technique was employed, and balloting was adopted where each community was given a unique number serially, 1 to 10, on separate paper, folded and shuffled, and then blindly drawn one at a time until a sample for the selection of five fishing points was selected (Lottery). The data were collected through interviews and structured questionnaires and then analyzed descriptively using tables, percentages, and simple means. The results showed little variation in the decline of fish species and fishing activities between communities. The study recommends supplying fish seeds to farmers to support sustainable food production and development.*

**Keywords:** Climate Change, Fish Species, Fishing Activities, Jama'are River

## INTRODUCTION

Fisheries play a vital role in global food supply, food security, and income generation. According to the Food and Agriculture Organization (FAO of the United Nations, 2018), approximately 43.5 million people are directly engaged in fisheries-related activities, the majority of whom reside in developing countries. When associated sectors such as processing, marketing, distribution, and supply industries are included, the fisheries sector supports nearly 200 million livelihoods worldwide. Aquatic foods are highly nutritious and contribute at least 20 percent of the average per capita animal protein intake for more than 1.5 billion people, particularly in developing countries. In addition, fish and fish products are among the most widely traded food commodities globally and constitute an important source of export earnings for many developing nations.

The significance of fisheries is particularly pronounced in small island states, where fish accounts for at least 50 percent of animal protein consumption (FAO of the United Nations, 2018). Climate change is projected to affect ecosystems, societies, and economies broadly, increasing pressure on livelihoods and food supplies, including those in the fisheries sector (Belhabib et *al*., 2016). 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. The fisheries sector differs from mainstream agriculture and has distinct interactions and needs with respect to climate change. Aquaculture complements and increasingly adds to supply; though more similar to agriculture in its interactions, it has important links with capture fisheries.

Recognizing the growing importance of climate change impacts on fisheries and aquaculture, the FAO Fisheries and Aquaculture Department organized an Expert Workshop on Climate Change

Implications for Fisheries and Aquaculture from 7–9 April 2008. The workshop aimed to provide the FAO Conference with a comprehensive understanding of climate change issues affecting fisheries and aquaculture. It also responded to the request of the twenty-seventh session of the FAO Committee on Fisheries (COFI), which urged FAO to identify key climate-related challenges facing fisheries, promote discussions on adaptation strategies and lead efforts to inform fishers and policymakers about the likely consequences of climate change on fisheries. This workshop marked FAO's first major initiative to address climate change concerns in the fisheries sector (FAO of the United Nations, 2018).

Evidence suggests that climate change is already influencing aquatic ecosystems globally. Warm-water fish species are gradually shifting toward higher latitudes, while changes in habitat size and productivity are becoming increasingly apparent. In a warmer climate, ecosystem productivity is projected to decline in most tropical and subtropical oceans, seas, and lakes, while productivity may increase in higher latitudes. Rising temperatures are also expected to alter fish physiological processes, producing both beneficial and adverse effects on fisheries and aquaculture depending on geographic location and environmental conditions.

The International Panel on Climate Change (IPCC, 2007b) has examined the implications of projected climate change for freshwater systems. Overall, it concludes that freshwater resources are vulnerable to, and could be strongly impacted by climate change. Expected changes include decreases of between 10 and 30 percent of average river runoff at mid-latitudes and in the dry tropics by mid-century (Kundzewicz *et al.*, 2008) and increases of 10–40 percent at high latitudes and in the wet tropics (Milly *et al.,* 2005); shifts in the form of precipitation from snow to rain and a consequent change in the timing of peak river flows; and changes in flood and drought frequency and intensity. The IPCC assessment also concluded that the impacts of climate change and effective adaptations will depend on local conditions, including socioeconomic conditions and other pressures on water resources (Kundzewicz *et al.,* 2008). Temperature change patterns in inland waters are expected to follow changes over land areas, which warm faster than global atmospheric annual means because less water is available for evaporative cooling and they have less thermal inertia than the oceans (Christensen *et al.,* 2007).

In many African countries, dependence on fish protein in diets, limited alternative sources of food and employment, and small, weak economies make them highly vulnerable to the effects of climate change on fisheries and aquaculture, socially and economically as well as ecologically (WorldFish Center, 2009b). Inland fisheries will be strongly affected by changes in rainfall and rising temperatures; some of these changes are already evident. Coral damage, particularly in East Africa, will affect reef fisheries and could increase ciguatera poisoning (IPCC, 2007a). Low-lying coastal areas will suffer from rising sea levels and damage to important coastal ecosystems such as mangroves. For instance, Lake Chilwa, Malawi, averages just 3m deep and can dry out completely during low rainfall. However, in high-rainfall years, it supplies up to 25% of Malawi's fish and employs 10,000 people (FAO, 2007). In lakes where stock levels are determined by highly variable water levels, management for stock conservation has been argued to be irrelevant. If biomass levels are tied to climatic variation, then controlling fishing effort only limits fishers' incomes. The most important measure to maintain the fishery is to keep the wetlands, which serve as a refuge for fish when the lake dries out, in good condition (Allison *et al*., 2005).

Similarly, in the Niger Delta, Nigeria, flooding and seawater intrusion have greatly affected the salinization of brackish waters, leading to the loss of indigenous aquatic species (Awosika, 1995). Seawater intrusion could seriously affect food security in the region by disrupting coastal agriculture. Rising temperatures have increased algal blooms in lakes, favouring invasive species, increasing stratification, and lowering lake levels. Other effects include flooding of fish ponds, especially those sited in wet farmlands near rivers (Idowu et al., 2011), and increased pond temperatures that raise mortality rates among cultivated fish in the region. Projected reductions in water flows and increases in sea level may negatively affect water quality and fish species in the region. This is expected to have economic effects on communities that depend on these resources, especially the fishermen and fish-keepers in the region whose occupation is mainly fishing and marketing of cultured fish.

Against this background, this study examines the effects of climate change on fish species composition and fishing activities along the Jama'are River. Specifically, the study assesses fishermen's perceptions of how changes in water volume affect fish catch and investigates variations in the decline of fish species and fishing activities across communities along the river.

## LITERATURE REVIEW

This review examines climate change and fisheries in relation to climate-induced ecological changes in fisheries, socioeconomic vulnerability and livelihoods, fish adaptation and biodiversity concerns, and institutional and management challenges.

Climate-Induced Ecological Changes in Fisheries: Several studies emphasize the direct influence of climate variability on fish production and aquatic ecosystems. Magrin *et al*. (2007) reported that climate variability significantly affects inland and marine fisheries by changing water stability, nutrient availability, and ecosystem productivity. For instance, reduced nutrient circulation in Lake Tanganyika led to declining pelagic fish catches, while El Niño and La Niña events altered marine productivity along the Peruvian coast. Similarly, Dawood *et al*. (2018) identified precipitation patterns, seasonal flooding, and water quality as major ecological determinants of fish yields, with impacts varying across regions. In the Indian subcontinent, Vass *et al. (2009) and Dey et al.* (2007) observed rising temperatures, changing monsoon patterns, and altered breeding cycles of Indian major carps, indicating that climate change can both disrupt and extend fish reproductive activities.

Socioeconomic Vulnerability and Livelihoods: Another major theme concerns the socioeconomic implications of climate change for fishing communities. Allison *et a*l. (2005) noted that subsistence fishing communities are highly vulnerable to environmental shocks, with resilience often depending on access to alternative livelihoods. Likewise, Allison *et al*. (2005) demonstrated that drought-induced fluctuations in Lake Chilwa's water levels strongly influenced fish productivity, forcing many fishers to diversify into farming, pastoralism, and migration to other fishing areas. At the global scale, FAO (2022) highlighted the importance of inland fisheries and aquaculture for food security, nutrition, employment, and economic development, particularly in developing countries where rural livelihoods depend heavily on fish resources.

Fish Adaptation, Biodiversity, and Sustainability: A third thematic area focuses on fish adaptation and biodiversity conservation under changing climatic conditions. Ficke et al. (2007) explained that fish species respond to environmental changes through adaptation, migration, or extinction, although rapid climate change may exceed many species' adaptive capacity. Grossmann (2005) further observed that dams and water diversions obstruct migratory routes and increase extinction risks for isolated fish populations. In support of this, Reid *et al*. (2019) stressed the importance of genetic plasticity and adaptive capacity for long-term species survival and ecosystem sustainability.

Institutional, Policy, and Management Challenges: The literature also identifies institutional weaknesses and poor resource management as critical factors exacerbating fisheries decline. FAO (2022) and the World Bank and FAO of the United Nations (2018) argued that inadequate fisheries data and the exclusion of informal fishing activities from national statistics undermine effective policy formulation. FDF (2021) recommended integrated water productivity and landuse approaches to address threats such as habitat modification and water competition. In the Hadejia–Jama'are and Komadugu–Yobe Basin, HJKYB (2005) identified institutional complexity and weak water governance frameworks as major barriers to effective resource management. The report warned that continued drought, flooding, sedimentation, and poor management could intensify environmental degradation, livelihood losses, conflicts, and poverty among fishing communities.

Overall, this demonstrates that climate change affects fisheries through interconnected ecological, socioeconomic, and institutional pathways. These studies collectively highlight the urgent need for adaptive fisheries management, improved governance and targeted research to sustain fish resources and protect the livelihoods of dependent communities.

## MATERIALS AND METHODS

### Study Area

The Jama'are River Valley (Figure 1) is located in the north/east zone of Nigeria, between latitude 12°00'N and 12°30'N and longitude 9°00'E and 11°00'E. The river has its source in the highlands of the Jos Plateau and flows in the northeast direction, forming the main drainage system in the western and northern parts of Bauchi State (Fig. 1). The river flows from an area of high rainfall into an arid region, like the other rivers of the Chad Basin. The study area covered five communities, i.e., Zigau, Disina, Jama'are, Walai, and Sakwa, in four local government areas in Bauchi State, Nigeria: Shira, Jama'are, Itas/Gadau, and Zaki. The study focuses on the Jama'are River, part of the Hadejia-Jama'are-Komadugu-Yobe Basin (HJKYB) in northeast Nigeria, which covers approximately 84,000 km². The river supports over 15 million people through agriculture, fishing, and livestock rearing. Originating in the Jos Plateau, the river flows northeast, meeting the Hadejia River to form the Yobe River before discharging into Lake Chad. The river basin's landscape includes seasonally flooded areas (fadamas) with levees, swamps, and oxbow lakes (Eduvie *et al*., 2021).

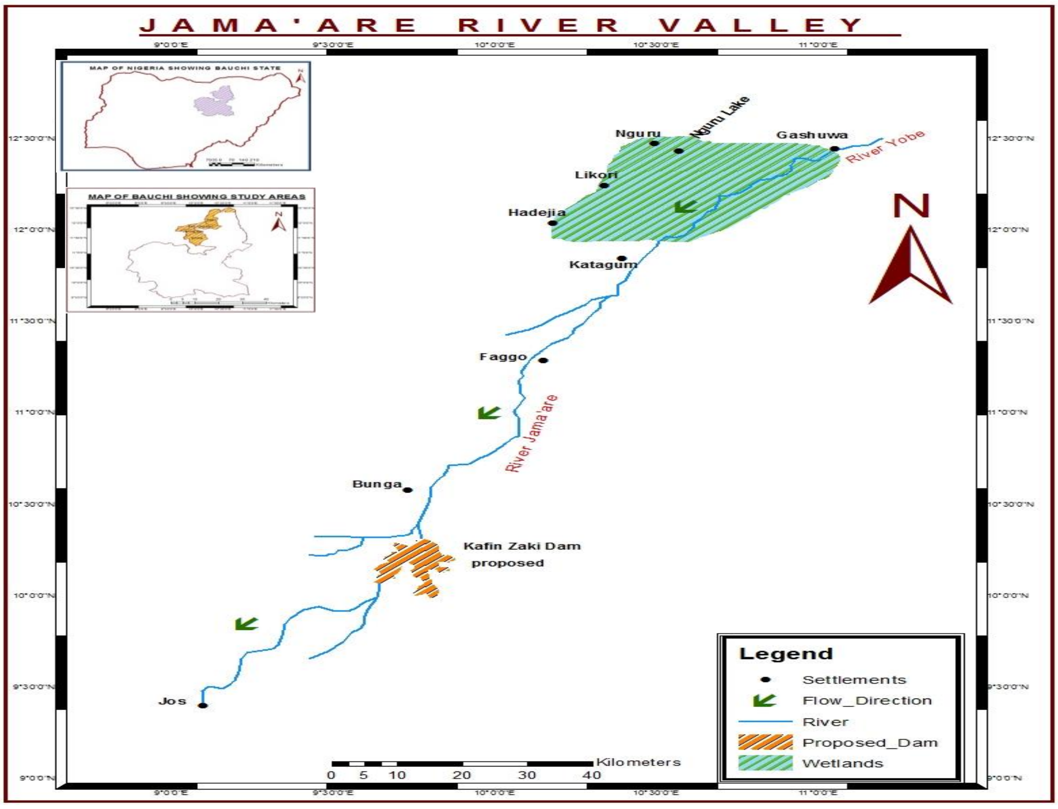


**Figure 1:** Jama'are River Valley

Climatically, the study area has distinct wet and dry seasons influenced by the Intertropical Convergence Zone. Annual rainfall varies from 1,000 mm in the upstream areas to less than 300 mm near Lake Chad. Vegetation transitions from Sudan Savannah with short grasses and trees to desertified zones in the north due to human activity and climate change. The soils range from ferruginous tropical soils to poorly drained hydromorphic soils. Hydrologically, the basin is prone to droughts and floods, with significant reliance on both surface and groundwater for agriculture and human needs (Salami *et al.,* 2025).

**Data Collection**

The study initially identified ten fishing communities within the study area. However, data collection was conducted in five communities that were randomly selected through a lottery sampling technique. The selected communities were Disina, Zigau, Jama'are, Walai, and Sakwa. The target respondents included fishers and other households directly engaged in fishing-related activities within the selected communities. Data were collected using structured questionnaires and interview schedules administered to respondents to obtain information on fishing activities, climate-related challenges, livelihood conditions, and socioeconomic characteristics.

A sample size of 224 respondents was obtained using a 50% sampling fraction derived from the Cochran sample size determination formula. The respondents were then proportionately selected from the five sampled fishing communities to ensure adequate representation of the study population.

**Data analysis**

The research combines descriptive and inferential statistical analyses to examine how climate change affects fish species composition and fishing activities along the Jama'are River. The chi-square test was used to examine the relationship between water level and fish catch volume along the Jama'are River associations to determine whether a significant relationship exists between environmental conditions and fisheries productivity. Descriptive statistics tools such as frequency counts, percentages, and tables were used to summarize respondents' opinions and explain trends in fish species composition, fish catch volume, and fishing activities. One-way ANOVA was also used to compare variation in fish species decline and fishing activities among different fishing communities.

**Composition of fish species and fishing activities**

We observed fish species composition and fishing activities, and present the results in Table 1. The table shows that the 26 species available along the Jama'are River Valley include 21 species from the 1980s and 1990s, 10 species from 2010 to 2015, and 11 species currently the most captured. This indicates a shift in fish species and fishing activities along the river valley, reflecting the strong relationships among climate, fish stocks, fishing, and freshwater ecosystems. The data in Table 1 were further subjected to a Chi-square test to test for the association between water level and fish catch volume along the Jama'are River, which was observed (Table 2), and the calculated chi-square yielded a value of 17.25, while the critical value at the 5% level of significance is 7.82, which is lower than the calculated value. This indicates an association between water level and fish catch volume along the Jama'are River.

**Table 1:** Observed changes in the volume of fish species and fishing activities along the Jama'are River valley

| S/NO | Available fish species | 80-90 species | 2010-2015 species | Presently, the top captured species |
|---|---|---|---|---|
| 1 | *Rainbow trout Oncorhynchus mykiss (Kanzai)* | + | - | - |
| 2 | *Mumyrusspp (Sawaya)* | + | - | + |
| 3 | *brown trout (Tata)* | + | - | - |
| 4 | *rainbow trout (Kurta)* | + | - | - |
| 5 | *Labeo salaganasis (Saro)* | + | - | + |
| 6 | *Synodontis spp. (Kwambami)* | + | - | - |
| 7 | *Hydrocynus spp or Tiger Fish (Tsage)* | + | + | - |
| 8 | *Common carp (Kausa)* | + | - | - |
| 9 | *Bagros Bayad (Masko)* | + | + | + |
| 10 | *S. Schall (Karaya)* | + | - | + |
| 11 | *Brycinus sp. (Kawara)* | + | + | - |
| 12 | *Perch spp(Lausa)* | + | - | - |
| 13 | *Auchenoglanisspp (Burdo)* | + | + | + |
| 14 | *Tilapia spp. (Karfasa)* | + | + | + |
| 15 | *Heterotis niloticus (Bargi)* | + | - | - |
| 16 | *Clarias spp. or Catfish (Tarwada)* | + | + | + |
| 17 | *Gymnacusspp (Zawo)* | + | - | - |
| 18 | *Prince Gymnacus (Yauni)* | + | - | - |
| 19 | *Tilapiaoreocrumis(Madde)* | + | + | + |
| 20 | *Marine spp(Jari)* | + | - | - |
| 21 | *Niloticaspp(Barya)* | + | - | - |
| 22 | *Leviour (Lulu)* | - | + | + |
| 23 | *S.Schall (Karaya)* | - | + | - |
| 24 | *Citharinusspp (Falfal)* | - | + | - |
| 25 | *Petrocephalus spp. (Faya)* | - | - | + |
| 26 | *Malaple-urusspp or electric catfish (Minjirya)* | - | - | + |
| **Total** | **26** | **21** | **10** | **11** |

Key: + = Present and - = Absent

**Table 2**: Chi-square of Association between water level and fish volume catch along the Jama'are River

| **Chi-Square Tests** | | | | **Calculated Value** |
|---|---|---|---|---|
| | Value | df | Asymp. Sig. (2-sided) | 17.25 |
| Pearson Chi-Square | 41.328[a] | 3 | .000 | |
| Likelihood Ratio | 46.562 | 3 | .000 | |
| N of Valid Cases | 876 | | | |

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 17.25.

**Decline of Fish Species and Fishing Activities**

The Key reasons for the decline in fish species include changes in size and population (35.6%), decreased water volume (30.6%), and inadequate food (17.4%) (Table 3). Other factors, such as temperature fluctuations and lack of breeding grounds, were also identified. The decline in dominant fish species was linked to environmental changes, human activities, and proximity to Lake Chad. Between 2010 and 2015, Tilapia spp. (*Karfasa*) and Clarias spp. (Catfish) were the most dominant fish species. Historical data from the 80s and 90s also highlighted other species, such as Nilotica spp. and Prince Gymnacus. Over time, species diversity declined, attributed to environmental pressures such as reduced water volume and human-induced activities. Reasons supplied for the decline in fish catch volume between 2000 and 2015 were low water levels (30.1%) and increased fishing occupation (21.9%). These were the primary causes of reduced fish catch volumes. Other reasons included rainfall fluctuations (12.8%), reduced floods (11.0%), and reduced water flow (10.0%) (Table 4).

**Table 3:** Reasons for the Decline of Fish Species and Fishing Activities along the Jama'are River

| Items | Response | Frequency | Percentage (%) |
|---|---|---|---|
| Reasons for changes in dominant fish species | Size and Population | 78 | 35.6 |
| | Proximity to Lake Chad | 3 | 1.3 |
| | Not enough food | 38 | 17.4 |
| | No breeding grounds for fishes | 5 | 2.3 |
| | Influence of fishermen | 7 | 3.2 |
| | Temperature fluctuation | 21 | 9.6 |
| | Decreased water volume | 67 | 30.6 |

**Table 4:** Reasons for Decline in Fish Catch Volume between 2000 and 2015

| Items | Response | Frequency | Percentage (%) |
|---|---|---|---|
| Reasons for the decline in fish catch volume between 2000 and 2015 | Low water levels | 66 | 30.1 |
| | Reduced floods | 24 | 11.0 |
| | Many people in the fishing occupation | 48 | 21.9 |
| | Reduced water flow | 22 | 10.0 |
| | No floodplains | 7 | 3.2 |
| | More temperature, more output | 11 | 5.0 |
| | Rainfall fluctuation | 28 | 12.8 |
| | No breeding ground for fishes | 13 | 5.9 |

**Effect of Climate Change**

Approximately 85.8% of respondents linked the decline in fishing activities to climate variability over the last two decades. Respondents also identified rising temperatures, sand deposits, and over-exploitation as significant factors through observation. Seasonal and spatial variations in fish species and fishing activities were also observed, with rising temperatures contributing significantly to declines. ANOVA results established variations in the decline of fish species and fishing activities across communities along the Jama'are River (Table 5). These declines were primarily due to climate impacts, sand deposition, and over-exploitation.

**Table 5:** Variation in declining fish species and fishing activities along the Jama'are River

| | Source of variation | Sum of squares | Df | Mean square | F ratio | Level of sig |
|---|---|---|---|---|---|---|
| Decline of fish species and fishing activities | SSA | 6.423 | 1 | 6.423 | 3.215 | 10% |
| | SSE | 2183.577 | 1093 | 1.998 | | |
| | SST | 2190.000 | 1094 | | | |

The calculated F value (3.215) is lower than the critical F value (161.4) at the 10% level of significance; therefore, we accept the null hypothesis that there is no variation in the demise of fish species and fishing activities between fishing communities along the Jama'are River. This indicates a decrease in the number of fish species due to rising temperatures in all fishing communities; at the same time, sand deposits along the river valley, climate variability, and over-exploitation affect fish availability and production.

## CONCLUSION AND RECOMMENDATIONS

The study revealed that climate variability has significantly influenced fish species composition and fishing activities along the Jama'are River. Findings showed a noticeable decline in fish diversity and catch volume over time, with only 10 species recorded between 2010 and 2015 compared to 21 species observed during the 1980s and 1990s, while only 11 species currently dominate catches along the river valley. This indicates that changes in climatic and environmental conditions have adversely affected aquatic ecosystems and fisheries productivity in the study area.

The Chi-square analysis further established a significant association between water level and fish catch volume, confirming that fluctuations in river water levels directly influence fish availability and fishing output. The study identified decreased water volume, changes in fish size and population, inadequate food supply, rainfall fluctuation, and temperature variation as major causes of declining fish species and reduced fishing activities.

In addition, most respondents linked the decline in fisheries to climate variability over the past two decades, while sand deposition, over-exploitation of fish resources, and reduced flooding were also identified as major contributing factors. The study therefore concludes that climate change and associated environmental stresses have negatively affected fish biodiversity, fish production, and the socioeconomic livelihoods of fishing communities along the Jama'are River.

Based on the findings of this work, it was recommended that:

1. Effective climate adaptation measures, including watershed conservation, afforestation, and floodplain restoration, should be implemented by the governments to reduce the adverse effects of climate variability on fisheries resources.

2. Hatchery development and fish breeding programmes should be encouraged to improve fish stock replenishment and conserve endangered fish species within the river basin. As such, local communities should be sensitized through environmental education and extension services on sustainable fishing practices and climate change adaptation strategies.

3. Alternative livelihood opportunities such as aquaculture, irrigation farming, and small-scale enterprises should be promoted to reduce excessive dependence on river fisheries. This should be accompanied by continuous monitoring, and research should be undertaken to assess long-term changes in fish species composition, water levels, and climatic conditions in order to provide reliable data for planning and policy formulation.

4. Collaboration among government agencies, research institutions, and local communities should be strengthened to ensure integrated management of fisheries and water resources

## REFERENCES

Allison, E. H., Adger, W. N., Badjeck, M.-C., Brown, K., Conway, D., Dulvy, N. K., Halls, A., Perry, A., & Reynolds, J. D. (2005). Effects of climate change on the sustainability of capture and enhancement fisheries important to the poor: Analysis of the vulnerability and adaptability of fisherfolk living in poverty. *MRAG/DFID Fisheries Management Science Programme*.

Awosika, L. F. (1995). Impacts of global climate change and sea level rise on coastal resources and energy development in Nigeria. In J. C. Umolu (Ed.), *Global climate change: Impact on energy development* (pp. 1–16). Damtech Press.

Belhabib, D., Lam, V. W. Y., & Cheung, W. W. L. (2016). Overview of West African fisheries under climate change: Impacts, vulnerabilities and adaptive responses of the artisanal and industrial sectors. *Marine Policy*, 71, 15–28. https://doi.org/10.1016/j.marpol.2016.05.009

Christensen, J. H., Hewitson, B., Busuioc, A., Chen, A., Gao, X., Held, L., Jones, R., Kolli, R. K., Kwon, W. T., Lapoise, R., Mearns, L., Mendez, C. G., Raisanen, J., Rinke, A., Sarr, A., & Whetton, P. (2007). Regional climate projections. *Cambridge University Press*.

Dawood, M. A. O., Koshio, S., Abdel-Daim, M. M., & Doan, H. V. (2018). Probiotic application for sustainable aquaculture. *Reviews in Aquaculture*. https://doi.org/10.1111/raq.12272

Dey, S., Srivastava, P. K., Maji, S., Das, M. K., Mukhopadhyay, M. K., & Saha, P. K. (2007). Impact of climate change on the breeding of Indian major carps in West Bengal. *Journal of the Inland Fisheries Society of India,* 39(1), 26–34.

Eduvie, M. O., & Garba, M. L. (2021). Appraisal of groundwater potential of fadama areas within Northern Nigeria: A review. *Journal of Geoscience and Environment Protection*, 9(3), 44–57. https://doi.org/10.4236/gep.2021.93004

Food and Agriculture Organization. (2007). The State of world fisheries and aquaculture 2006. FAO.

Food and Agriculture Organization of the United Nations. (2018). Impacts of climate change on fisheries and aquaculture: Synthesis of current knowledge, adaptation and mitigation options (FAO Fisheries and Aquaculture Technical Paper No. 627). https://openknowledge.fao.org/server/api/core/bitstreams/9aeb8ade-a623-4954-8adf-204daae3b5de/content

Food and Agriculture Organization. (2022). The State of world fisheries and aquaculture. FAO.

Ficke, A. D., Myrick, C. A., & Hansen, L. J. (2007). Potential impacts of global climate change on freshwater fisheries. *Reviews in Fish Biology and Fisheries*, 17, 581–613.

Grossmann, M. (2005). The impact challenge: Conducting impact assessments for the EMPRETEC programme. Centre on Skills, Knowledge and Organisational Performance (SKOPE).

Hadejia-Jama'are-Komadugu-Yobe Basin Trust Fund. (2005). Water management issues in the Hadejia-Jama'are-Komadugu-Yobe Basin: DFID-JWL and stakeholders' experience in information sharing, reaching consensus, and physical interventions.

Idowu, A. A., Ayoola, S. O., Opele, A. I., & Ikenweiwe, N. B. (2011). Impact of climate change in Nigeria. *Iranian Journal of Energy & Environment*, 2(2), 145–152.

Intergovernmental Panel on Climate Change. (2007a). Climate change 2007: Synthesis report—Contribution of Working Groups I, II, and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. IPCC.

Intergovernmental Panel on Climate Change. (2007b). Climate change 2007: The physical science basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press.

Kundzewicz, Z. W., Mata, L. J., Arnell, N. W., Doll, P., Jimenez, B., Miller, K., Oki, T., Sen, Z., & Shiklomanov, I. (2008). The implications of projected climate change for freshwater resources and their management. *Hydrological Sciences Journal*, 53, 3–10.

Magrin, G., Gay García, C., Cruz Choque, D., et al. (2007). Latin America. In M. L. Parry, O. F. Canziani, J. P. Palutikof, P. J. van der Linden, & C. E. Hanson (Eds.), Climate change 2007: Impacts, adaptation and vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press.

Milly, P. C. D., Dunne, K. A., & Vecchia, A. V. (2005). Global pattern of trends in streamflow and water availability in a changing climate. *Nature,* 438, 347–350.

Reid, A. J., Carlson, A. K., Creed, I. F., Eliason, E. J., Gell, P. A., Johnson, P. T. J., Kidd, K. A., MacCormack, T. J., Olden, J. D., Ormerod, S. J., Solomon, C. T., Taylor, W. W., Tockner, K., Vermaire, J. C., Dudgeon, D., & Cooke, S. J. (2019). Emerging threats and persistent conservation challenges for freshwater biodiversity. *Biological Reviews*, 93(3), 849–873. https://doi.org/10.1111/brv.12480

Salami, K. D., Bawa, B. S., & Bashir, M. G. (2025). Assessing climatic impact drivers and human activities on riparian agroforestry: Evidence from Komadugu-Yobe River Basin, Nigeria. FUDMA Journal of Agriculture and Agricultural Technology, 11(3), 23–36. https://doi.org/10.33003/jaat.2025.1103.03

Vass, K. K., Das, M. K., Srivastava, P. K., & Dey, S. (2009). Assessing the impact of climate change on inland fisheries in the River Ganga and its plains in India. *Aquatic Ecosystem Health & Management,* 12(2), 138–151.

WorldFish Center. (2009). Don't let fish slip through the climate change net. http://www.worldfishcenter.org/wfcms/HQ/article.aspx?ID=684