# Review ~~of~~ on the ~~Ichthyofauna~~ ichthyofaunal ~~Biodiversity~~ biodiversity in the Inland waters of Sudan

Abstract:

The freshwater fish diversity and composition in Sudan were reviewed, revealing significant findings; A total of 148 fish species from 27 families and 68 genera were identified, marking an increase from previous reports. The White Nile exhibited the highest biodiversity, with 127species, followed by Lake Nubia and the Blue Nile; seasonal rivers and the Um Dafoug storage dam showed varied species richness comparing with the White Nile 96 % of species were recorded; Sudan's Nile system contrasts with other African rivers, such as the Niger and Congo, in species composition and richness; Threats to freshwater fish biodiversity include climate change, human activities like dam construction, habitat loss, pollution, and invasive species; conservation efforts are crucial to safeguard Sudan's freshwater fish resources, urging coordinated research and management initiatives.

Keywords:

Fish, conservation, Nile

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**Comment [AS3]:** Atleast 5 keywords

## Introduction

Fish is a major source of protein all over the world, and the economy of many rural communities is heavily dependent on inland fisheries due to the rapid increase of the human population and the consequent huge demand on fish (Leveque, and Paugy, 2017)

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**Comment [AS5]:** Check journal citation style and follow throughout

Inland fisheries provide critical and diverse sources of protein, essential fatty acids, and micronutrients to many people around the world. More than 90% of inland capture fisheries are for human consumption, indicating that they are particularly important for food security.Although, Freshwater habitats cover less than 1% of the world's surface, yet, they provide a home for over 25% of all described vertebrates.A strict freshwater species completes all or part of their life cycle in fresh or brackish water ecosystems, and have physiological and behaviouraladaptions to the freshwater environment andhas a strong association

with freshwater ecosystems for shelter, food andbreeding habitat(FAO, 2016, 2019).

The inland waters of Sudan occupy about 110,000 square kilometers during periods of high water level, with a projected total fish production of 550,000 metric tons per year (Hamza, 2014). The freshwater fisheries sector in Sudan represents an important source of livelihoods, nutritional benefits and well-being for individuals and communities, as well as a potential source to provide cheap protein rich food, employment, income generation, export earnings and food security to the riparian communities and the entire country (FAO, 2017).

Biological diversity (Biodiversity) can be defined as "the variety and variability of living organisms, including the genetic variability within species, their populations, life forms, interactions among complexes of associated species, and the ecological processes which influence their performance. Species richness and relative abundance of fish describe key elements of biodiversity. However, fish species are not the only important indicators of good health of the ecosystem, but they also help in maintaining the balance in the food chain by consuming plankton and other small aquatic animals, and at the same time form food for many animals. (Huntley, (1989). According to Reid, *et. al.,* (2019), freshwater ecosystems are among the most biologically diverse habitats which harbor an impressive variety of fish species. The highest diversity of freshwater fish species is typically found in large tropical rivers and lake basins, such as Amazon, Congo and Mekong, as well as in ancient lakes like those in the Rift Valley of East Arica. In contrast, islands generally exhibit lower levels of freshwater fish diversity compared to continental areas of similar size (Reference).

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The ray-finned bony fishes is the most diverse group of vertebrates and is well represented in tropical African freshwaters. Currently over 3,360 fresh and

brackish water fish species, belonging to 529 genera and 89 families have been discovered, drawn and described from African freshwaters (Lévêque *et al*., 2008). However, the precise number of extant fish species remains to be determined. Linnaeus (1758) listed about 478 species of teleost fishes. Since then, the global number of fish species has increased considerably. Eschmeyer (2005) in his Catalog of fishes provided an estimate of 27,300 valid fish species comprising about 40–43% of all fishes occurring in freshwaters. Berra, (2001) predicted the presence of about 31,500 fish species when all inventories are completed, while Nelson (2006) estimated a total number of almost 28,900 species of freshwater and marine), representing 2,513 genera and 207 families.Although, Leveque, (2008) stated that the strictly freshwater fish species living in tropical African lakes and rivers comprise almost 13,000 species, belonging to 48 fish families, of which about 15 families are endemic, and the bulk of these fishes occur in relatively few orders, e.g. the Characiformes, Cypriniformes, Siluriformes, and Gymnotiformes, the Perciformes (especially the family Cichlidae), and the Cyprinodontiformes, yet, Frickeet. *al.*, (2020) estimated that the global rivers, lakes and wetlands harbor approximately 18.000 fish species.

The present review was undertaken in an attempt tothrow some light on the present status of the biodiversity of fish species in Sudan inland waters. It focusesmainly on updating the available published documentson native fish species of the River Nile and its tributaries,as well as other freshwater bodies ofSudan.The review also seeks conservation and management solutions aimed atreducing and~~/ or~~ mitigating the harmful impacts on the diversity of freshwater fish fauna in Sudan.

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**Current status of studies on the freshwater ichthyofauna diversity in Sudan**

The majority of Sudan freshwater fish species occur in permanent rivers, man-made lakes and dam reservoirs. However, temporary water bodies are not entirely devoid of fishes, and are inhabited by some species that evolved specific life history strategies to cope with these extreme habitats. It is estimated that Approximately 70 species of freshwater fish species are likely to occur in the River Nile between Khartoum and Lake Nubia (the southern part of Lake Nasser created as a result of construction of Aswan High Dam) (Reference).

Early studies of freshwater fishes of Sudan included illustrated guides with identification keys andlists on species composition, distribution and habitats of freshwater fishes of the Nile River Basin and its tributaries in Sudan, achieved byseveral naturalists and scientists, includingBoulenger,1907; Pekkola (1918 and 1919); Giris (1948); Sandon, (195o); Sandon and Al Tayib (1953); Amir Thalingham and Khalifa (1965) and Monakov (1969); Abu Gideiri (1984) and Bailey (1994).

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Later, numerous scientists and investigators studied fish diversity, species composition, distribution, habitats and some ecological aspects of the freshwater fishes of Sudan, and published several identification keys, lists and notes on the freshwater fishes of the River Nile, man-made lakes, reservoirs and temporary and seasonal water bodies in Sudan, including Hammerton (1972); Mishrigi (1972);Adam (1975 and 1976); Greenwood (1976) Mohamed (2012); Bianco (1981);Hamza (1981); Abu Gideiri (1984); Coates (1984; Abdel Rahman (1985); Hickley and Bailey (1986, and 1987 b); Ali, 1987; Bailey (1994); Leveque (1991); Kara (1999); Abdel-Rahman (2003); Bashier (2007); Hamza, Witte *et. al.*, (2009), Elagba (2011); Mohamed (2012); Khalid *et al*., (2016); Neumann *et al*. (2016); Ahmed *et al;*(2018); Khalid and Adam (2016); Obeida *et al*; (2019); Moritz *et. al*., (2019); Mahmoud*et al*; (2020).

With respect to Main Nile River, the diversity of fishes and species distribution were studied by Greenwood (1976). He recorded 320 fish species under 60 genera.Abu Gideiri (1984) studied the freshwater of Sudan. While, Lévêque *et. al.,* (1991) described about 128 species of fish representing 27 families that are native to the River Nile system in Sudan. He added that more fish speciesoccur in rivers than in lakes. Bailey (1994), in his guide to the fishes of the River Nile in Republic of the Sudan,described 127 species with notes on the distribution and ecology of the species, while Moritz, T. (2007) described*Labeo meroensis* n. sp. (Cyprinidae)as a speciesnew to science,from the Main River Nile betweenthe 6th and 5th cataractsin Sudan.

However, (Witte *et. al.,* 2009) reported that the total number of fish species in the Nile drainage basin is currently estimated at more than 800, Of these about 128 species belonging to 27 families of fish occur in the Nile system (the River Nile and its tributaries, reservoirs and man-made lakes). He addedthat members of Cichlidae, Cyprinidae, Mormyridae, and Mochokidae comprise the majority of the fish species in the Nile drainage basin, and accounted for more than half the number of fish species in the inland waters of Sudan. Neumann *et. al.,* (2016), studied the fishes of the Main Nile Basin in the Sudan and Egypt and enlisted about 150 species out of which 133 species were confirmed in Sudan freshwaters, and that 107 species were endemic representing, 62 genera and 28 families, in addition to 10 introduced species and description 3 new species. On the other hand, FishBase.org (2019) reported that about 502 species have been recorded for Sudan, including both marine and freshwater species; out of which about 143 species were strictly freshwater fish species,belonging to 33 families and 16 orders.

On the other hand, various studies were carried out by several scientists and investigators on the diversity of the fish fauna of the White Nile and Jebel

Auliadam reservoir.Adam (1976) studied the distribution and abundance of fishes in Jebel Aulia Reservoir, White Nile, and recorded 48 species belonging to 26 genera and 14 families. Fishes of the central part of Jebel Aulia reservoir were investigated by Bashier (2007) and recorded 43 species under 19 genera and 15 families. Mosa, *et al;* (2009) studied the freshwaterfish species at Jelhack area, White Nile, Sudan, and enlisted 64 species, falling into 37 genera and 20 families, whileMohamed (2012) investigated the composition of fishes in Jebel Aulia Dam reservoir, and stated that the downstream of the reservoir harbors a total number of 23 species

representing 13 families, while only 13 species under 9 families were recorded in the vicinity of the reservoir. Ahmed (2017) recorded asimilar number of species (23) belonging to 14 families in the neighborhood of the reservoir.Moreover, Moritz *et. al*., (2019) conducted two fish surveys in the Area between Kosti and Al-Jabalain, White Nile. He recognized 82 species belonging to 48 genera and 23 families. He identified *Labeo latebra*n. sp. (Moritz & Neumann, 2017) from Aba Island near Kosti, as a new to science, as well as two other new species;the distichodontid,*Paradistichodusdimidiatus* (Pellegrin, 1904), and the cyprinid *Enteromiusmacrops* (Boulenger, 1911), for the first time in the area between Kosti and Al Jabalain,White Nile. Other species confirmed present in the White Nile, included the small mochokid catfish, *Mochokus brevis*(Boulenger, 1906), three endemic Nile Mormyrid, *Mormyrushasselquistii*(Valenciennes, 1847), *Petrocephaluskeatingii*(Boulenger, 1901) and *Cyphomyruspetherici* (Boulenger, 1898). The distichodontidae, *Neolebiastrewavasae* (Poll & Gosse, 1963)was recorded from Aba Island near Kosti, White Nile. Furthermore, Mahmoud *et al*; (2019) revised, corrected and updated the FishBase, org. checklist of freshwater fishes of Sudan, and reported 121 species under 27 families and 10 orders.He

concluded that the inland fish species within Sudan consist of 124 species, 61 genera,26 families and 10 orders. Later, Mahmoud *et. al*., (2020) studied the fish fauna in the area around Kosti City, White Nile,and recognized 64 species representing 37 genera distributed over 20 families.

Regarding fishes of the Blue Nile and Lake Roseires, Sudan, Abu Gideiri (1967) investigated fishes of the Blue Nile between Khartoum and Roseires,andpublished an illustrated guide for the identification of the freshwater fishes of the Sudan. Similarly, Mishrigi (1970) investigated the species composition of Lake Roseires and enlisted; Kara, A. M (1999) studiedthe biological aspects of fish as indicator species prior to the expected heightening of Roseires Dam, and the subsequent changes offish population, ecology and biology of the reservoir. However, Mahmoud *et al*; (2009) prepared a technical report on proposed fisheries projects requested by Lake Roseires Dam Heightening Projects, whileSMEC (2010), while Elsayed, M.A.R (2012) studied some characteristics of thefisheries of Lake RoseiresReservoir. Moreover, Ahmed *et. al.,* (2018) investigated the species composition and abundance of fish in Roseires reservoir, Blue Nile, and recorded 34 species belonging to 13 families. He added that members of family Mormyridae were most abundant in the Lake reservoir (7 species), followed by Characidae (6 species), then Cyprinidae (5 species).

Recently,Mahmoud and Hagar (2019) studied the fish fauna of Lake Roseires and recorded 53 species under 19 genera and 16 families. Later, Mahmoud *et. al*., (2019) recognized 124 fish species representing 61 genera, 26 families and 10 orders from the inland waters within Sudan. In addition, two unpublished lists of fishes of Lake Roseires (Blue Nile) were prepared by Omer and Hagar (2014) and Hagar (2017),may be a useful monitorfor the impact of the Grand Ethiopian

Renaissance Dam (GERD) on Lake Roseires fish fauna upon itscompletion and operation.

The species composition, diversity and distribution of fish in man-made Lake Nubia, on the extreme northern part of Sudan, was initially investigated byGeorge T.T (1971) and presented a preliminary account of the fish and fisheries of the Lake during the early stages of its formation (1967-1968), while Adam (1975) studied the species composition and seasonal abundance of the commercial fishes in Lake Nubia, Wadi Halfa, Sudan. In turn, Ali (1984) studied the fish and fisheries of Lake Nubia and recorded 26 species belonging to 10 families, while El-Shabrawy, J.M (2009) enlisted about 32 species from the same lake.

Furthermore, Mahmoud (2019) studied the fish diversity in Lake Nubia in relation to water level, and indicated that over a period of four decades, the fish species dropped from 42 to 34, and the fish families dropped from 17 to 12. He reported that Families Bagridae, Mormyridae and Alestiidae dominated the fish catch in Lake Nubia, and that out of the 10 Cichlidsreported by Witte *et al*; (2009) from the inland waters of Sudan, only by *O. niloticus*, *S. galilaeus*and *C. zilli*, were present in Lake Nubia.

The fish population structure and species composition of the seasonal rivers and temporary water bodies of Sudan received due attention by several workers. Mahmoud,M (1984)investigated the species composition and distributionofichthyofauna of Dinder National Park, while Egbal, O (2002)studiedthe productivity and fisheries of Atbara River and Khashm El-Girba Reservoir in relation to annual flushingof the dam reservoir. Later, Ibrahim and Mahmoud (2013) reviewed the composition of fish species of Atbara River and Khashm El-Girba reservoir. However, Khalid*et. al.*, (2016) studied the change in the ichthyofauna of River Dinder flood plains (a tributary of the Blue Nile), and

recorded 31 species, under 20 genera and 13 families, representing about 14.4 % of the total number species in River Nile within Sudan, while Adam *et al*; (2018),reviewed the fish population of three flood plains in Dinder National Park, Sudan, and listed only 8 species in 6 families out of a total number of 32 fish species previously recorded in Dinder River flood plains.

Obeida *et. al.,* (2019), conducted preliminary observations on the fish fauna of Um-Dafoug Water Storage reservoir, South Darfur State, Sudan, and recorded 13 species belonging to 9 families, representing about 11.3 % of total freshwater fishes of Sudan.

Fish species introduced for aquaculture purposes during the period of 2003 to 2006 included*Gibelioncatla* (Family: Cyprinidae), *Oreochromis urolepis* and the crossbreeds of *O. niloticus*, such as GIFT tilapia, Chi strain, red tilapia and supper male Tilapia



**Results and discussion**

Table I: References: **The Nile** (1: Sandon, 1950; 2: Bailey, 1994; 3: Neumann, *et. al*., 2016); **White Nile** (4: Ahmed, 2017; 5: Moritz *et. al*., 2019; 6: Mahmoud *et. al*., 2020); **Blue Nile** (7: Mishrigi, 1970; 8: Ahmed *et. al.*, 2018; 9: Mahmoud and Hagar, 2019) **Nubia Lake** (10: Ali, 1984; 11: El-Shabrawy, 2009); **Atbara River** (12: Salih, 1994; 13: Ahmed, 2002; 14 : Ibrahim and Mahmoud, 2013); **Dinder River** (15: Khalid, *et. al*., 2016) and **Um Dafoug** (16: Obeida, *et. al.*, 2019).

Table 1: Fish species reported from the freshwaters of Sudan (Nile River and its tributaries, Man-made lakes, seasonal rivers and temporary water storage bodies)

| Taxon | The Nile | White Nile | Blue Nile | La ke | Atbar a | Di nd | U m | |
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| | | | | | | | | | | | | Nubia | | River | | | er | Dafoug | Abundance |
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| Family | Genus | Species | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | |
| Protopteridae | Protopterus | *P. aethiopicus* | √ | √ | √ | √ | √ | √ | | √ | | | √ | | | | | | ** |
| | | *P. annectens* | | √ | | | | √ | | | | | | | | | | √ | * |
| Polypteridae | Polypterus | *P. bichir* | √ | √ | √ | | | √ | | √ | √ | | √ | | | | √ | | ** |
| | | *P. endlicherii* | √ | √ | √ | | | √ | | | | | | | | | | | * |
| | | *P. senegalus* | √ | √ | √ | | √ | √ | | | √ | | | | | | | √ | ** |
| Anguillidae | Anguilla | *A. anguilla* | √ | √ | | | | | | | | | | | | | | | - |
| Arapaimidae | Heterotis | *H. niloticus* | √ | √ | √ | √ | √ | √ | | | | | | | | | √ | | * |
| Notopteridae | Papyrocranus | *P. afer* | | √ | | | | √ | | | | | | | | | | | * |
| | Xenomystus | *X. nigri* | √ | √ | | | | | | | | | | | | | | | - |
| Mormyridae | Mormyrus | *M. caschive* | √ | √ | √ | √ | √ | √ | | √ | √ | | √ | | | | | | ** |
| | | *M. hasselquistii* | √ | √ | √ | | √ | √ | | √ | √ | | | | | | | | * |
| | | *M.* | √ | √ | √ | | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ | | *** |

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| | | *kannume* | | | | | | | | | | | | | | | | |
| | | *M. nilotic us* | | √ | √ | | √ | √ | | | | | | | | | | * |
| | Hyperopisus | *H. bebe* | √ | √ | √ | √ | √ | √ | | √ | √ | √ | √ | | | | √ | ** |
| | Mormyrops | *M. anguilloides* | √ | √ | √ | | √ | √ | √ | √ | √ | √ | √ | | | | | ** |
| | Petrocephalus | *P. bane* | √ | √ | √ | | √ | √ | √ | √ | √ | √ | | | | | √ | ** |
| | | *P. bovei* | √ | √ | | | | √ | | | | | | | | | | * |
| | | *P. keatingii* | √ | √ | | | | √ | | | | | | | | | | * |
| | Marcusenius | *M. cyprinoides* | √ | √ | √ | √ | √ | √ | | | √ | | | | | | | * |
| | | *M. macrolepidotus* | √ | √ | | | | √ | | | | | | | | | | * |
| | Brevimyrus | *B. niger* | | √ | √ | | √ | √ | | | | | | | | | | * |
| | Hippopotamyrus | *H. harringtoni* | | √ | | | | √ | | | | | | | | | | * |
| | | *H. pictus* | | √ | | | | √ | | | | | | | | | | * |
| | Pollimyrus | *P. isidori* | | √ | √ | | √ | √ | | | | | √ | | | | | * |
| | | *P.* | | √ | | | √ | √ | | | | | | | | | | * |

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| | | *pethe rici* | | | | | | | | | | | | | | | | | |
| | Gnath onemu s | *G. cypri noide s* | √ | √ | | | | | √ | √ | √ | | √ | | | | | | * |
| | | *G. pictus* | √ | | | | | | | | √ | | | | | | | | * |
| Gymna rchidae | Gymn archus | *G. niloti cus* | √ | | √ | | √ | √ | | | | | √ | | | | | | * |
| Kneriid ae | Crome ria | *C. niloti ca* | √ | √ | | | | √ | | | | | | | | | | | * |
| Alestid ae | Hydro cynus | *H. brevis* | √ | √ | √ | | √ | √ | √ | | | | √ | | | | √ | | ** |
| | | *H. forska hlii* | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ | | *** |
| | | *H. vittat us* | | √ | | | | √ | | | √ | | √ | | | | √ | | ** |
| | | *H. linnea tus* | √ | √ | | | | √ | | √ | √ | | | | | | | | * |
| | Brycin us | *B. nurse* | √ | √ | √ | √ | √ | √ | √ | √ | | √ | √ | √ | √ | √ | √ | √ | *** |
| | | *B. macr olepid otus* | √ | √ | √ | | √ | √ | √ | √ | √ | | | | | √ | √ | | ** |
| | Aleste s | *A. bare moze* | √ | √ | √ | | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ | | | ** |
| | | *A. dente x* | √ | √ | √ | √ | √ | √ | √ | √ | √ | | √ | | | | √ | | ** |
| | Micral estes | *M. acutid* | √ | √ | | | | √ | | | | | | | | | | | * |

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| | | *M. elongates* | | √ | √ | | √ | √ | | | | | | | | | | * |
| Distichodontidae | Ichthyborus | *I. besse* | √ | √ | √ | | √ | √ | | | | | | | | | | * |
| | Distichodus | *D. brevipinnis* | √ | √ | | | | √ | √ | | √ | | | | | | | ** |
| | | *D. engycephalus* | √ | √ | | | √ | √ | | | | | | | | | | * |
| | | *D. nefasch* | | √ | √ | | √ | √ | | | | | | | | | | * |
| | | *D. niloticus* | √ | √ | | √ | | √ | | | | √ | √ | | | √ | √ | | ** |
| | | *D. rostratus* | √ | √ | √ | | √ | √ | √ | | √ | | | | | | √ | | ** |
| | Paradistichodus | *P. dimidiatus* | | | | | √ | | | | | | | | | | | | - |
| | Neolebias | *N. unifasciatus* | | √ | | | √ | √ | | | | | | | | | | | * |
| | Nannocharax | *N. niloticus* | √ | √ | | | | √ | | | | | | | | | | | * |
| Citharinidae | Citharinus | *C. citharus* | √ | √ | √ | | | √ | √ | | √ | √ | √ | | | | √ | | ** |
| | Citharinus | *C. latus* | √ | √ | √ | | | √ | | | | | √ | | | | √ | | ** |
| Cyprinidae | Barbus | *B. anem* | √ | √ | | | | √ | | | | | √ | | | | | | * |

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| | | *B. leonensis* | √ | √ | | | | √ | | | | | | | | | | * |
| | | *B. nigeriensis* | √ | √ | | | | √ | | | | | √ | | | | | | * |
| | | *B. perince* | √ | √ | | | | √ | | | | | √ | | | | | | * |
| | | *B. pumilus* | √ | √ | | | | √ | | | | | | | | | | | * |
| | | *B. stigmatopygus* | √ | √ | | | | √ | | | | | √ | | | | | | * |
| | | *B. tongaensis* | | √ | | | | √ | | | | | | | | | | | * |
| | | *B. yeiensis* | √ | √ | | | | √ | | | | | | | | | | | * |
| | Labeo | *L. forskalii* | √ | √ | √ | | | √ | | √ | √ | | | | | | | | * |
| | | *L. coubie* | √ | √ | √ | | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ | *** |
| | | *L. horie* | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ | | | | √ | | ** |
| | | *L. nilotiticus* | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ | | *** |
| | | *L. parvus* | | √ | | | | √ | | | | | | | | | | | * |
| | | *L. meroe* | | | √ | | | | | | | | | | | | | | - |

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| | | *nsis* | | | | | | | | | | | | | | | | |
| | | *L. latebra* | | | | | √ | | | | | | | | | | | - |
| | | *L. bynni* | √ | √ | √ | √ | | √ | √ | √ | √ | √ | √ | √ | √ | √ | | *** |
| | Garra | *G. dembeensis* | | √ | | | | | | | | √ | | | | | | * |
| | | *G. vincigueraee* | √ | √ | √ | | | | | | | | | | | | | - |
| | Chelaethiops | *C. bibie* | √ | √ | √ | | √ | √ | | | | √ | | | | | | * |
| | Leptocypris | *L. niloticus* | | √ | √ | | √ | √ | | | | √ | | | | | | * |
| | Neobola | *N. niloticа* | | √ | | | | √ | | | | | | | | | | * |
| | Raiamas | *R. senegalensis* | | √ | √ | | | √ | | | | √ | | | | | | * |
| Bagridae | Bagrus | *B. bajad* | √ | √ | | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ | | *** |
| | | *B. docmak* | √ | √ | | √ | √ | √ | √ | √ | √ | √ | √ | √ | | √ | | | ** |
| Clarotei dae | Auchenoglanis | *A. biscutatus* | √ | √ | | | √ | √ | | √ | √ | | √ | √ | √ | √ | | | ** |
| | | *A. occidentalis* | √ | √ | | √ | | √ | √ | | √ | √ | √ | | | | √ | | ** |
| | Clarotes | *C. latice* | √ | √ | | | √ | √ | √ | | √ | | √ | | √ | √ | √ | | *** |

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| | | *ps* | | | | | | | | | | | | | | | | |
| | Enteromius | *E. anema* | | | √ | | √ | | | | | | | | | | | * |
| | | *E. neglectus* | | | √ | | √ | | | | | | | | | | | * |
| | | *E. prince* | | | √ | | √ | | | | | | | | | | | * |
| | | *E. pumilus* | | | √ | | √ | | | | | | | | | | | * |
| | | *E. stigmatopygus* | | | √ | | | | | | | | | | | | | - |
| | | *E. macrops* | | | | | √ | | | | | | | | | | | - |
| | | *E. werneri* | | | | | √ | | | | | | | | | | | - |
| | Chrysichthys | *C. auratus* | √ | √ | √ | √ | √ | √ | | √ | √ | √ | √ | √ | | | | | ** |
| | | *C. ruppelli* | | √ | | | | √ | | | | | √ | | | | | | * |
| Schilbeidae | Schilbe | *S. intermedius* | | √ | √ | | √ | √ | | | √ | | | | | | √ | √ | ** |
| | | *S. mystus* | √ | √ | √ | √ | √ | √ | √ | √ | √ | | √ | √ | √ | √ | √ | | *** |
| | | *S. uranoscopu* | √ | √ | √ | | √ | √ | √ | √ | √ | √ | √ | √ | √ | | | | ** |

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| | | *S. arabi* | | √ | | | | | √ | | √ | | | | | | | * |
| | Eutropis | *E. niloticus* | √ | | | | | | | √ | √ | √ | √ | √ | √ | | | ** |
| | Silurano don | *S. auritus* | | | √ | | √ | √ | | | | | √ | | | | | * |
| | Parailia | *P. pellucida* | √ | √ | √ | | | √ | | | | | | | | | | * |
| Clariidae | Clarias | *C. alluaudi* | | √ | | | | √ | | | | | | | | | | * |
| | | *C. anguillaris* | √ | √ | √ | | √ | √ | | | √ | | √ | | | √ | | ** |
| | | *C. engelseni* | | √ | √ | | | √ | | | | | | | | √ | | * |
| | | *C. gariepinus* | √ | √ | | √ | √ | √ | √ | √ | √ | √ | √ | √ | | √ | √ | *** |
| | | *C. liocephalus* | | √ | | | | √ | | | | | | | | | | * |
| | | *C. werneri* | √ | √ | | | √ | √ | | | | | | | | | | * |
| | Heterobranchus | *H. bidorsalis* | √ | √ | √ | | | √ | | | √ | | √ | √ | √ | √ | | ** |
| | | *H. longifilis* | √ | √ | √ | | | √ | | | | | √ | | | | | * |
| Amphiliidae | Andersonia | *A. leptura* | √ | √ | √ | | | √ | | | | | | | | | | * |

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| Malapteruridae | Malapterurus | *M. electricus* | √ | √ | √ | √ | √ | √ | | √ | √ | | √ | | | | | | ** |
| Mochokidae | Chilogalanis | *C. niloticus* | √ | √ | √ | | | √ | | | | | √ | | | | | | * |
| | Mochokus | *M. brevis* | √ | √ | | | √ | √ | | | | | | | | | | | * |
| | | *M. niloticus* | √ | √ | √ | | | √ | | | | | √ | | | | | | * |
| | Brachysynodontis | *B. batensoda* | √ | √ | √ | | | √ | | | √ | | | | | | √ | √ | ** |
| | Synodontis | *S. clarias* | √ | √ | | | | √ | | | √ | | √ | | | | | | ** |
| | | *S. caudovittatus* | √ | √ | √ | | √ | √ | | | | | | | | | | | * |
| | | *S. filamentosus* | √ | √ | | | √ | √ | | | | | | | | | | | * |
| | | *S. frontosus* | √ | √ | √ | | √ | √ | | | | | | | | | | | * |
| | | *S. khartoumensis* | | √ | √ | | √ | √ | | | | | | | | | | | * |
| | | *S. membranaceus* | √ | √ | | | √ | √ | | | | | | | | | √ | | * |
| | | *S. nigrita* | √ | √ | √ | | √ | √ | | | | | | | | | | | * |

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| | | *S. schall* | √ | √ | √ | | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ | *** |
| | | *S. serratus* | √ | √ | √ | | √ | √ | | | √ | √ | √ | | | | | | ** |
| | | *S. sorex* | √ | √ | √ | | | √ | | | | | | | | | | | * |
| | | *S. eupterus* | √ | √ | | | | √ | | | | | | | | | | | * |
| Nothobranchiidae | Nothobranchius | *N. bellemansi* | √ | √ | | | | √ | | | | | | | | | | | * |
| | | *N. nubaensis* | √ | | | | | √ | | | | | | | | | | | * |
| | | *N. occultus* | | | | | | √ | | | | | | | | | | | - |
| | | *N. rubroreticulatus* | | | | | | √ | | | | | | | | | | | - |
| | | *N. virgatus* | | | | | | √ | | | | | | | | | | | - |
| | Epiplatys | *E. bifasciatus* | √ | √ | √ | | √ | √ | | | | | | | | | | | * |
| | | *E. spilargyreius* | √ | √ | √ | | √ | √ | | | | | | | | | | | * |
| Poeciliidae | Aplocheilichthys | *A. huteraui* | √ | √ | | | | √ | | | | | | | | | | | * |
| | | *A. kingii* | √ | √ | | | | √ | | | | | | | | | | | * |
| | Porop | *P.* | | √ | √ | | √ | √ | | | | | | | | | | | * |

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| | anchax | *normani* | | | | | | | | | | | | | | | | |
| | Micropanchax | *M. loati* | | √ | √ | | | √ | | | | | | | | | | * |
| | Gambusia | *G. affinis* | | √ | √ | | | √ | | | | | | | | | | * |
| Channidae | Parachanna | *P. obscura* | √ | √ | | | | √ | | | | | | | | | | * |
| Latidae | Lates | *L. niloticus* | √ | √ | √ | √ | | √ | √ | √ | √ | √ | √ | √ | √ | √ | | ** |
| Cichilidae | Haplochromis | *H. loati* | √ | √ | | | √ | √ | | | | | | | | | | * |
| | | *H. wingatti* | √ | | | | | | | | | | | | | | | - |
| | Pelmatochromis | *P. exsul* | √ | | | | | | | | | | | | | | | - |
| | Thoracochromis | *T. wingatii* | | √ | | | | √ | | | | | | | | | | * |
| | Pseudocrenilabrus | *P. multicolor* | | √ | | | | √ | | | | | | | | | | * |
| | Hemichromis | *H. fasciatus* | √ | √ | √ | | √ | √ | | | | | | | | | | * |
| | | *H. letourneuxi* | | √ | √ | | √ | √ | | | | | | | | | | * |
| | Oreochromis | *O. niloticus* | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ | *** |
| | | *O. aureu* | | √ | | | √ | √ | | | | | √ | | | | | * |

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| | Copto don | *C. zillii* | √ | √ | √ | | √ | √ | | | √ | | √ | √ | √ | | | | ** |
| | Saroth erodon | *S. galila eus* | √ | √ | √ | | √ | √ | √ | | √ | √ | √ | | | | √ | √ | *** |
| Eleotrid ae | Kribia | *K. nana* | √ | √ | √ | | √ | √ | | | | | | | | | | | * |
| Anaban tidae | Cteno poma | *C. murie i* | √ | √ | | | √ | √ | | | √ | | | | | | | | * |
| | | *C. pethe rici* | √ | √ | √ | | √ | √ | | | | | | | | | | | * |
| Tetraod ontidae | Tetrao don | *T. lineat us* | √ | √ | √ | √ | √ | √ | | √ | √ | | √ | | | | | | ** |
| Su m 27 | 68 | 148 | 101 | 127 | 79 | 22 | 76 | 127 | 29 | 33 | 50 | 25 | 58 | 20 | 18 | 19 | 30 | 13 | |
| Percentage % | | | 80 | 100 | 62 | 17 | 60 | 100 | 23 | 26 | 39 | 20 | 46 | 16 | 14 | 15 | 24 | 10 | |

*(- indicate very rare; * rare; ** common; *** widespread)

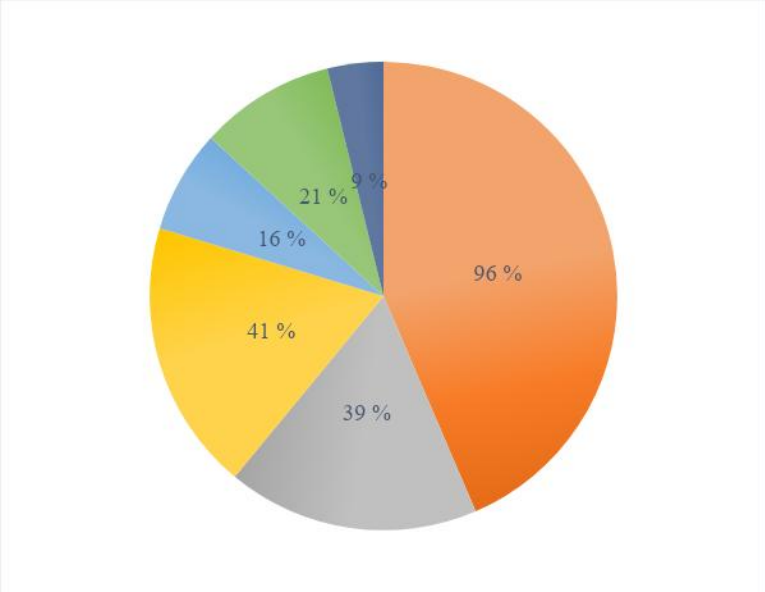


Figure 1: Percentage compositionof fishspecies in the Nile River and its

Table 1 and Fig.1 show the diversity and percentage composition of thefreshwaters fishes of Sudanrespectively. A total number of 148 species belonging to 68 genera and 27 families were recognized during in this study, revealing a substantial increase in number of species, compared to the previous number of 127 species reported by Bailey (1994). This increase in species can be attributed to revisions and re-classification effortscarried out by several scientists, with addition of new species to science, new records to Sudan fishes, and new speciesintroduced for aquaculture purposes.

It is noteworthy that the White Nile exhibited the highest biodiversity and richness of species, with 96% of the recorded species found in this region. Lake Nubia and the Blue Nile were second in diversity with percentages of 41% and 39 %, respectively. Seasonal rivers, such as Atbara and DinderRivers showedrelatively

low species diversity and represented 21 % and 16 % of the recorded number of species respectively, while Um Dafougwater storage dam in (south-western Sudan) exhibited the lowest percentage of species composition (i.e. 9.0 %).

In relation to specific regions within Sudan, the highest diversity of species (127 species) was recorded in the White Nile. The Blue Nile ranked second with 92 species, followed by a moderate fish diversity in Nubia Lake with 25 species. Theseasonal rivers **(**Dinder and Atbara rivers)was less significant and contributed only 30 and 20 species to the fish diversityrespectively. However,the lowest fish diversity was recorded at the Um Dafoug storage dam in western Sudan.

The diversity and richness of fish species encountered in Sudan Nile system differ greatly compared with thoseof similar tropical African rivers, like Niger and Congo Rivers.It has been observed thatthe Nile River system harboursabout 148 species under 28 genera, while the Niger and Congo River basins include 243 species belonging to 36 families; and 787 species under 31 families respectively (Teugels& Thieme, 2005; Neumann *et al*; 2008, and Witte *et al.*, 2009).Due todifferent morphological features, size variations, more habitat diversity and potential niches exploited by fishes,large rivers usuallyharbourlarger fish populations than smaller ones(Sleen and Albert, 2021).Hence,richness of fish species may be considered a good measure of fish diversity in the freshwater body, while the poor richness and decreasing number of many fish species pose serious threats to the diversity and distribution of native freshwater fish species.

Despite of that, freshwater fish biodiversityand species richness face serious threats caused by climate change,natural disasters, and particularly human-related issues, such ascreation of dams across rivers blocking fish migration routes, diversion of river course, loss of habitat and niches, modification of water flow, over-exploitation, invasion by exotic species, water pollution, eutrophication,

**Comment [AS10]:** What is the reason behind this, habitat specific data supporting this observation should be added

**Comment [AS11]:** Richness is not measured only number of species has been counted from literature survey, therefore don't use the term.

sedimentation, impact on water quality due to runoff from agricultural and urban areas, shrinking of habitats resulting from water withdrawal for human use, draining of wetlands for development projects , seasonal fluctuations of precipitation patterns, thermal, toxic and chemical stressors (Albert *et. al*., 2020; Dudgeon 2019; IPBES 2019;Reid *et al*., 2019)., Birk et al., 2020). Therefore, it is hoped that fisheries scientists and stakeholders in Sudan would organize andimplement sound future research programmers aimed at conserving and managing the richness and diversity of these valuable resources of the freshwater fisheries of the country.



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Comment [AS12]: Follow guidelines througouht

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