First Assessment of Mormyridae diversity and abundance in the Niger River at Niamey, Niger

S. M. N. SOULEY[1]*, H. MAHAMAN[2], A. M. IBRAHIM[2], Y. ISSIAKA[3]

[1] *Universidade Técnica do Atlantico, ISECMAR Ribeira de Julião, Mindelo, São Vicente, Cabo Verde*

[2] *Directorate of Fisheries and Aquaculture, General Directorate of Water and Forests, Niamey, Niger*

[3] *Department of Rural Engineering, Water and Forestry, Faculty of Agronomy and Environmental Sciences, Dan Dicko Dankoulodo University, Maradi, Niger*

**Corresponding author*
ssouley@uta.cv

Received 08/09/2024
Accepted 04/11/2024

Abstract

To assessment Mormyridae diversity and abundance in the Niamey fisheries on the Niger River, a study was conducted from August to November 2022. Fish data were collected bimonthly from artisanal fishing landings using gillnets, sparrowhawk nets, baited traps, and baited longlines. A total of 1279 individuals from fifteen species across nine genera were inventoried. Numerically, *Mormyrus rume* dominated the fish assemblages, comprising 29.9% of the mormyrid sub-community, followed by *Marcusenius cyprinoides* (15.0%), *Campylomormyrus tamandua* (12.9%), *Marcusenius senegalensis* (0.08%), *Petrocephalus bovei* (0.08%) and *Hippopotamyrus pictus* (0.16%). The Shannon-Weaver index of species diversity was moderate, reaching H' = 2.96. Major threats to the growth and survival of Mormyrids in the Niger River included over-exploitation and anthropogenic disturbances such as domestic uses (e.g., ditch cleaning, clothes washing, bathing), invasion of floating plants (*Echhornia crassipes*), sand dragging, human waste dumping and the use of chemical fertilizers and pesticides in adjacent agriculture. The results of this study will contribute to the design of a holistic species management scheme that includes habitat protection, species conservation and valorisation.

Keywords: River Niger, Diversity, Characterization, Niger, Mormyridae

INTRODUCTION

Ocean, lakes, and watercourses provide essential food, employment, and economic benefits, supplying over 70% of the proteins for the African population (FAO, 218; Micha et Franck, 2004; Ticheler, 2000; Idowu, 2010). Tropical rivers have a vast diversity of ichthyology, which is not well known taxonomically or in terms of species biology and ecology (Byanikiro *et al.*, 2017). Studying these aspects is crucial for conserving and monitoring ichthyological population (Mbimbi, 2006).

The Mormyridae family, endemic to sub-saharan African, includes 22 genera and 228 species (Hopkins *et al.*,2007; Kisekelwa *et al.*,2016; Byanikiro *et al.*,2017). They are found in many watercourses such as the Nile, Niger, Volta, Senegal, Zambezi, Gambia, Oueme, Mono, Chad, Congo, Ebrié, Kainji, Malawi, Tangamyika, Bagoé, Sassandra, Bandama, Comoé and Benoué (Blache, 1964; Daget and Illtis, 1965; Daget, 1960; Lowe-McConnell, 1969; Hopkins *et al.*, 2007).Most Mormyridae measure between 9 and 50 cm, though some reach 1.5 m. They form shoals in murky rivers, aided by unique sensory organs (Kramer, 2009). Species in the Mormyridae family are among the commonly encountered on the River Niger at Niamey. The lack of knowledge about this family in the study area is very crucial. This family is the first to react when the ecosystem is altered, and knowledge concerning this family is more than important for the development, management and sustainable use of this family. The studies conducted by Hamadou (2019) and Ibrahim (2018) revealed that the Mormyridae family is the most represented in the ichthyological inventories of the Say and Boubon regions in Niger. These studies highlight the dominance of this family of electric fish, common in Africa, within local aquatic communities. This prevalence could be explained by their strong adaptability to the specific ecological conditions of the Niger River, as well as their crucial role in local fisheries. The significant presence of Mormyridae in these ecosystems serves as an important indicator of biodiversity and reflects the overall state of fisheries in these areas.

In Niamey, the Niger River faces increasing pressure due to the establishment of numerous industries along its banks, encroaching on the natural habitat of these fish. As key species, Mormyridae play a fundamental role in the structure and productivity of aquatic ecosystems, contributing to the balance of these environments. It is therefore essential to better understand the ecology, diversity, and community structure of this family, both to ensure the sustainable management of populations and to use these species as bio-indicators of hydrosystem health. They are useful for monitoring biodiversity (Kerckhove, 2012). However, limited knowledge of their distribution and abundance complicate conservation efforts (Lundberg *et al.*,2000; Pigneur, 2005).

The aim of this study is to characterise the Mormyridae population of the River Niger through its diversity and exploitation. This is based on the evaluation of the ecological quality of this hydro-system through the physico-chemical parameters, the inventory of the species of Mormyridae, determination of the typology of the fishing gears used in the capture and determine the parameters of exploitation of the abundant species of Mormyridae.

MATERIALS AND METHODS

Study location and choice of study stations

The study area is Niamey town (South-West Niger) at the latitude 13°30'49"N and longitude 2°6'35.3"E. Three stations were selected with the help of the National Fisheries and Aquaculture Directorate: Tondibia (13°33'52.0"N, 2°00'33.8"E), Barrage Yantalla (13°31'9"N, 2°4'18"E) and Gamkalley (Figure 1). The selection criteria included accessibility during the sampling period, presence of Mormyridae species in fishermen's catches, easy collaboration with local fishermen and fishmongers, and distance between stations to ensure representative coverage of the sector.

Evaluating Habitat Characteristics

The water quality of the Niger river was assessed *in situ* at each sampling site. Depth and transparency were measured to the nearest 1 cm using a Secchi disc. Temperature and dissolved oxygen were measured to the nearest 0.1°C and 0.1 mg/l using a multi-parameter device (EcoSense ODO200). pH was measured to the nearest 0.1 using a pH (Hanna HI 9813-6). Conductivity was measured to the nearest 1.1 µS/cm using a conductivity meter (Hanna model). Fish samples size was measured using an ichthyometer.

Fish collection

Each station was visited twice a month between 7 a.m. and 10 a.m. to check catches. Mormyridae samples were collected from 34 fishermen and 9 fishmongers. The numerical abundance of Mormyridae were surveyed. Various fishing gears (shape, size, mesh size, and techniques) were examined to maximize the chances of harvesting specimens of all sizes (Lalèyè, 1995).

After identification, the following morphometric characteristics of the species were measured:

- **Total length (Lt):** Length from the mouth to the end of the caudal fin.
- **Standard length (Ls):** Length from the mouth to the base of the tail.
- **Total weight** of each fish.

Data Analysis

Data processing of physico-chemical parameter measurements generated a summary table (mean, standard deviation, minimum, maximum, and coefficient of variation). The kurskal-Walli's test was used to assess station or month effects (Adandédjan, 2012). If variation existed, the Mann Withney test compared stations and months in pairs. Statview, Past (Paleontological Statistics) and Python were used for these tests.

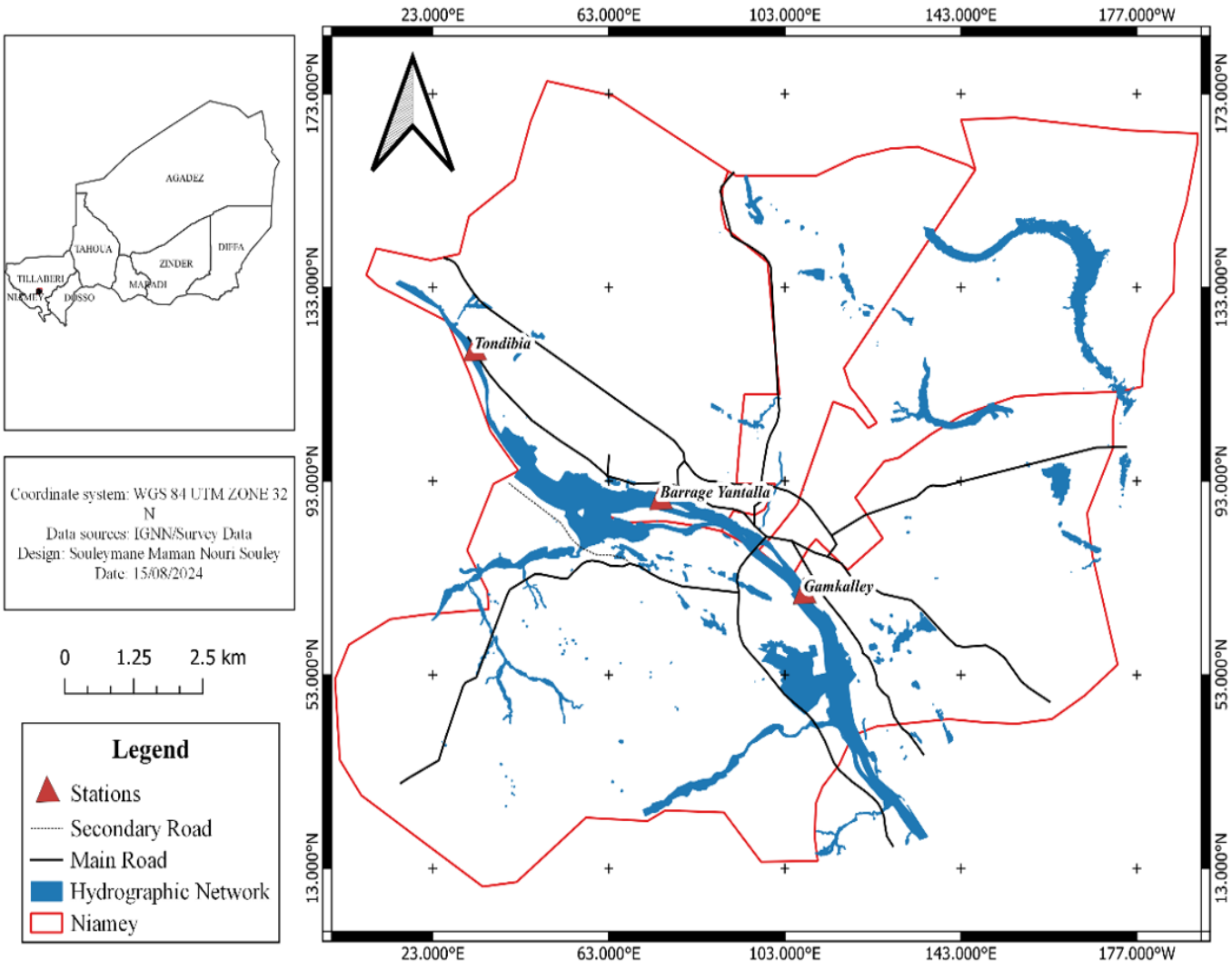

Figure 1: Study area

Diversity, exploitation, and growth parameters

Diversity indices and conservation status

The Mormyridae specimens collected were identified using the identification key (1990), Paugy *et al*. (2003) and Fish Base (2013), with confirmation by the DPA (Fish and Aquaculture Directorate). The specific richness of Mormyridae (S), representing the number of species in each environment, was determined:

• *Specific richness of Mormyridae (S):* The number of species in each environment.

Predicted richness (Ŝ): The probable number of species in the study area using the Jackknife method.

$$\hat{S} = S + \frac{(n+1)}{n}K$$

With S = the number of species observed at all stations and K = the number of unique species and n = the number of stations.

The Shannon-Wiener diversity index (H') is used to characterise species diversity, as it is independent of sample size and considers the relative abundance of each species (Daget, 1979). Expressed in bits per individual, a higher H' indicate greater diversity and (Washington, 1984) is calculated using the equation:

$$H' = -\sum(Pi\ \log 2(Pi))$$

The equitability (Eq) index (Pielou, 1969) measures the regularity of species distribution in each ecosystem. It ranges from 0 to 1, with values near 1 indicating equal abundance of all species (Amanieu and Lasserre, 1982). An Eq value of 0 mean a single species dominates (Da Fronseca, 1968). The equitability index (Eq) is calculated using the formula:

$$Eq = \frac{H'}{\log_2 S}$$

Jaccard's Similarity Index (JSI): is an intercommunity specific diversity index that indicates whether there is similarity between the different stations sampled. Its expression is:

$$IJ = 100\frac{c}{a+b-c}$$

a + b total number of species in the two communities combined and c is the number of shared species.

Conservation status of Mormyridae species

The CITES and IUCN websites were used to collect data on the conservation status of the fish population (CITES, 2017; IUCN, 2018). This status assesses a species risk of extinction at a given time and can change based on threats to its existence. Conservation status is periodically reassessed using rigorous risk assessment systems (IUCN, 2018).

RESULTS

Physico-chemical parameters

Table 1 summarizes the value of the physico-chemical parameters of the water during the four months of sampling. No significant differences (P>0.05) were observed between stations except for the depth, where the Man Whitney test showed a significant difference between the Tondibia and Yantalla Dam stations. The mean water temperature was 29 °C, with the lowest in August (27.9 °C) and the highest in November (31.0 °C). The average pH ranged from 6.73 in November to 7.2 in August. Dissolved oxygen averaged 6.60 mg/l, with the lowest in August (5.12 mg/l) and the highest in November (7.04 mg/l). Oxygen saturation followed similar trends. The average TDS was 0.26 ppm, with monthly variation from 0.165 ppm in November to 0.40 ppm in September. Water conductivity ranged from 36.4 mS in November to 38.3 mS in August and September. Depth varied, with a maximum of 9.67 m in September and a minimum of 6.53 m in August.

Community of Mormyridae

Fish Diversity

Table 2 illustrates the species recorded during the study. The Mormyridae community in the Niger River between August and November comprised 15 species across 10 genera. *Hippopotamyrus, Marcusenius, Mormyrus,* and *Pollimyrus* each had two species, *Mormyrops* had three, and the other genera had one species each. The Jackknife estimated (Ŝ) species richness at 17.

Diversity Indices and Conservation Status

Overall, the Shannon-Wiener diversity index is equal to 2.96 bits and the Pielou equitability is equal to 0.76. Mormyridae diversity is therefore average (H' ε [2.6; 3.9]) and no one species is dominant (Eq ε [0.7; 0.8] within the Mormyridae community.

Table 1: Physico-chemical parameters by sites from August to November 2022 in river Niger at Niamey

Parameters	Gamkalley			Barrage Yanatala			Tondibia		
	Average	Min	Max	Average	Min	Max	Average	Min	Max
Depth (m)	6.28	5.00	7.60	7.13	5.00	9.00	10.5	7.00	15.0
Transparency (cm)	10.0	5.00	13.0	6.50	4.00	8.00	4.13	3.00	5.50
Dissolved oxygen (mg/l)	6.46	5.34	6.97	6.54	4.96	7.48	6.82	5.06	7.53
% Saturation of Oxygen	80.4	68.2	91.9	94.0	80.2	103.4	98.8	94.1	101.6
Ambient Temperature	29.4	28.3	31.6	31.0	28.8	36.2	30.1	29.2	31.3
Water Temperature	29.7	28.5	30.7	29.7	27.4	31.4	29.7	27.9	31.0
Conductivity (mS)	37.2	35.0	40.0	35.0	33.0	37.0	37.0	34.0	40.0
TDS (ppm)	0.40	0.40	0.40	0.13	0.03	0.40	0.26	0.04	0.40
pH	6.98	6.70	7.60	6.70	6.50	6.90	7.00	6.80	7.50

Spatial variations in diversity indices

Table 3 summarizes the diversity indices across Tondibia, Barraye Yantalla, and Gamkalley stations. Richness is low at all stations (H'=1.63, 1.82, 1.69) with Tondibia showing lower Pielou equitability (0.66) compared to the average equitability at Barrage Yantalla and Gamkalley (0.73, 0.74). Mormyridae communities at these stations are dominated by *Mormyrus rume* and *Pollimyrus isidori*, representing 33.7% and 40.7% of catches respectively.

Table 3: Spatial variations in diversity indices

Stations	Diversity Indices			
	Taxa (S)	Individuals	Shannon (H)	Equitability (J)
Tondibia	12	469	1.63	0.66
Barrage Yantalla	12	456	1.82	0.73
Gamkalley	10	354	1.69	0.74

Temporal variations in diversity indices

Table 4 summarizes diversity index change over time. In August, H' was 1.77 and Eq was 0.77, indicating low diversity with no specific Mormyridae dominance. October and November showed similar low diversity (H' around 1.33) and Eq values (around 0.53), with no clear species dominance. However, September had lower H' (1.33) and Eq (0.53), indicating a dominance of *Mormyrus rume*, which accounted for 66 % of the catches that month.

Table 4: Temporal variation in diversity indices

Stations	Diversity Indices			
	Taxa (S)	Individuals	Shannon (H)	Equitability (J)
August	10	299	1.77	0.77
September	12	329	1.33	0.53
October	11	379	1.92	0.80
November	9	272	1.54	0.70

Jaccard index

To understand the relationships between the Mormyridae communities at the different stations, Jaccard's index was calculated (Table 5). This index shows that there is a similarity between the Mormyridae communities at the Barrage Yantalla and Tondibia stations and between the Gamkalley and Barrage Yantalla stations, but the Mormyridae community at the Gamkalley station is different from the Tondibia station.

Table 5: Inter-community relationships of Mormyridae of the three stations

Stations	Tondibia	Barrage Yantala
Tondibia		
Barrage Yantala	60,0	
Gamkalley	46.7	69.2

Table 2: List of species recorded at the three stations during the sampling period

Genera	Species
Briernomurus	*Brienomyrus niger* (Günther, 1866)
Campylomormyrus	*Campylomormyrus tamandua* (Günther, 1864)
Hippopotamyrus	*Hippopotamyrus pictus* (Marcusen, 1864)
	Hyppopotamyrus pssittacus (Boulenger, 1897)
Hyperopisus	*Hyperopisus bebe* (Lacépède, 1803)
Marcusenius	*Marcusenius cyprinoides* (Linnaeus, 1758)
	Marcusenius senegalensis (Steindachner, 1870)
Mormyrops	*Mormyrops anguiloides* (Linnaeus, 1758)
	Mormyrops deliciosus (Leach, 1818)
	Mormyrops oudoti (Daget, 1954)
Mormyrus	*Mormyrus rume* (Valenciennes, 1846)
	Mormyrus macrophthalmus (Günther, 1866)
Petrocephalus	*Petrocephalus bovei* (Valenciennes, 1846)
Pollimyrus	*Pollimyrus ihuysi* (Steindachner, 1870)
	Pollimyrus isidori (Valenciennes, 1847)

Conservation Status of the Fish Population

Based on the classification of the International Union for Conservation of Nature (IUCN), the fish species collected during this study on the Niger River and identified down to the specific level can be divided into three (03) categories (Figure 2). These are the categories: Data Deficient (DD); Not Evaluated (NE); Least Concern (LC).

Of all the species identified up to the specific level, one (01) *Mormyrops oudoti* (i.e. 6.67%) is described as Data Deficient (DD). The conservation status of 3 of the species observed such as *Campylomormyrus tamandua*, *Pollimyrus ihuysi* and *Mormyrus macrophthalmus* (i.e. 20%) has not yet been assessed (NE). Most species in the River Niger have been described as species of Least Concern (LC), representing 73.3% of the population.

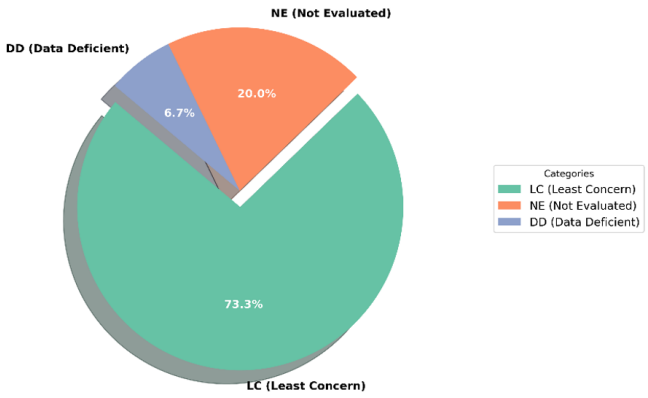

Figure 2: Percentage of fish species in the Niger River (Niger) classified by conservation status according to the International Union for Conservation of Nature. DD: Data Deficient; NE: Not Evaluated; LC: Least Concern

DISCUSSION

Physico-chemical characteristics of stations

Water's importance isn't just about availability and quantity but also its quality, crucial for supporting aquatic and terrestrial life (Ajibade *et al*., 2008). Physico-chemical parameters, influenced by factors like precipitation, evaporation, and human activities, affect fish community indices (Adite *et al*., 2013). Water temperature ranged from 27.4°C to 31.4°C (average 26.7°C), like previous studies (Hassane, 2017). pH ranged from 6.5 to 7.6 (average 6.89), within optimal ranges for aquatic life (IBGE, 2005). Dissolved oxygen averaged 6.60 mg/L and 91.1% saturation, adequate for fish survival (Odokuma and Okpokwasili, 1993). Conductivity averaged 36.4 mS, with total dissolved solids (TDS) averaging 0.26 ppm. Despite generally favorable conditions for fish, human activities like domestic uses and agricultural practices impact water quality negatively.

Community of Mormyridae

Specific Richness

The Mormyridae species richness in the study area along the Niger River includes 15 species across 9 genera. *Mormyrus rume* and *Marcusenius cyprinoides* are the most represented species. Overall, Mormyridae species richness at the three stations was moderate (H' = 2.96), with no dominant species (Eq = 0.76). This family is highly represented in the Niger River with 9 species (PGIPAP, 2012), while Oumarou (2018) recorded 14 species in restored fisheries by the PLCE/BN on the Niger River in Niger. Ibrahim (2018) and Hamadou (2019) reported Mormyridae as the most abundant family in their study areas, with 7 species in Boubon fisheries and 11 species in Say fisheries in Niger, respectively. Other various studies also highlight Mormyridae's prevalence: Lalèyé *et al*. (2004), Chikou (2006), Sirima *et al*. (2009), Montcho (2011), Sanogo *et al*. (2012), Bamogo (2016), and Alphonse *et al*. (2019) reported 12 species in the Ouémé river, 10 species in the Coemé basin in Burkina Faso, 21 species in the Pendjari river, 13 species in the Baoulé river basin in Mali, 7 species in the Ziga dam in Burkina Faso, and 11 species in the Niger river at Malenville and Gaya. *Mormyrops oudoti*, reported by PGIPAP (2012), was also encountered during this study. The estimated species richness was 17, compared to the 15 species sampled during the four-month study period. Sampling duration and study scope likely influenced this discrepancy. Ahouansou Montcho (2011) notes that biases in assessing species diversity are common, as sampling must be exhaustive to accurately determine total species richness (Walther and Moore, 2005; Walther and Morand, 1998; Novotny and Basset, 2000; Mao and Colwell, 2005).

Spatio-temporal variations in the Mormyridae Community and Conservation Status

From August to November, the inventory revealed 12 species at Tondibia, 12 species at Yantalla Dam, and 10 species at Gamkalley, with diversity indices H' of 1.63, 1.82, and 1.69 respectively. Jaccard's index indicated differences between Mormyridae communities at Gamkalley and Tondibia. October showed lower diversity (H' = 2.29, Eq = 0.80), coinciding with species migration to spawning grounds. Most Mormyridae (73.3%) in the River Niger are classified as "Least Concern" by IUCN, like findings in Aghien Lagoon (Assi, 2019). Conservation status is dynamic and requires regular reassessment due to changing threats (IUCN, 2018).

CONCLUSION

The recent ichthyological study of the Niger River offers significant insights into the Mormyridae family's richness, abundance, diversity, distribution, and habitat conditions. Conducted over four months at Tondibia, Barraga Yanatalla, and Gamkalley stations, the research identified fifteen Mormyridae species, including *Mormyrus rume, Marcusenius cyprinoides, Campylomormyrus tamandua, Pollimyrus isidori, Brienomyrus niger,* and *Hyperopisus bebe*. Notably, five new species were documented beyond those listed by PGIPAP in 2012, bringing the total to fifteen.

The study also revealed issues with fishing regulation compliance, posing threats to sustainable management. These threats include river silting, agricultural runoff, invasive vegetation, waste dumping, and climate change. This research advances our understanding of the Niger River's ichthyofauna, addressing a gap since Coenen's (1987) study. However, it is limited by its focus on a single fish family over a brief period. To ensure sustainable fisheries management, ongoing and comprehensive studies are crucial. The Mormyridae family, as indicators of ecological water quality, plays a key role in monitoring the biotic integrity of this aquatic ecosystem.

REFERENCES

Abdou I. (2015). Écologie et exploitation de la faune ichtyologique de la mare de Lassouri, dans la région de Zinder au Niger. Mémoire de master, Faculté des Sciences Agronomique/Université d'Abomey Calavi, (Bénin), 72 p.

Adandédjan D. (2012). Diversité et déterminisme des peuplements de macroinvertébrés benthiques de deux lagunes du Sud-Bénin: la Lagune de Porto-Novo et la Lagune Côtière. Thèse de doctorat unique, Université d'Abomey Calavi, (Bénin), 240 p.

Adite A, Imorou Toko I., Gbankoto A. (2013). Fish assemblages in the degraded mangrove ecosystems of the coastal zone, Benin, West Africa: implications for ecosystem restoration and resources conservation. *Journal of Environmental Protection,* 4: 1461–1475.

Ahouansou Montcho S. (2003). Etude de l'écologie et de la production halieutique du lac Toho au Bénin. Mémoire de DESS/FSA/UNB. 87 p.

Ahouansou Montcho S. (2011). Diversité et Exploitation des poissons de la rivière Pendjari (Bénin, Afrique de l'Ouest). Thèse du grade de Docteur de l'Université d'Abomey-Calavi, 234 p.

Alhou B. (2007). Impact des rejets de la ville de Niamey (Niger) sur la qualité des eaux du fleuve Niger. Thèse de doctorat unique, Facultés Universitaires Notre Dame de la Paix Namur (Belgique), 229 p.

Alphonse Adite, Kayodé Nambil Adjibade, Hamidou Arame, Rachad Sidi Imorou, Stansilas Pejanos Sonon (2019). Biodiversity and Community Structure of Mormyridae (Pisces: Teleostei: Osteoglossiformes) from Niger River in Northern Benin: Threats, Conservation and Valorization Perspectives. *International Journal of Sciences,* 8: 107-116.

Amanieu M., Lasserre G. (1982). Organisation et évolution des peuplements lagunaires. *Oceanologica Acta*, 4: 201-213.

Assi Sonan Romuald (2019). Diversité et dynamique des populations des principals espèces ichtyologiques de la lagune Aghien (Sud-Est Côte d'Ivoire). Thèse de doctorat, l'Université Jean Lorougnon Guede, (Côte d'Ivoire), 181 p.

Bamogo L.L. (2016). Diversité des poissons et gestion des pêcheries du lac de barrage de ziga (Burkina Faso). Mémoire de master, Faculté des Sciences Agronomiques/Université d'Abomy Calavi (Bénin), 60 p.

Blache J., Milton F., Stauch A., Iltis A., Loubens G. (1964). Les poissons du bassin du Tchad et du bassin adjacent du Mayo-Kebbi. Etude Systématique et Biologique. *Mémoire Orstom*, 4: 483 p.

Byanikiro R.M., Nsila J.N., Busanga A.K., Ulyelali-Patho J., Micha J.C. (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.

Cakpo Kiossa C. (2012). Biodiversité et exploitation de quelques espèces de poissons de la rivière sô au Benin. Mémoire de master, Université polytechnique de Bobo Dioulasso, (Burkina Faso), 113 p.

Carlander K.D. (1969). Handbook of freshwater fishery biology, Vol. 1. Iowa State University Press, Ames, IA, 752 p.

Chikou A. (2006). Etude de la démographie et de l'exploitation halieutique de six espèces de poisson chat (Teleostei, siluriformes dans le delta de l'Ouémé au Benin. Thèse doctorat unique, Université de Liège (Belgique), 322 p.

Da Fronseca C. (1968). Théorie de l'information et diversité spécifique. *Bulletin du Musée National d'Histoire Paris, 2ème série*, 38: 961-968.

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

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

Daget J. (1979). Contribution à la faune de la République Unie du Cameroun. Poissons de l'Ayina, du Dja et du Bas Sanaga. *Cybium*, 3: 55-64.

Etienne B., Jacques M., Sana B. (1994). Aspects hydrobiologiques et pisciculture d'eau en zone soudano-sahélienne. Centre techniques de coopération agricole et rurale (CTA), commission des communautés européennes (CCE), Bruxelles, 250 p.

FAO (2018). La situation actuelle des pêches et de l'aquaculture 2018. Atteindre les objectifs du Developpement Durable. Rome.

Hamadou Yacouba (2019). Analyse de la biodiversité ichtyologique et de la productivité des pêcheries de Say au Niger. Mémoire de master, Faculté des Sciences Agronomiques/Université d'Abomey-Calavi (Bénin) 66 p.

Hamani H. (2015). Etude de l'exploitation de la faune ichtyologique de la rivière Sô au Bénin (Afrique de l'Ouest). Mémoire de master, Faculté des Sciences Agronomiques/Université d'Abomey-Calavi (Bénin) 189 p.

Hassane Younoussi H. (2017). Performances immunitaires du poisson-chat *Clarias gariepinus* (Burchell, 1822) exposé aux métaux lourds issus des rejets industriels et hospitaliers dans le Fleuve Niger à Niamey. Mémoire de master, Faculté des Sciences Agronomiques/Université d'Abomey Calavi (Bénin), 76 p.

Hile R. (1936). Age and growth of the cisco *Leucichthys artedi* (Le Sueur), in the lakes of the north-eastern highlands, Wisconsin. *Bulletin of the United States Bureau of Fisheries,* 48: 211–317.

Hopkins C.D., Lavoué S., Sullivan J.P. (2007). Mormyridae. *The fresh and brackish water fishes of Lower Guinea, West-Central Africa*: 219-334. Muséum national d'Histoire naturelle, Paris.

Ibrahim ADO (2018). Influence de la pêche sur la structure des stocks de poisson dans les pêcheries de Boubon au Niger. Mémoire de master, Faculté des Sciences Agronomiques/Université d'Abomey Calavi (Bénin), 99 p.

Idowu A.A. (2010). Effect of some socioeconomic activities on fish diversity of lagoon systems in Ogun waterside Local Government of Ogun State, Nigeria. *Int. J. Biol. Chem. Sci.*, 4: 88-99.

Institut Bruxellois pour la Gestion de l'Environnement (2005). Qualité physicochimique et chimique des eaux de surface: cadre général, 16 p.

Kerckhove O. (2012). Espèces ou association d'espèces de poissons en tant que bio indicateur de l'état de santé des récifs coralliens. Mémoire de maîtrise, Fac. Sc. Université de Sherbrooke, Québec.

Kisekelwa T., Boden G., Snoeks J., Vreven E. (2016). *Marcusenius kaninginii*, a new species of elephant fish from the Lowa River basin, Democratic Republic of the Congo (Osteoglossiformes: Mormyridae). *Ichthyological Exploration of Freshwaters*, 26: 341-352.

Kramer B. (2013). Differentiation in morphology and electrical signalling in four species of para- and sympatric *Marcusenius* (Teleostei: Mormyridae) from Côte d'Ivoire, West Africa. *Marine and Freshwater Behaviour and Physiology,* 46: 105–133.

Lalèyè P. (1995). Ecologie comparée de deux espèces de *Chrysichthys*, poissons siluriformes (claroteidae) du complexe lac Nokoué-lagune de Porto/Novo au Bénin. Thèse de Doctorat Université de Liège (Belgique). 199 p.

Lalèyé P., Akalé D., Philippart J-C. (2005). La pêche traditionnelle dans les plaines inondables du fleuve Ouémé au Bénin. *Cahiers d'Ethologie*, 22: 25-38.

Lalèyè P., Chikou A., Philippart J.-C., Teugels G., Vandewalle P. (2004). Étude de la diversité ichtyologique du bassin du fleuve Ouémé au Bénin (Afrique de l'Ouest). *Cybium*, 28: 329-339.

Lederoun D. (2006). Etude et exploitation des ressources halieutiques de la lagune de Porto Novo, au Bénin. Mémoire de fin de cycle pour l'obtention du diplôme d'ingénieur des travaux (DIT),69 p.

Lowe-McConnell R.H. (1969). Speciation in tropical freshwater fishes. *Biological Journal of the Linnean Society,* 1: 51–75.

Mao C.X., Colwell R.K. (2005). Estimation of species richness: mixture models, the role of rare species, and inferential challenges. *Ecology,* 86: 1143–1153.

Mbimbi M. (2006). Contribution à l'étude de la biologie et de l'écologie de *Marcusenius greshoffi* (Schilthuis, 1891). Mémoire de DEA. Unikin, Kinshasa

Micha J-C, Franck V. (2004). Etude perspective pour la relance du secteur pêche et aquaculture en Côte d'Ivoire. Ministère de la Production Animale et des Ressources Halieutiques, Abidjan, 60 p.

Novotny V., Basset Y. (2000). Rare species in communities of tropical insect herbivores: pondering the mystery of singletons. *Oikos,* 89: 564–572.

Odokuma L.O., Okpokwasili G.C. (1993). Seasonal influences on inorganic anion monitoring of the New Calabar river, Nigeria. *Environmental Management*, 17: 491-496.

Oumarou Amadou (2018). Diversité et exploitation des populations de Mormyridae dans le secteur du fleuve Niger sous influence du Programme de Lutte Contre l'Ensablement (PLCE) au Niger. Mémoire de master, Faculté des Sciences Agronomiques/Université d'Abomey Calavi (Bénin), 73 p.

Paugy D., Lévêque C., Teugels G.G. (2003). Poissons d'Eaux Douces et Saumâtres de l'Afrique de l'Ouest (Tome I et II). IRD, MNHN et MRAC, Paris.

Pielou E.C. (1966). The measurement of diversity in different types of biological collections. *Journal of Theoretical Biology,* 13: 131–144.

Programme de Gestion Intégrées des Plantes Aquatiques Proliférantes (2012). Répertoire de la faune aquatique de la zone d'intervention du projet. 36 p.

Sabine E. (1990). Limnologie, note de cours. Institut pratique de développement rural, IPDR, Kollo, TRD3 Eaux et Forêts, 60p.

Sanogo Y., D. Traoré F., Samaké A. Koné (2012). Les communautés ichtyologiques de la rivière Baoulé dans le bassin du fleuve Niger au Mali. *Tropicultura,* 30: 65-71.

Shannon C.E. (1948). A Mathematical Theory for Communications. *Bell Systems Technology Journal,* 27: 379–423.

Sirima O., Toguyen A., Kabore-Zoungrana C.Y. (2009). Faune piscicole du bassin de la Comoé et paramètres de croissance de quelques espèces d'intérêt économique. *Int. J. Biol. Chem. Sci.,* 3: 95-106.

Ticheler A. (2000). Conservation de la biodiversité des poissons dans les zones humides de l'Afrique de l'Ouest. Plan d'action Régional 2000, Wetlands International.

UICN (2018). IUCN Red list of threatened species. Union Internationale de la Conservation de la Nature (IUCN). Version 2018-2. http://www.iucnredlist.org.

Walther B.A., Morand S. (1998). Comparative performance of species richness estimation methods. *Parasitology,* 116: 395–405.

Youssoufa Issiaka, Oumarou Ali Abdou, Bassirou Alhou, Philippe A. Laleye (2018). Caractérisation hydrobiologique et gestion de la mar de Rouafi dans le Département de Konni, Niger.