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Fish assemblage associated with tidal channels of mangrove forest in Kribi (South Region, Cameroon)

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Abstract

The nursery function of mangroves for a range of macroinvertebrates and various species of fish is important. Despite this importance, very few studies have been conducted to assess ichthyological diversity in mangrove of Cameroon experienced an increasingly degradation mainly due to human activities. This survey aims to compare the diversity of fish between two tidal channels with different environmental characteristics. Physico-chemical parameters and heavy metals concentrations of each tidal channel of mangrove were measured during each collection campaigns. Two sampling methods were used for Ichtyofauna collection: experimental fishing in the two channels and investigations into boat landing stages along this mangrove channels. Heavy metals concentrations in water were high in Mpolongwè (Pb = 1.23mg.l^{-1} and Hg = 0.89mg.l^{-1}), while in Eboundja these concentrations were Pb = 0.31mg.l^{-1} and Hg = 0.65mg.l^{-1}, this suggests that degradation is high in Mpolongwé. A total of 1137 fishes belonging to 19 species grouped in 17 genera and 12 families were taken into account. The most abundant families were Carangidae, Clupeidae and Scianidae with 3 species each, followed by Polynemidae (2 species), while the last 8 families were represented by single species each. The ACP analysis has shown the mains environmental parameters which influenced the distribution of ichtyofauna within the two sites.

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Introduction

The ecological role of mangroves as nursery habitats and enhancing the diversity and fisheries within the ecosystem and also its adjacent ecosystems has been well documented (Mumby *et al.,* 2004).

They are very important nursery areas for a large variety of fish and invertebrates, providing refuge and food for many of these species during the first development stages (Walton *et al.,* 2006; Long *et al.,* 2014). However, due to their restricted geographical distribution and their proximity to intense anthropogenic activities (Polidoro *et al.,* 2010), they are frequently under strong pressure (Spalding *et al.,* 2010) and are among the most threatened marine ecosystems (Duke *et al.,* 2007).

Although mangrove habitats comprise a significant part of the biodiversity, their flora and fauna are still poorly documented in many regions. In Cameroon, numerous studies highlight the biodiversity of mangroves, in particular the flora which has been widely characterized (Din, 2001; Nfotabong-Atheull *et al.,* 2013; Essome-Koum *et al.,* 2017).

Studies on the Cameroonian mangrove fauna have focused most on macroinvertebrates such as crabs (Boyé *et al.,* 1975; Guiral *et al.,* 1999; Longonje 2008; Longonje *and* Raffaelli 2013; Ngo-Massou *et al.,* 2012; 2014; 2016; Din *et al.,* 2014) and molluscs (Plaziat 1974; Boyé *et al.,* 1975; Bandel *and* Kowalke, 1999; Guiral *et al.,* 1999; Ngo-Massou *et al.,* 2012; Kottè-Mapoko *et al.,* 2017).

However, the vertebrate fauna remains little known, especially the ichthyofauna of the tidal channels of mangroves, for which data is scarce or even non-existent. Though the connectivity between mangrove forests and the adjacent ecosystems for the ichthyofauna has already been elucidated through the world (Nagelkerken *et al.,* 2012).

Most African cities, especially those located in coastal areas, face an amplification of rampant industrialization, population growth and anarchic urbanization (Priso *et al.,* 2014). Cameroon's coastal towns are no exception to this reality. This is the case of the town of Kribi and its surroundings, where the development of structuring projects such as the deep-water port, the gas power station and numerous agri-food industries could affect the mangrove ecosystem and hence its biological diversity. In view of all these threats to mangroves, the question is to know what about the ichthyological diversity and the quality of the channels of these ecosystems. This work aims to compare the diversity of fish in two tidal channels with different environmental characteristics.

Materials and methods

Study area

Located on the maritime coast of Cameroon, in the southern region, the mangroves of Kribi and its surroundings are part of the large group of mangroves of Rio Ntem. This area is subjected to an equatorial climate characterized by four clearly individualized seasons: two dry seasons (December-March and July-August) and two rainy seasons (September-November and April-June).

There is significant rainfall throughout the year in Kribi. Even in the driest months, the showers still persist. Surface water temperatures generally range from 15 to 29°C along the coast. The average temperature in Kribi is 25.7°C. The tides are semi-diurnal and the average rainfall can reach more than 2,950mm per year. The mangroves are supplied with fresh water by small streams which merge into a small river that flows into the Atlantic Ocean.

Its flow decreases considerably during the great dry season. At this period, the water supply is almost insured by the tide.

Two mangrove sites: Mpolongwe (N 03°01'50.1 '' and E 09°57'42.1'') and Eboundja (N 03°01 '43.9' ' and E 09°58'07.9''), with different environmental characteristics were chosen for this survey (Fig. 1). The artisanal fishing activity is practiced by the riparian populations at these two sites but the waters in the Mpolongwe site are severely degraded compared to the waters of Eboundja.

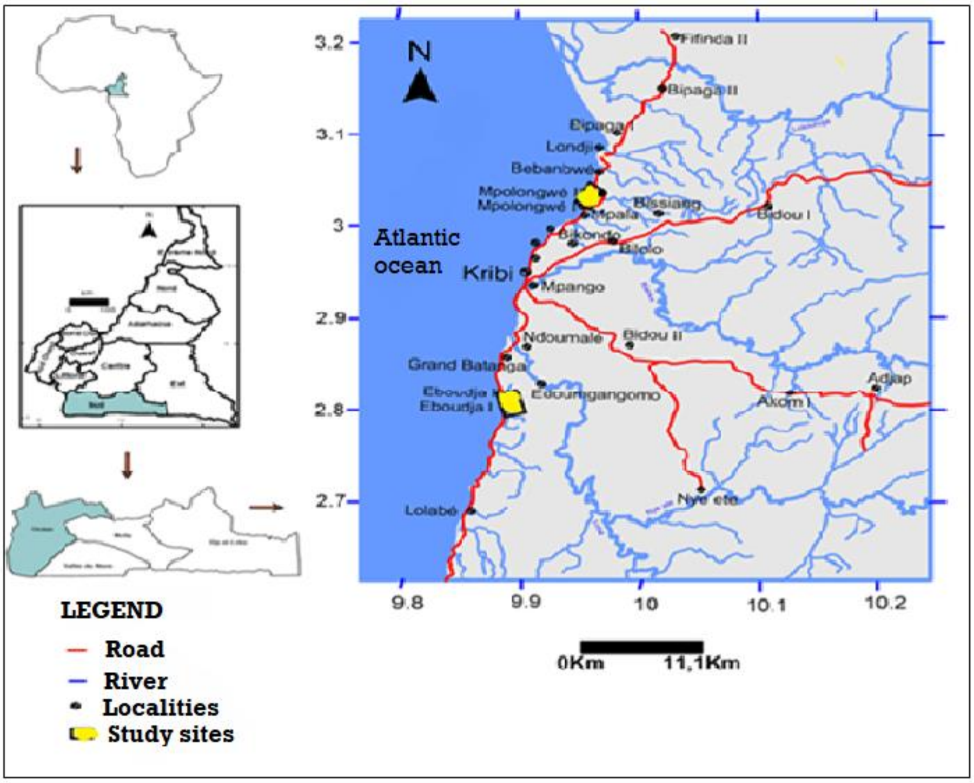

Fig. 1. Location of sampling sites.

Field survey and assessment of environmental parameters

Field campaigns were conducted in August-October 2019. A U-50 HORIBA series multi-parameter permitted to measure water temperature, pH, Turbidity, salinity, dissolved oxygen, total dissolved solids (TDS) and conductivity at each sampling site during each sample campaign. Once these parameters have been recorded, at each sampling site, water samples were collected in 1l plastic bottles for further analysis to laboratory of other parameters not determined directly on field such as heavy metals (Pb and Hg) present in these waters and BOD_5 (Biochemical Oxygen Demand over five days) according to the method described by Rodier (2009).

Sampling of ichtyofauna

The ichthyofauna sampling strategy of this study is based on two methods: experimental fishing and investigation in the landing stages located along the different tidal channels. Two sampling stations per site were chosen for the experimental fishery (SFA, 2011). In each sampling station, with the help of fishermen from the area, gillnets (20mm, 40mm and 60mm mesh) were deposited at high tide on either side of the channels and removed at low tide. The lengths of these nets varied between 100 m and 300 m and were 1.20m high. These nets deployed vertically in the water trap fish entering or leaving mangroves via these channels during the movement of the tides. Once removed, the catch from the nets is unloaded and during each unloading a sorting is carried out in order to identify the different species present in each station. The identification of the different specimens required the use of FAO identification keys established for marine fishes on Guinea gulf (Carpenter and De Angelis, 2016a; 2016b) and completed with another on low Guinea (Stiassny *et al.,* 2007). Once the sorting is done, the local name, the common name and the scientific name of each species are noted, then. The following morphometric data are taken for each fish caught: total length (LT) and standard length (LS) using an ichthyometer or calliper.

Twice a week, surveys have been carried out among fishermen who unload their catches in the landing stages located along the mangrove associated tidal channels. When the fishermen allowed it, the fish present in their catch were identified and morphometric data also taken for each specimen. The specimens that could not be identified in the field were taken for later identification at the laboratory of the Specialized Station for Experimental Research on Marine Ecosystems (SERECOMA).

Data analysis

The bioecological parameters used to describe fish communities in this work are total abundance (A), number of species per site (S) and species richness (R). The estimation of absolute density and the frequency of occurrence of each species were taken into account. Depending on the calculated frequency of occurrence (Tessier 2005), a species will be qualified as rare (0-15%), occasional (15-25%), frequent (25-50%), constant (50-75%) or ubiquitous (75-100%).

Three classic univariate measures in ecology have been used here to demonstrate the homogeneity or heterogeneity of stands: the H 'diversity index of Shannon and Weaver (1948), and the N1 and N2 indices of Hill (1973). The equitability index, also called regularity (Frontier, 1985) and which measures the distribution of individuals within species, regardless of specific richness was also calculated. Statistical processing and graphs were carried out using Microsoft Excel 2013 and XLSTAT 2014 software. The results are expressed in the form of the mean ± standard deviation.

Results

Environmental Characteristics

Variation of environmental characteristics of both the upstream and downstream for the two sampling sites is shown in Fig. 2 below. Analysis of these parameters shows that the highest mean value of pH (9.4 ± 0.05) was in downstream along the Mpolongwe site (Fig. 2a). The water temperature (Fig. 2b) shows little variation in the both sites (26.4 ± 1.42°C upstream, 27.17 ± 1.57°C downstream in Eboundja and 26.79 ± 0.37°C in upstream, 26.65 ± 0.2°C in downstream in Mpolongwe).

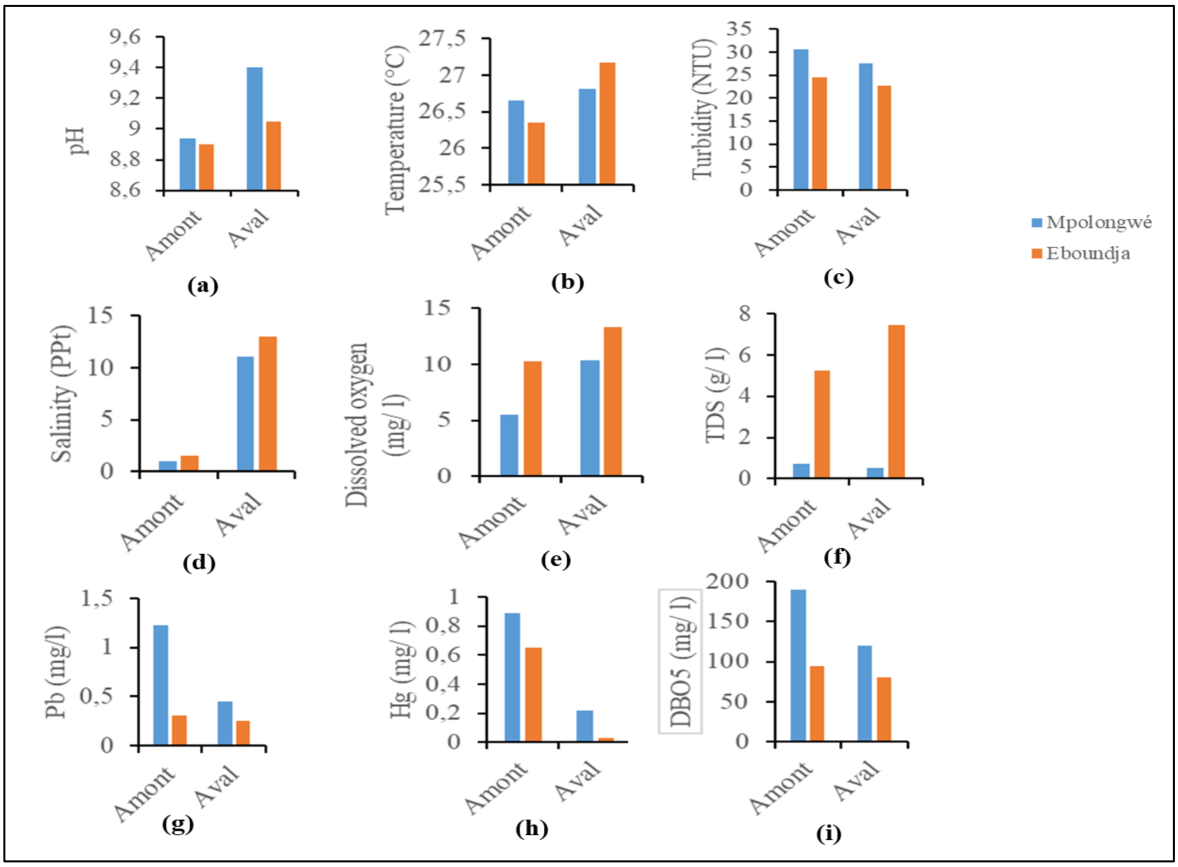

Fig. 2. Variation of environmental parameters upstream and downstream in different tidal channels.

The highest values of turbidity were obtained in downstream (24.7 ± 0.1 NTU in Eboundja and 30.5 ± 4.24 NTU in Mpolongwe) and the lowest values downstream (22.65 ± 0.63 NTU in Eboundja and 27.6 ± 2.82 NTU in Mpolongwe) (Fig. 2c). The lowest salinity was taken upstream on both sites (1.5 ppt at Eboundja and 1 ppt at Mpolongwe) and the highest values downstream (Fig. 2d). Significant variation in dissolved oxygen was observed from upstream to downstream 5.49mg.l^{-1} and 10.31mg.l^{-1} against 10.21mg.l^{-1} and 13.41mg.l^{-1} respectively in Mpolongwe and Eboundja (Fig. 2e). In Eboundja, the TDS values were 6.9g.l^{-1} upstream and 13.6g.l^{-1} downstream and in Mpolongwe these values were 1.25 g.l^{-1} upstream and 0.95g.l^{-1} downstream (Fig. 2f). The concentration of Pb (Fig. 2g) decreases from upstream to downstream with values of 1.25mg.l^{-1} and 0.45mg.l^{-1} at Mpolongwe against 0.31mg.l^{-1} and 0, 25mg.l^{-1} in Eboundja. Concentration of Hg evolves in the same manner on the both sites. It decreases from upstream to downstream, with high values noted in Mpolongwe with 0.89mg.l^{-1} upstream and 0.22mg.l^{-1} downstream and in Eboundja. The concentration of Hg decreases from 0.65mg.l^{-1} upstream to 0.03mg.l^{-1} downstream (Fig. 2h). BOD_5 (Fig. 2i) evolves in the same direction as Pb concentration, with even higher values measured in Mpolongwé where it decreases from upstream (190mg.l^{-1}) to downstream (120mg.l^{-1}).

Composition and distribution of Ichthyofauna

In total, 1137 fishes grouped in nineteen (19) species among seventeen (17) genera and twelve (12) families were collected. 17 species were collected in Mpolongwe while Eboundja had 14 species. However, 12 species or 63.16% of all collected fishes were common to both sites. Garangidae, Clupeidae and Scianidae are the most represented families with three (03) species each followed by Polymenidae with two (02) species and eight (08) families (Ariidae, Cichlidae, Cynoglossidae, Drepaneidae, Monodactylidae, Mugilidae, Pomadasyidae and Trichuriidae) were represented by single species (Table 1). According to the occurrence of the nineteen species, five (05) species are rares, three (03) are occasionals, three (03) are frequents, five (05) are constants and three (03) are ubiquitous (Fig. 3).

Table 1. Fish composition and occurrence within the two sites.

Families	Species	Sites		Occurrence
		Eboundja	Mpolongwe	(%)
Ariidae	*Arius heudeloti* (Valenciennes, 1840)	+	+	20
	Alectis alexandrinus (Geoffray saint- Hilaire, 1817)	-	++	20
Carangidae	*Caranx hyppos* (Linnaeus, 1758)	++	+++	70
	Selene dorsalis (Gill, 1816)	++	+++	58
Cichlidae	*Oreochromis niloticus (*Gunther, 889)	+	-	12
	*Ethmalosa fimbriata (*Bowdich, 1825)	++	++	41
Clupeidae	*Ilisha africana* (Bowdich, 1825)	++	++	87
	Sardinella maderensis (Lowe, 1839)	++	+++	54
Cynoglossidae	*Cynoglossus sénégalensis* (Kaup, 1858)	++	+++	70
Drepaneidae	*Drepane africana (*Osori, 1892)	++	++	50
Monodactylidae	*Monodactylus sebea* (Cuvier, 1829)	-	+	8
Mugilidae	*Liza falcipinnis* (Valenciennes, 1838)	++	-	12
Pomadasyidae	*Pomadasys. jubelini* (Bowdich, 1825)	++	++	37
Polynemidae	*Galeoides decadactylus* (Bloch, 1795)	++	+++	75
	Pentanemus quinquarus (Linnaeus, 1758)	-	++	16
	Pseudotolithus canariensis (Valenciennes, 1843)	-	+	12
Scianidae	*Pseudotolithus senegalensis* (Valenciennes, 1833)	+++	+++	91
	Pseudotolithus typus (Bleeker, 1863)	+++	+++	95
Trichuiridae	*Trichuirus lepturus* (Linnaeus, 1758)	-	++	12

(-) Absent; (+) Rare; (++) Abundant; (+++) Most abundant

Table 2. Diversity indices of the two sites: A= total number of individuals; S= Number of species; R= Margalef index; H'= Shannon-Weaver index; N1 and N2= Hill diversity index; J= Pielou index.

Sites	A	S	R	H'	N1	N2	J'
Eboundja	383	14	1,51	3,53	34,28	10,28	0,93
Mpolongwe	754	17	1,67	3,66	39,09	10,61	0,89

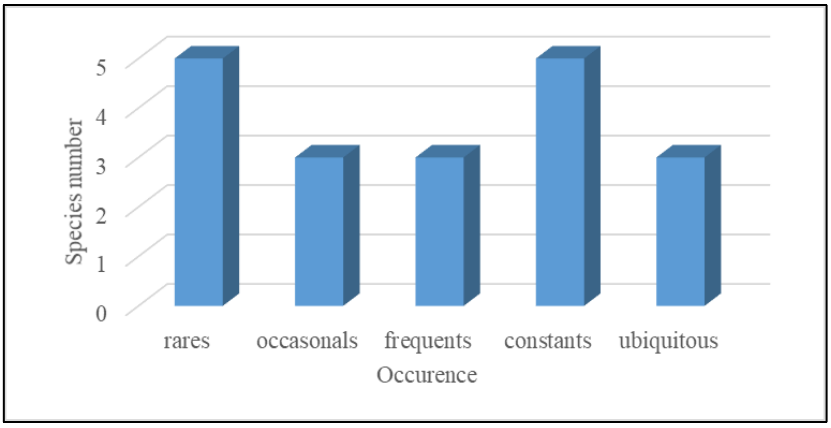

Fig. 3. Occurrence of all collected species.

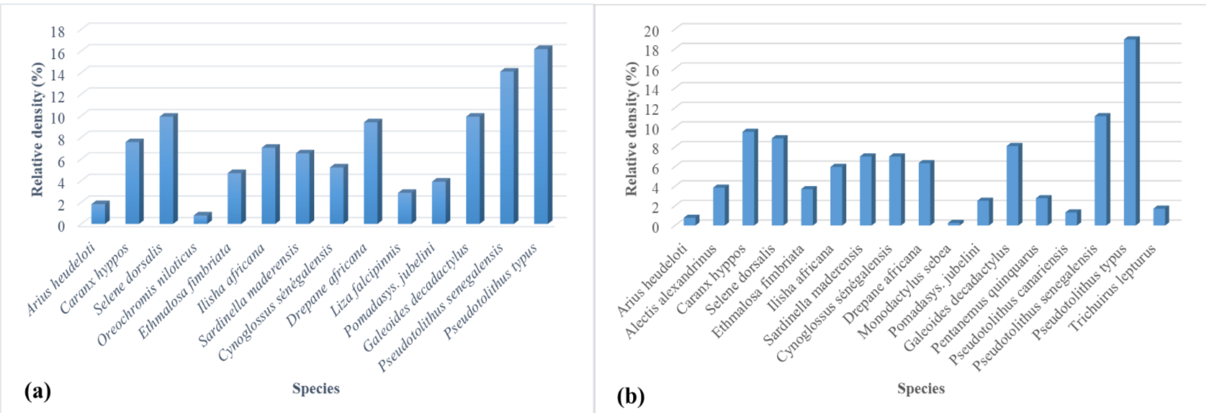

Fig. 4. Relative densities of ichtyofauna within the different sites: (a) Eboundja (b) Mpolongwe.

Fig. 4 below shows relative densities of collected fishes. *Pseudotolithus typus* and *Pseudotolithus senegalensis* were the species with the highest relative densities within the two sites respectively 16.18% and 14.09% in Eboundja, 18.96% and 11.14% in Mpolongwe. Whereas *Oreochromis niloticus* (RD = 0.78%) in Eboundja and *Monodactylus sebea* (RD = 0.26%) in Mpolongwe were the species with the lowest relative densities.

Margalef's species richness index (R), the Shannon-Weaver diversity index (H') and the two indices of Hill in the two sites were in order of Mpolongwe > Eboundja and Pielou eveness was high in Eboundja (J'= 0.93) than in Mpolongwe (J'= 0.89).

The PCA below (Fig. 5) shows main physico-chemical parameters that influences the distribution of the ichthyological diversity within the two sites. The species *O. niloticus* and *L. falcipinnis* were sensitives to salinity, total dissolved solids (TDS) and temperature. The second group consisting of *P. senegalensis, S. maderensis, A. heudoloti, P. jubelini, I. africana, C. hyppos, S. dorsalis, D. africana, G. decadactylus, C. senegalensis, P. typus* and *E. fimbriata* has shown an affinity to BOD_5, mercury and Lead and finally a third group composed of *alexandrinus, P. canariensis, P. quinquarus* and *T. lepturus has species* that were sensitives to pH.

Length size structure

Among all individuals of the ichtyofauna collected, *Oreochromis niloticus* was the species that has presented individual with the minimum length size (8cm) in Eboundja while in Mpolongwe, *Ilisha Africana* has presented the individual with à minimum length size (10cm).

The individuals with the higher length size in both site (41cm in Eboundja and 40.5cm in Mpolongwé) belonging to same species (*Pseudotolithus typus*). Most individuals had length sizes ranging from 5cm to 20cm (Fig. 6). In Eboundja, two species (*P. senegalensis and P. Typus*) had individuals in all length size classes, while *O. niloticus* has individuals only in the length size range of [10-15]cm (Fig. 6a). In Mpolongwe the species *Pseudotolithus typus* has individuals in all length size categories while *Monodactylus sebae* has a single individual within the length size class of [10-15]cm (Fig. 6b).

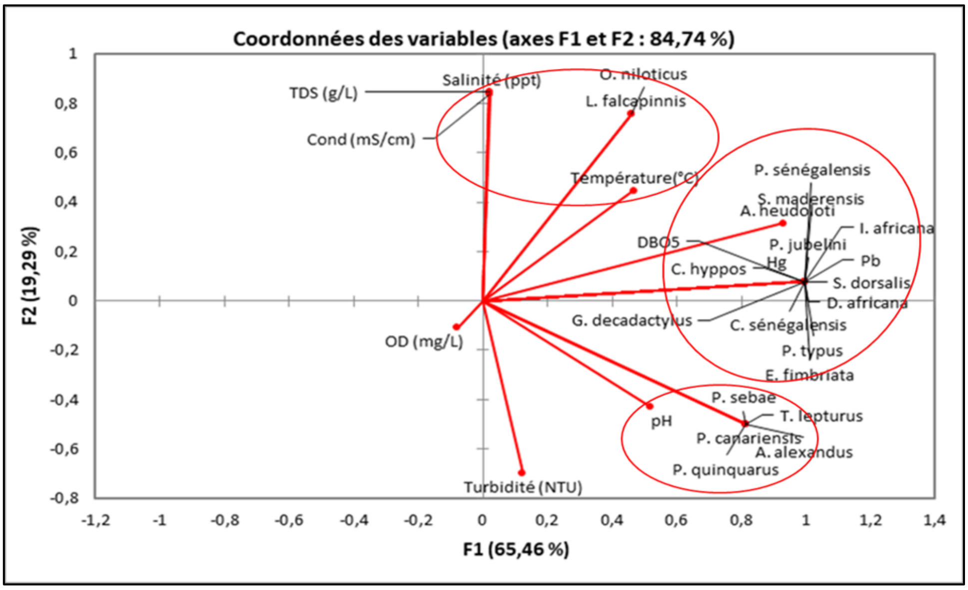

Fig. 5. PCA Showing correlation of the different species with the environmental parameters.

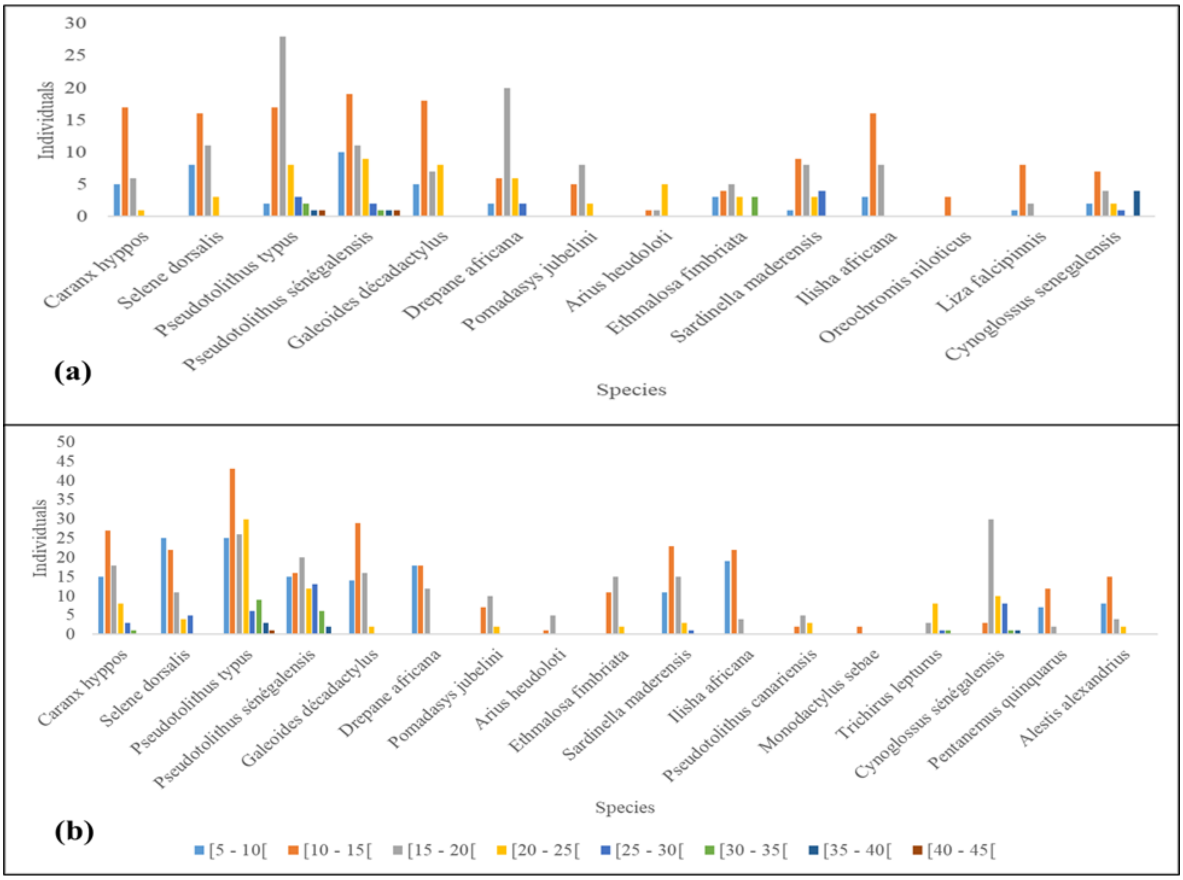

Fig. 6. Length size distribution among all collected fishes in two sites: (a) Eboundja; (b) Mpolongwe.

Discussion

Knowledge of the physico-chemical parameters of water is essential for the life of fish. According to Chikou *et al.* (2008), temperature and dissolved oxygen are the most important parameters for proper fish growth. In the present study, the average of temperature obtained from the two sites ranges between 26 – 28°C and they are within the optimum temperature range (23-31 °C) as proposed by Lalèyé *et al.* (2005) for favourable conditions that enhances the life of ichthyofauna in waterbodies and rivers. Thus, the mean temperature observed indicates that the water in these mangrove channels is relatively warm. The measured values from dissolved oxygen during sampling correspond to good quality water.

The pH of any natural water sometimes varies from 4 to 10 depending on the acidic or basic nature of the surrounding terrain. Often, very acidic pH indicates risk associated to the presence of toxic ions from heavy metals. On the other hand, high pH values, increases the concentrations of ammonia, which is toxic for fish. The obtained pH values from tidal channels within the range 6.5 and 8.5 characterizes optimal waters where life thrives. This pH values are similar to those obtained by Bilounga *et al.* (2020). The alkaline nature of surface water during the dry season is because of evaporation and as such tends to influence the oceanic waters.

Salinity is low with values ranging between 1.5 and 13.2 ppt at Eboundja and between 1 and 12.1 ppt at Mpolongwé. The low salinity is as result of the presence of many networks of small rivers flowing into these mangrove channels as well as the high precipitation within the study area, having approximately 3000mm of precipitation yearly.

The difference in salinity between the upstream and downstream is because of the fact that upstream always seems to have large quantities of freshwater arriving. The obtained BOD_5 from this study is well above the accepted threshold value that characterizes good quality river water, with values ranging 120 and 190mg.l^{-1}, which is more prominent in Mpolongwé as compared to Eboundja. This degradation is largely due to the amount of organic matter poured into the mangrove tidal channels.

According to the requirements of De Villier (2005), waters within these two mangrove tidal channels are of very poor quality. Heavy metals like Mercury and Lead, characterize certain types of pollution. Mercury in particular, can be release into nature either via natural routes or from chemical industries like textiles and dyes. Often, lead is associated with diffuse pollution (usually from road transport and misused industrial sites). We observed high levels of Mercury (0.89; 0.65 and 0.22mg.l^{-1}) and Lead (1.23; 0.45 and 0.31mg.l^{-1}) as compared to the ordinary standards for surface water, with the threshold value of mercury being 0.001mg/l and 0.05mg/l for lead (De Villier, 2005). The heavy metals found within the mangrove tidal channels of Mpolongwé and Eboundja, may be originating from a natural source either from the altering in bedrocks, erosion or atmospheric inputs. They can also be originating from anthropogenic sources such as agricultural practices, urban, domestic and livestock effluents, pesticides, municipal and industrial wastes.

Ichthyofauna of the different sites undertaken for this study shows great diversity which includes about 12 families, 17 genera that is divided into about 19 species. The specific composition varies from both sites. Whereas, the different species of fish found within these tidal channels usually go there for different reasons. There are certain species that spend almost their entire life cycle there for example *Monodactylus sebae*. Others spend part of their life cycle in this environment either to feed or for reproduction, it is the case for *Ethmalosa fimbriata, Ilisha africana* and *Liza falcipinnis*. While others like *Arius heudoloti, Sardinella maderensis* are only present during their larval or juvenile phases of their life and finally those that go there simply to feed themselves like the *Pseudotolithus senegalensis*. These results are similar to those of Gning (2008). These results are similar to the findings of Ndour *et al.* (2017) in the Marine Protected Area of Joal

Fadiouth in Senegal. The approach by which the different species occupy the space varies from family to family. Four families represent more than 50% of fishes found at Eboundja and the same in Mpolongwé. This result is contrary to Sarr *et al.* (2018), in the Marine Protected Area of Joal Fadiouth in Senegal, having sites where a single family represents more than 78% of the individuals like the case of Hemulidae. Size structure shows an abundance of small individuals with a low proportion of large individuals. Most of the fish found had size between 5 and 20cm, showing that they constitute essentially a breeding/ spawning and nurturing ground for juveniles and fish larvae. Mbock *et al.* (2020) study shows that size structure of fish landed in the 19 sampled sites on Littoral and South coast Cameroon regions is dominated by small individuals, with over 62.05% of the fish measured having a total length of less than 30cm. The large individuals of *Pseudotolithus senegalensis* and *Pseudotolithus typus* present in the catches enter for nutrition.

Conclusion

The present work on ichthyological diversity associated with two mangrove tidal channels, reveals similarities in these two sites, with the most abundant and frequent fish families include Scianidae, Carangidae, Clupeidae and Polynemidae, representing more than 50% of the total catches. The most abundant species within the samples included, *Pseudotolithus typus* (26.09%), *Pseudotolithus senegalensis* (12.30%), *Selene dorsalis* (9.27%), *Caranx hyppos* (8.88%) and *Galeoides decadactylus* (8.93%) and least abundant been *Mondactylus sebae* (0.66%). The different ecological indices used affirmed this trend. The following environmental parameters in particular, temperature, salinity, pH and turbidity, dissolved oxygen, TDS, conductivity, BOD_5, Pb and Hg, did play a vital role in influencing the distribution of ichthyofauna especially after the interpretation of the PCA. The results present very high values of Mercury and Lead in the waters around Mpolongwé, far exceeding the standards for the release of heavy metals into the aquatic environment, $0.89 mg.l^{-1}$ for Hg and $1.23 mg.l^{-1}$ for Pb. Thus, it is important to analyze factors influencing various environmental parameters that are key in affecting the distribution of fish within mangrove tidal channels in order for the development of a comprehensive integrated management plan.

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