Diversity and distribution of ichthyofauna in the inland waters of Sudan: A review

Abstract:

Previous studies of the freshwater fish diversity and composition in Sudan were reviewed. A total number of 148 fish species belonging to 68 genera and 27 families were identified from the rivers, lakes and wetlands in Sudan, showing a significant increase in species richness compared to previous reports. The majority of these species belonged to families such as Cichlidae, Cyprinidae, Mormyridae, Mochokidae and Bagridae. The White Nile exhibited the highest biodiversity and richness of species, with 127 fish species (96 %), followed by Lake Nubia (41%) and the Blue Nile (39 %). Seasonal rivers (Atbara and Dinder Rivers) showed relatively low diversity, representing 21 % and 14.4 % of the total recorded number of species respectively; while Um Dafoug rainwater reservoir showed the lowest species diversity, representing only 9.0 % of the total number of species recorded in Sudan inland waters.

Keywords:

Ichthyofauna, Inland waters, Biodiversity, Blue Nile, Lake Nubia, Main River Nile, White Nile.

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 [1].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. They have physiological and behavioural adaptions to the freshwater environment and a strong association with freshwater ecosystems for shelter, food and breeding habitat[2 and 3].

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 [4]. 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 [5].

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 [6]. According to [7], 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 Africa. In contrast, islands generally exhibit lower levels of freshwater fish diversity compared to continental areas of similar size [8].

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 [9]. 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. [10] in his Catalog of fishes provided an estimate of 27,300 valid fish species comprising about 40–43% of all fishes occurring in freshwaters. [11] predicted the presence of about 31,500 fish species when all inventories are completed, while [12] estimated a total number of almost 28,900 species of freshwater and marine), representing 2,513 genera and 207 families. Although, [9] 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, [13] estimated that the global rivers, lakes and wetlands harbor approximately 18.000 fish species.

The present review was undertaken in an attempt to throw some light on the current status of the studies carried out on the biodiversity of freshwater fishes of the Republic of Sudan. It deals mainly with the studies and investigations previously published on fish species recorded from the main River Nile and its tributaries, and inland water bodies of Sudan. Additionally, this review is intended to assist other investigators to utilize the underlying information to carry out further investigations aimed at maintaining and conserving the freshwater fisheries resources of Sudan.

Current status of studies on the diversity of freshwater ichthyofauna 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 [14].

Early studies of freshwater fishes of Sudan included illustrated guides with identification keys and lists on species composition, distribution and habitats of freshwater fishes of the Nile River Basin and its tributaries in Sudan, achieved byseveral naturalists and scientists, including [14;15;16; 17; 18; 19; 20;21; 22; and 23].

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: [24; 25;26; 27; 28;29;30; 14; 31; 32; 33; 34; 35; 23; 36; 37;38; 39; 40; 41; 42; 4; 43; 44; 45; 46; 47 and 48].

With respect to Main Nile River, the diversity of fishes and species distribution were studied by [28]; He recorded 320 fish species under 60 genera.while, [36] described about 128 species of fish representing 27 families that are native to the River Nile system in Sudan; He added that more fish species occur in rivers than in lakes. [23], 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 [49] described *Labeo meroensis* n. sp. (Cyprinidae)as a species new to science,from the Main River Nile between the 6th and 5th cataracts in Sudan.

However, [40]reported that the total number of fish species in the Nile drainage basin is currently estimated at more than 800;Of these about 128 fish species belonging to 27 families occur in the Nile system (the River Nile and its tributaries, reservoirs and man-made lakes). He addedthat the 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. [44], 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, [50] 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.

The diversity of fish species in the White Nile, particularly those of Jebel Aulia dam reservoir, were studied by several investigators. [27] 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 [39] and recorded 43 species under 19 genera and 15 families. [51] studied the freshwaterfish species at Jelhack area, White Nile, Sudan, and enlisted 64 species, falling into 37 genera and 20 families, while[42] 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 comprising 13 families, while only 13 species belonging to 9 families were recorded in the vicinity of the reservoir. Similarly, in the vicinity of the reservoir, [52] recorded a total number of (23) fish species belonging to 14 families.However, [47] 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. [53] from Aba Island near Kosti, as a new to science, as well as two other new species; the distichodontid, *Paradistichodus dimidiatus* (Pellegrin, 1904), and the cyprinid *Enteromius macrops* (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, *Mormyrus hasselquistii* (Valenciennes, 1847), *Petrocephalus keatingii* (Boulenger, 1901) and *Cyphomyrus petherici* (Boulenger, 1898). The distichodontidae, *Neolebias trewavasae* (Poll & Gosse, 1963) was recorded from Aba Island near Kosti, White Nile. Furthermore, [54] 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, [48] 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, [55] investigated fishes of the Blue Nile between Khartoum and Roseires,and published an illustrated guide for the identification of the freshwater fishes of the Sudan. [56] investigated the species composition of Lake Roseires, while [37] studied the biological aspects of fish as indicator species prior to the expected heightening of Roseires Dam, and the subsequent changes of fish population, ecology and biology of the reservoir. However, [57] prepared a technical report on proposed fisheries projects requested by Lake Roseires Dam Heightening Projects, while, while [58] studied some characteristics of the fisheries of Lake Roseires Reservoir. Moreover, [45] 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); While [56] reported 53 species across 30 genera falling in 16 families.

Recently, [59] studied the fish fauna of Lake Roseires and recorded 53 species under 19 genera and 16 families. Later, [54] recognized 124 fish species representing 61 genera, 26 families and 10 orders from the inland waters within Sudan. In addition, unpublished lists of fishes of Lake Roseires (Blue Nile) were prepared by [60], may be a useful monitor for the impact of the Grand Ethiopian Renaissance Dam (GERD) on Lake Roseires fish fauna upon its completion 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 by [61] and presented a preliminary

account of the fish and fisheries of the Lake during the early stages of its formation (1967-1968), while [26]studied the species composition and seasonal abundance of the commercial fishes in Lake Nubia, Wadi Halfa, Sudan. In turn, [62] studied the fish and fisheries of Lake Nubia and recorded 26 species belonging to 10 families, while [63] enlisted about 32 species from the same lake.

Furthermore, [64] 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 Cichlids reported by [40] 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.[65] investigated the species composition and distribution of ichthyofauna of Dinder National Park, while [66] studiedthe productivity and fisheries of Atbara River and Khashm El-Girba Reservoir in relation to annual flushing of the dam reservoir. Later,[67] reviewed the composition of fish species of Atbara River and Khashm El-Girba reservoir. However, [43] 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. [68], reviewed the fish population of three flood plains in Dinder National Park, Sudan, and listed 8 species in 6 families out of a total number of 32 fish species previously recorded in Dinder River flood plains.

[46], conducted a preliminary observation on the fish fauna of Um-Dafoug rainwater reservoir, south of Darfur State, Sudan (surface area about 13 km^2, and about 4.0 million cubic meters of storage water), and recorded 13 species belonging to 9 families, representing about 11.3 % of total freshwater fishes of Sudan.

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

Results and discussion

Table I: References: **The Nile** (1: [19] Sandon, 1950; 2: [23] Bailey, 1994; 3: [44] Neumann, *et. al*., 2016); **White Nile** (4: [52] Ahmed, 2017; 5: [47] Moritz *et. al*., 2019; 6: [48] Mahmoud *et. al*., 2020); **Blue Nile** (7: [56] Mishrigi, 1970; 8: [45] Ahmed *et. al.*, 2018; 9: [59] Mahmoud and Hagar, 2019) **Nubia Lake** (10: [62] Ali, 1984; 11: [63] El-Shabrawy, 2009); **Atbara River** (12: [69] Salih, 1994; 13: [66] Ahmed, 2002; 14: [67] Ibrahim and Mahmoud, 2013); **Dinder River** (15: [43] Khalid, *et. al*., 2016) and **Um Dafoug** (16: [46] 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			Lake Nubia		Atbara River			Dinder	Um Dafoug	Abundance
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. kannume	√	√	√		√	√	√	√	√	√	√	√	√	√	√		***
		M. niloticus		√	√		√	√											*
	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. petherici		√			√	√											*
	Gnathonemus	*G. cyprinoides*	√	√					√	√	√		√						*
		G. pictus	√								√								*
Gymnarchidae	Gymnarchus	*G. niloticus*	√		√		√	√					√						*

		us																	
Kneriidae	Cromeria	*C. nilotica*	√	√				√											*
Alestidae	Hydrocynus	*H. brevis*	√	√	√		√	√	√				√				√		**
		H. forskahlii	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√		***
		H. vittatus		√				√			√		√				√		**
		H. linneatus	√	√				√		√	√								*
	Brycinus	*B. nurse*	√	√	√	√	√	√	√	√		√	√	√	√	√	√	√	***
		B. macrolepidotus	√	√	√		√	√	√	√	√					√	√		**
	Alestes	*A. baremoze*	√	√	√		√	√	√	√	√	√	√	√	√	√			**
		A. dentex	√	√	√	√	√	√	√	√	√		√				√		**
	Micralestes	*M. acutidens*	√	√				√											*
		M. elonga		√	√		√	√											*

		tes																	
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. anema*	√	√				√					√						*
		B. leonensis	√	√				√											*
		B. nigeriensis	√	√				√					√						*
		B. perince	√	√				√					√						*
		B. pumilus	√	√				√											*
		B. stigmatopygus	√	√				√					√						*
		B. tongaensis		√				√											*
		B. yeiensis	√	√				√											*
	Labeo	*L. forskalii*	√	√	√			√		√	√								*
		L. coubie	√	√	√		√	√	√	√	√	√	√	√	√	√	√	√	***

		L. horie	√	√	√	√	√	√	√	√	√	√	√				√		**
		L. nilotic us	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√		***
		L. parvus		√				√											*
		L. meroe nsis			√														-
		L. latebra					√												-
		L. bynni	√	√	√	√		√	√	√	√	√	√	√	√	√		√	***
	Garra	*G. dembe ensis*		√								√							*
		G. vincigu errae	√	√	√														-
	Chelaet hiops	*C. bibie*	√	√	√		√	√				√							*
	Leptocy pris	*L. nilotic us*		√	√		√	√				√							*
	Neobol a	*N. nilotic a*		√				√											*
	Raiama s	*R. senega*		√	√			√				√							*

		lensis																	
Bagridae	Bagrus	*B. bajad*	√	√		√	√	√	√	√	√	√	√	√	√	√	√	√		***
		B. docmak	√	√		√	√	√	√	√	√	√	√	√		√				**
Claroteidae	Auchenoglanis	*A. biscutatus*	√	√			√	√		√	√		√	√	√	√				**
		A. occidentalis	√	√		√		√	√		√	√	√				√			**
	Clarotes	*C. laticeps*	√	√			√	√	√		√		√		√	√	√			***
	Enteromius	*E. anema*			√		√													*
		E. neglectus			√		√													*
		E. prince			√		√													*
		E. pumilus			√		√													*
		E. stigmatopygus			√															-
		E. macro					√													-

		ps																	
		E. werneri					√												-
	Chrysichthys	*C. auratus*	√	√	√	√	√	√		√	√	√	√	√					**
		C. rueppelli		√				√					√						*
Schilbeidae	Schilbe	*S. intermedius*		√	√		√	√			√						√	√	**
		S. mystus	√	√	√	√	√	√	√	√	√		√	√	√	√	√		***
		S. uranoscopus	√	√	√		√	√	√	√	√	√	√	√	√				**
		S. arabi		√					√		√								*
	Eutropis	*E. niloticus*	√							√	√	√	√	√	√				**
	Siluranodon	*S. auritus*			√		√	√					√						*
	Parailia	*P. pellucida*	√	√	√			√											*
Clariidae	Clarias	*C. alluau*		√				√											*

		di																	
		C. anguillaris	√	√	√		√	√			√		√				√		**
		C. engelseni		√	√			√									√		*
		C. gariepinus	√	√		√	√	√	√	√	√	√	√	√		√	√	√	***
		C. lioceph alus		√				√											*
		C. werneri	√	√			√	√											*
	Heterobranchus	*H. bidorsalis*	√	√	√			√			√		√	√	√	√			**
		H. longifilis	√	√	√			√					√						*
Amphiliidae	Andersonia	*A. leptura*	√	√	√			√											*
Malapteruridae	Malapterurus	*M. electricus*	√	√	√	√	√	√		√	√		√						**
Mochokidae	Chilogl anis	*C. nilotic us*	√	√	√			√					√						*

	Mochokus	*M. brevis*	√	√			√	√											*
		M. niloticus	√	√	√			√					√						*
	Brachysynodontis	*B. batensoda*	√	√	√			√			√						√	√	**
	Synodontis	*S. clarias*	√	√				√			√		√						**
		S. caudovittatus	√	√	√		√	√											*
		S. filamentosus	√	√			√	√											*
		S. frontosus	√	√	√		√	√											*
		S. khartoumensis		√	√		√	√											*
		S. membranaceus	√	√			√	√									√		*
		S. nigrita	√	√	√		√	√											*
		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	√	√	√		√	√											*
Poeciliid	Aploch	*A.*	√	√				√											*

ae	eilichthys	*hutereaui*																	
		A. kingii	√	√				√											*
	Poropanchax	*P. normani*		√	√		√	√											*
	Micropanchax	*M. loati*		√	√			√											*
	Gambusia	*G. affinis*		√	√			√											*
Channidae	Parachanna	*P. obscura*	√	√				√											*
Latidae	Lates	*L. niloticus*	√	√	√	√		√	√	√	√	√	√	√	√	√	√		**
Cichilidae	Haplochromis	*H. loati*	√	√		√	√												*
		H. wingati	√																-
	Pelmatochromis	*P. exsul*	√																-
	Thoracochromis	*T. wingatii*		√				√											*
	Pseudocrenilabrus	*P. multicolor*		√				√											*

		Hemichromis	*H. fasciatus*	√	√	√		√	√											*
			H. letournouxi		√	√		√	√											*
		Oreochromis	*O. niloticus*	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	***
			O. aureus		√			√	√					√						*
		Coptodon	*C. zillii*	√	√	√		√	√			√		√	√	√				**
		Sarotherodon	*S. galilaeus*	√	√	√		√	√	√		√	√	√				√	√	***
Eleotridae		Kribia	*K. nana*	√	√	√		√	√											*
Anabantidae		Ctenopoma	*C. muriei*	√	√			√	√			√								*
			C. petherici	√	√	√		√	√											*
Tetraodontidae		Tetraodon	*T. lineatus*	√	√	√	√	√	√		√	√		√						**
Sum	27	68	148	101	127	79	22	76	127	29	33	50	25	58	20	18	19	30	13	

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

Results and dissection

A total number of 148 species belonging to 68 genera and 27 families were recognized during this study, revealing a substantial increase in number of species, compared to the previous number of 127 species reported by [23]. This increase in species may be attributed to revisions and re-classification efforts carried out by several scientists, and the addition of new species to science, new records to Sudan fishes, and new speciesintroduced for aquaculture purposes.

The study revealed 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 ranked second in diversity representing 41% and 39 %, respectively of the total number of species. On the other hand, seasonal rivers (Atbara and Dinder Rivers) showed relatively low species diversity and represented 21 % and 14.4 % of the recorded number of species respectively. However, Um Dafoug rainwater reservoir (south-western Sudan) exhibited the lowest percentage of species composition (i.e. 9.0 %).

With respect of 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 Nubia Lake with a moderate fish species diversity of 25 species, Dinder and Atbara rivers with species diversity of 30 and 20 species respectively. The lowest fish diversity was recorded at the Um Dafoug rainwater reservoir with only 13 fish species.

The diversity and richness of fish species encountered in Sudan Nile system differ greatly compared with similar tropical African rivers, like Niger and Congo Rivers. It has been observed that while the Nile River system harbours about 148 species, the Niger and Congo River basins include 243 species belonging to 36 families; and 787 species under 31 families respectively [70 and 40]. This may be due to different morphological features, size variations, more habitat diversity and potential niches exploited by fishes,large rivers usuallyharbour larger fish populations than smaller ones [71]. 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.

However, the biodiversity and species richness of inland waters of Sudan face serious threats related to over-exploitation, use of illegal fish gear, creation of dams across rivers, diversion of

river course, loss of habitat and niches, modification of water flow, water pollution, impact on water quality due to runoff from agricultural and urban areas, and other chemical stressors [72; 73; 74; 7 and75].

Conclusion:

The Sudan Nile River basin contrasts markedly with other large African rivers in terms of diversity, richness and composition of the fish fauna. The major challenges and threats facing the richness of fish species of the aquatic ecosystems of Sudan are related to factors such as the volume of discharge of the river basins, seasonal and annual changes in hydrological regime of different rivers, habitat loss and degradation, pollution sources, overexploitation and illegal fishing. Moreover, the size of the catchment area, and the diversity of aquatic habitat

s available for fish play a key role in determining the richness and composition of the fish communities inhabiting the freshwater ecosystem.

It is, therefore, recommended that further sound research programmers need to be organized andimplemented to study the fish fauna of the River Nile and its tributaries and other water bodies aimed at not only conserving diversity of the existing fish species, but also implement sound exploitation measures to sustainably manage the valuable fisheries resources of the inland waters of Sudan.

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