International Journal of Sciences

Research Article Volume 8 – May 2019 (05)

Biodiversity and Community Structure of Mormyridae (Pisces: Teleostei: Osteoglossiformes) from Niger River in Northern Benin: Threats, Conservation and Valorization Perspectives

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Abstract: Mormyrid fishes are of great commercial and economic importance in the artisanal fisheries of the Niger River in Benin. We investigated species composition and community structure of this taxa in order to contribute to species management and sustainable exploitation. Mormyrid individuals were collected monthly from February 2015 to July 2016 using cast nets, gill nets and seines. Among a total of 6825 individuals collected, eleven (11) species belonging to 9 genera were inventoried. Numerically, *Marcusenius senegalensis* dominated the fish assemblages and made 43.74% of the mormyrid sub-community followed by *Mormyrus macrophthalmus* (14.87%), *Hyperopisus bebe*, (11.43%), *Petrocephalus bovei* (11.21%), *Mormyrus rume* (8.54%) and *Hippopotamyrus pssittacus* (4.69%). The Shannon-Weaver index of species diversity was moderate and reached H'=2.54. Overall, percentage occurrences (PO) of Mormyrids in the 5 selected sites ranged between 40 and 100%, with *Marcusenius senegalensis* (PO=100%) and *Hyperopisus bebe* (PO=100%) widely distributed in all 5 sites. In the Niger River, Mormyrid abundances significantly (r=0.70; P<0.01) increased with dissolved oxygen. The overexploitation and other antropogenic disturbances such as domestic uses (ditch cleanings, clothe washings, bathings), invasion of floating plants (*Echhornia crassipes*), sand dragging, human wastes dumping, the use of chemical fertilizers and pesticides for adjacent agriculture etc. constituted some major threats for the growth and survival of the Mormyrids in the Niger River. The results of this study will contribute to design a holistic species management scheme that includes habitat protection, species conservation and valorization.

Keywords: Benin, Community Structure, Conservation, Management, Mormyrids, Niger River, Shannon-Weaver Index

Introduction

The fishes of the Mormyridae family are of high commercial and fisheries importance and display a very large distribution in tropical Africa. These weakly electrical fishes are endemic in African riverine ecosystems and among the Osteoglossiformes, the Mormyridae is the most speciose family comprising 22 genera and about 228 species (Hopkins *et al.*, 2007; Kisekelwa *et al.*, 2016; Rich *et al.*, 2017). Adjibade et *al*. (*in press*) reported that the Mormyrids widely occurred in top rivers such as the Nile, Niger, Volta, Senegal, Zambezi, Gambia, Oueme, Mono etc. Also, the species of this family occurred in water bodies and streams such as Tchad (Blache , 1964), Congo, Ebrié, Kainji, Malawi, Tanganyika, Bagoé, Sassandra (Daget and Iltis, 1965), Bandama, Comoé, Bénoué (Daget, 1960; Lowe-McConnell, 1969; Hopkins *et al.*, 2007) etc.

In general, Mormyrid fishes possess an electric organ that enable a weak electric discharge used for sex and species identification, communication, orientation and prey detection (Moller, 1995; Hopkins *et al.*, 2004; Schugardt and Kirschbaum, 2004; Lévêque *et al.*, 2005; Lavoué *et al.*, 2008; Kramer, 2013). The body is elongate to deep, laterally compressed and covered by small cycloid scales (Lévêque *et al.*, 2005; Adjibade *et al.*, 2019). The fishes show a non-protrusible mouth with a snout of variable forms (see description in Adjibade, 2019).

In Benin, the mormyrid fishes occurred preferentially in running waters where they constituted an important component of the fisheries. In particular, in the Niger River in Benin, the elephant fishes represented 12.65% of the commercial catches and appeared to be the second family most prominent in

Published at: http://www.ijsciences.com/pub/issue/2019-05/
DOI: 10.18483/ijSci.2068; Online ISSN: 2305-3925; Print ISSN: 2410-4477

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this northern riverine water (Koba, 2005). However, notwithstanding their great importance in artisanal fisheries, not much is known about the Mormyridae fishes in the Niger River in Benin. Overall, in contrast with the Southern-Benin, the aquatic ecosystems from the Northern region have not received intensive fisheries research and bioecological studies on key family such as Cichlidae, Claroteidae, Siluridae, Osteoglossidae, Mochokidae, Mormyridae etc. are scant. In particular, in this disturbed running water characterized by a deep modification of climatic factors, high pollution due to garbage dumpings and intrusion of chemical fertilizers and pesticides, invasion of floating plants, overfishings etc., nothing is known about the fish fauna and community structure of the elephant fishes. Complete knowledge on the community indices is crucial to document and to characterize the structure of the fish biodiversity in order to design and to implement an appropriate management scheme that includes habitat protection, species conservation and valorization (Gbaguidi *et al.*, 2016).

This fisheries ecological survey in the Niger River in northern Benin aimed to assess the mormyrid fish biodiversity and its community structure in order to better conserve and manage the species for a sustainable exploitation. Specifically the study 1) assessed the fishes and structure of the community, 2) evaluated the relationships between environment parameters and fish community indices and 3) suggested grassroots with key actions for resource conservation and management.

Material and Methods

Study location

The study area is Malanville town (North-East Benin) situated at latitude 11°52'216"N, longitude 3°21'111"E, around the Niger River that serves as frontier between Niger and Benin countries. Malanville town extended on 3.016 km² and human population reached 168,641 people. The Northern Benin exhibited a soudano-sahelian climate and is characterized by a rainy season from May to July, a flood season from August to September and a long dry period occurring October-April (PDC Malanville, 2006). Average annual rainfall computed for the last five years (2013-2017) is about 750 mm with a peak reaching 1000 mm (Aboubacar and Humphrey, 2007). The northern region showed a dominant wind, the harmattan that blowed between November-January causing ambient temperatures depletion up to 16°C (PDC Malanville, 2006). In Benin, the Niger river displayed three (3) tributaries, Alibori (338 km), Mekrou (410 km) and Sota (250 km) that crossed Malanville and other towns of North Benin such Karimama. Also, the Niger River in Benin displayed a huge floodplain that covered about 300 ha. This floodplain constituted an important spawning and nursery grounds for the fish community (Moritz *et al.*, 2006). Though the Niger River basins exhibited a clayed-sandy and ferruginous soils, in general, the region of Malanville were composed of gneiss. Dominant aquatic plants species were *Eichornia crassipes, Echinochloa stagnina, Pistia stratiotes, typha australis, Mimosa sp, Mimosa pigra, paspalum serobiculatum, Ipomoea aquatica, Cyperus cyperoides, Ipomoea asarifolia, Senna occidentalis, Ludwigia senegalensis, Ludwigia abyssinica, Ludwigia adscendens, Ludwigia erecta, Achyranthes aspera, Azolla africana etc.* Intense commercial fishing activities that involved fishermen from South-Benin, Burkina Faso, Ghana, Mali, Togo etc. occurred on the Niger River in Benin.

Currently, the Niger river in Benin is under multiple uses that continously degrade the ecosystem. These were adjacent agricultures that used chemicals fertilizers and pesticides, the withdrawal of water for agriculture and domestic uses, the dumping of domestic wastes, overfishing, ditching, bathing and clothe washings. All these activities caused changes in water quality and in fish community structure, contributing to fish stock depletion and species extinction (Laë *et al.*, 2004; Hauber, 2011).

Sampling sites

In this study, five sampling locations were identified for the evaluation of the water quality and for Mormyrid collections. Site selections were based on accessibility, quantitative importance of fish landed and habitat characteristics. An exploratory outing on the study location was carried out twice before data collection started. Site1 and Site2 were located on Sota stream. Site 1 was covered by dense vegetation where domestic wastes were rejected whereas Site2, located at Tounga village, was polluted by bathing, dishes and clothe washings. In addition, due to the proximity of rice farming, Site2 was under chemical pollution because of the use of fertilizers and pesticides. Site3 was situated on the main channel at Gaya village in Niger Republic. The substratum of this site was rocky with rotten trees that constituted a good habitat for Mormyrids. Site4 is located at Money village, on the main channel and communicate with Alibori stream. This site was less degraded and fishing activities were intense during the dry season. Site5 was located under Benin-Niger Bridge and also located on the main channel of Niger River. This site was polluted and degraded because of intense anthropogenic disturbances. At the five sites, samplings were performed in the “aquatic vegetation habitat” at the edge of the stream as well as in the “open water habitat” exempt of vegetation (Figure 1**)**.

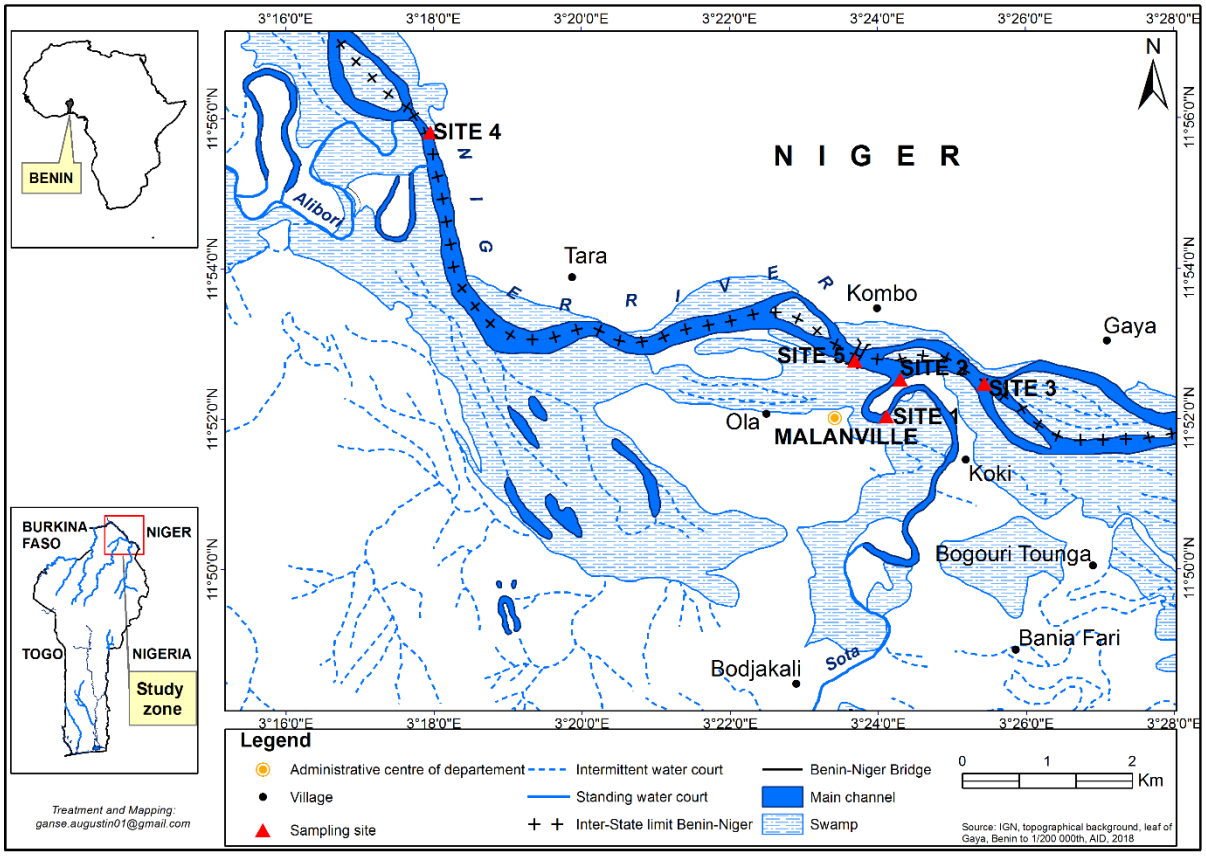

Figure 1: Map showing River Niger at Malanville (North-Benin) and the five study locations; 1= Sota Stream (DP) ; 2= Tounga; 3= Gaya (Niger Country) ; 4=Money; 5= Benin-Niger Bridge (BNB)

Evaluation of habitat characteristics

The water quality of the Niger River was assessed in situ at each sampling site. The depth was measured to the nearest 1 cm using a graduated rope attached to a water sampler. Transparencies were measured to the nearest 1 cm using a 20 cm diameter - Secchi disc. The temperature and the dissolved oxygen were measured respectively to the nearest 0.1 °C and 0.1 $mg.l^{-1}$ using a digital multi-probe (HANNA model 9150 waterproof). pHs were measured to the nearest 0.1 using a pH meter "model 3150 waterproof". Conductivities were measured to the nearest 1 µS/cm using a conductivity meter (HANNA model). Aquatic plants were sampled, preserved and send to "Herbier National du Benin" of the Faculty of Sciences and Technics, University of Abomey-Calavi for identification.

Fish collection

Mormyrid samples were collected monthly for eighteen (18) consecutives months (February 2015 to July 2016) in "whedo" habitat (traditional fishpond built in proximity to the river) , in aquatic vegetation and in open water with traps, gillnet (50 m × 1 m, 40 mm-mesh; 50 × 1 m, 30 mm-mesh; 50 m × 1 m, 20 mm-mesh), cast net (6 m-diameter, 20 mm-mesh) and seine (6.15 m × 2 m, 16 mm-mesh). Gillnets and traps were set for 12 hours. Five to ten rounds of seining were done at each location. Samplings were performed with the help of local professional fishermen. In order to approach the total biodiversity, fishes were also sampled directly from fishermen captures. Thus, per species, one-third of the fisherman total catches was sampled when the number of individuals was 50 and above. In contrast, when the number was less than 50, all the individuals were sampled. Fish specimens collected were then identified to species level in situ using references such as Van Thielen *et al.* (1987), Paugy *et al.* (2003) and Nelson (2006). They were then preserved in 10% formalin and shipped to the "Laboratoire d'Ecologie et de Management des Ecosystèmes Aquatiques" where they were removed from the formalin and preserved in 70% ethanol to facilitate other biological observations (Schreck and Moyle, 1990; Murphy and Willis, 1996). In the laboratory, scientific names were confirmed and verified through http://www.fishbase.org. At each sampling site, the total number of individuals per species was recorded. For each specimen, the total length (TL) and the standard length (SL) were measured to the nearest 0.1 cm with an ichtyometer and the total weight (W) was measured to the nearest 0.1g with an electronic balance (CAMRY 0.1g/5 kg).

Data analysis

Abiotic data (depth, transparency, temperature, pH, dissolved oxygen concentration, percentage of dissolved oxygen saturation, conductivity) collected to assess the water quality, and the data on the fish biodiversity were recorded in SPSS 21 (Morgan *et al.*, 2001) and Excell spreadsheets. For water factors, ranges and average values were computed by site (Table1). The relative abundance of each mormyrid was computed using the numerical abundance of each species in the fish assemblage. The species richness (*d*) was determined following Margalef index (Margalef, 1968):

$$d = (S - 1)/\ln N$$

where *S* is the number of species and *N* the number of individuals in the sample. The species diversity (*H'*) of the Mormyrids was determined following Shannon & Weaver index of species diversity (Shannon and Weaver, 1963):

$$H' = -\Sigma(pi) \times \log_2 (pi)$$

where *H'* is the index of species diversity, $pi = ni/N$ the proportion of total sample belonging to *i*th species, *ni* the number of individuals of each species in the sample, *N* the total number of individuals of all species in the sample. The evenness measure (*J*) of Shannon & Weaver (Shannon and Weaver, 1963) was computed following the formula:

$$J = H'/\log_2 S$$

where (*J*) is the evenness measure, *H'* is the Shannon & Weaver index of diversity, *S* is the number of species in the sample. The Correspondance Analysis (CA) (Legendre and Legendre, 1998) and the Hierachical Clustering on Principal Components were performed to produce a dendrogram in order to search for any association between species abundances and sampling sites. The R software version 3.4.3 (R Core, 2017) package ''vegan'' was used to generate the species diversity and evenness indexes and to run the Correspondance Analysis.

To evaluate the relationship between the fish community structure attributes and the abiotic factors, the Canonical Correspondance Analysis (CCA) was performed using the CANOCO computer program, Version 4.5 (ter Braak, 1989).

Results

Physicochemical parameters

Table 1 presents means, minimum and maximum values of water features across sampling sites within the Niger River. Overall, during the study periods, depth ranged between 151 (Dry Port) and 950 cm (Gaya) and transparency between 0 (all sites) and 70 cm (Money). Water temperature varied from 21.4 (Tounga) to 35.6 °C (Money), pH from 6.1 (Dry Port) to 8.8 (Gaya) and conductivity ranged between 200 (Dry Port, Money, Benin-Niger Bridge) and 500 µ/cm (all sites). The concentration of dissolved oxygen varied from 2.18 (Dry Port) to 11.9 mg/l (Gaya) with percentage of saturation ranging between 29.3% (Benin-Niger Bridge) and 171.3% (Gaya).

Table 1: Physicochemical parameters by sites from February 2015 to July 2016 in River Niger at Malanville

Parameters	Sota Stream (Sota stream)		Tounga		Gaya		Money		Benin-Niger Bridge	
	Mean	Interval	Mean	Interval	Mean	Interval	Mean	Interval	Mean	Interval
Depth (cm)	215.56	151-286	437.28	326-620	456.17	250-950	335.39	253-422	273.28	165-345
Transparency (cm)	17.78	0.0-49	18.94	0.0-45	28.44	0.0-66	26.61	0.0-70	26.61	0.0-41
Dissolved Oxygen (mg/l)	4.15	2.18-6.77	5.72	3.06-8.64	7.48	3.06-11.9	6.94	3.68-11.14	4.83	2.68-7.14
% saturation of oxygen	54.54	34.1-88.8	79.18	34.1-121.3	97.74	34.1-171.3	90.34	49.3-137.6	64.39	29.3-97.6
Ambient Temperature (°C)	30.49	21.3-37.3	31.62	21.3-35.9	32.05	27.2-35.9	31.27	24.7-38.6	31.18	24.7-36.6
Water Temperature (°C)	29.23	22.3-34.5	29.24	21.4-33.5	29.36	22-33.3	29.05	21.6-35.6	29.6	22-34.6
Conductivity (µS/cm)	3.44	02.0-05.0	3.89	03.0-05.0	3.94	03.0-.05.0	3.72	02.0-05.0	4.056	02.0-05.0
pH	6.61	6.1-6.96	7.03	6.3-8.15	7.18	6.2-8.8	7.35	6.3-8.7	6.67	6.2-7.23

Mormyrids richness, abundance and sizes

Among a total of 6825 mormyrid individual collected during eighteen (18) months in the Niger River at Malanville, eleven (11) species belonging to 9 genera were inventoried. Numerically, *Marcusenius senegalensis* was the most abundant species and made 43.74% of the mormyrid sub-community followed by *Mormyrus macrophthalmus* (14.87%), *Hyperopisus bebe*, (11.43%), *Petrocephalus bovei* (11.21%), *Mormyrus rume* (8.54%) and *Hippopotamyrus pssittacus* (4.69%) (Table 2). These six (6) species made together 94.49% of the fish assemblages (Table 2). In term of biomass, *Marcusenius senegalensis* alone accounted for about 37% of the fish assemblages, followed by *Mormyrus rume* (25.11%), *Hyperopisus bebe* (19.03%), *Mormyrus macrophthamus* (9%), *Mormyrops anguilloides* (3.02%) and *Petrocephalus bovei* (2.57). Like the numeric abundance, these six (6) fishes cumulated 95.59% of the fish community and the five

(5) remaining species made together for only 4.41% and none of them made more than 2.14% of the fish biomass (Table 2).

In the current study, the mormyrid fish assemblages exhibited variable sizes. Regardless of species, standard lengths (SL) varied from 3.8 cm (*Pollimyrus isidori*) to 44.7 cm (*Mormyrops anguilloides*) with weights ranging between 1.0 g and 859 g (Table 2). Also, the mean standard length of the fishes ranged between SL_m =5.46 cm (*Pollimyrus isidori*) and SL_m = 21.25 cm (*Campylomormyrus tamandua*) and corresponding mean weights varied from 2.8 g to 94.32 g. Large Mormyrid recorded were *Mormyrops anguilloides* showing a maximun standard length SL_m = 44.7 cm that corresponded to a weight W = 859 g, *Mormyrus rume* with SLm = 42.1 cm and W = 611 g, *Hyperopisus bebe* with SLm = 35.9 cm and W = 380.5g, *Campylomormyrus tamandua* SLm = 24.3 cm with W =116.5g, *Marcusenius senegalensis* with SL_m = 23.6 cm and W = 220.1 g, *Mormyrus macrophthalmus* with SL_m= 22.8 cm and W =129.7, *Mormyrus hasselquisti* with SL_m = 21.1 cm and W =112.7g.

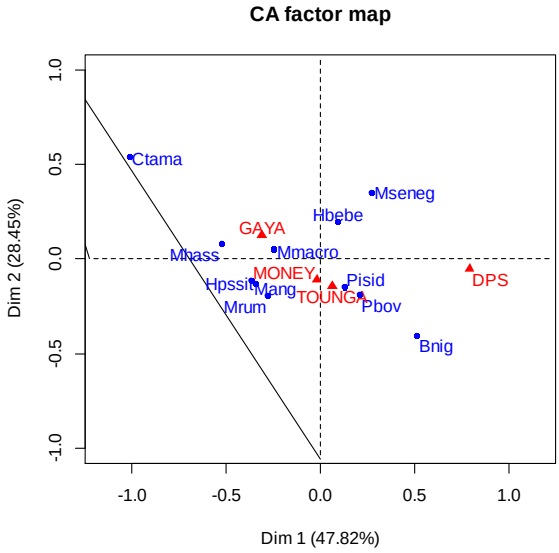

Figure 2: Correspondence analysis on the 11 dominant Mormyrids from Niger River in Northern Benin. Bnig=Brienomyrus niger, Ctama=Campylomormyrustamadua; Mhass=Mormyrus hasselquisti, Mmacro=Mormyrus macrophtalmus; Mang=Mormyrus anguilloides; Hpssit=Hippopotamyrus pssittacus; Mrum=Mormyrus rume; Mseneg=Marcusenius senegalensis; Hbebe=Hyperopisus bebe; Pisid=Pollimyrusisidori; Pbov=Petrocephalus bovei.

Table 2: Fish species composition: Abundance, mean size and weight, size and weight range of the fish in the Niger River at Malanville (North Benin)

Species	Abundance	Relative Abundance %	Mean SL (cm)	Range SL (cm)	Means Weight (g)	Range Weight (g)	Total Weight (g)	Percentage Weight
Brienomyrus niger	139	2.04	8.58	5.7-15.5	8.97	2.5-32.9	1246.10	0.85
Campylomormyrus tamandua	11	0.16	21.25	16.5-24.3	94.32	46-116.5	1037.50	0.70
Hyperopisus bebe	780	11.43	16.16	5.8-35.9	35.92	3.6-380.5	28017.72	19.03
Hippopotamyrus pssittacus	320	4.69	8.56	4.8-15.2	9.84	1.8-37.6	3150.20	2.14
Marcusenius senegalensis	2985	43.74	11.28	6.0-23.6	18.15	3.9-220.1	54370.20	36.92
Mormyrops anguilloides	64	0.94	17.88	7.7-44.7	69.60	5.0-859	4454.59	3.02
Mormyrus hasselquisti	9	0.13	17.68	8.7-21.1	69.84	6.9-112.7	628.60	0.43
Mormyrus macrophthalmus	1015	14.87	10.75	5.6-22.8	12.97	2.4-129.7	13169.00	8.94
Mormyrus rume	583	8.54	17.83	10.0-42.1	63.43	6.7-611	36979.60	25.11
Petrocephalus bovei	765	11.21	6.45	4.7-12.5	4.94	1.4-22.2	3781.20	2.57
Pollimyrus isidori	154	2.26	5.46	3.8-7.9	2.80	1.0-6.0	431.20	0.29
	6825	100					147265.91	100

Shannon-Weaver indices

Table 3 showed the matrix of Shannon-Weaver index of species diversity (H') by sampling sites, habitats type, fishing gears and seasons. Overall, in the Niger River, the Shannon-Weaver index of species diversity computed for the mormyrid assemblages reached H'=2.48. Aquatic vegetation habitat exhibited the highest species diversity with H'=2.91 whereas the "whedo", a traditional fishpond built at the edge of the river was less diverse with H' = 1.49. With regards to sites, H' ranged between 1.12 (Benin-Niger Bridge) and 2.54 (Money). Among fishing gears, fish assemblages from gill net were more diverse and showed the highest H'=2.62. Seasonally, the wet periods displayed the highest mormyrid diversity with H'=2.50. The Shannon-Weaver evenness index (J) for the mormyrid sub-community was E=0.72 and ranged between E=0.56 (Benin-Niger Bridge) and E=0.93 (Sota stream) (Table 3).

Table 3: Diversity indices by sites, habitat types, fishings gears and seasons in Niger River at Malanville (North Benin)

		Species richness (d)	Shannon-Weaver index H'	Evenness J
Sampling sites	Sota Stream	5	2.15	0.93
	Gaya	11	2.33	0.67
	Money	10	2.54	0.77
	Benin-Niger Bridge	4	1.12	0.56
	Tounga	10	2.31	0.69
Habitat types	Open water	11	2.34	0.68
	Aquatic vegetation	10	2.91	0.87
	Whedo	4	1.49	0.75
Fishing gears	Gill net	11	2.62	0.76
	Cast net	11	2.3	0.66
	Seine	7	2.29	0.81
Seasons	Wet	10	2.5	0.75
	Dry	11	2.3	0.7
	Flood	10	2.26	0.68
Total (Fish community)		11	2.34	0.72

Spatial distribution of Mormyrids

In general, the percentage occurrence (PO) of Mormyrids in the five (5) selected sites ranged between 40 and 100%. Two species, *Marcusenius senegalensis* and *Hyperopisus bebe* with PO= 100% consistently occurred in the 5 sites. Other fishes of large distribution were *Mormyrus macrophthalmus*, *Petrocephalus bovei*, *Mormyrus rume*, *Pollimyrus isidori* and *Brienomyrus niger*, all with PO reaching 80%. Momyrids with restraint distribution and recorded in only two (2) sampling sites (PO = 40%), were *Mormyrus hasselquisti* and *Campylomormyrus tamandua*. Also, the Correspondance Analysis (CA) performed on the Mormyrid assemblages indicated that the two first axis explained 76.27 % of the total inertia with AxisI = 47.82% and AxisII = 28.45% (Figure 2). The resulting Hierarchical Clustering Analysis showed that the eleven (11) Mormyrid species inentoried were categorized and distributed in four (4) groups or clusters that comprised 4, 2, 2 and 3 species respectively (Table 4 & Figure 3).

Table 4: Mormyrid Fish repartition by clusters

Cluster: 1	Cluster: 2	Cluster: 3	Cluster: 4
C. tamadua *M.hasselquisti*	*M.anguilloides* *H.pssittacus* *M. rume* *M. macrophtalmus*	*M.senegalensis* *H.bebe*	*B.niger* *P.bovei* *P. isidori*

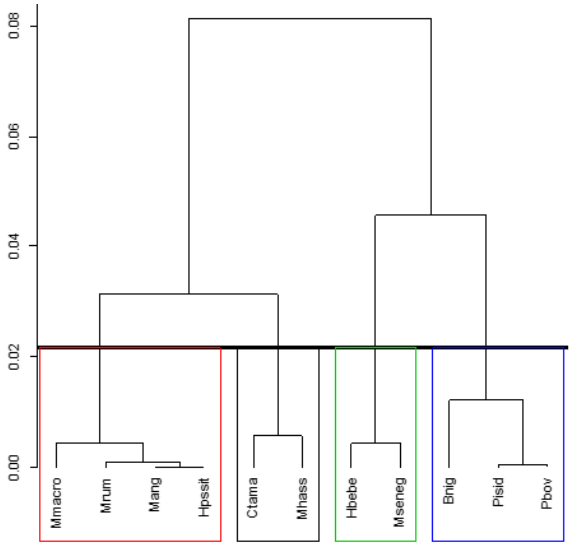

Figure 3: Hierarchical Clustering based on the abundance of the 11 Mormyrids from Niger River in Northern Benin. Bnig=Brienomyrus niger, Ctama=Campylomormyrus tamadua; Mhass=Mormyrus hasselquisti, Mmacro=Mormyrus macrophtalmus; Mang=Mormyrus anguilloides; Hpssit=Hippopotamyrus pssittacus; Mrum=Mormyrus rume; Mseneg=Marcusenius senegalensis; Hbebe=Hyperopisus bebe; Pisid=Pollimyrus isidori; Pbov=Petrocephalus bovei.

Environmental relationships

Table 5 showed the matrix of correlation coefficients (*r*) generated by the regressions between the water physicochemical parameters (depth, transparency, dissolved oxygen, % of saturation, water temperature, pH) and the Mormyrid community attributes mainly, fish abundances and species richness. Overall, (*r*) ranged between -0.26 and 0.73 in the regressions between fish numerical abundances and water parameters. Likewise, the regression between the species richness and the water characteristics follow the same trends with a matrix of correlation coefficients (*r*) varying from -0.44 to 0.37. In addition, the output from the Canonical Correspondance Analysis (CCA) performed on the eleven (11) Mormyrid abundances and the six (6) water parameters indicated that the first two axes (Axis1; Axis2) explained together 70.5% of the observed correlations between Mormyrid abundance and physicochemical parameters with Axis 1 making 50.9% and Axis 2, 19.6%. Associated correlation coefficients were respectively r_1 =0.83 and r_2 =0.78, significant at P<0.05. Also, the CCA output revealed the existence of three groups of species (Figure 4).

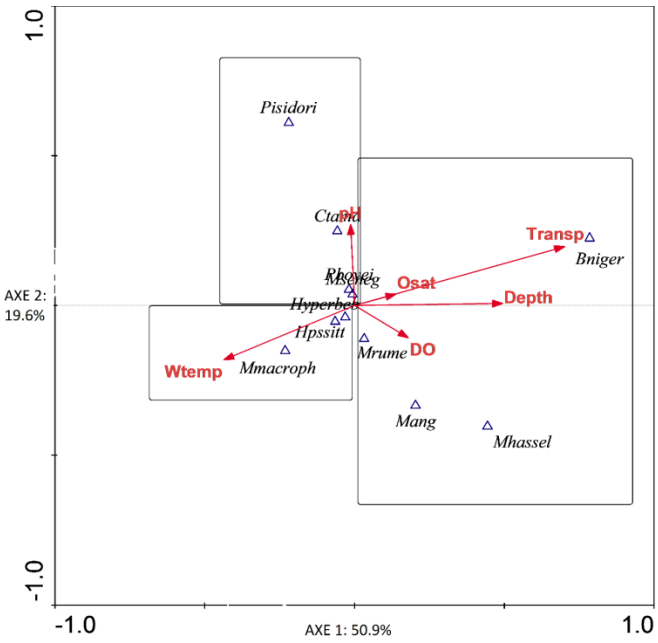

Figure 4*:* Result of Canonical Correspondence analysis (CCA) showing relationship between environnemental variables and Mormyrids species of Niger River. *Environnemental variables: DO= dissolved oxygen, Trans= transparence, Depth= warer depth, pH= Hydrogen potential; Wtemp= water temperature; Osat= oxygen saturation (%). Bnig= Brienomyrus niger, Ctama= Campylomormyrus tamadua; Mhass= Mormyrus hasselquisti, Mmacro=Mormyrus macrophtalmus; Mang= Mormyrus anguilloides; Hpssit= Hippopotamyrus pssittacus; Mrum= Mormyrus rume; Mseneg=Marcusenius senegalensis; Hbebe=Hyperopisus bebe; Pisid= Pollimyrus isidori; Pbov=Petrocephalus bovei.*

Table 5: Matrix of correlation coefficients (r) obtained from the regressions between water parameters and species abundance/species richness of fishes captured in Niger River in Northern Benin. Number of observations N= 18.

Physicochemical Parameters	Numerical Abundance	Species richness
Depth	-0.26	-0.08
Water transparence	0.42	0.36
Dissolved oxygen	**0.70***	0.33
% O_2 of saturation	**0.73****	0.37
water temperature	-0.14	-0.44
pH	0.42	0.34

** Correlations are significant at 0.01 level
* Correlations are significant at 0.05 level

Discussion

The importance of water as resources is not only tied to its availability and quantity, but also to its quality as it supports various aquatic and terrestrial life forms (Ajibade *et al.*, 2008). The quality of water is assessed in general by its physicochemical and biological properties. In the present work, though the water characteristics of the Niger River was globally suitable for fish well-being, some antropogenic disturbances such as domestic uses (ditch cleanings, clothe washings, bathings), invasion of floating plants (*Echhornia crassipes*, *Pistia stratiotes*, *Nymphea sp*), sand dragging, human waste dumpings, irrigation, the use of synthetic fertilizers and pesticides for adjacent agriculture etc. greatly affected the water quality. Indeed, water transparencies were lower at all sampling locations and particularly at Sota stream and Tounga sites where transparencies averaged 17.78±17.79 cm and 18.94±18.34 cm, respectively. Likewise, water temperatures at Money and Sota Stream sites were high and reached 35.6°C and 34.5°C, respectively. Though pHs were alkaline at most sites, at Sota stream under permanent antropogenic disturbances (ditch cleanings, clothe washings, bathing), pHs were acid and averaged 6.61±0.24. The relatively low dissolved oxygen in Sota stream (4.15±1.16 mg/l) and in Benin-Niger Bridge (4.83 ±1.24mg/l) were critical for the optimal growth of some fishes. The proliferation of water hyacinth (*Echornia crassipes*) in these sites, in addition of reducing the primary production, caused the reduction of dissolved oxygen (Liu *et al.*, 2017).

According to Swann (1997), dissolved oxygen is the most important parameter in fish culture and consumption by fish is directly linked to size and feeding rate and should be maintained at a level of about 5 mg/l and more to obtain an optimal growth. Besides, physicochemical parameters are affected by rainfall, evaporation, evapotranspiration, erosion, flood and infiltrations that influence the fish community indices such richness, abundance, diversity, equitability, distribution etc (Adite *et al.*, 2013).

In this study, the 11 elephant species inventoried in this part of the Niger River corresponded to a relatively high Shannon-Weaver diversity index H'= 2.48. In Benin, this Mormyrid richness is similar to that of the Ouémé River that harbored 12 species (Laleye *et al.*, 2004). In contrast, in Southern Benin, the freshwater ecosystems such as the Sô stream, the Mono River and Lake Hlan exhibited lower Mormyrid richness and diversity (Laleye *et al.*, 2004; Montchowui *et al.*, 2008; Hazoume *et al.*, 2017).

Among the eleven (11) Mormyrid fishes inventoried, the six (6) dominant species and numerically more abundant were *Marcusenius senegalensis* (43.74%), *Mormyrus macrophthalmus* (14.87%), *Hyperopisus bebe* (11.43%), *Petrocephalus bovei* (11.21%), *Mormyrus rume* (8.54%) and *Hippopotamyrus pssittacus* (4.69%) that aggregated about 94.49% of the Mormyrid sub-community. Indeed, except *Hippopotamyrus pssittacus*, these species were largely distributed in the river and recorded in all type of habitats and sampling sites and thus, exhibited high occurrences of 100%, 100%, 80%, 80% and 80%, respectively. In particular, the high prominence of *Marcusenius senegalensis* was the result of its high niche breadth because consume a large range of foods including phytoplankton, invertebrates, detritus etc. In addition, this dominant mormyrid showed a relatively high fecundity (F=11,000) (Adjibade *et al.*, 2019) and tolerated polluted sites. All these biological traits may have favored the high colonization of *Marcusenius senegalensis* in the Niger River. As reported by Lemoalle (2006), fish species can be maintained in a hydrosystem when he finds suitable conditions that allow him to grow up and to reproduce. Though always present in their fish assemblages, Koba (2005) reported lower abundances of *Marcusenius senegalensis*, *Mormyrus macrophthalmus*, *Hyperopisus bebe*, *Petrocephalus bovei*, *Mormyrus rume* probably because of the difference in sampling strategy and periods. Indeed, the present study encompassed 18 months of intense fish samplings whereas fish collections by Koba during year 2004 last only four (4) months (January-April). In the Okpara Stream (Ouémé River) of Northern Benin, Sidi Imorou and Adite (in press) reported nine (9) species of Mormyridae, and like our findings in the Niger River, *Marcusenius senegalensis* was the most dominant species accounting for 84.32% of the Mormyrid sub-community. In Lake Hlan of Southern Benin, Montchowui *et al.* (2008) recorded four (4) species of Mormyrids, *Hyperopisus bebe*, *Mormyrus rume*, *Marcusenius senegalensis* and *Brienomyrus niger*, but in contrast with the current survey from the Niger River, *Hyperopisus bebe* was the most dominant species. The level of environmental degradation, the type of life history strategy, the niche breadth and the degree of trophic plasticity coupled with the capability of the species to adapt to changes could act to cause differential abundances of the Mormyrid fishes.

In contrast with the six dominant Mormyrids, almost all the five (5) remaining species, *Mormyrus hasselquisti*, *Campylomormyrus tamandua*, *Petrocephalus bovei*, *Pollimyrus isidori* and *Mormyrops anguilloides* showed reduced distribution, accounted together for only 5.51% and none of them made more than 2.26% of the Mormyrid sub-cmmunity probably because of the

high habitat disturbance and low tolerance to critical environmental factors. In contrast with the other genera that were constituted of only one species, the genus *Mormyrus* was most speciose and comprised three (3) species, *Mormyrus hasselquisti*, *Mormyrus rume* and *Mormyrus macrophthalmus*. Also, in the mormyrid assemblages, species such as *Mormyrus hasselquisti*, *Mormyrops anguilloides* and *Campylomormyrus tamandua* were of trivial abundances and made 0.13%, 0.16% and 0.94%, respectively (Table 2). Though numerically weak, the biomass of *Mormyrus rume* was high and reached 25.11% because of its large size and come after the dominant species *Marcusenius senegalensis* that represented 37% of the total Mormyrid biomass.

Because less degraded, sites Gaya, Money and Tounga showed a relatively high Mormyrid richness, d=11, d=10, d=10 respectively, and computed Shannon-weaver indexes were relatively high and reached H'=2.33, H'=2.54 and H'=2.31, respectively. Inversely, the degraded sites, Sota stream and Benin-Niger Bridge, exhibited low species richness d=5 and d=4, respectively, and weak Shannon-weaver indexes H'=2.15 and H'=1.12, respectively. In general, degradation factors in the Niger River at Malanville included the withdrawal of river water for irrigation, the use of chemical fertilizers and pesticides around the rivers for the production of rice, peper, water melon, onion etc., the dumping of domestic wastes, clothe washings, ditches, the proliferation of floating vegetation and the use of detrimental fishing gears. The high Shannon-Weaver species diversity (H'=2.91) recorded in aquatic vegetation is the result of the high food availability in this habitat that harbored a relatively high diversity. Also, the aquatic vegetation habitat is a potential spawning ground where many species migrate to reproduce. With regard to season, because the wet period is the potential reproduction period, the Shannon-Weaver index (H'=2.50) was higher compared to flood and dry seasons. In this study, the species evenness (J) computed were relatively high (0.66-0.87) showing that Mormyrid fishes in the Niger River were well distributed even though *Marcusenius senegalensis* was largely predominant. As reported by Barbault (2000), a well organized fish assemblage is shown by their evenness (J) close to 1.

With regards to environmental correlates, the positive correlation (r= 0.70) between dissolved oxygen and fish abundances indicated that in the Niger River the aggregated Mormyrid abundances significantly (P < 0.01) increased with dissolved oxygen. The same trend was observed for the correlation between dissolved oxygen and species richness with r = 0.33, but not significant ($P \geq 0.05$). As reported by Swann (1997) and Jackson (2012), dissolved oxygen is one of the formost water factor that influences the productivity of aquatic ecosystems, fish survival and growth. Though not significant ($P \geq 0.05$), the water transparency and pH were positively correlated with fish abundances and species richness. The insignificant ($P \geq 0.05$) negative correlations between depth and Mormyrid abundance (r= -0.26) and between depth and species richness (r= -0.08) were due to the fact that depths were always moderately high regardless of space and season. In response to the relatively high depth, mean water temperatures showed less variations (29.05-29.60°C) between sites, thus generating insignificant ($P \geq 0.05$) negative correlations between temperature and fish abundance (r= -0.14) and between temperature and species richness (r= -0.44). When considering the abundance of each Mormyrid, the output of the Canonical Correspondance Analysis (CCA) performed on the abundance of the eleven (11) Mormyrid and the six (6) water parameters, three clusters of species were recorded (Figure 4). The first cluster comprised *Brienomyrus niger*, *Mormyrops anguilloides*, *Mormyrus hasselquisti* and *Mormyrus rume* which abundance increased with water depth, transparency, dissolved oxygen and O_2 saturation percentage but decreased with water temperature and pH. The second cluster included *Brienomyrus niger*, *Campylomormyrus tamadua*, *Petrocephalus bovei*, *Pollimyrus isidori* and *Marcusenius senegalensis* that were positively correlated with pH, but negatively correlated with water temperature and dissolved oxygen. The third group, *Petrocephalus bovei*, *Hippopotamyrus pssittacus*, *Mormyrus rume*, *Hyperopisus bebe*, and *Mormyrus macrophtalmus* was positively correlated with water temperature but negatively correlated with depth, transparency, dissolved oxygen and O_2 saturation percentage. As reported by Sidi and Adite (2019), the differential tolerance of each Mormyrid to physicochemical parameters greatly accounted for the species guilds recorded. The conservation, valorization and the substainable exploitation of the Mormyrids from the Niger River require a holistic management scheme that must be implemented in collaboration with local populations and grassroots.

Conclusion

The current ichtyological study on the Niger River provides valuable information and database on Mormyrids richness, abundance, diversity, distribution patterns and their habitat conditions. The survey revealed eleven (11) mormyrids species numerically dominated by *Marcusenius senegalensis*, *Mormyrus macrophthalmus*, *Hyperopisus bebe*, *Petrocephalus bovei*, *Mormyrus rume* and *Hippopotamyrus pssittacus*. Major anthropogenic disturbances that degraded the fish resources and habitats were the use of synthetic fertilizers and

pesticides for adjacent agriculture, the proliferation of invasive floating vegetation such as water hyacinth, the dumping of garbages and domestic wastes and the introduction of invasive fish such as *Oreochromis niloticus*. Species conservation, valorization and sustainable exploitation require habitat restauration and protection and ecosystem follow-up.

Conflit of Interest

There is no conflit of interest.

Aknowledgements

We thank the Government of Benin Republic for providing us a grant through the program « Appui aux Doctorants ». The authors are also grateful to the « Laboratoire d'Ecologie et de Management des Ecosystèmes Aquatiques (LEMEA) », University of Abomey-Calavi for its logistic assistance. I thanks Mama Razack and all the the fishermen for their assistance in fish collection. We sincerely thank the numerous reviewers for their thorough peer-review of this manuscript.

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