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Preliminary inventory and distribution of the ichthyological biodiversity of the watershed of the Doubou River Ngounié Province, Gabon

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Abstract

The composition and distribution of the ichthyological diversity of the Doubou basin were studied during the month of August 2020. The fish were caught using dip nets, seines and nets. In total, 343 specimens were collected, totaling to 42 species divided into 13 families and 7 Orders. Four (4) species show high relative abundances, namely *Brycinus kingsleyae* (13.70%), *Brycinus bartoni* (12.83%), *Brycinus longipinnis* (9.33%) and *Epiplatys ansorgii* (6.71%). The Shannon diversity index (H') and the Pielou fairness index (J) give values of 3,131 bits and 0.838, respectively, indicating great fish diversity and a regular distribution of species. Factor Correspondence Analysis (FCA) shows that the depth and width of rivers influence species richness.

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Introduction

Continental aquatic ecosystems cover only about 1% of the planet's surface, but serve as a habitat for more than 40% of fish species (FAO, 2019). African fresh and brackish waters are home to a rich ichthyological biodiversity and nearly 3,200 species of fish are known from the continent (Leveque and Paugy, 2006; Froese and Pauly, 2021). Despite this high number of species, obtained for the most part in the rivers, the number of fish species in Africa could increase with continued inventories in more remote regions that could potentially shelter new species.

This is the case of Gabon where the ichthyological fauna is still very poorly understood. Of Gabon's six hydrographic basins, 235 freshwater species are currently documented (Mbega, 2004; Mamonekene *et al.,* 2006; Stiassny *et al.,* 2007; Ibanez *et al* 2007; Chirio *et al.,* 2018 and Cutler *et al.,* 2019). The Ogooué basin, especially its lower course, has so far been the most investigated. It is necessary to intensify faunal inventories in remote or isolated watersheds and rivers, in order to identify the maximum number of species, to promote sustainable management of aquatic ecosystems and help preserve biodiversity. These inventories provide the basic tools necessary for the rational management of aquatic environments. It is in this perspective that this contribution is made, which establishes the first list of ichthyological biodiversity in the Doubou watershed.

Material and methods

Study zone

The study was carried out in the watershed of the Doubou River, a tributary of the Ngounié River in the Ngounie province in southern Gabon. The Doubou river crosses the national road near the village of Doubou at the point of geographical coordinates (-1°46 '21 .7600"S; + 10°55 '0"E), about 18 km northwest from the town of Mouila.

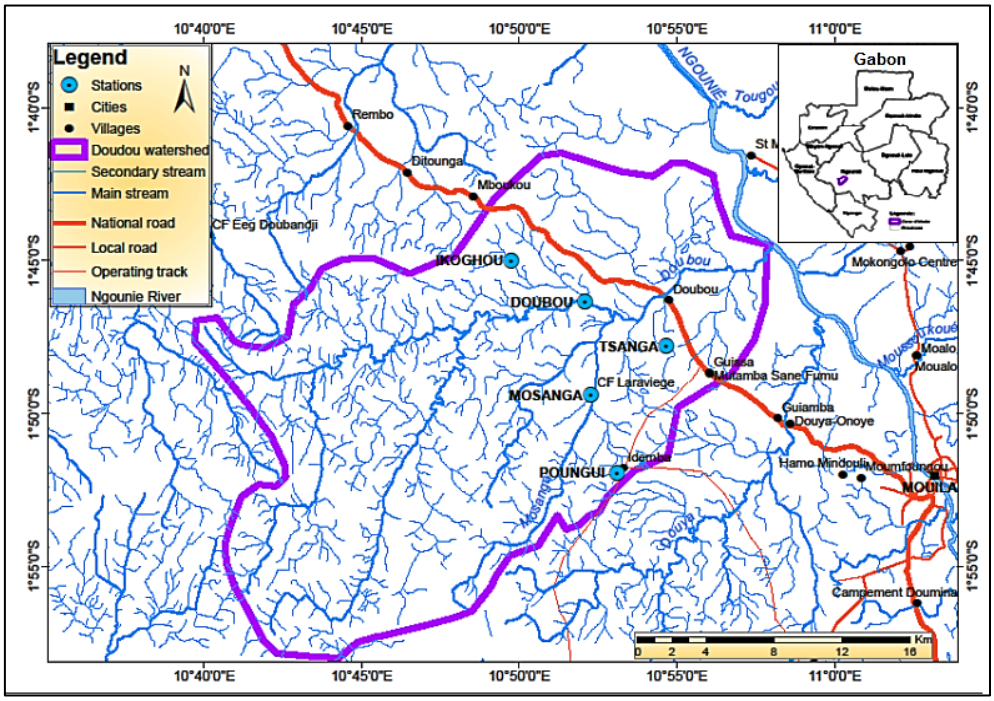

Fig. 1. Sampling locations in the Doubou watershed.

Sampling methods

The fish were collected during a sampling campaign in August 2020, using a combination of active sampling techniques (seines of length 20 m and mesh 5mm, and dip nets of diameter 80cm and mesh 5mm) in shallow rivers and passive techniques (experimental gillnets with panels of 10, 27 and 40mm mesh, 20 m length and 1.5 m drop height) used in deep river reaches. A total of five (5) stations were included in this study; one station on the

mainstem Doubou, and four on tributaries; the Pongui, Ikoghou, Mboukou and Tsanga. Seine and dip net sampling was carried out between 8 AM and 3 PM, while the gillnets were set at 5 PM and retrieved the next day at 7 AM.

The captured specimens were grouped by stations, counted, dated and placed in jars containing 10% formaldehyde and sealed for analysis at the Laboratoire d'Hydrobiologie et d'Ichtyologie (LHI) of the Institut des Recherches Agronomiques et Forestières (IRAF). Each specimen was identified using the keys and determination guide provided by Stiassny *et al.,* 2007 and Mbega & Teugels (2003) then verified using Eschmeyer's Catalog of Fishes (Fricke *et al.*, 2020).

Data analysis

We evaluated the composition of fish fauna using analysis of variance (ANOVA) to detect the difference between sampled stations. Five descriptors of biodiversity were calculated: relative abundance, species richness, the Shannon and Simpson diversity indices and fairness.

The relative abundance of fish species is calculated using the formula : $\frac{n}{N} \times 100$

n: abundance of the species and N: total number of specimens collected (Dajoz, 1996). Species richness (S) corresponds to the total number of taxa present in each sample. The Shannon Diversity Index is a biotic measure of multidimensional information (Legendre & Legendre, 1984). This index reflects changes in community composition and visualizes their variations in space (Evrard, 1996). The analysis of the Shannon diversity index theoretically makes it possible to know whether we are in the presence of an evolved biocenosis (high diversity) or, on the contrary, if it is a young population (low diversity) (Diouf, 1996). It is expressed by the following relation:

$$H' = -\sum(\frac{n}{N})\ln(\frac{n}{N})$$

With, H '= Shannon index; n = number of individuals of the taxon; N = total number of individuals in the population. The Simpson Index (D) indicates the dominance of one or more species. It is calculated according to the following formula (Grall and Coïc, 2005):

$$D = \sum \frac{(ni(ni-1))}{N(N-1))}$$

ni = number of individuals in species I; N = total number of individuals in the sample. When D tends towards 0, it expresses the maximum diversity, i.e. there is no dominance or it is weak and when D tends towards 1, it expresses the minimum diversity therefore that there is a strong dominance of one or two species. Equitability, defined as the ratio of real diversity to maximum diversity is obtained by dividing the Shannon diversity index by the base 2 logarithm of the specific richness (Pielou, 1969), to see if the station or living conditions are the best for different species. This is why the formula below proposed by Dajoz (1996) was used:

$$E = \frac{H'}{\log 2\ (S)}$$

With,

(1) E = fairness

(2) H '= Shannon & Weaver index (1949)

(3) S = specific richness

Equitability varies between 0 and 1. The closer it is to 1, the more the observed community structure reflects the progressive adjustments of the different species to the constraints resulting from their biotic and abiotic environment. Cancela Da Fonseca (1968), Daget (1979), Hermi and Aissa (2002) estimate that values less than 0.8 reflect low stability of stand structure. The various indices were calculated using PAST software (version 3.1.2), and Factor Correspondence Analysis (FCA) using XLStat 2007 software.

Results

Sampling of the ichthyofauna of the Doubou basin yielded 42 species divided into 13 families and 7 Orders. The order of Siluriformes (38.46%) is the most represented, followed by Characiformes (23.08%). Cyprinifromes (7.69%), Cyprinodontiformes (7.69%), Osteoglossiformes (7.69%), Perciformes (7.69%), and Anabantiformes (7.69%) (Fig. 2A). Five families dominate the ichthyological population of the Doubou

basin. These are Cichlidae (14.63%), Cyprinidae (14.63%), Mormyridae (12.20%), Alestidae and Distichontidae with 9.76% each. Followed by Claroteidae (7.32%), Notobranchiidae (7.32%), Anabantidae (4.88%), Clariidae (4.88%), Mochokidae (4.88%), Schilbeidae (4.88%), Hepsetidae (2.44%) and Malapteruridae (2.44%) (Fig. 2B).

Among the 343 specimens captured, four species were most abundant; *Brycinus kingsleyae* (13.70%), *Brycinus bartoni* (12.83%), *Brycinus longipinnis* (9.33%) and *Epiplatys ansorgii* (6.71%). Followed by, *Hemichromis elongatus* (4.96%), *Parananochromis longirostris* (4.96%), *Paramormyrops batesii* (4.66%), *Microctenopoma nanum* (4.37%), *Clarias* sp (4.08%), *Enteromius sublinaetus* (2.92%), *Pelmatolapia cabre* (2.62%) and *Enteromius holotaenia* (2.04%). The other species have abundant values of less than 2% (Table 1). Only two species (*Microctenopoma nanum* and *Epiplatys ansorgii*) werecollected at all the stations. 13 species (*Ctenopoma gabonense, Brycinus macrolepidotus, Distichodus notospilus, Xenocharax spilurus, Hepsetus kingsleyae, Enteromius prionacanthus, Labeobarbus progenys, Petrocephalus sullivani, Pelmatolapia cabre, Clarias gabonensis, Chrysichthys ogooensis, Schilbe grenfelli* and *Schilbe multitaeniatus)* were sampled only in the Doubou; three species (*Enteromius holotaenia, Microsynodontis* sp and *Synodontis batesii*) were captured exclusively in the Ikoghou station; four species (*Hemistichodus vaillanti, Enteromius* sp, *Enteromius sublinaetus* and *Notoglanidium macrostoma*) were collected only in the Mosanga station; four species (*Nannocharax parvus, Epiplatys singa, Paramormyrops sp* and *Stomatorhinus* sp) were captured only in the Poungui station; four species (*Enteromius trispilomimus, Marcusenius moorii, Sarotherodon mvogoi* and *Tilapia sp)* were sampled exclusively in Tsanga station (Table 1).

Table 1. Biodiversity, abundance and distribution of species collected in the Doubou basin.

Orders	Families	Species	Codes	N	Relative abundance (%)	Distribution				
						Doubou	Ikoghou	Mosanga	Poungui	Tsanga
ANABANTIFORMES	Anabantidae	*Ctenopoma gabonense*	*C.ga*	3	0.87	+				
		Microctenopoma nanum	*M.nan*	15	4.37	+	+	+	+	+
CHARACIFORMES	Alestidae	*Brycinus bartoni*	*B.bar*	44	12.83	+		+	+	
		Brycinus kingsleyae	*B.kin*	47	13.70	+		+	+	
		Brycinus longipinnis	*B.lon*	32	9.33	+	+	+		
		Brycinus macrolepidotus	*B.mac*	6	1.75	+				
	Distichodontidae	*Distichodus notospilus*	*D.not*	1	0.29	+				
		Hemistichodus vaillanti	*H.vai*	1	0.29			+		
		Nannocharax parvus	*N.par*	4	1.17				+	
		Xenocharax spilurus	*X.spi*	3	0.87	+				
	Hepsetidae	*Hepsetus kingsleyae*	*H.kin*	2	0.58	+				
		Hepsetus lineata	*H.lin*	4	1.17	+		+		
CYPRINIFORMES	Cyprinidae	*Enteromius holotaenia*	*E.hol*	7	2.04		+			
		Enteromius prionacanthus	*E.pri*	5	1.46	+				
		Enteromius sp	*E.sp*	1	0.29			+		
		Enteromius sublinaetus	*E.sub*	10	2.92			+		
		Enteromius trispilomimus	*E.tri*	6	1.75					+
		Labeobarbus progenys	*L.pro*	3	0.87	+				
CYPRINODONTIFORMES	Nothobranchiidae	*Epiplatys ansorgii*	*E.ans*	23	6.71	+	+	+	+	+
		Epiplatys huberi	*E.hub*	5	1.46			+		+
		Epiplatys singa	*E.sin*	4	1.17				+	
OSTEOGLOSSIFORMES	Mormyridae	*Marcusenius moorii*	*M.moo*	2	0.58					+
		Paramormyrops batesii	*P.bat*	16	4.66		+	+	+	+
		Paramormyrops sp	*P.sp*	1	0.29				+	
		Petrocephalus sullivani	*P.sul*	2	0.58	+				
		Stomatorhinus sp	*S.sp*	1	0.29				+	
PERCIFORMES	Cichlidae	*Hemichromis elongatus*	*H.elo*	17	4.96	+	+			+
		Parananochromis axelrodi	*P.axe*	6	1.75	+		+		
		Parananochromis longirostris	*P.lon*	17	4.96	+	+		+	+
		Pelmatolapia cabre	*P.cab*	9	2.62	+				
		Sarotherodon mvogoi	*S.mvo*	1	0.29					+
		Tilapia sp	*T.sp*	5	1.46					+
SILURIFORMES	Clariidae	*Clarias gabonensis*	*C.gab*	3	0.87	+				
		Clarias sp	*C.sp*	14	4.08	+			+	+
	Claroteidae	*Chrysichthys ogooensis*	*C.ogo*	4	1.17	+				
		Notoglanidium macrostoma	*N.mac*	2	0.58			+		
		Parauchenoglanis punctatus	*P.pun*	4	1.17	+				+
	Malapteruridae	*Malapterurus oguensis*	*M.ogu*	4	1.17	+	+			
	Mochokidae	*Microsynodontis sp*	*M.sp*	1	0.29		+			
		Synodontis batesii	*S.bat*	5	1.46		+			
	Schilbeidae	*Schilbe grenfelli*	*S.gre*	1	0.29	+				
		Schilbe multitaeniatus	*S.mul*	2	0.58	+				

*(+) present of the species.

Table 2. Ecological diversity indices calculated for the stations sampled.

Diversity indices	Dou (N=110)	Iko (N=66)	Mos (N=86)	Pou (N= 32)	Tsa (N= 49)	Basin (N= 343)
Specific richness (S)	25	10	13	8	12	42
Shannon (H)	2.793	1.881	1.915	2.307	2.36	3.131
Simpson (D)	0.917	0.801	0.797	0.895	0.899	0.935
Fairness (J)	0.879	0.817	0.747	0.962	0.950	0.838

* DOU=Doubou; IKO= Ikoughou; MOS= Mosanga; POU= Poungui; TSA= Tsanga;

n = Numbers of specimens collected.

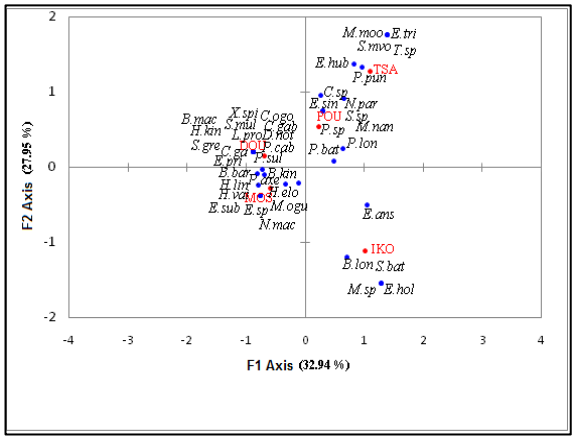

Fig. 3. Factor Correspondence Analysis (FCA) applied to stations and species captured in the Doubou basin. Species codes are shown in Table 1.

The data on the diversity indices are reported in Table 2. Species richness (S) varied according to the stations sampled. It was highest in the mainstem Doubou (25 species), followed by Mosanga (13 species), Tsanga (12 species), Ikohou (10 species), and Poungui (8 species) (Table 2). Shannon index values also show variations between stations, the highest value was recorded at the Doubou station (2.793), followed respectively by: Tsanga (2.36), Poungui (2.307), Mosanga (1.915), and Ikoghou (1.881). The same variation is observed for the Simson index. The highest value is observed at Doubou station (0.916) and the lowest at Mosanga station (0.797). As for the fairness of Pielou, the highest value is observed at Poungui station (0.962) and the lowest at Mosanga station (0.747). Factor Correspondence Analysis (FCA), applied to sampled stations and species, shows the differences in the fish composition of the different sampled stations. On the F2 axis, the fauna of the Doubou (main course) and Mosanga stations is opposed to the fauna of the Tsanga, Poungui and Ikoghou stations. And on the F1 axis, the ichthyological fauna of the Doubou (main course), Poungui and Tsanga stations is opposed to the fauna of the Mosanga and Ikoghou stations.

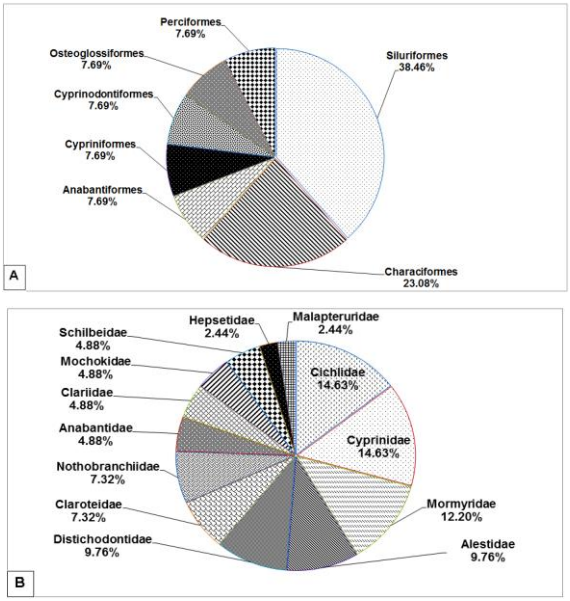

Fig. 2. Taxonomic richness of the species captured in the Doubou basin. A: Orders; B: Families.

Discussion

During our surveys of the Doubou watershed in August 2020, we collected and identified 42 species of fish belonging to 13 families. Of the 42 species inventoried in this study all are freshwater species. The populations found in the Doubou basin are mainly dominated in the long dry season by Alestids including *Brycinus kingslayae*, *Brycinus longipinis* and *Brycinus Bartoni* with about 12% relative abundance. The species richness we observed is likely much lower than the actual diversity of the region. Further sampling in the region, including during the wet season, and using more diverse sampling equipment would likely increase the species richness.

When comparing our results to other similar studies including those in the Rabi region in the Ogooué-Maritime province where 67 species belonging to 23 families were obtained (Mamonekene *et al.*, 2006), and the Congo Kindu river where 28 species belonging to 13 families have been identified (Ngoy *et al.*, 2020) we find intermediate diversity in the Doubou watershed.

The difference in the number of species caught could be due to the technique used but also to the size and number of stations which may not have allowed for sampling of all habitats. According to Williamson (1988), Teugels *et al.*, 1994, the number of species present in a given biotope depends on the diversity of habitats.

The Shannon index (H ') calculated over the entire Doubou basin (3,131) indicates that the actual diversity may be much higher than the measured diversity. This inventory also indicates the presence of two species belonging to the Hepsetidae family: *Hepsetus lineata* and *Hepsetus kingsleyae*, of which the latter was considered until then as endemic to the Ogooué basin (Decru *et al.*, 2013) but is reported for the first time in the Ngounié sub-basin in this study.

The high value of the Pielou equity index in the whole basin (0.838), reflects an equitable distribution of species in the basin. However, taken individually, lower values of the fairness index observed in certain stations such as Mosanga (0.747) indicate a poor distribution of fish fauna which could be linked to an onset of disturbance of the environment by human activities. The Doubou watershed is relatively accessible and lacks some of the protections afforded to more remote watersheds. The Doubou is situated on a national road and close to OLAM's oil palm plantations. Our team observed human impacts especially at the sites on Ikoghou, Poungui and Tsanga describe in more detail and hopefully provide photographic proof.

The distribution of species in the Doubou basin shows that only two species (*Microctenopoma nanum* and *Epiplatys ansorgii*) were found in all the stations. The FCA results show differences in the ichthyological composition between the different stations sampled. Thus, the F2 axis distinguishes the fauna of the stations of Doubou (main course) and Mosanga (its main tributary) from the other rivers. This distinction is characterized by greater biological diversity, greater depth and wider river beds versus less diversity, shallower depth and restricted beds in other rivers. While the F1 axis distinguishes the stations of Doubou (main course), Poungui and Tsanga, richer in species and characterized by dense forest vegetation and a substrate dominated by mud from the stations of Mosanga and Ikoghou characterized by a mixed clay-sand substrate and vegetation dominated by Arecaceae. This variation in the distribution of species under the influence of environmental variables is demonstrated in the work of Aboua *et al.*, 2010, and Kouadio *et al.*, 2006, Kamelan *et al.*, 2013.

The preliminary results obtained in the Doubou basin (343 fish individuals divided into 42 species and 13 families) contribute to our basic understanding of the freshwater ichthyological diversity in Gabon. A more thorough inventory of the region could be conducted including sampling in both the rainy and dry season, including more sites, and integrating selective fishing gears (particularly traps used for catching certain species of Mormyridae).

Conclusion

We conducted a preliminary inventory of the ichthyological fauna of the Doubou River watershed aimed to establish a baseline of the species present in this region. A total of 42 fish species were identified, with 23 families and 7 orders. The results indicate a significant diversity of species with a dominance of Alestidae: *Brycinus kingsleyae, Brycinus bartoni* and *Brycinus longipinnis* being the three most numerically abundant species. With regard to the values of the Shannon and equitability indices, it appears that the Doubou basin has great fish diversity and a regular distribution of species. These data serve as reference for the ichthyological biodiversity of this area and will contribute to the knowledge on ichthyological biodiversity at the national level.

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