International Journal of Fisheries and Aquatic Research
ISSN: 2456-7248
Impact Factor: RJIF 5.44
www.fishjournals.com
Volume 2; Issue 6; November 2017; Page No. 11-15

The impact of climate change on Nile Fish abundance and fishery landings in Khartoum state

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Abstract
The study investigated the impact of climate change on Nile fish production and species abundance in Khartoum State over the period 2001-2015. Data on rainfall, temperature and the Nile level were extracted from the meteorological records. In 2015, total landings of fish in Khartoum was 11782956 Km compared to 529673Km and 6807550Km in 1993 and 2001, respectively. At the highest temperature of 44◦C and 42◦C in 2004 and 2005, respectively, a significant decrease in total catch was detected, when the temperature started to decrease fish catch increased. A drop in total fish catch was detected and correlated with drop in rainfall. Some species of the Nile-fishes like *Citharus citharus* (Bitkoya) completely disappeared from fish catch. Only 66 species are now available in the main Nile, 95 Blue Nile, 50 in White Nile, 66 in Lake Nubia. Changing fish distributions and abundances will undoubtedly affect the communities of humans who harvest these stocks. More attention should be paid to climate research.

Keywords: climate change, impact, nile-fish, production, rainfall, temperature

1. Introduction
Climate change is one of the most important issues on the global political and economic agenda, yet it has taken at least 20 years to become an international priority [1]. Climate change is a great threat to fish production, as it is responsible for water scarcity globally as a result of increase in evaporation from the surface of the sea [2]. The effects of climate change could be particularly profound for both freshwater and marine fishes and aquatic ecosystems [3, 4]. Current and future global climatic changes include an increase in mean air temperature, shifting precipitation patterns, and an increase in extreme weather events. Changes in the availability of rain water will also affect fisheries and aquaculture. The change will alter the hydrological processes of water available for fish production and pose a serious threat to the aquatic environment and production of healthy fish on sustainable basis [5]. Several studies have been reported on climate change impact on fish production and catch [6, 7, 8, 9, 10, 11, 12, 13]. Climate change poses new challenges to fisheries and aquaculture with serious implications for the 520 million people who depend on them for their livelihoods, 400 million of the world's poorest people [14] and the nearly 3 billion for whom fish is an important source of animal protein. According to [15] the impacts of climate change and variability on inland fisheries and aquaculture production will be different. The vulnerability of fish populations and communities to climate change will vary based on local conditions and the amount of change that occurs.
Production of fish in Sudan is important not only for domestic food security, but also to community livelihoods and national economies. In the Sudan, local extinctions of fish species, reduced primary production of fish, all clearly show the impact of climate change on aquatic fauna in the Nile. Based on these problems, the present study was designed to assess the effects of climate change on fish production and landings in Khartoum State, and the effect of this change on the abundance and distribution of species in the Nile water. This study examines the vulnerability of fish production in Sudan, particularly as it relates to the predicted impacts from climate change. The study builds upon information from fisheries production in Sudan to provide a more in-depth understanding of issues facing the fishery industry.

2. Material and Methods
The study basically adopted a library search design of reviewing literatures of climate change impact on aquatic lives. Climate data were also extracted from literatures to explain the evidence of climate change in Sudan especially on Nile fish production. Climate data (annual average surface air temperature and rain fall) were obtained from the records of the Metrological Unit over the last 24 years. The annual catches and abundance of fish species in addition to the Nile level were obtained from the records of the Federal Ministry of Animal wealth and Fisheries. Data were analyzed and processed to assess the impact of the fluctuation of air temperature, rain fall and Nile levels on fish catches and fishery resources in Sudan.

3. Results and Discussion
Meteorological data (rainfall and temperature) extracted from the records explained the evidence of climate changed over the period (2001-2015). This change was translated to climate change because in one and half a decade (15-year period) it showed a 2 ◦C rise in temperature from 2001 to 2015 and a decrease of 51.3 mm in the amount of rainfall (Fig. 1) in Khartoum. The change in the Nile level was not found to be affected by rise or decrease in temperature (Fig. 2). A noticeable correlation was found between the rainfall and total

fish catch in the period (1992-2015). In 2015, the total landings of fish in Khartoum was 11782956 Kg/year compared to 5296730 and 6807550 Kg/year in 1993 and 2001, respectively (Fig. 3).

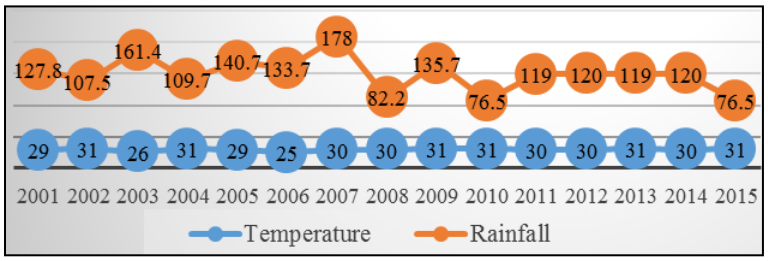

Fig 1: Mean annual temperature and annual rainfall in Khartoum State (2001-2015).

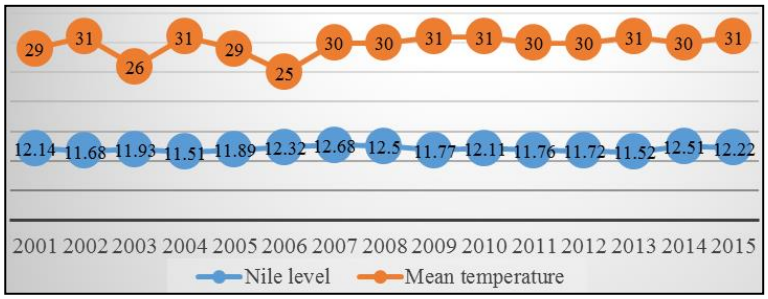

Fig 2: Mean annual Nile level and annual temperature in Khartoum State (2001-2015).

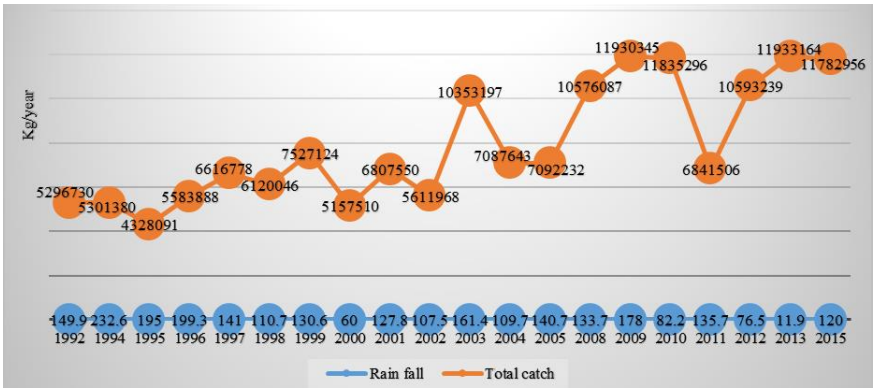

Fig 3: Mean annual variations of rainfall and total fish catch in Khartoum State (1992-2015)

Clear drop in total fish production was correlated with drop in rainfall. A noticeable increase was detected in the fluctuations of fish production and high temperature since 2001 to 2015 in Khartoum. When the highest peaks of 44◦C and 42◦C were reached in 2004 and 2005, respectively, a significant drop in total catch was detected. When the temperature started to decrease fish catch increased, indicating a positive significant relationship between temperature and fish landings (Fig. 4). Fluctuation in Nile level was detected, but was not significantly related to fish landings (Fig. 5).

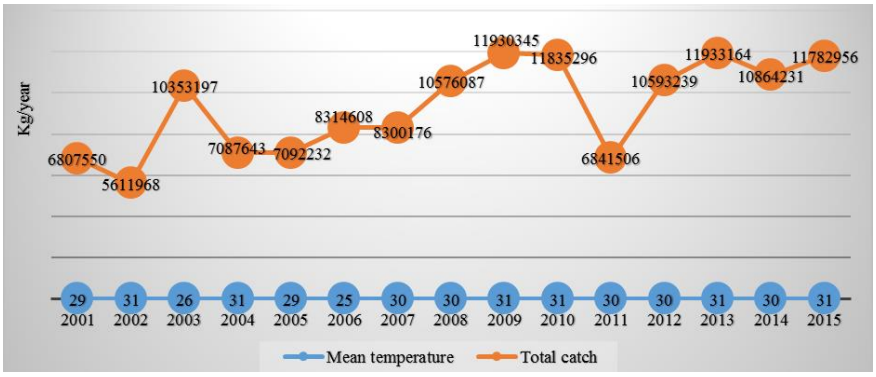

Fig 4: Mean annual temperature and total fish catch in Khartoum State (2001-2015)

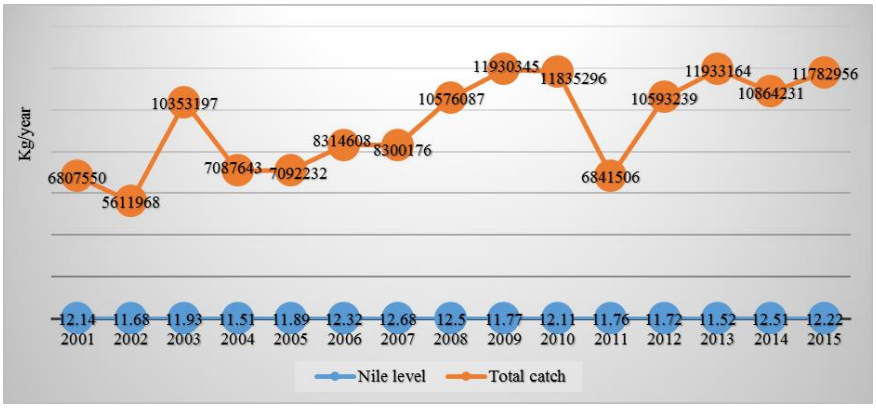

Fig 5: Mean annual Nile level and total fish catch in Khartoum State (2001-2015)

At the population level, the records of species distribution indicated a clear change in abundance of some Nile species in the Nile and its different tributaries (Fig. 6).

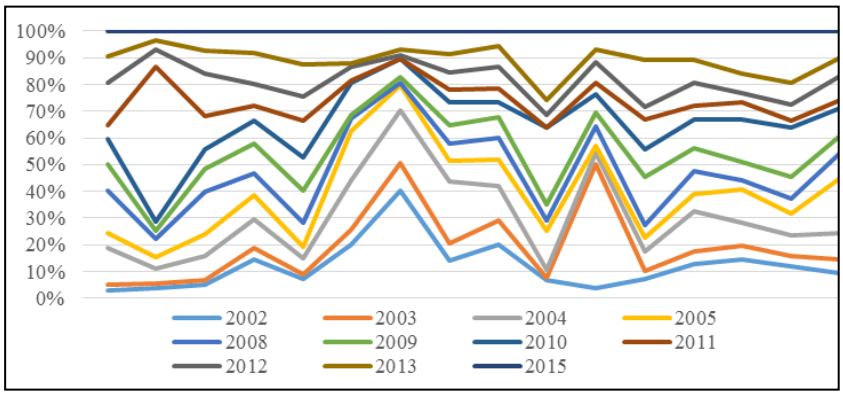

Fig 6: Annual abundance (%) of commercial species of Nile fish in total fish catch of Khartoum State (2001-2015).

Thus, it is very clear that the climate is changing over time in Sudan, affecting fish abundance and productivity. The change in total fish catch and abundance of species is certainly due to the fact that the aquatic fauna in the Nile is facing a new habitat of different environmental characters and may no longer be able to adapt to the changes.

The populations of fish and other aquatic organisms are greatly influenced by several factors such as physical, chemical, biological and meteorological factors. One of the leading factors is the temperature of the surface layers of the water and there is a very close correlation between the catches and variations of annual air temperature [16, 17]. According to [18], the important changes for fishes and their habitats will be driven by air temperature and precipitation. The present results are in line with [8] who reported a noticeable increase in the fluctuations of fish biomass and high water temperature since 1996 in the Polish EEZ.

[2] Also reported that the variations in the catches of cod, herring, mackerel, anchovy and sardines in the Northeast Atlantic since 1945 are related to the variations in the ocean temperature.

The requirement of fish for dissolved oxygen (DO) also varies with temperature, physiological state, age, time of the day, season, food consumption etc. The metabolic activity in fish was found to increases by 10% for every 1◦C rise in temperature of the aquatic environment. Fish need 10% more oxygen for 1◦C rise in oxygen is the most important limiting factor in the aquatic system. On the other hand, phytoplankton acts as primary producers in aquatic food chain, and their growth depends on the concentration of nutrients in the water and also on external factors such as temperature and light illumination [2, 20, 21, 22, 23]. The mortality and respiration rates of phytoplankton and zooplankton also depend on the temperature of the water. It has been reported that both planktons and fish are an appropriate level for tracking the impacts of environmental change [24]. This has been examined for fish [25, 26], plankton [27, 28], and other plants or animal communities [29]. Thus the species which is the most sensitive to change will be at risk of extinction. This was clear in the abundance of fish in the Nile and the extinction of some like *Citharus citharus* (bitkoya) which completely disappeared from the fish catch. The dynamic of fish populations in such changing environment will be affected and species of prey cannot survive and will consequently disappear [30, 31]. In the absence of prey the predators will either modify their body structure and function in order to tolerate and adapt the change in climate, migrate to new and comfortable habitat or even stand the risk of becoming extinct. The current distribution of the Nile fished throughout the Nile System is a good evident of such adaptation.

Climate change in Sudan has led to local extinctions of fish species, reduced primary production and modifying the

distribution of the Nile fishes. To overcome these problems gaps in knowledge should be filled to assess the vulnerability of aquatic ecosystems, fisheries and aquaculture to climate change. Human and institutional capacity should be strengthened to identify the risks of climate change to communities and fishing industries, and to implement adaptation and mitigation measures. New water management reform and policy implementation, government investment in advanced technology should be introduced to solve the challenge of climate change in Sudan.

4. Acknowledgements
Our thanks are due Dr. Abd- Allah Kiar, from the Institute of Environmental Studies, University of Khartoum, and Ustza Tayseer, from the Ministry of Agriculture and Animal Resources to for their valuable help in providing data.

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