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Community structure of Mochokidae (Jordan, 1923) fishes from Niger River at Northern Benin: implications for conservation and sustainable exploitation

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Abstract

In Niger River in Benin, Mochokid fishes constitute valuable fishery resources of high commercial and economic importance. An ichtyological survey targeted to Mochokidae family was conducted in Niger River to document the community structure of these taxa in order to contribute to species management and sustainable exploitation. Fish individuals were sampled every month from February 2015 to July 2016 from artisanal fisheries and experimental catches using gillnets, cast nets, seines and longlines. The results indicated that the Niger River in Benin was rich of fourteen (14) species belonging to one (1) genus, *Synodontis*. Numerically, three (3) species, *Synodontis schall* (74.50%), *Synodontis membranaceus* (16.79%) and *Synodontis nigrita* (2.24%) were the most abundant. Likewise, three (3) Mochokidae, *Synodontis schall*, *Synodontis membranaceus* and *Synodontis clarias* showed a wide distribution and consistently occurred in all sampling sites. Seasonaly, the flooding period was the most diverse season showing the highest Shannon-Weaver index of species diversity H' =1.65. Though under many degradation factors, the water quality of the Niger River was globally favorable for primary production and for the survival and growth of fishes. Overall, cumulated Mochokidae abundances significantly (P<0.05) increased with dissolved oxygen concentration. The multitude threats depicted were overfishing, dumping of domestic wastes, invasion of floating plants, introduction of exotic fish species, and the use of chemicals fertilizers/pesticides for adjacent agriculture require a community-based approach of ecosystem management that should include habitat protection, species conservation and valorization in order to guaranty the sustainable exploitation of the Mochokidae fishes in the Niger River.

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Introduction

The Mochokidae (Pisces: Teleostei: Siluriformes) family is the most morphologically diverse and largely distributed catfishes in Africa and comprises 11 genera with about 223 species (http://www.fishbase.org) (Froese and Pauly, 2018). The top five genera were *Synodontis,* the most speciose genus comprising 155 species, *Microsynodontis* with 13 species, *Hemisynodontis* with 1 species, *Mochokiella* with 1 species and *Brachysynodontis* with 1 species. Also called upside-down catfishes because most of them swim upside-down, the Mochokidae originated from Africa where they inhabit only freshwater mediums and constitute an important component of artisanal fisheries. In addition, because of their colorful body, most Mochokidae are utilized as ornemental fishes. Indeed, about 104 species (46%) are being kept by registered keepers for aquarium (Brummett and Teugels, 2004).

According to Skelton (1993), two (2) genera, the squeakers (*Synodontis*) and the suckermouth catlets (*Chiloglanis*) aggregating about 17 species were known for Southern Africa. The genus *Synodontis* comprises species that are moderately large and inhabiting habitats with slow-flowing vegetated waters whereas *Chiloglanis* are small fishes found in fast current water habitats (Skelton, 1993). In Western Africa, five (5) genera of Mochokidae, *Chiloglanis*, *Mochokus*, *Microsynodontis*, *Mochokiella*, and *Synodontis* aggregating about 48 species were recorded, with *Synodontis* the most speciose genus comprising 36 species (Paugy and Roberts, 2004). As reported by Paugy and Levêque (2004), the Niger River alone harbored about thirty-three (33) Mochokid species belonging to three (3) genera, *Mochokus*, *Chiloglani*s and *Synodontis*, the dominant genus comprising 28 species.

As common characteristics, the Mochokidae species possessed a naked body without scales, and nasal barbels are absent. They show three pairs of barbels constituted of a pair of maxillary barbels and two pairs of mandibular barbells (Paugy, 2003 and Fermon, 2007). In some genera such *Atopochilus, Chiloglanis*, and *Euchilichthys*, the mandibular barbels are absent and the lips are then modified in an adhesive disk, a suckermouth (Paugy, 2003). The adipose fin is sometimes rayed and usually very long. The first ray of the pectoral fin is spiny and denticulated. The dorsal fin is rayed and shows a spine at the anterior part. These spines are usually strong and possess a locking mechanism (www.revolvy.com/topic/Mochokidae).

In Benin, the Mochokidae species are widely distributed in rivers and streams such as Mono, Oueme, Sô, Hlan, Zou, Niger and at a lower level in brackish waters (Lake Nokoue, Porto-Novo Lagoon, Lake Aheme etc.) where they constitute valuable fishery resources of high commercial and economic importances (Arame *et al.,* 2019). In Southern Benin, annual total catches of Mochokidae reached 600 metric tons that approximately correspond to 2.17% of the country total fish production. In the Niger River in Benin in particular, Mochokidae accounted for about 10.80% of the artisanal catches Koba (2005), and thus, represented one of the most abundant family in Niger River fish community and in the fish market at Malanville town.

Despite the high fisheries and commercial importance of the Mochokidae in Niger River, the diversity and community structure are unknown and not investigated. Meanwhile, the river is under severe degradation pressures that could jeopardize the quality and the fish biodiversity of this running water. Major degradation factors included proliferations of invasive floating vegetations, dumpings of domestic wastes, overfishing, introduction of invasive exotic fishes, uses of chemical fertilizers and pesticides for agriculture etc. Consequently, knowledge on the fish community structure is important to assess the status of the fish biodiversity in order to contribute to document an ecosystem restoration scheme targeted to habitat protection, species conservation and valorization.

This ichtyofaunal research in Niger River in Benin aimed to document the Mochokidae fishes and its structure in order to better manage the species. Specific objectives of this study were 1) to inventory the dwelling Mochokidae species and and evaluate the

community structure, 2) to assess the relationships between physicochemical factors and the Mochokidae community indices and 3) to recommend actions for ecosystem restoration in order to assure the sustainable exploitation of the fishes.

Materials and methods

Study area

The study was carried out on the Niger River in Northern Benin around Malanville town. Malanville municipality extended on 3.016km² with an average altitude of 200 m. This town is situated between 11°52'05″ North latitude and 3°22′59″ East longitude. Malanville is limited to the North by Niger Republic, a neighbor country, on the South by the municipality of Kandi and Ségbana, on the West by the municipality of Karimama, and on the East by the Federal Republic of Nigeria, also a neighbor country. The study area shows a Sudano-Sahelian climate characterized by a dry season from November to April and a rainy season from May to October along with Harmattan, a dominant wind that blows in all directions from November to January and displaying temperatures varying between 16 and 25°C. Every year, the Niger River, with its three tributaries in Benin, Mekrou, Sota and Alibori cause severe inundations on about 275km² at peak flood (Welcomme, 1985). These periodic floodings created a vast wetland extending on about 300 ha at the border of the two countries, Niger and Benin. This wetland stands as an important reproduction and nursery grounds for the fish fauna (Moritz *et al.*, 2006; Adite *et al.,* 2017).

In general, Malanville region displayed gneissic and gravelly soils with raw minerals for most part of the territory (Arame *et al.,* 2019). Inversely, the Niger River valley and its tributaries showed sandy-clayish and ferruginous soils. During the rainy season, muddy, alluvial and sandy loamy soils were sometimes found on the high terraces that were covered with a grassy savanna dominated by trees. The region comprised a hunting area that extended from Djona to Torozougou village, and some protected forests. Aquatic vegetation included *Typha domingensis, Ludwigia spp, Echinochloa colona, Marsilea sp, Ipomoea aquatic, Echhornia crassipes, Pistia stratiotes*, and *Nymphaea spp* (Hauber, 2011). Multi-species artisanal fisheries involving many ethnic groups occurred on the Niger River in Benin with Mochokidae, one of the foremost taxa exploited and commercialized in the fish market of Manlanville (Adjibade *et al.*, 2019).

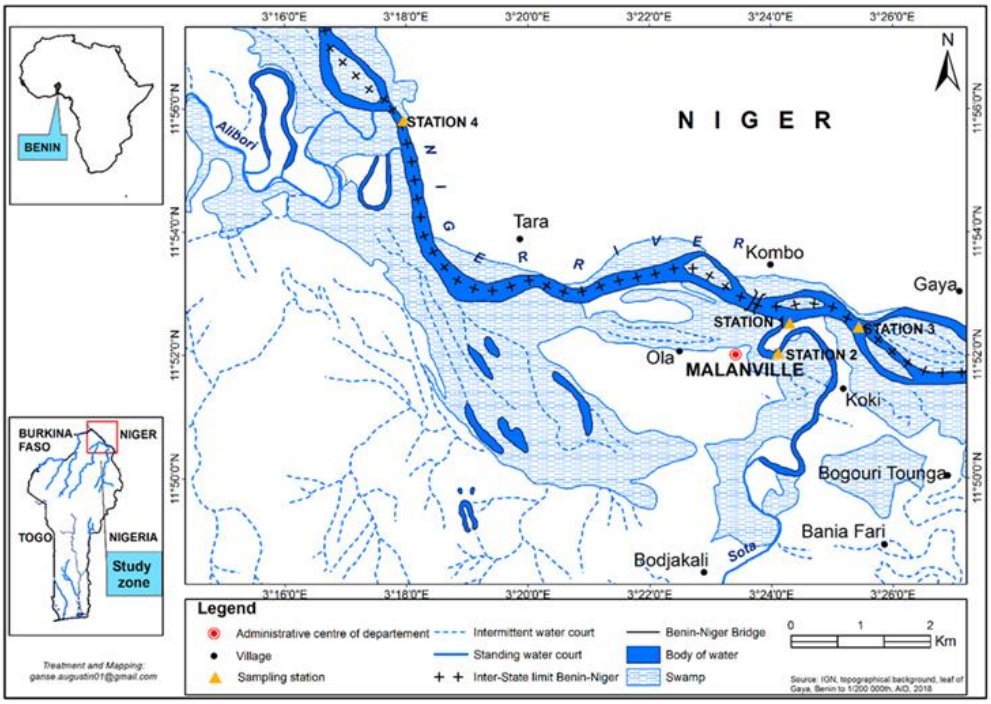

Fig. 1. Study region and sampling stations**:** Station 1= Tounga village, Station 2= Behind dry port, Station 3= Gaya village and Station 4= Money village.

Sampling sites

Overall, four (4) sampling sites were considered for the collection of the Mochokidae fishes. These were (1) Tounga village located at 11°52'216"N, 3°23'907"E and highly degraded where occurred moderate fishing activities, (2) Behind Dry Port also degraded and located at 11°52'216"N, 3°23'907"E, (3) Money village, less degraded and situated at 11°52'987"N, 3°20'819"E and (4) Gaya village, the only site from Niger country, also less degraded and located at 11°52'675"N, 3°25'329"E. Sites (3) and (4) were relatively deeper with intense fishing activities.

Mochokidae sampling and identification

Fish collections were performed once a month for 18 months (February 2015- July 2016) at the four selected sites. Samplings were done in adjacent aquatic vegetation and in open water habitats. Experimental captures were performed using laboratory seine (6.15m × 2m, 16mm-mesh), cast nets (6m-diameter, 20mm-mesh), gillnets (50m × 1m, 40mm-mesh; 50 × 1m, 30mm-mesh; 50m × 1m, 20mm-mesh), experimental gillnet (3000m × 500m, 1m² -mesh) and traps. Eight (8) to ten (10) seine hauls on about 10 meters were made at each sampling site (Adite *et al.,* 2017). Experimental gillnet and traps were set for 12 hours. Also, to approach the diversity of the whole Mochokids, samplings were made from fishermen that used many types of fishing techniques and fishing gears such as cast nets, gillnets, longlines and ‘‘acadja”. Mochokid samplings from fisherman captures were made on the basis of one third of species abundance when this latter exceeded 50 individuals. In case the abundance is less than 50 for a given species, all individuals of this species were considered for the sample (Kakpo, 2011; Okpeicha, 2011). After sampling, the Mochokid fishes were identified in situ using identification keys and guides such as Van Thielen *et al.* (1987), Levêque *et al.* (1990; 1992), Paugy *et al.* (2003a,b), Levêque and Pauly (2004), Levêque and Paugy (2006). The fish assemblages were then preserved in 10% formalin and shipped to the Laboratory of Ecology and Management of Aquatic Ecosystems (LEMEA) of the Faculty of Sciences and Technics, University of Abomey-Calavi. Fish individuals were then removed from the formalin and transferred in to 70% ethanol to facilitate future biological observations. Species names were confirmed using http://www.fishbase.org (Froese and Pauly, 2018). After identification, lengths (total length, standard length) of each individual were measured to the nearest 0.1cm using an ichthyometer and the individual weight (W) was measured to the nearest 0.01g using an electronic scale (CAMRY 0.1g/ 500g; AWS) (Arame *at al.,* 2019).

Data analysis

Physicochemical parameters such depth, transparency, temperature, pH, dissolved oxygen concentration, percentage of dissolved oxygen saturation and conductivity were measured to evaluate the quality of the Niger River water. The morphometric (total length, standard length, weight) data of Mochokid fishes were recorded in Excell spreadsheet 2017 and SPSS (Morgan *et al.,* 2001) spreadsheets. Mean values and ranges of physicochemical parameters along with standard deviations (±SD) were computed by sampling site using SPSS (Morgan *et al.,* 2001) software in order to evaluate the variability between stations (Table 1). The fish community structure indexes such as species richness, relative abundances, species diversity, and heterogeneity index were calculated using SPSS (Morgan *et al.*, 2001) software. The species richness (*d*) was computed using Margalef (1968) index of species richness (d):

$$d = S - \frac{1}{\ln N}$$

Where S is the number of species, N is the number of individuals in the sample.

The Mochokidae diversity was computed using Shannon and Weaver (1963) diversity index (H’):

$$H' = -\sum_{i=1}^{n} [Pi * \log_2(pi)]$$

where *H*’ is the index of species diversity, *pi* = *ni*/*N,* the proportion of total sample belonging to *i* species, *ni* the number of individuals of each species in the sample, *N* the total number of individuals in the sample.

The evenness measure (J) of Shannon & Weaver (Shannon and Weaver, 1963) was calculated following the formula:

$$J=\frac{H'}{Log_2 S}$$

Where (J) is the evenness measure, H' is the Shannon & Weaver index of diversity, S is the number of species in the sample. Also, the Simpson index of diversity was calculated using the following formula:

$$Ds=\sum \mathbf{Ni(Ni-1)}\Big/\mathbf{N(N-1)}$$

Where Ds is the Simpson index, Ni is the number of individuals of each species and N is the total number of individuals. The Simpson index varies from 0 to 1. Ds=0 indicates the maximum diversity, and a value of 1 indicates the minimum diversity. The Berger-Parker (1970) index of dominance was computed using the following formula:

$$d=N_{max}/N$$

Where N_{max} is the number of individuals in the most abundant species, N is the total number of individuals.

In order to determine the different assemblages and the spatial distribution of Mochokidae fishes, the Factorial Correspondence Analysis and the Hierarchical Clustering Analysis (Dendrogram) were performed using the FactoMineR package statistical analysis software, version R 3.2.4 (Husson *et al.,* 2016). The relationships between relative abundances of dominant species and water physicochemical parameters were assessed through spearman correlation coefficients using SPSS 21 (Morgan *et al.,* 2001) and the Canonical Correspondence Analysis of (CCA) using CANOCO software, version 4.5 (ter Braak and Smilauer, 1998).

Results

Water quality

Means and ranges of physicochemical parameters of the Niger River in Benin are shown in Table 1. Water depths ranged between 110 and 960cm (mean: 415.94±241.28) and water transparencies ranged from 0 to 60cm (mean: 34.50 ± 27.80). Water temperatures varied from 21 to 34.2°C and averaged 30.13±3.17°C. Dissolved oxygen ranged between 2.60 and 9.36 mg/l (mean: 6.92±1.32) with percentages of saturation varying between 35.1 and 131.7% (mean: 94.13±17.5). pHs averaged 7.49±0.52 and varied between 6.20-8.90. In general, the water quality of the river was suitable for primary production and for the survival and growth of fishes.

Table 1. Means (±SD) and ranges of physicochemical parameters measured in Niger River in Northern Benin from February 2015 to July 2016.

Parameters	Gaya		Money		Tounga		Behind dry port	
	Mean ±SD	Interval	Mean ±SD	Interval	Mean ±SD	Interval	Mean ±SD	Interval
Ambient temperature (°C)	32.46±4.03	25.8-43.6	32.62±3.76	27.2-42.3	29.69±5.48	20.1-35.8	28.08±5.29	20.1-34.8
Water temperature (°C)	29.79±3.47	21.0-33.3	30.02±2.71	23.0-34.2	28.86±4.08	22.4-33.5	28.38±4.37	22.8-34.2
Depth (cm)	427.06±230.4	187-960	311.83±144.68	130-800	183.06±24.8	120-230	183.61±26.57	110-230
Transparency (cm)	32.11±25.02	0 – 73	34.50±27.80	0-75	34.33±28.66	0-62	33.33±27.36	0-60
Dissolved O_2 (mg/l)	7.09±1.61	4.28-9.22	6.99±1.63	4.68-9.36	6.32±1.66	2.40-8.80	6.49±1.63	2.60-8.90
% O_2	91.87±23.86	47.8-131.7	94.13±22.23	49.3-31.4	87.73±18.83	35.1-116.1	89.60±19.05	36.8-115
pH	7.20±0.70	6.40-8.80	7.52±0.60	6.60-8.70	7.07±0.52	6.30 - 8.20	7.17±0.63	6.20-8.90

Fish composition and abundances

From February 2015 to July 2016 (18 months), a total of 4240 individuals of Mochokidae were sampled in the Niger River in Benin at Malanville Township. Among them, fourteen (14) species belonging all to one (1) genus, *Synodontis*, were inventoried. Numerically, three (3) species, *Synodontis schall* (74.50%), *Synodontis membranaceus*, (16.79%) and *Synodontis nigrita* (2.24%) were the most abundant species. Species such as *Synodontis frontosus*, *Synodontis courteti*, *Synodontis*

nigrita b, *Synodontis macrophthalmus* and *Synodontis ocellifer* were uncommon with trivial abundance varying between 3-15 individuals (relative abundance: 0.07-0.35%) during the 18 months of collection (Fig. 2). In term of biomass, the two (2) species, *Synodontis schall* and *Synodontis membranaceus* dominated the Mochokid sub-community and made 68.24% and 20.43%, respectively, with cumulative weight percentages reaching 88.67% of the fish assemblages (Fig. 3).

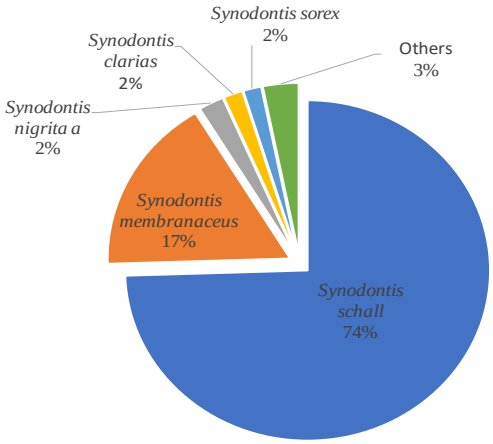

Fig. 2. Numerical abundances of Mochokid fishes captured in Niger River (Northern Benin) from February 2015 to July 2016.

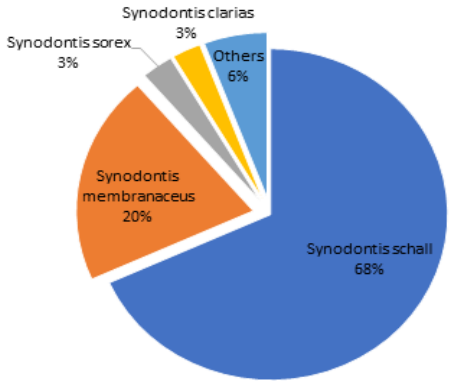

Fig. 3. Weight Abundance of Mochokid fishes captured in Niger River (Northern Benin) from February 2015 to July 2016.

Diversity indices

In the Niger River in Benin, the Shannon-Weaver index of species diversity (H') computed for the Mochokidae sub-community was moderate and reached H'=1.31. Spatially, the highest Shannon-Weaver index (H'=1.42) was recorded in Gaya site whereas the lowest (H'=1.01) was recorded in Tounga site. With regards to habitats, the open water showed the highest species diversity H'=1.34 whereas the aquatic vegetation habitat exhibited the lowest Shannon-Weaver species diversity H'=0.87. Though the species diversity was higher in "whedo" (traditional fishpond built at the edge of the river) with H'=1.36, only three (3) species, *S. schall*, *S. membranaceus and S. clarias* were recorded in this traditional farming system. Seasonal records indicated that the flooding showed the highest Shannon-Weaver species diversity H' =1.65 with lower species richness (7 species) whereas the dry season, with 14 species, had the lowest diversity index (H'=1.27). Fishing gears such as castnets and seines exhibited higher diversity H'=1.28 and H'=1.36, respectively, with cast net, less selective, showing the highest species richness d=13. The index of equitbility (*J*), computed for the Mochokid sub-community was *J*=0.95, and varied between *J*=0.45 for "Behind Dry Port" site and *J*=0.90 for Tounga site (Table 2). Also, the Simpson1-D index and the Berger-Parker index followed approximately identical trends as the Shannon-Weaver diversity index (Table 2).

Size of fishes

In the current ichthyological survey, the standard lengths (SL) of the Mochokid assemblages ranged between 4.5cm (*Synodontis schall*) and 25cm (*Synodontis membranaceus*). Mean standard length varying from 7.89cm (*Synodontis nigrita* a) to 15.80cm (*Synodontis budjetti*), and mean weight ranged between 17.99g for *Synodontis nigrita a* to 110.15g for *Synodontis budjetti*. Large species collected were *Synodontis membranaceus* reaching a maximum standard length SLm= 25cm with a maximum weight Wm= 451.3g, *Synodontis budjetti* with SLm= 21.0cm and Wm= 237.6g, *Synodontis courteti* with SLm= 21.0cm and Wm= 221.3g, *Synodontis sorex* SLm= 20cm and Wm= 176.5g, *Synodontis schall* with SLm= 20cm and Wm= 237.5g, *Synodontis clarias* with SLm= 19.5g and Wm= 178.3g and *Synodontis melanopterus* with SLm= 18.5cm and Wm= 108g (Table 3). Moderate sized-Mochokid collected were *Synodontis violaceus* with SLm= 17.5cm and Wm= 142.6g, *Synodontis macrophthalmus* with SLm= 15.0cm and Wm= 105.3g. Small-sized Mochokid sampled were *Synodontis nigrita* a, *Synodontis nigrita* b, *Synodontis frontosus*, *Synodontis filamentosus* and *Synodontis ocellifer* (Table 3).

Table 2. Diversity indexes of Mochokidae fishes collected between February 2015 and July 2016 in Niger River in Northern Benin.

Collection factors		Species richness (d)	Shannon-weaver diversity index (H')	Simpson 1-D diversity index	Berger-Parker diversity index	Evenness (J)
Sampling stations	Gaya	11	1.42	0.55	0.53	0.83
	Money	12	1.01	0.28	0.84	0.89
	Tounga	12	1.25	0.33	0.82	0.90
	Behind dry port	3	1.04	0.47	0.64	0.48
Fishing gears	Gillnet	9	1.18	0.37	0.78	0.77
	Cast net	13	1.28	0.43	0.73	0.92
	Experimental gill net	4	1.14	0.46	0.67	0.53
	Seine of the laboratory	4	1.36	0.54	0.58	0.55
	Longline	10	1.16	0.31	0.83	0.84
Seasons	Wet	11	0.96	0.27	0.84	0.87
	Flood	7	1.65	0.62	0.44	0.72
	Dry	14	1.27	0.40	0.76	0,93
Habitats	Open water	14	1.34	0.43	0.73	0.95
	Aquatic vegetation	8	0.87	0.25	0.86	0.73
	"Whedo"	3	1.36	0.58	0.48	0.50
River		14	1.31	0.41	0.74	0.95

Table 3. Abundances, standard length (SL) and weight of Mochokidae fishes captured in Niger River in Northern Benin from February 2015 to July 2016.

Species	Abundance	Relative Abundance (%)	SL mean (cm)	SL range (cm)	Weight mean (g)	Weight range (g)	Total weight (g)	% Weight
Synodontis membranaceus	712	16.79	10.24	5.0-25	36.09	4.5-451.3	25 695.02	20.43
Synodontis schall	3159	74.50	9.61	4.5-20	27.49	3.4-237.5	85 836.86	68.24
Synodontis clarias	72	1.70	11.73	8.5-19.5	45.90	15.3-178.3	3 305.10	2.63
Synodontis filamentosus	23	0.54	9.80	6.5-14	18.87	5.2-48.4	434.00	0.35
Synodontis nigrita a	95	2.24	7.89	6-10.5	17.99	3.2-44.3	1 709.24	1.36
Synodontis nigrita b	6	0.14	8.20	7-9.5	20.15	10.0-27	120.90	0.10
Synodontis melanopterus	30	0.71	11.37	6.0-18.5	42.78	6.5-108	1 283.30	1.02
Synodontis sorex	68	1.60	12.66	7.0-20.0	53.37	7.5-176.5	3 629.10	2.89
Synodontis macrophthalmus	14	0.33	11.68	7.5-15.0	44.97	11.2-105.3	629.60	0.50
Synodontis ocellifer	15	0.35	9.38	7 .5-14.5	22.27	11.2-83.7	334.02	0.27
Synodontis courteti	3	0.07	15.00	12.0-21.0	97.50	41.4-221.3	292.50	0.23
Synodontis frontosus	3	0.07	12.00	10.0-13	52.43	23.3-74.3	157.30	0.13
Synodontis violaceus	30	0.71	11.39	8.0-17.5	42.06	11.1-142.6	1 261.70	1.00
Synodontis budjetti	10	0.24	15.80	10.9 -21	110.15	32.5-237.6	1 101.50	0.88
Total	4240	100					125 790.14	100

Spatial and seasonal distribution

Overall, the percentage occurrence (PO) of Mochokids fishes in the five sites including "Whedo" varied between 20 and 100%. Three (3) Mochokids, *Synodontis schall*, *Synodontis membranaceus* and *Synodontis clarias* with PO = 100% consistently occurred in all sampling sites. Nine (9) species displayed moderate distribution with PO ranging between 40 and 60%. Only two (2) Mochokids, *Synodontis budjetti* and *Synodontis frontosus* of trivial abundances, 3 and 10 individuals, respectively, showed weak distributions and were recorded in only one (1) site (PO = 20%) (Table 9).

When considering the major habitats, the 14 Mochokids inventoried occurred in the open water habitat (Table 4) and numerically made 89.17% of the Mochokid fish assemblages. Inversely, only 8 Mochokids were recorded in the aquatic vegetation habitat and made only 10.83% of the Mochokid sub-community (Table 5). Seasonally, dry and wet seasons were the most diverse periods dwelling 14 and 11 species (Tables 6, 7), with relative abundances reaching 63.01% and 25.21%, respectively. In contrast, only 7 Mochokids (Table 8) were recorded in the flood period with a low relative abundance of 11.78%.

Table 4. Abundances, standard length (SL) and weight of Mochokidae fishes captured in the open water of Niger River (Northern Benin) from February 2015 to July 2016.

Species	Abundance	Relative Abundance (%)	SL mean (cm)	SL range (cm)	Weight mean (g)	Weight range (g)	Total weight (g)	% Weight
Synodontis membranaceus	678	17.93	10.19	5.0-25	35.77	4.5-451.3	24 253.12	22.00
Synodontis schall	2776	73.42	9.55	4.5-20	26.30	3.4-237.5	73 003.10	66.22
Synodontis clarias	68	1.80	11.86	8.5-19.5	47.28	15.3-178.3	3 214.80	2.92
Synodontis filamentosus	23	0.61	9.80	6.5-14	18.87	5.2-48.4	434.00	0.39
Synodontis nigrita a	72	1.90	7.77	4.5-10.5	16.99	3.2-38.1	1 223.10	1.11
Synodontis nigrita b	5	0.13	8.30	7-9.5	20.66	10.0-27	103.30	0.09
Synodontis melanopterus	30	0.79	11.37	6.0-18.5	42.78	6.5-108	1 283.30	1.16
Synodontis sorex	61	1.61	12.71	7.0-20.0	54.85	7.5-176.5	3 345.70	3.03
Synodontis macrophthalmus	8	0.21	10.76	7.5-13.5	31.04	11.2-47.7	248.30	0.23
Synodontis ocellifer	14	0.37	9.51	8.2-14.5	23.06	11.5-83.7	322.80	0.29
Synodontis courteti	3	0.08	15.00	12.0-21.0	97.50	29.8-221.3	292.50	0.27
Synodontis frontosus	3	0.08	12.00	10.0-13	52.43	23.3-74.3	157.30	0.14
Synodontis violaceus	30	0.79	11.39	8.0-17.5	42.06	11.1-142.6	1 261.70	1.14
Synodontis budjetti	10	0.26	15.80	10.9 -21	110.15	32.5-237.6	1 101.50	1.00
Total	3781	100					110 244.52	100

Table 5. Abundances, standard length (SL) and weight of Mochokidae fishes captured in aquatic vegetation of Niger River (Northern Benin) from February 2015 to July 2016.

Species	Abundance	Relative Abundance (%)	SL mean (cm)	SL range (cm)	Weight mean (g)	Weight range (g)	Total weight (g)	% Weight
Synodontis membranaceus	21	4.91	10.27	8.5-12	28.99	16.9-424	608.80	4.21
Synodontis schall	368	85.98	10.18	4.6-20	34.39	3.9-237.5	12 657.04	87.46
Synodontis clarias	1	0.23	11.00	11.0-11.0	26.06	26.06-26.06	26.06	0.18
Synodontis nigrita a	23	5.37	8.25	6.5-10.5	21.14	10.8-44.3	486.14	3.36
Synodontis nigrita b	1	0.23	7.70	7.7-7.7	17.60	17.6-17.6	17.60	0.12
Synodontis sorex	7	1.64	12.29	10.5-14.0	40.49	26.1-59.4	283.40	1.96
Synodontis macrophthalmus	6	1.40	12.90	9.0-15.0	63.55	16.3-105.3	381.30	2.63
Synodontis ocellifer	1	0.23	7.50	7.5-7.5	11.22	11.22-11.22	11.22	0.08
Total	428	100					14 471.56	100

Table 6. Abundances, standard length (SL) and weight of Mochokidae fishes captured in dry season in Niger River (Northern Benin) from February 2015 to July 2016.

Species	Abundance	Relative Abundance (%)	SL mean (cm)	SL range (cm)	Weight mean (g)	Weight range (g)	Total weight (g)	% Weight
Synodontis membranaceus	407	15.23	10.05	6.0-25	30.17	4.8-451.3	52 602.54	9.93
Synodontis schall	2033	76.09	9.13	4.50-18.5	23.00	3.4-184.7	68 954.94	13.01
Synodontis clarias	59	2.21	11.58	8.5-14.5	43.67	15.3-88.80	56 242.64	10.61
Synodontis filamentosus	15	0.56	9.03	6.5-11,0	14.08	5.20-22.60	54 102.34	10.21
Synodontis nigrita a	34	1.27	7.54	4.5-10.5	15.60	3.2-38.1	52 436.74	9.90
Synodontis nigrita b	5	0.19	8.30	7.0-9.5	20.66	10.0-27.0	44 535.04	8.40
Synodontis sorex	59	2.21	12.41	7.0-19.0	50.94	75.1-161.9	50 196.34	9.47
Synodontis macrophthalmus	2	0.07	9.60	9.0-10.2	26.95	20.9-33.0	53.90	0.01
Synodontis ocellifer	8	0.30	9.64	7.5-14.5	26.21	11.2-83.70	53 899.24	10.17
Synodontis melanopterus	25	0.94	11.99	7.9-18.5	47.86	11.6-108.0	20 152.80	3.80
Synodontis violaceus	14	0.52	12.78	8.0-17.5	59.90	11.1-142.6	41 687.64	7.87
Synodontis courteti	3	0.11	15.00	12.0-21,0	97.50	29.8-221.3	34 160.04	6.45
Synodontis frontosus	3	0.11	12.00	10.0-13.0	52.40	23.3-74.3	157.30	0.03
Synodontis budjetti	5	0.19	18.10	13.0-21.0	149.80	49.1-237.6	749.20	0.14
Total	2672	100					529 930.70	100

Table 7. Abundances, standard length (SL) and weight of Mochokidae fishes captured in wet season in Niger River (Northern Benin) from February 2015 to July 2016.

Species	Abundance	Relative Abundance (%)	SL mean (cm)	SL range (cm)	Weight mean (g)	Weight range (g)	Total weight (g)	% weight
Synodontis membranaceus	98	9.17	15.71	6.1-22	102.81	8.7-214.5	10 075.80	5.14
Synodontis schall	904	84.57	10.11	5.5-20.0	30.93	3.9-237.5	40 585.00	20.72
Synodontis clarias	13	1.22	12.39	10.0-19.5	56.10	23.1-178.3	36 230.20	18.50
Synodontis filamentosus	3	0.28	10.33	10.0-11.0	22.13	17.9-30.2	10 706.70	5.47
Synodontis nigrita a	13	1.22	7.09	5.5-9.0	12.11	3.6-20.4	28 940.90	14.78
Synodontis sorex	9	0.84	14.33	9.5-20.0	69.30	19.4-176.5	36 928.30	18.86
Synodontis melanopterus	5	0.47	8.3	6.0-10.0	17.38	6.5-30.8	86.90	0.04
Synodontis macrophtalmus	6	0.56	11.15	7.5-13.5	32.40	11.2-47.7	6 003.10	3.07
Synodontis ocelifer	7	0.65	9.09	8.2-10	17.76	11.5-23.9	124.30	0.06
Synodontis violaceus	6	0.56	11.45	8.0-13.5	35.93	14.0-48.1	25 812.60	13.18
Synodontis budjetti	5	0.47	13.50	10.9-16.0	70.50	32.5-115.2	352.30	0.18
Total	1069	100					195 846.10	100

Table 8. Abundances, standard length (SL) and weight of Mochokidae fishes captured in the flood period in Niger River (Northern Benin) from February 2015 to July 2016.

Species	Abundance	Relative Abundance (%)	SL mean (cm)	SL range (cm)	Weight mean (g)	Weight range (g)	Total weight (g)	% Weight
Synodontis s membranaceus	207	41.48	8.03	5.0-21.5	16.14	4.5-105.9	12 900.00	25.06
Synodontis schall	222	44.49	11.78	5.7-176.0	50.11	6.3-156.9	15 563.20	30.23
Synodontis filamentosus	5	1.00	11.78	10.0-14.0	31.28	17.1-48.4	156.40	0.30
Synodontis nigrita a	48	9.62	8.34	7.0-10.5	21.28	1.6-44.3	16 176.50	31.42
Synodontis nigrita b	1	0.20	7.70	7.7-7.7	17.60	7.6-17.6	17.60	0.03
Synodontis macrophthalmus	6	1.20	12.90	9.0-15.0	63.50	16.3-105.3	381.30	0.74
Synodontis violaceus	10	2.00	9.39	8.0-13.0	20.81	13.1-48.1	6 291.00	12.22
Total	499	100					51 486	100

Table 9. Percentage occurences of fishes collected in Niger River (Northern Benin) from February 2015 to July 2016.

Species	Money	Tounga	Behind dry port	Gaya	''Whedo''	Occurrence (%)
Synodontis schall	+	+	+	+	+	100
Synodontis membranaceus	+	+	+	+	+	100
Synodontis clarias	+	+	+	+	+	100
Synodontis nigrita a	+	+		+		60
Synodontis nigrita b	+	+		+		60
Synodontis sorex	+	+		+		60
Synodontis violaceus	+	+		+		60
Synodontis filamentosus	+	+		+		60
Synodontis ocellifer	+	+		+		60
Synodontis melanopterus	+			+		40
Synodontis courteti	+			+		40
Synodontis macrophthalmus	+	+				40
Synodontis budjetti		+				20
Synodontis frontosus		+				20

Table 10. Matrix of correlation coefficients (r) obtained from the regressions between water parameters and both species abundance and Margalef species richness of fishes captured in Niger River (Northern Benin) from February 2015 to July 2016.

Water parameters	Numeric abundance	Species richness
Depth (cm)	-0.065	-0.007
Transparency (cm)	0.303	0.361
Dissolved oxygen (mg/l)	0.562*	0.198
Oxygen Saturation (%)	0.486*	0.241
Water temperature (°C)	0.059	-0.360
pH	0.448	0.273

*Correlation is significant at the 0.05 level.

In addition, a Factorial Correspondance Analysis (AFC) performed on the Mochokid sub-community indicated that the two first axis cumulated 99.70% of the total inertia with Axis1 = 85.53% and Axis 2 = 14.17% (Fig. 4.). A dendrogram obtained from the Hierarchical Clustering Analysis indicated that the fourteen (14) species inventoried were grouped and distributed into three (3) clusters (Fig.5.). The first cluster included nine (9) Mochokidae such as *Synodontis schall*, *Synodontis clarias*, *Synodontis nigrita* a, *Synodontis sorex*, *Synodontis violaceus*, *Synodontis nigrita* b, *Synodontis melanopterus*, *Synodontis macrophthalmus* and *Synodontis courteti*. The second group was represented by four (4) species, *Synodontis budjetti*, *Synodontis frontosus*, *Synodontis ocellifer* and *Synodontis filamentosus* and the third cluster consisted only of *Synodontis membranaceus*.

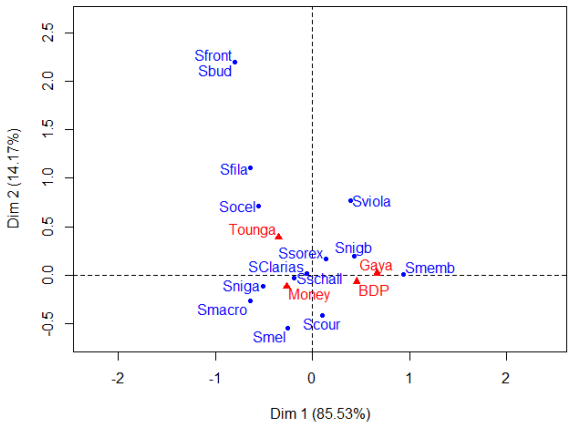

Fig. 4. Factoriel Correspondance Analysis of Mochokid fishes captured in Niger River (Northern Benin) from February 2015 to July 2016.

*Smembr: Synodontis membranaceus; Sschall: Synodontis schall; Sclarias: Synodontis clarias, Snig*A: *Synodontis nigrita* a*; Ssorex: Synodontis sorex; Sviola: Synodontis violaceus; Sfila: Synodontis filamentosus; SnigrB: Synodontis nigrita* b*; Smelano: Synodontis melanopterus; Smacro: Synodontis macrophthalmus; Soce: Synodontis ocellifer; Scourte: Synodontis courteti; Sfronto: Synodontis frontosus and Sbud: Synodontis budjetti.* Wat.temp: water temperature; Dis.oxy: Dissolve oxygen; Sat.Oxy: Percentage of oxygen saturation; Trans: Transparency.

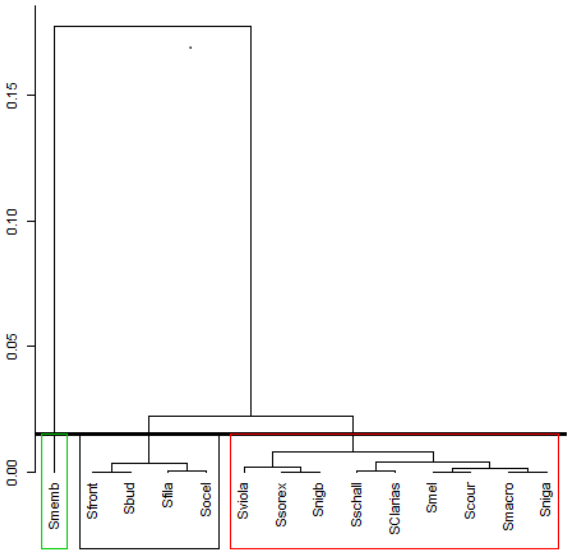

Fig. 5. Hierarchical Clustering Analysis of Mochokid fishes captured in Niger River (Northern Benin) from February 2015 to July 2016.

*Smembr: Synodontis membranaceus; Sschall: Synodontis schall; Sclarias: Synodontis clarias, Snig*A: *Synodontis nigrita* a*; Ssorex: Synodontis sorex; Sviola: Synodontis violaceus; Sfila: Synodontis filamentosus; SnigrB: Synodontis nigrita* b*; Smelano: Synodontis melanopterus; Smacro: Synodontis macrophthalmus; Soce: Synodontis ocellifer; Scourte: Synodontis courteti; Sfronto: Synodontis frontosus and Sbud: Synodontis budjetti.* Wat.temp: water temperature; Dis.oxy: Dissolve oxygen; Sat.Oxy: Percentage of oxygen saturation; Trans: Transparency.

Environmental correlates

To assess environmental relationships, regressions between water physicochemical parameters and gross abundances/richness were performed. The ouputs revealed that the correlation coefficients (r) varied between -0.065 and 0.562 for the regressions between Mochokidae abundances and water characteristics, mainly depth, transparency, dissolved oxygen, % of saturation, water temperature and pH (Table 10). In particular, cumulated abundances significantly (P<0.05) increased with dissolved oxygen concentration. Though not significant (P>0.05), the regressions between species richness and physicochemical factors gave a matrix of correlation coefficients (r) ranging between -0.360

and 0.361 (Table 10). Also, the results from the Canonical Correspondance Analysis (CCA) performed on physicochemical parameters and abundances of the fourteen (14) Mochokid fishes indicated that the first two axes explained and aggregated 55.8% of the observed correlations with Axis 1 = 31.9% and Axis 2 = 23.9%. Significant (P<0.05) correlation coefficients r_1 =0.80 and r_2 =0.78 were respectively associated to these axes (Fig.6).

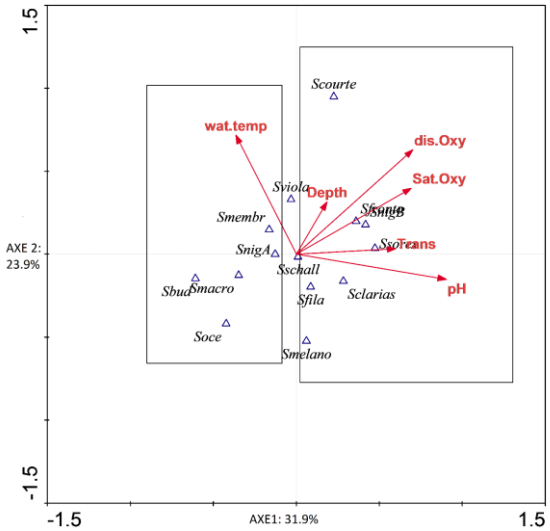

Fig. 6. Canonical Analysis of Correspondence (CCA) of water features and Mochokid fishes captured in Niger River (Northern Benin) from February 2015 to July 2016.

Discussion

Notwithstanding the multiple degradation factors occurring currently on the Niger River in Benin, the water quality still relatively favorable for the survival and growth of the dwelling fish resources. Particularly, the mean values of temperature (30.13±3.17°C), dissolved oxygen (6.92±1.32mg/l), percentages of saturation (94.13±17.5%) and pH (7.49±0.52) along with depths varying between 105 and 960cm were suitable to improve the condition and the well-being of the Mochokid fishes (Coke, 1968). However, water transparencies (0-75cm; mean: 34.50±27.80cm) were reduced and resulted from domestic wastes discharges. In addition to the reduction of photosynthesis process and primary production, the suspended materials could damage the gill of the fishes, thus affecting their respiratory functions. In general, the physicochemical parameters recorded agreed with those reported by Koba (2004) on Niger River in Benin where the dissolved oxygen approximated 7mg/l and pH ranged between 7 and 8.8. Adjibade *et al.* (2019) reported almost the same trends of water quality, but with a relatively higher dissolved oxygen reaching 11.9 mg/l corresponding to a percentage of saturation of 171.3%.

The current ichtyological survey in the Niger River in Benin revealed a relatively high Mochokid richness reaching fourteen (14) species belonging all to a single genus, *Synodontis*, with *Synodontis schall*, the most abundant species making numerically, 74.50% of the fish assemblages. In the whole Niger River, Paugy and Levêque (2004) reported about thirty-three (33) species of Mochokidae, but belonging to three (3) genera, *Mochokus*, *Chiloglanis* and *Synodontis*, the dominant genus comprising 28 species with *Synodontis schall*, the dominant species. The dominance of *Synodontis shall* has been also reported by Koba (2005) in the Niger River in Benin where among the eigth (8) Mochokidae inventoried, *Synodontis schall* was the formost and the most abundant species in this sub-community. In Okpara stream of Oueme River in Northern Benin, *Synodontis schall* was also prominent and accounting for about 75% of the Mochokidae sub-community and 2.89% of the Okpara fish community (Sidi Imorou *et al.*, 2019). In the Sô stream of Southern Benin, Hazoume *et al.* (2018) reported only two (2) Mochokidae, *Synodontis schall* and *Synodontis nigrita*. Similarly, in the Tovè River in South Benin, Djidohokpin *et al.* (2017) encountered only one (1) Mochokidae, *Synodontis schall*.

With regards to habitat, passed ichtyological investigations coupled with the present result indicated that Mochokidae fishes prefer and colonize running waters (streams, rivers) and were of trivial importance in most lentic habitats (lakes, lagoons). For example, at the Benin coastal lagoon, Adite *et al.* (2013) reported only one (1) individual of *Synodontis schall*. In Lake Hlan, a floodplain of the Oueme River-Hlan River system, no Mochokidae was found, whereas in the river floodplain, Montchowui *et al.* (2007) reported one (1) Mochokidae, *Synodontis nigrita* a.

Among the fourteen (14) Mochokid fishes inventoried in Niger River in Benin, the three (3) dominant species, *Synodontis schall* (74.50%), *Synodontis membranaceus*, (16.79%) and *Synodontis nigrita* (2.24%) cumulated about 93.53% of the total abundances. The eleven (11) species remaining accounted together for only 6.47% and none of them made more than 1.70% of the Mochokidae fish assemblages (Table 2). Because the three fourth (3/4) of the species abundances originated from *Synodontis schall*, the dominant species, the Shannon-Weaver index of species diversity (H') computed for the sub-community was moderate with H'=1.31. The highest Shannon-Weaver index (H'=1.42) was recorded in Gaya, a less degraded site whereas the lowest index (H'=1.01) was recorded in Tounga, a disturded and degraded site. In contrast with the aquatic vegetation habitat that showed a lowest diversity index H'=0.87, the open water displayed a high Shannon-Weaver index (H'=1.34) indicating that the species of this taxa tolerate more dynamic habitats. This ecological behavior was also shown by the high diversity index (H' =1.65) recorded during the flooding period, a very dynamic season.

The large distribution of *Synodontis schall* and *Synodontis membranaceus* (percentage occurrence-PO: 100%) was probably due to their high tolerance to critical water conditions. In particular, *Synodontis schall* showed a relatively high tolerance to degraded habitats. This ecological behavior coupled with its moderate fecundity (F=7.920 eggs) (Arame *et al.,* 2019) favored its rapid propagation. In addition, *Synodontis schall* exhibited a high diet breadth, thus ingesting a wide range of food items including benthic resources, detritus, seeds, phytoplankton, insects, and worms that may have favored a trophic plasticity behavior and its prominence in the Niger River in Benin. It was also the case of *Synodontis nigrita* a, *Synodontis nigrita* b, *Synodontis sorex*, *Synodontis violaceus*, *Synodontis ocellifer* and *Synodontis filamentosus*, but showing a moderate distribution with a percentage occurrence of 60%. The weak distribution displayed by *Synodontis budjetti* and *Synodontis frontosus* may probably be the results of their low tolerance to physicochemical parameters or/and to the low capacity of recolonization as for species displaying a k-selected demographic strategy (Pianka, 1988).

When considering the influence of the water quality on the Mochokidae fishes, the positive correlation (r= 0.562) generated by the regression between dissolved oxygen and fish abundances showed that in the Niger River, the gross abundance of Mochokid significantly (P<0.05) increased with dissolved oxygen concentration. Though not significant (P≥0.05), similar model was recorded for the regression between dissolved oxygen and the Mochokid richness with a correlation coefficient r= 0.33. Dissolved oxygen appreared to be the main physicochemical factor of the water quality because purifies polluted water by degrading organic matters. Also, dissolved oxygen is the key factor in fish breathing, growth and survival (Swann, 1997). The lack of correlation between water depth and Mochokid abundance (r= - 0.065) and between water depth and Mochokid richness (r= - 0.007) was the result of the relatively high depth (105-960cm; mean: 415.94±241.28cm) recorded regardless of season and space (Adjibade *et al.,* 2019). In general, the pH and the water transparency were positively correlated with fish abundances (r_{pH}= 0.448; r_t= 0.303) and species richness (r_{pH}= 0.273; r_t= 0.361), but not significant (P≥0.05).

In addition, the output from the Canonical Correspondance Analysis (CCA) performed on physicochemical factors and abundances of the fourteen (14) Mochokid fishes showed the existence of three groups of species (Fig. 6.). The first group, less tolerant to abiotic factors, was composed of species like *Synodontis membranaceus*, *Synodontis ocellifer*; *Synodontis budjetti*, *Synodontis macrophthalmus*, *Synodontis nigrita* a, *Synodontis violaceus* that were positively correlated with water temperature and negatively correlated with pH, O_2 saturation percentage, dissolved oxygen, water transparency, and depth. The second group, also less tolerant, was constituted of *Synodontis clarias*, *Synodontis Sorex*, *Synodontis filamentosus*, *Synodontis nigrita* b, *Synodontis courteti*, *Synodontis frontosus*, *Synodontis melanopterus* positively correlated with pH, O_2 saturation percentage

of water, dissolved oxygen, water transparency and depth, and negatively correlated with water temperature. The third group included only *Synodontis schall*, a highly tolerant and widely distributed species in the river (Fig. 6.). According to Adite *et al.* (2017) and Adjibade *et al.* (2019), the species guilds depicted were probably the result of the differential tolerance of each Mochokidae to abiotic factors.

Conclusion

This ichtyological research on the Niger River in Benin revealed fourteen (14) species of Mochokidae belonging to one (1) genus, *Synodontis* and numerically dominated by three (3) species, *Synodontis schall*, *Synodontis membranaceus* and *Synodontis nigrita* with *Synodontis schall*, the most abundant species making about 74.50% of the Mochokid asemblages. Species such as *Synodontis frontosus*, *Synodontis courteti*, *Synodontis nigrita* b, *Synodontis macrophthalmus* and *Synodontis ocellifer,* though present, were uncommon and of trivial abundances. The multitude threats recorded during this survey require an implemention of a community-based approach of ecosystem management that should include habitat protection, species conservation and valorization in order to guaranty a sustainable exploitation of the Mochokid fishes in the Niger River in Benin.

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