



## RESEARCH PAPER

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## The fish fauna of the Mormyridae (Pisces: Teleostei: Osteoglossiformes) from Niger River in Northern Benin

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### Abstract

In Niger River, the family of Mormyridae, also called elephant fishes, is one of the most speciose taxa that constitutes an economically and commercially important fishery resource in tropical Africa. From February 2015 to July 2016, Mormyrids fishes were collected monthly with gill net, cast net and seine. Eleven (11) Mormyrid fish species belonging to nine (9) genera have been recorded. The genus *Mormyrus* was the most speciose with 3 species *Mormyrus macrophthalmus*, *Mormyrus rume*, and *Mormyrus hasselquisti*. Because most Mormyrids are intolerant to pollution, less degraded sites such as “Gaya” and “Money” villages harbor the highest diversity, 11 and 10, respectively, whereas degraded locations such as “Sota stream” and “under Benin-Niger Bridge” were less diverse with 5 and 4 Mormyrid species. Major threats to Mormyrid fish species were climate changes, pollution, uses of detrimental fishing methods, overfishing and the non-respect of fishing regulation. A holistic management scheme of the Niger River in Benin is required for a sustainable exploitation of the Mormyrid fishes.

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## Introduction

The elephant fishes (Mormyrids) are widespread in tropical Africa and constitute an economically and commercially important fishery resource. Mormyrids are endemic in African Rivers and are by far the largest and the most speciose family among the Osteoglossiformes, with about 228 species belonging to 22 genera (Hopkins *et al.*, 2007; Kisekelwa *et al.*, 2016; Rich *et al.*, 2017). These electric fishes are often dominant in running waters, but also colonize floodplains and natural lakes (Lowe-McConnell, 1969; Hopkins *et al.*, 2007). In Tropical Africa, Mormyrids display a very large distribution in African top rivers and streams such as the Zambezi (Winemiller and Adite, 1997), Nile, Senegal (Reizer *et al.*, 1973), Gambia (Svensson, 1933), Volta (Daget, 1957), Mono, Oueme, Bagoé, Sassandra (Daget and Iltis, 1965), Bandama, Comoé (Daget, 1960), Ogun–Oshun, Bénoué (Blache *et al.*, 1964), Congo, Ebrié etc. Also, the elephant fishes inhabit some African Lakes such as Tchad, Kainji, Malawi, Tanganyika etc. In the Congolese ichthyofaunal province (Central Africa), Mormyrids reached their high diversity with more than 100 species (Roberts, 1975; Lavoué *et al.*, 2000). In Anambra and Warri rivers in Nigeria (Nwani *et al.*, 2004; Olele, 2013), Mormyrids made about 30% of the total catches during the wet period.

Taxonomically, Mormyrid species show an elongate to deep and laterally compressed body covered by small cycloid scales. The mouth is small and non-protrusible, the snout variable in form and sometimes tubular (Hopkins *et al.*, 2007), and the chin occasionally bears a mental lobe. The species of this family are characterized by the presence of an electric organ (located in the caudal peduncle) that enable a weak electric discharge used for orientation, prey detection in murky waters or at night, communication, sex and species identification (Moller, 1995; Winemiller and Adite, 1997; Schugardt and Kirschbaum, 2004; Arnegard and Carlson, 2005; Lévêque *et al.*, 2005; Hopkins *et al.*, 2007; Lavoué *et al.*, 2008; Kramer and Wink, 2013). Most Mormyrids are nocturnal or crepuscular species, and are considered as bio-indicators because react first to environmental changes (Hay *et al.*, 1996; Hugueny *et al.*, 1996).

In Benin, the elephant fishes appear to be an important component of the fisheries and consistently occur in rivers and streams such as Oueme, Okpara, Zou, Sô, Mono, Niger etc. and associated floodplains where cumulated annual production reached 248 metric tons (Direction des Pêches, 1990). In particular, Mormyrid fishes in Niger River were numerically the second family most abundant making 12.65% of the total catches after Cichlids (14.02%) (Koba, 2005). Furthermore, species of this family occurred in adjacent traditional fishponds where they were cultured for subsistence and sales. In fish markets at Malanville city (North-Benin), Mormyrids were one of the foremost commercial fishes well-appreciated and highly priced.

Despite their great importance in artisanal fisheries in the Niger River, little is known about the Mormyridae in the Benin part of this regional running water (Nwani *et al.*, 2006). Particularly, the fish biodiversity of Mormyrids is unknown and their ecology and biology in this degrading environment are not documented. Indeed, climate changes and the multiple uses of the river have caused a reduction of water volume and changes in water quality. In addition, non-ecological practices such as the use of chemical fertilizers and pesticides in adjacent agriculture, dumping of domestic wastes and the use of detrimental fishing gears have led to habitat fragmentations, spawning ground destructions, changes in fish community structure, and thus, contributing to stock depletion and fish biodiversity losses (Laë *et al.*, 2004; Hauber, 2011). Knowledge on the Mormyrids diversity of Niger River is crucial to fill the gap of ichthyological information that will serve to implement a holistic approach of ecosystem restoration.

The current study was undertaken in Niger River at Northern Benin to document Mormyrids fish biodiversity in order to improve habitat protection, species conservation and valorization and overall ecological sound ecosystem management that contribute to a sustainable exploitation.

## Material and methods

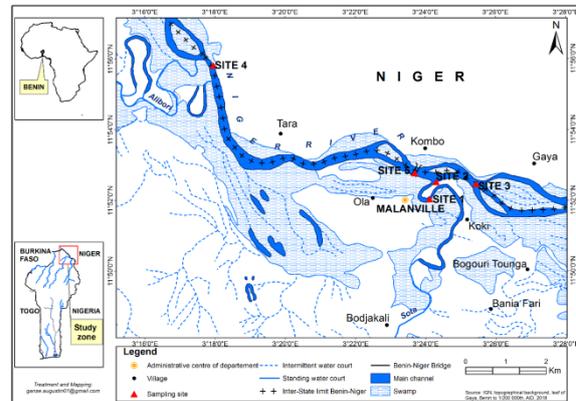
### Study location

The study location is Niger River at Malanville Township. Malanville is located in North-East Benin

around latitude 11°52'216"N, longitude 3°21'111"E where Niger River stands as frontier between Benin and Niger Republic. The climate in this part of Benin is Soudano-sahelian and marked by a long dry season extending from October to April, a rainy season from May to July dominated by violent winds, and a flood season usually occurring in August and September (PDC Malanville, 2006). Mean annual rainfall recorded the last five years is about 750 mm with a peak reaching 1000 mm (Aboubacar and Humphrey 2007). The dominant wind is harmattan blowing from November to January along with low ambient temperatures that may deplete up to 16°C (PDC Malanville, 2006). Malanville town is crossed by the Niger River main channel and its tributaries Alibori, Mekrou and Sota that are usually flooded in August and September. The Niger River basin covers an area of 440.000 km<sup>2</sup>. In North-Benin, the river is composed of a vast floodplain extending on about 300 ha representing an important seasonal habitat that play a crucial role in fish diversity and fisheries because stand as spawning grounds (Moritz *et al.*, 2006). Before the year 1960, the annual water flow was about 1140(m<sup>3</sup>/s) and depleted to 800m<sup>3</sup>/s in 2004. Soils in Malanville region are composed of gneiss, but the Niger River basins and its tributaries show argilo sandy and ferruginous soils.

The plant community in the Niger River at Malanville is composed of floating species such as *Lemna aequinoctialis*, *Pistia stratiotes*, *Echhornia crassipes*, bottom-rooted like *Nymphaea spp*, *Marsilea sp* and submerged plants like *Typha domingensis*, *Echinochloa colona*, *Commelina benghalensis*, *Neptunia oleracea*, *Mimosa pigra*, *Sesbania rostrata*, *Ipomoea aquatica* and *Ludwigia spp*. Plant species such as *Cassia mimosoides*, *Cleome viscosa*, *Coldenia procumbens*, *Heliotropium indicum*, *Amaranthus viridis* and *Setaria pumila* are essentially terrestrial (Hauber, 2011). With regards to water quality, depths varied between 130-410cm and transparencies between 0-66cm. Dissolved oxygen ranged between 3.8-9.17mg/l and the percentage of dissolved oxygen saturation between 47-211.14%. Water temperature varied from 21.6 to 35.6 °C, pH

from 6.2 and 8.7 and conductivity from 100 to 400  $\mu$ /cm (Adjibade *et al.*, 2019). Malanville has an important fish market where a huge quantity of commercial fishes are sold every day, including Mormyrids fishes.



**Fig 1.** Map showing Niger River (Northern Benin) and the five study locations : 1= Sota Stream, 2= Tounga, 3= Gaya (Niger Country), 4=Money, 5= Under Benin-Niger Bridge.

#### Sampling sites

Five (5) sampling sites (Table 1) were selected for this study. Site1 is located on Sota stream, a tributary of Niger River. This site is covered by dense vegetation and under severe pollution because of the proximity of a “Dry Port” where occurred degrading human activities. Site2 is also situated on Sota stream at Tounga village where grassroots get in the water to take bath and to wash ditches and clothes directly in the water. Rice farming is also developed at this site and may increase water pollution from the uses of fertilizers and pesticides. Site3 is located on the main channel of the River at Gaya Village in Niger Republic. Less degraded, this site showed a high depth and a rocky substratum that favored Mormyrids fishes. During dry season, intense fishing activities occurred at site3. Site4 is located at Money Village, on the main channel of Niger River that communicates with Alibori stream. Also less degraded, this site showed a relatively high depth with intense fishing activities during the dry season. Site5 is located under Benin-Niger Bridge, on the main channel of Niger River. This site is polluted and degraded because of intense human activities.

**Table 1.** Geographic coordinates of sampling sites in Niger River in Northern Benin.

Site	Location	Latitude	Longitude
Site 1	Dry Port	11°52'216"N	3°23'907"E
Site 2	Tounga village	11°52'112"N	3°23'672"E
Site 3	Gaya village	11°52'675"N	3°25'329"E
Site 4	Money village	11°52'987"N	3°20'819"E
Site 5	Benin-Niger Bridge	11°52'970"N	3°21'111"E

*Collection of Mormyrid fishes*

Specimens of Mormyrids were monthly sampled from February 2015 to July 2016 at all sampling sites in the “aquatic vegetation” habitat and in the “open water” habitat using various fishing gears such as seine (6.15 m × 2m, 16mm-mesh), cast nets (6m-diameter, 20mm-mesh), experimental gill net (50m × 1m, 40mm-mesh; 50 × 1m, 30mm-mesh; 50m × 1m, 20mm-mesh) and traps. Seining was done in the marginal aquatic vegetation by setting the seine stationary, and kicking the vegetation to drive the fish in to the net (Winemiller and Adite, 1997). Cast nets and gillnets were used in the “open water”. Also, samplings were made in artisanal captures of local fishermen to add species that were not caught during experimental samplings (Hauber *et al.*, 2011a). After collection, the fish individuals were identified in situ using references such as (Nelson, 2006), (Paugy *et al.*, 2003), (Reed *et al.*, 1967) and (Van Thielen *et al.*, 1987). Fish individuals were then preserved in a cooler and transported to the “Laboratoire d’Ecologie et de Management des Ecosystèmes Aquatiques (LEMEA)” of the Faculty of Sciences to confirm identifications. Scientific names were confirmed using <http://www.fishbase.org>. In the lab, each fish individual was measured, weighed and preserved in 10% formalin and later in 70% ethanol for further biological observations.

**Results**

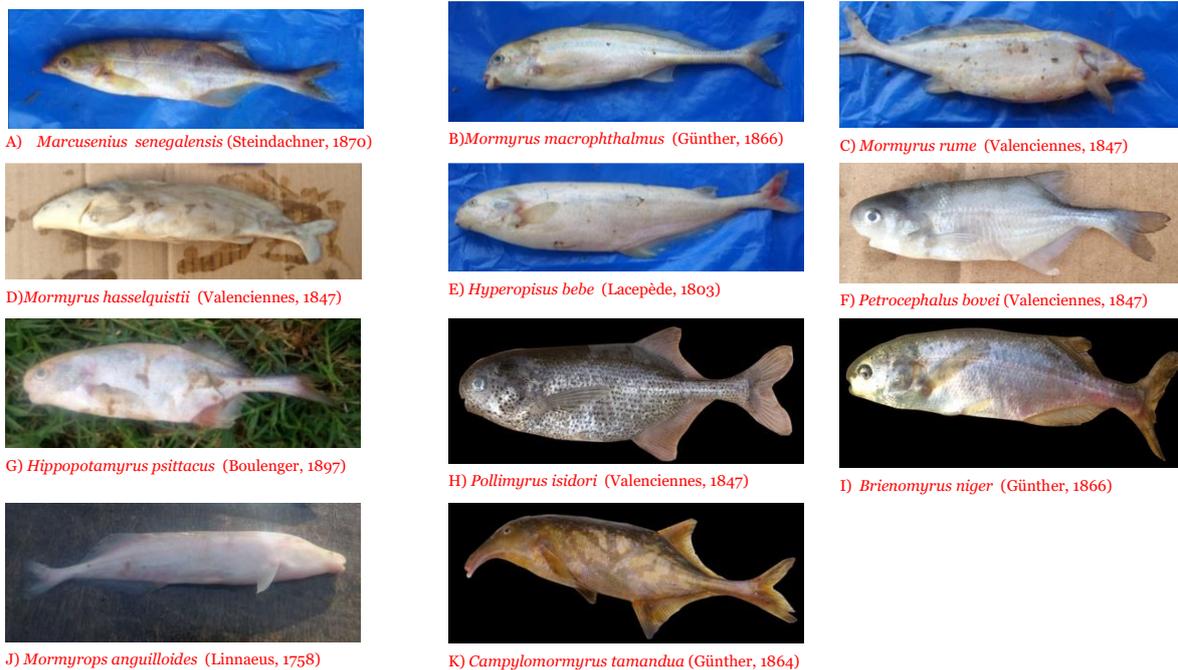
Table 2 presents the list of Mormyrids fishes inventoried in the Niger River at Malanville. A total of eleven (11) species, *Marcusenius senegalensis* (Fig. 2A), *Mormyrus macrophthalmus* (Fig. 2B), *Mormyrus rume* (Fig. 2C), *Mormyrus hasselquisti* (Fig. 2D), *Hyperopisus bebe* (Fig. 2E), *Petrocephalus bovei* (Fig. 2F), *Hippopotamyrus psittacus* (Fig. 2G), *Pollimyrus isidori* (Fig. 2H), *Brienomyrus niger* (Fig. 2I), *Mormyrops anguilloides* (Fig. 2J) and *Campylomormyrus tamandua* (Fig. 2K), belonging to 9 genera have been inventoried in this part of the Niger River. *Mormyrus* is the most speciose genus with three (3) species, *Mormyrus macrophthalmus*, *Mormyrus rume* and *Mormyrus hasselquisti*. Spatially, species richnesses were higher at sites Gaya, Money and Tounga where eleven (11), ten (10) and ten (10) species were recorded, respectively. In contrast, lower species numbers were recorded at the “Dry Port” and “Benin-Niger Bridge” sites where a maximum of five (5) and four (4) Mormyrid species were respectively inventoried. Species like *Marcusenius senegalensis* and *Hyperopisus bebe* were commonly found at all sampling sites. *Mormyrus hasselquisti* have been recorded at Gaya and Tounga while *Campylomormyrus tamandua* was found only at Gaya and Money. Seasonally the dry season was the most speciose period where eleven (11) species were recorded. Though the numbers of species recorded were high during the wet and flood periods with ten (10) and ten (10) species, respectively, *Mormyrus hasselquisti* and *Campylomormyrus tamandua* were absent during these two periods, the wet and flood seasons, respectively (Table 3).

**Table 2.** Mormyrids fishes species inventoried by sampling site in Niger River in Northern Benin.

Genera	Species	GAYA	MONEY	UBNB	TOUNGA	Dry Port
<i>Marcusenius</i>	<i>Marcusenius senegalensis</i> (Steindachner, 1870)	+	+	+	+	+
	<i>Mormyrus macrophthalmus</i> (Günther, 1866)	+	+	+	+	
<i>Mormyrus</i>	<i>Mormyrus rume</i> (Valenciennes, 1847)	+	+	+	+	
	<i>Mormyrus hasselquisti</i> (Valenciennes, 1847)	+			+	
<i>Hyperopisus</i>	<i>Hyperopisus bebe</i> (Lacepède, 1803)	+	+	+	+	+
<i>Petrocephalus</i>	<i>Petrocephalus bovei</i> (Valenciennes, 1847)	+	+		+	+
<i>Hippopotamyrus</i>	<i>Hippopotamyrus psittacus</i> (Boulenger, 1897)	+	+		+	
<i>Pollimyrus isidori</i>	<i>Pollimyrus isidori</i> (Valenciennes, 1847)	+	+		+	+
<i>Brienomyrus</i>	<i>Brienomyrus niger</i> (Günther, 1866)	+	+		+	+
<i>Mormyrops</i>	<i>Mormyrops anguilloides</i> (Linnaeus, 1758)	+	+		+	
<i>Campylomormyrus</i>	<i>Campylomormyrus tamandua</i> (Günther, 1864)	+	+			
	Number of genera : 09					
	Number of species : 11					

**Table 3.** Mormyrid fishes species inventoried by season in Niger River in Northern Benin.

Genera	Species	Flood	Wet	Dry
<i>Marcusenius</i>	<i>Marcusenius senegalensis</i> (Steindachner, 1870)	+	+	+
	<i>Mormyrus macrophthalmus</i> (Günther, 1866)	+	+	+
<i>Mormyrus</i>	<i>Mormyrus rume</i> (Valenciennes, 1847)	+	+	+
	<i>Mormyrus hasselquistii</i> (Valenciennes, 1847)	+	+	+
<i>Hyperopisus</i>	<i>Hyperopisus bebe</i> (Lacepède, 1803)	+	+	+
<i>Petrocephalus</i>	<i>Petrocephalus bovei</i> (Valenciennes, 1847)	+	+	+
<i>Hippopotamyrus</i>	<i>Hippopotamyrus psittacus</i> (Boulenger, 1897)	+	+	+
<i>Pollimyrus</i>	<i>Pollimyrus isidori</i> (Valenciennes, 1847)	+	+	+
<i>Brienomyrus</i>	<i>Brienomyrus niger</i> (Günther, 1866)	+	+	+
<i>Mormyrops</i>	<i>Mormyrops anguilloides</i> (Linnaeus, 1758)	+	+	+
<i>Campylomormyrus</i>	<i>Campylomormyrus tamandua</i> (Günther, 1864)		+	+
Number of genera : 09				
Number of species : 11				



**Fig 2.** (A-K): Photos of Mormyrid fishes caught in Niger River in Northern Benin.

**Discussion**

Due to the high number (18 months) of samplings carried in different sites and habitats of Niger River at Malanville, it is probable that all Mormyrids fish species have been recorded during this survey. Overall, eleven (11) Mormyrid fish species belonging to nine (9) genera has been assessed in the Niger River at Malanville in northern Benin. Though Koba (2005) reported the same number of Mormyrids, species such as *Pollimyrus isidori* and *Mormyrus hasselquistii* recorded in the present study were not found by (Koba, 2005). Also, the Mormyrid *Marcusenius thomasi* recorded in (Koba, 2005) fish assemblage was absent in the current survey.

The variability in fishing gear used, fishing efforts, sampling sites and sampling periods may explain the difference in the fish composition. Spatially, site3 (Gaya village) and site4 (Money village), less degraded, showed the highest species number, 11 and 10, respectively. Indeed, these sites showed suitable and favorable environmental conditions, indicated by the higher depths (456.17±155.50cm), transparencies (28.44±25.5cm) and dissolved oxygen (7.49±2.93 ppm). In addition, the rocky substratum that characterized this site and the presence of rotten trees and fruits boosted the production of insect larvae, one of the major preys of Mormyrid species. Site2 (Tounga village), though degraded because of domestic uses (dishes cleanings, clothe washings,

bathing) concentrated a relatively high fishes (10 species) probably because of the proximity of rice farming that fertilized this habitat. The highly degraded sites, site1 (Dry port) and site5 (Under Benin-Niger Bridge), exhibited lower species richness, five (5) and four (4) species, respectively, because of their proximities with human habitations where activities like, sand dragging, clothes washings, bathing and dumping of human wastes occurred and polluted these part of the river. Indeed, the low transparencies ( $17.78 \pm 17.79\text{cm}$ ;  $26.61 \pm 27.01\text{cm}$ ), the acid pHs ( $6.61 \pm 0.24$ ;  $6.67 \pm 0.26$ ) and the low dissolved oxygen concentrations ( $4.15 \pm 1.16\text{mg/l}$ ;  $4.83 \pm 1.24\text{mg/l}$ ) recorded respectively in these sites prevented fishes from accumulating in these habitats. As reported by Hugueny *et al.* (1996), Mormyrid fishes are intolerant to pollution and their scarcity in site1 and site5 may be the result of the high pollution observed in these locations. However, among Mormyrids inventoried, the species *Brienomyrus niger* possesses an accessory breathing organ that allows him to support hard environmental conditions. This ecological adaptation may explain its occurrence in critical habitats such as the “Dry port” and the “Whedo”, a traditional fish pond built in adjacent swamps (Moritz and Linsenmair, 2007; Hauber *et al.*, 2011b; Jackson *et al.*, 2013).

Compared to other geographic regions of Niger River, the species richness recorded in Malanville is much lower than that (31 species) reported by Hopkins *et al.* (2007) and Froese & Pauly (2011) from the Upper Niger in Guinea to the lower Niger in Nigeria. Probably, this difference was due to the higher collecting space between Guinea and Nigeria compared to Benin that encompassed a lower sampling space. In Benin, the number of Mormyrid recorded in Niger River is consistent with that of Ouémé River and Okpara Stream dwelling 12 and 9 species, respectively (Laleye *et al.*, 2004). In contrast, the species richness at Malanville was higher than those reported in Mono River (5 species), Lake Hlan (9 species) and Sô stream (2 species) (Laleye *et al.*, 2004; Montchowui *et al.*, 2008; Hazoume *et al.*, 2017). In the Sô stream in particular, the intrusion of brackish water from Lake Nokoué may prevent the concentration of Mormyrids in this running water.

In most water bodies of Tropical Africa, the numbers of Mormyrid fishes (between 7 and 13) reported were nearly consistent with that obtained in Niger River at Malanville. Indeed, twelve (12) species were found in Bagoé River in Mali (Sanogo *et al.*, 2015), thirteen (13) in Baoulé River in Middle Niger River in Mali (Sanogo *et al.*, 2012, 2015), twelve (12) in the lower Benue River in Nigeria, seven (7) in Lake Ayamé in Côte d'Ivoire (Adou *et al.*, 2017), nine (9) in Lake Kainji in Nigeria (Blake, 1977), eight (8) in Yoko reservoir in Congo (Byanikiro *et al.*, 2017), eight (8) in Ikpoba River in Nigeria (Victor and Tetteh, 1988), seven (7) in Central Delta of Niger River (Laë, 1995) and eight (8) in Comoé basin in Côte d'Ivoire. In contrast, the current findings in Niger River at Malanville, was much lower than those reported in Ivindo River and surrounding streams in Gabon (Hopkins, 1980) and in Burkina-Faso rivers with 18 and 18 Mormyrids species recorded, respectively (Ouédraogo, 2010; Meulenbroek, 2013). These variabilities in the species richness were probably the results of the variability in hydrologic regimes, water qualities and environmental disturbances. Seasonally, though dry period showed the highest species richness with 11 Mormyrids species recorded, the numbers of fish species were also high in wet and flood periods with 10 and 10 species, respectively. Particularly, in dry season, water pumping for rice farming along with evaporations reduced water level, concentrating the fishes that become more confined and vulnerable to fishing gears. Major degradation factors of the Niger River at Malanville were climate changes, intense human's activities in and around the river, the use of detrimental fishing gears causing overfishing and the loss of spawning and nursery grounds of many species. The sustainable exploitation of Niger River fish resources requires a holistic management scheme including surveys on Mormyrid community structure coupled with the implementation of community-based approaches of ecosystem management.

### Conclusion

This ichthyological investigation revealed that the Niger River in Northern-Benin harbored about eleven (11) Mormyrid fish species belonging to nine (9) genera. Major degradation factors such the non-respect of fishing regulation, climate changes, intense

human's activities leading to pollution, the use of controversial fishing gears causing overfishing and the loss of spawning/nursery grounds constituted the major threats of the elephant fishes. A holistic management scheme of the Niger River is required for a sustainable exploitation of the fish fauna, including Mormyrids species.

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### References

**Aboubacar A, Humphrey S.** 2007. *Atlas Bassin du Niger*. Autorité du bassin du Niger, ABN, Niamey.

**Adjibade KN, Adite A, Arame H, Sidi Imorou R, Sonon SP.** 2019. Biodiversity and community structure of Mormyridae (Pisces: Teleostei: Osteiglossiformes) from Niger River at Malanville (North-Benin): Threats, conservation and valorization perspectives. In press.

**Adou YE, Blahoua KG, Bamba M, Yao SS, Paul E, Douba VN.** 2017. Premières données sur l'inventaire du peuplement ichthyologique d'un lac ouest Africain situé entre deux barrages hydroélectriques : Lac d'Ayamé 2 (Côte d'Ivoire). *Journal of Applied Biosciences* **2**, 10808–10818.

**Arnegard ME, Carlson BA.** 2005. Electric organ discharge patterns during group hunting by a mormyrid fish. *Proceedings of the Royal Society of London : Biological Sciences* **272**, 1305–1314.

**Blache J, Milton F, Stauch A, Iltis A, Loubens G.** 1964. Les poissons des bassins du Tchad et du bassin adjacent du Mayo Kebbi: Etude systématique et biologique. *Mémoire Orstom*, **4(2)**, 1-486.

**Blake BF.** 1977. Food and feeding of the mormyrid fishes of Lake Kainji, Nigeria, with special reference to seasonal variation and interspecific differences. *Journal of Fish Biology* **11**, 315-328.

**Byanikiro RM, Nsila JN, Busanga AK, Ulyelali-Patho J, Micha JC.** 2017. Caractérisation et écologie des peuplements des mormyridae dans la réserve de Yoko (Kisangani, RD Congo). *International Journal of Biological and Chemical Sciences* **11**, 967-999.

**Daget J.** 1957. Données récentes sur la biologie des poissons dans le delta central du Niger. *Hydrobiologia* **9**, 321-347.

**Daget J.** 1960. Report on the Kainji dam project (Fisheries). C. R. 4ème colloque sur l'hydrobiologie et pêches en eau douce. Fort-Lamy, CCTA/CSA n° **76**, 69-76.

**Daget J, Iltis A.** 1965. Poissons de la Côte d'Ivoire (eaux douces et saumâtres). *Mémoire Institut Français d'Afrique Noire* **74**, 385p.

**Froese R, Pauly D.** 2011. FishBase 2011. World Wide Web Electronic Publication. <http://www.fishbase.org>.

**Hauber ME.** 2011. Description and Improvement of the 'Whedo'-Aquaculture-System in Malanville (North of Benin). Dissertation Zur Erlangung Des, Naturwissenschaftlichen Doktorgrades Der Bayerischen Julius-Maximilians-Universität Würzburg. 203p.

**Hauber ME, Bierbach D, Linsenmair KE.** 2011a. A description of teleost fish diversity in floodplain pools (Whedos) and the Middle-Niger at Malanville (north-eastern Benin). *Journal of Applied Ichthyology* **27**, 1095-1099.

**Hauber ME, Bierbach D, Linsenmair KE.** 2011b. The Traditional Whedo Aquaculture System in Northern Benin. *Journal of Applied Aquaculture* **23**, 67-84.

**Hay CJ, Zyl BJ Van, Steyn G J.** 1996. Quantitative assessment of the biotic integrity of the Okavango River, Namibia, based on fish. *Water SA* **22**, 263-284.

- Hazoume RUS, Chikou A, Koudenoukpo CZ, Adite A, Bonou CA, Mensah GA.** 2017. Length-weight relationships of 30 species of fish of the river Sô in Benin (West Africa). *International Journal of Fisheries and Aquatic Studies* **5**, 514-519.
- Hopkins CD.** 1980. Evolution of electric communication channels of mormyrids. *Behavioral Ecology and Sociobiology* **7**, 1-13.
- Hopkins CD, Lavoué S, Sullivan JP.** 2007. Mormyridae. In: Stiassny MLJ, Teugels GG, Hopkins CD, Ed. *Poissons d'eaux douces et saumâtres de basse Guinée, ouest de l'Afrique centrale*. Vol. 1. Paris: IRD Éditions 220-334.
- Hugueny B, Camara S, Samoura B, Magassouba M.** 1996. Applying an Index of Biotic Integrity Based on fish assemblages in a West African river. *Hydrobiologia* **331**, 71-78.
- Jackson AT, Adite A, Roach KA, Winemiller KO, Jackson AT.** 2013. Primary production, food web structure, and fish yields in constructed and natural wetlands in the floodplain of an African river. *Canadian journal of fisheries and aquatic sciences* **11**, 295-306.
- Kisekelwa T, Boden G, Snoeks J, Vreven E.** 2016. *Marcusenius kaninginii*, a new species of elephantfish from the Lova River basin, Democratic Republic of the Congo (Osteoglossiformes: Mormyridae). *Ichthyological Exploration of Freshwaters* **26**, 341-352.
- Koba G.** 2005. Les pratiques de pêches dans le Fleuve Niger au Bénin et leurs impacts sur la faune ichtyologique. Mémoire de DEA. Université d'Abomey-Calavi. 73p.
- Kramer B, Wink M.** 2013. East-west differentiation in the *Marcusenius macrolepidotus* species complex in Southern Africa : the description of a new species for the lower Cunene River, Namibia (Teleostei : Mormyridae). *Journal of Natural History* **47**, 2327-2362.
- Laë R.** 1995. Climatic and anthropogenic effects on fish diversity and fish yields in the Central Delta of the Niger River. *Aquatic Living Resources* **8**, 43-58.
- Laë R, Williams S, Morand P, Mikolasek O.** 2004. Review of the present state of the environment, fish stocks and fisheries of the river Niger (West Africa). In: *Proceedings of the Second International Symposium on the Management of Large Rivers for Fisheries: Sustaining livelihoods and biodiversity in the new millenium*. Vol. I. Ed. by Welcomme R. and T. Petr. Rome: FAO, 199-277. Phnom Penh, Cambodge. <ftp://ftp.fao.org/docrep/fao/007/AD525e/ad525e09.pdf>
- Laleye PA, Chikou A, Philippart JC, Teugels GG, Vandewalle P.** 2004. Etude de la diversité ichtyologique du bassin du fleuve Ouémé au Bénin (Afrique de l'Ouest). *Cybium* **28**, 329-339.
- Lavoué S, Bigorne R, Lecointre G, Agnese JF.** 2000. Phylogenetic relationships of mormyrid electric fishes (Mormyridae; Teleostei) inferred from cytochrome b sequences. *Molecular phylogenetics and evolution* **14**, 1-10.
- Lavoué S, Arnegard ME, Sullivan JP, Hopkins CD.** 2008. *Petrocephalus* of Odzala offer insights into evolutionary patterns of signal diversification in the Mormyridae, a family of weakly electrogenic fishes from Africa. *Journal of Physiology-Paris* **102**, 322-339.
- Lévêque C, Balian EV, Martens K.** 2005. An assessment of animal species diversity in continental waters. *Hydrobiologia* **542**, 39-67.
- Lowe-McConnell RH.** 1969. Speciation in tropical freshwater fishes. *Biological Journal of the Linnean society* **1**, 51-75.
- Meulenbroek P.** 2013. Fish Assemblages and Habitat Use in the Upper Nakambe Catchment, Burkina Faso. Master of Science Thesis, University of Natural Resources and Life Sciences, Vienna, Austria. 61p.

- Moller P.** 1995. Electric Fishes: History and Behaviour. Fish & Fisheries Series, Chapman&Hall, London, NewYork 584p.
- Montchowui E, Chikou A, Philippe MK.** 2008. Biodiversité et structure des communautés de poissons du lac Hlan au Bénin. International Journal of Biological and Chemical Sciences **2**, 196-206.
- Moritz T, Linsenmair KE.** 2007. The air-breathing behaviour of *Brevimyrus niger* (Osteoglossomorpha, Mormyridae). Journal of Fish Biology **71**, 279-283.
- Moritz T, Laleye PA, Koba G, Linsenmair KE.** 2006. An annotated list of fishes from the River Niger at Malanville, Benin, with notes on the local fisheries. Verhandlung der Gesellschaft für Ichthyologie **71**, 279-283.
- Nelson JS.** 2006. Fishes of the World. John Wiley and Sons, New York, NY, USA, Fourth edition. 601p.
- Nwani CD, Inyang NM, Joseph Effiong Eyo.** 2004. Sex discriminating among four mormyrid species of Anambra river system, Nigeria. Animal Research International **1**, 169-172.
- Nwani CD, Eyo JE, Udeh EF.** 2006. Food and feeding habits of *Campylomormyrus tamandua* in Anambra river, Nigeria. Animal Research International **3**, 410-414.
- Olele NF.** 2013. Food items and general condition of *Hyperopisus bebe occidentalis* (Lacepede, 1803) caught in Warri River , Nigeria. African Journal of Environmental Science and Technology **7**, 402-409.
- Ouédraogo R.** 2010. Fish and fisheries prospective in arid inland waters of Burkina Faso, West Africa. PhD Thesis. University of Natural Resources and Life Sciences, Vienna, Austria.
- Paugy D, Lévêque C, Teugels GG.** 2003. Faune des poissons d'eaux douces et saumâtres de l'Afrique de l'Ouest. Tome 1. Collection Faune et Flore tropicales 40. IRD, Paris.
- PDC Malanville.** 2006. Monographie de la commune de malanville. Mission de Decentralisation. Programme d'Appui au Demarrage des Communes. Afrique Conseil. Cotonou. 48p
- Reed W, Burchard J, Hopson AJ, Jannes J, Yaro I.** 1967. Fish and Fisheries of Northern Nigeria, 1st edition, Ministry of Agriculture, Northern Nigeria.
- Reizer C, Mattei X, Chevalier JL.** 1973. Contribution à l'étude de la faune ichtyologique du bassin du fleuve Sénégal. III. Mormyridae. Bulletin IFAN **35**, 665-704.
- Rich M, Sullivan JP, Hopkins CD.** 2017. Rediscovery and description of *Paramormyrops sphekodes* (Sauvage, 1879) and a new cryptic *Paramormyrops* (Mormyridae: Osteoglossiformes) from the Ogooué River of Gabon using morphometrics, DNA sequencing and electrophysiology. Zoological Journal of the Linnean Society **180**, 613-646.
- Roberts TR.** 1975. Geographical distribution of African freshwater fishes. Zoological Journal of the Linnean Society **57**, 249-319.
- Sanogo Y, Traore D, Samaké F, Koné A.** 2012. Les communautés ichtyologiques de la rivière Baoulé dans le bassin du fleuve Niger au Mali. Tropicicultura **30**, 65-71.
- Sanogo Y, Samake F, Kone A, Traore D.** 2015. Diversité du peuplement ichtyologique de la rivière Bagoé (Bassin du Niger, Mali). Agronomie Africaine **27**, 47-56.
- Schugardt C, Kirschbaum F.** 2004. Control of gonadal maturation and regression by experimental variation of environmental factors in the mormyrid fish, *Mormyrus rume proboscirostris*. Environmental Biology of Fishes **70**, 227-233.
- Svensson GSO.** 1933. Fresh water fishes from the Gambia River (British West Africa). Results of the Swedish expedition 1931. Almqvist & Wiksells.

**Van Thielen R, Hounkpe C, Dagba L, Agon G.** 1987. Guide de détermination des Poissons et Crustacés des Lagunes et Lacs du Bas-Bénin. Direction des Pêches, Cotonou, Bénin.

**Victor R, Tetteh JO.** 1988. Fish communities of a perturbed stream in Southern Nigeria. *Journal of Tropical Ecology* **4**, 49-59.

**Winemiller KO, Adite A.** 1997. Convergent evolution of weakly electric fishes from floodplain habitats in Africa and South America. *Environmental Biology of Fishes* **49**, 175-186.