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Impact of environmental features on the distribution of *Marcusenius* species (Pisces, Mormyridae) in Malebo Pool of Kinshasa in the Congo River

Jean Métis NTUMBA MABEDI[1,5*], Victorine MBADU ZEBE[1], Victor PWEMA KIAMFU[1], Lise-Marie PIGNEUR[2], Johan R. MICHAUX[2.3] and Jean-Claude MICHA[4,5]

[1]Laboratoire D'hydrobiologie, Faculté Des Sciences, Université de Kinshasa, Kinshasa, Congo.
[2]Laboratoire de Génétique de la Conservation, Université de Liège, Belgium.
[3]ASTRE, CIRAD, INRAE, F-34398 Montpellier, France.
[4]Unité de Recherche en Biologie Environnementale et Evolutive (URBE), Université de Namur, Belgium.
[5]Ecole Régionale Post Universitaire D'aménagement et Gestion Intégrée des Forêts et Territoires Tropicaux, Congo.

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The current anarchic exploitation of *Marcusenius* fish in the Malebo Pool located in the Congo River stands as a threat of extinction to certain species, while the ecology of most of them are hardly known. This study aims at evaluating the impact of environmental factors on the distribution of *Marcusenius* fish caught in six fishing stations in the Malebo Pool. Canonical correspondence analysis of environmental factors classified the stations into two groups, which differ in vegetation formation, bottom substrates, water current velocity, pH, suspended particles and in dissolved oxygen. Thus, the five stations located upstream and in the middle of the pool are characterized by low water current velocity, slightly acidic pH, bottom substrates composed of silt, plant debris, clay, silt and sand. The predominant *Echinocloa* and *Eichhornia* plant formations found in these sites provide shelter, food sources and impact on the distribution and abundance of seven *Marcusenius* species in Malebo pool. The rocky substrate of Kinsuka station associated with the plant formation dominated by *Ledermanniella* and *Pennisetum,* and a high-water current constitute a habitat that is not favourable for *Marcusenius* species.

Key words: Abundance, ecology, flora, *Marcusenius*, fishing, substrate, Malebo Pool.

INTRODUCTION

Currently, ichthyological resources are subject to anarchic exploitation in Malebo Pool by fishermen from several fishing camps along the River in Kinshasa, such as Ngamanzo, Kimpoko, Kinkole, Kingabwa and Kinsuka pêcheur. These camps are crowded areas exerting great pressure on the aquatic environment (Tembeni et al., 2019), and constitute a threat of extinction to most of the species whose ecology is little known. Knowledge of the

*Corresponding author. Email: mabedi.ntumba@gmail.com. Tel. 00243827300897.

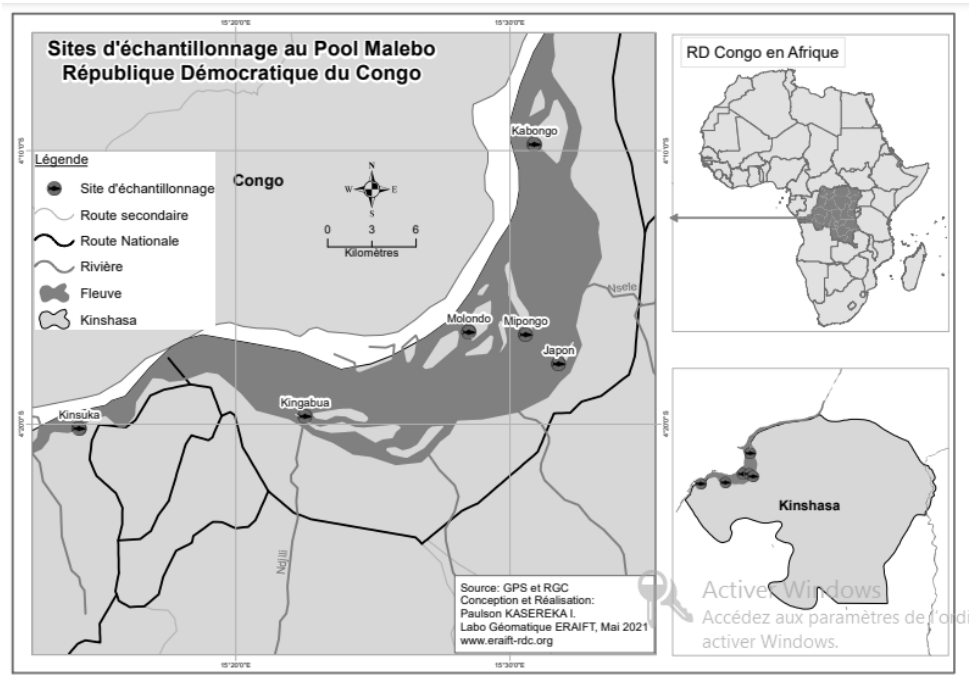

Figure 1. Map of the Malebo Pool Congo River showing the 6 sampling sites for *Marcusenius* fish from July 2010 to June 2021.

ecology of species is essential to ensure proper management of fisheries resources. It is the basis for the understanding of their dynamics population and life history strategies (Tembeni et al., 2019). The rational exploitation and conservation of this fishery resource in Malebo Pool can be properly planned (Zango et al., 2016). Fishes of the Mormyridae family are not exempted from this pressure. Mormyridae are nocturnal with small eyes covered by a thick skin and generally live in murky, dark and muddy waters. They have electrical organs of muscular origin located in their caudal peduncles that emit electrical signals to locate prey, objects and communicate with other species (Stiassny et al., 2007, Decru et al., 2019). This family, which is particularly diversified in Malebo Pool, represents 20 to 22% of the catches using passive nets after 12 h a day of fishing effort (Mbadu, 2010). These fishes are divided into 12 genera and 47 species, 8 of which belong to the genus *Marcusenius* (Kramer et al., 2016; Manda et al., 2018; Tembeni et al., 2019).

Most of the studies done on fishes of the genus *Marcusenius* have been mainly devoted to taxonomic and systematic aspects (Adjibade et al., 2020; Stiassny et al., 2007; Maake et al., 2014; Decru et al., 2016; Kisekelwa et al., 2016; Decru et al., 2019) and few to biological aspects (Lévêque and Paugy, 2006; Amira et al., 2019; Ndinga et al., 2021; Seraphin et al., 2022). However, there have been no in-depth studies on ecology on these species of the genus *Marcusenius* living in Malebo Pool. Suggestions were made therefore, to study and classify the habitats of the seven species of the genus *Marcusenius* (*M. macrolepidotus, M. monteiri, M. schilthuisiae, M. stanleyanus, M. greshoffii, M. moorii and M. fuscus*) out of the eight cited by Hanssens et al. (2008), living together in Malebo Pool, which would contribute to a better understanding of this high diversity in this large section of the Congo River.

MATERIALS AND METHODS

Study sites

The study was conducted in Malebo Pool which is located on the lower middle reaches of the Congo River between Kinshasa and Brazzaville at 4°20' South latitude and 15°30' East longitude (Figure 1). It belongs to the ichthyo-geographic province of Congo (formerly Zaire) which contains the entire Congo River basin, Lake Tanganyika and Lake Kivu (Lévêque and Paugy, 2006).

Fish sampling and identification

The fish samples were collected using the passive gillnet fishing technique organized once a month from July 2020 to June 2021, during the dry and rainy seasons in six sites: Kabongo, Mipongo, Molondo, Japon, Kingabwa and Kinsuka (Figure 1). To limit the biasness of the selectivity of gillnets (Carvalho and Tejerina-Garro, 2015) a battery of nets with mesh sizes of 15, 25, 35, 50, 80 and 100 mm between nodes, 50 to 100 m long and 1 to 2 m high was used. After every fishing campaign, Mormyridae fish were separated from the other species and grouped by genus and identified using the key of Stiassny et al. (2007). Species of the genus *Marcusenius* were identified using the key of Boden (Decru et al., 2016).

Measurement of environmental variables

For every field trip, environmental factors were measured at each station. The fishing stations were georeferenced using a Garmin map 62 st GPS. Surface water temperature, pH, conductivity, salinity and turbidity were measured in the field using a multi-parameter Oyster series, pH/Conductivity/TDS/Salinity/ORP Meter 341350 A. Turbidity was measured using the Secchi disk. Water depth was measured using the Math Dip device. Water current velocity was measured by timing the movement of a 0.5 L plastic bottle half full of water over a 7 m distance (Djidohokpin et al., 2017). Dissolved oxygen was measured using the Dissolved oxygen meter AZ 8403. Water samples were collected for the laboratory analysis of Ca^{+2}, Mg^{+2}, K^{+}, SO_4^{-2}, PO_4^{-3} and NO_3^{-} using a spectrometer Hach DR 2400.

Substrate analysis and characterisation of aquatic vegetation

Substrates collected from each station were sent to the University of Kinshasa, Faculty of Agricultural Sciences' soil laboratory for particle size analysis based on Pauwels method (Mulaji et al., 2016). 100 g of each dried sample was mechanically sieved from different trunks. The quantity retained on every sieve was weighted on a 0.0001 g precision analytical balance (Orhus®). The characteristic plant species of every fishing site were collected and identified based on the APG system (Angiosperm Phylogeny Group) in collaboration with the botanists at the UNIKIN Herbarium. Observation of the plant formations made it possible to establish the list of species present in every site and quantitative evaluation based on the scale of abundance-dominance of Braun-Blanquet (Mucina et al., 2016). Subsequently, the abundance-dominance coefficients of the dominant species (0; 1; 2; 3; 4 and 5) corresponding respectively with a partial or total cover (< 1%, 1-5%, 5-25%, 25 - 50%, 50 - 75%, 75 - 100%) were recorded using Excel® file along with the other environmental parameters. The resulting table was imported into Past Version 2.17c Software for analysis.

Statistical processing

Canonical correspondence analysis

Canonical Correspondence Analysis was performed using Past version 2.17c software in order to identify the stations that have similar environmental features. These features can explain the distribution of fish species of the genus *Marcusenius* in different stations (Tessier et al., 2016).

Species diversity indices of Mormyridae and Marcusenius

At the end of every fishing campaign, the list of species of genus *Marcusenius* caught including the total number of fish was established. To categorize this set of *Marcusenius* in Malebo Pool, several diversity indices were evaluated. Shannon diversity index "H'" (Tembeni et al., 2019) is expressed by the following relation:

$$H' = -\sum_{i=1}^{m}\left(\left(\frac{n_i}{N}\right)\times \log_2\left(\frac{n_i}{N}\right)\right)$$

ni = number of individuals of taxon i; N = total number of individuals in the community. Equitability (E, R or J'): Its mathematical relationship is: $E = H'/\log_2 S$. In this expression H' = Shannon index, S = species richness (Tembeni et al., 2019).

According to Tshijik et al. (2016), this index can vary from 0 to 1. It is maximal when the species have identical abundances in the population and minimal when a single species dominates the entire population.

Regardless of the species richness, it is very helpful to compare potential dominance between the stations and the sampling dates. For this, the Simpson's diversity index is used:

$D = \Sigma\, fi^2$.

Whereby fi = ni/N and N the total number of ni individuals of the given species. 1 stands for maximum diversity and 0 for minimum diversity.

For the purpose of this study, these indices were calculated using Past version 2.17c and Microsoft Excel 2010 software.

RESULTS

The results summarized in Table 1 show that the average pH of the water varies between 6.2 and 6.8, and temperature between 27.6 and 28.2 °C. The water depth measured at the locations where the nets were set varied from 219.1 ± 32.0 to 416.5 ± 73.3 cm. Dissolved oxygen varies between 5 -7 $mg.l^{-1}$ for Kabongo, Mipongo, Japan, Molondo and Kingabwa stations, where water current velocity varies between 0.20 and 0.38 $m.s^{-1}$. The highest dissolved O_2 (8.03 $mg.l^{-1}$) was recorded at Kinsuka with water velocities around 0.45 $m.s^{-1}$. Substrate analysis showed that Kabongo, Mipongo and Molondo stations are characterized by a high amount of silt, plant debris and less sand compared to Japan and Kingabwa stations. Kinsuka station is located on a substrate composed of rocks, gravel and sand. The results summarized in Table 2 showed that floristic inventory carried out in the six fishing stations showed the presence of 32 plant species belonging to 21 families. Kabongo, Mipongo and Molondo stations were colonized by *Echinocloa pyramidalis, Cyclosorus gongylodes, Salvinia molesta, Comelina diffusa* and *Ipomoea aquatic*, in addition to the species found in all the fishing stations. *Polygenum lanigerum, Eichhornia crassipes, Ludwigia abissineca*. Kingabwa and Japon stations were colonized by *Salvinia molesta, Alternanthera sessilis,* and *Cyperus papyrus* in addition to the species found in all the tations. These plant formations are dominated by *Echinocloa pyramidalis* and *Eichhornia crassipes.* The banks of Kinsuka station were colonized by a special vegetation formation dominated by the *Pennisetum retens* and *Ledermanniella tenuissima* species. It was also dominated by several other species identified in the other stations: *Pennisetum retens, Pennisetum nodiflorun, Aechinomenum sensiva, Phyllanthus muellerianus* and *Stachytarpheta indica.* Total *Marcusenius* species sample in Malebo Pool is shown in Table 3.

A total of 403 *Marcusenius* belonging to 7 species were caught with gillnets in Molondo and Mipongo stations, which are respectively the first and second most

Table 1. Physico-chemical characteristics of the water (mean with standard deviation) and substrates (%) of the six Malebo Pool fisheries stations.

Parameter/station	Kabongo	Mipongo	Japon	Molondo	Kingabwa	Kinsuka
Water temperature (°C)	27.9±1.2	27.6±0.9	28.2±1.1	28.1±1.3	27.7±1.1	28.2±0.9
pH	6.7±0.3	6.4±0.1	6.3±0.1	6.2±0.2	6.6±0.3	6.8±0.3
Conductivity (µS/cm à 25°c)	22.7±1.1	21.7±1.4	22.4±1.4	22.1±1.5	26.7±2.3	23.9±2.0
Salinity ($mg.l^{-1}$)	11.6±0.8	11.4±0.7	11.8±0.8	12.1±0.6	13.0±1.0	12.3±1.3
Turbidity ($mg.l^{-1}$)	14.9±0.9	13.2±1.0	13.6±1.6	14.4±1.1	14.5±1.02	14.1±0.8
Transparency (cm)	49.1±3.1	47.7±2.9	49.4±3.8	48.6±2.7	47.5±2.2	48.5±2.5
Depth (cm)	416.5±73.3	312.7±49.5	219.1±32.0	329.6±5	206.0±23.4	187.9±16.3
Water speed ($m.s^{-1}$)	0.38± 0.04	0.25±0.02	0 .27±0.02	0.20±0.04	0.29±0.03	0.45±0.02
Dissolved O_2 ($mg.l^{-1}$)	7.40±0.50	6.11±0.54	5.9±048	5.97±0.58	6.07±0.54	8.03±0.60
Mg^{++} ($mg.l^{-1}$)	1.37±0.3	1.49±0.4	1.62±0.32	1.52±0.3	1.35±0.3	1.67±0.4
Ca^{++} ($mg.l^{-1}$)	0.19±0.1	0.36±0.4	0.49±0.35	0.23±0.2	0.24±0.9	0.42±0.3
NO_3^- ($mg.l^{-1}$)	0.14±0.1	0.17±0.4	0.24±0.18	0.12±0.1	0.23±0.1	0.18±0.5
PO_4^{-3} ($mg.l^{-1}$)	1.14±0.3	1.09±0.4	1.06±0.34	1.30±0.2	1.37±0.4	1.31±0.3
SO_4^{-2} ($mg.l^{-1}$)	1.02±0.4	1.25±0.6	1.1±0.58	0.59±0.3	0.92±0.6	1.23±0.5
Substrates (%)	**Kabongo**	**Mipongo**	**Japon**	**Molondo**	**Kingabwa**	**Kinsuka**
Plant debris	5.03	7.53	2.81	6.45	3.01	0.88
Sand	29.61	34.15	46.55	32.09	44.16	7.5
Silt	14.05	15.02	17.09	18.10	16.24	0
Clay	37.6	28.11	23.9	27.15	24.69	0
Vase	13.71	15.21	9.65	16.21	11.9	0
Gravel	0	0	0	0	0	2.3
Rock	0	0	0	0	0	89.32
Total	100.00	100.02	100.00	100.00	100.00	100.00

Table 2. Aquatic and semi-aquatic plant families and species identified in the six Malebo Pool fishing stations from July 2020 to June 2021.

No.	Family	Species	Kabongo	Mipongo	Japon	Molondo	Kingabwa	Kinsuka
1	*Aracaceae*	*Pistia stratiotes* L.	+	+	+	+	+	+
		Salvinia molesta D.S.Mitchell	+	+	+	+	+	-
		Colocasia esculenta L.	+	-	-	+	-	-
2	*Amarentaceae*	*Alternanthera sessilis* L.Peter	+	+	+	-	+	-
3	*Asteraceae*	*Ethulia conizoides* L.	+	-	-	-	-	-
4	*Boraginaceae*	*Heliotropium indicum* L.	-	-	-	-	+	-
5	*Comelinaceae*	*Comelina diffusa* Burm. F.	+	+	+	+	-	-
6	*Convolvulaceae*	*Ipomoea aquatica* Forsk	+	+	+	+	-	-
7	*Cyperaceae*	*Cyperus divers* L.	-	-	-	-	+	-
		Cyperus papirus L.	+	-	+	-	+	-
		Fimbristylis hispidule Vahl	-	-	-	-	+	-
8	*Fabaceae*	*Aechinomum sensitiva* Swartz	+	-	+	-	-	+
		Aeschynomene fluitans Peter	-	+	-	-	-	-
9	*Gisekiaceae*	*Gisekia pharnaceiodes* L.	-	+	+	-	-	-
10	*Nymphaeaceae*	*Nymphaea lotus* L.	+	-	-	+	-	-
11	*Onacraceae*	*Ludwigia abissineca* A.Rich	+	+	+	+	+	+
		Ludwigia leptocarpa (Nutt) H.Hara	-	-	-	+	-	-
		Ludwigia gradifolia (Michx.)Greuter & Burdet	-	+	-	-	-	-
12	*Poaceae*	*Echinocloa pyramidalis* L.	+	+	+	+	-	-

Table 2. Contd.

		Leersia hexandra (Sw)	-	-	-	+	-	-
		Pennisetum nodiflorum Franch.	-	-	-	-	-	+
		Pennisetum retens L.	-	-	-	-	-	+
		Panicum repens L.	-	-	-	-	-	+
13	*Phyllanthaceae*	*Phyllanthus muellerianus* (Kunte) Exell	-	-	-	-	-	+
14	*Podostemaceae*	*Ledermanniella tenuissima* (Hauman) C.Cusset	-	-	-	-	-	+
15	*Polygonaceae*	*Polygonum lanigerum* R. Br.	+	+	+	+	+	+
16	*Pontederiaceae*	*Eichhornia crassipes* (Mart.) Solms	+	+	+	+	+	+
17	*Rubiaceae*	*Oldenlandia affinis (*Roem et Schult.)	-	+	-	-	-	-
18	*Sapndaceae*	*Cardiospermum sp*	+	-	-	-	-	-
19	*Selaginellaceae*	*Selaginella myosurus* L.	-	-	-	+	-	-
20	*Thelipteridaeae*	*Cyclosorus gongylodes* (Schkuhr) Link	+	-	-	-	-	-
21	*Verbenaceae*	*Stachytarpheta indica* (L.) Vahl	-	-	-	-	-	+
	Species by site		15	13	12	13	10	11
	Families per site		13	11	11	9	7	9
	Overalll species	32						
	Overall family	21						

important in terms of number of specimens (119 and 93). *M. fuscus* species were also found in the above mentioned stations. *M*. *monteiri* species were caught in three fishing stations, namely, Kabongo, Mipongo and Molondo. Two specimens of *M*. *stanleyanus* were collected in Kinsuka station. Diversity index values calculated for *Marcusenius* species caught are listed in Table 4 which also shows that *Marcusenius* fish species were not evenly distributed in the stations studied. The species diversity of *Marcusenius* in Kabongo, Mipongo, Molondo Japon and Kingabwa stations, and the Simpson index have values close to 1. These species have an almost equal distribution in Mipongo, Molondo and Kabongo (H' between 1.6 and 1.8) and an equal repair in Japon and Kingabwa (H' around 1.5). For the Shanon Diversity index, H' = 0 at Kinsuka with all the collected specimens belonging to the M*. stanleyanus* species. The Equitability index is also maximal in the five stations mentioned with an identical abundance in the stand and strong structural stability (values > 0.8) of the communities. The correlation between environmental features, bottom substrates and the presence of *Marcusenius* species is visualized in Figure 2, which is a representation of the environmental features of the six fishing stations on both plans:

Cycl: Cyclosorus gongylodes
Lud: Ludwigia
Ech: Echinocloa pyramidalis
Eich: Eichhornia crassipes
Ipo: Ipomoea aquatica
Led: Ledermanniella tenuissima
Pen: Pennisetum
T°: temperature
pH: hydrogen potential
cond: electrical conductivity
Ppm: particles in suspension
Trans: transparency
Oxy: dissolved oxygen
K^+: Potassium
Ca^{2+}: Calcium
Mg^{2+}: Magnesium
$PO4^{3-}$: Phosphate
$NO3^-$: Nitrate
$SO4^{-2}$: Sulphate
Prof: depth
Vit: water current speed
Veg: plant debris
Sab: sand
Lim: silt
Arg: clay
Grav: gravel
Roc: rock
Sal: salinity
Kab: Kabongo
Kins: Kinsuka
Jap: Japan
Mol: Molondo
Mip: Mipongo
Kab: Kabongo
Kins: Kinsuka

Kinsuka station is positively correlated with axis 1 and is different from the other stations by its rocky and gravelly substrate associated with a plant formation dominated by species of the genera *Pennisetum* and *Ledermanniella*; high temperature and water velocity, and high O_2 concentration. Kabongo station is positively correlated with axis 1 because of its depth. Japon and Kingabwa stations are negatively correlated with axis 1 for sand and

Table 3. Overall of the seven *Marcusenius* species sample caught in gillnets in the six fishing stations in Malebo Pool from July 2020 to June 2021.

Species	Station							
	Kabongo	Mipongo	Molondo	Japon	Kingabwa	Kinsuka	No. of specimens	Relative Abundance (%)
M. schilthuisiae	9	21	25	8	20	0	83	20.6
M. stanleyanus	13	22	29	19	16	2	101	25.1
M. monteiri	22	14	18	0	0	0	54	13.4
M. macrolepidotus	8	13	21	15	17	0	74	18.4
M. greshoffii	6	9	8	11	5	0	39	9.6
M. moorii	2	8	14	8	10	0	42	10.4
M. fuscus	0	6	4	0	0	0	10	2.5
Total (%)	60 (14.9)	93 (23.1)	119 (29.5)	61(15.1)	68 (16.9)	2 (0.5)	403 (100)	

Table 4. Index values for *Marcusenius* species caught with gillnets at six stations in Malebo Pool from July 2020 to June 2021.

Index	Kabongo	Mipongo	Molondo	Japon	Kingabwa	Kinsuka
Taxa_S	6	7	7	5	5	1
Individuals	60	93	119	61	68	2
Simpson_1-D	0.77	0.83	0.82	0.78	0.77	0
Shannon_H'	1.60	1.85	1.81	1.55	1.52	0
Equitability_J	0.89	0.95	0.93	0.96	0.95	0

silt. Mipongo and Molondo stations are close and negatively correlated with axis 1 for silt, plant debris, low water velocity and less sand. *Echinocloa* and *Eichhornia* dominated plant formations are all positively correlated with axis 1 in the five stations other than Kinsuka. The canonical correspondence analysis performed between abiotic features, plant flora and species of the genus *Marcusenius* is shown in Figure 3.

Representation of species and environmental features of six fishing stations on both plans: *M. monteiri*, *M. stanleyanus*, *M. macrolepidotus* and *M. schilthuisiae*, *M. fuscus*, *M. greshoffii* and *M. moorii* species are negatively correlated with axis 1 whose plant formations are dominated by the *Echinocloa pyramidalis* and *Eichhornia crassipes* species. These plant formations are fixed on the bottom substrates, made up of plant debris, sand, clay and mud.

DISCUSSION

Physico-chemical features of the water

Variation in mean water temperature can impact the abundance and temporal distribution of fish species (Mahamba et al., 2018). Mean temperatures measured ranged from 27.6 to 28.2°C. Low temperatures were recorded during the dry season and high temperatures during the rainy season but do not justify a heterogeneous distribution of *Marcusenius* species. Generally, it is a small fluctuation of the water temperature under the influence of the air temperature. The pH measured in all the stations is slightly acidic and close to neutral. It varies from 6.2 to 6.8. The lowest values were recorded in Molondo station, while the highest values were recorded in Kinsuka. This is probably due to the proximity between Molondo station and Mbamu Island with a forest flap and the dead leaves could lower the pH and produce macro invertebrates which some *Marcusenius* species consume. On the contrary, the slightly higher values observed in Kinsuka could be related to the enormous wastes from NDjili River, Funa River and the industries close to the Kingabwa fishing station presented in Figure 1. It is also the reason electrical conductivity of these waters in Kingabwa is slightly higher (26.7 $\mu S.cm^{-1}$) compared to Molondo and Mipongo stations (22.1 $\mu S.cm^{-1}$). Given that dissolved oxygen is an ecological factor that can impact the distribution of Mormyridae fish, its variation impacts the species distribution (Tessier et al., 2016). Dissolved O_2 values measured at all stations varied between 5.9 - 8 $mg.l^{-1}$, but the highest values were observed in Kinsuka.

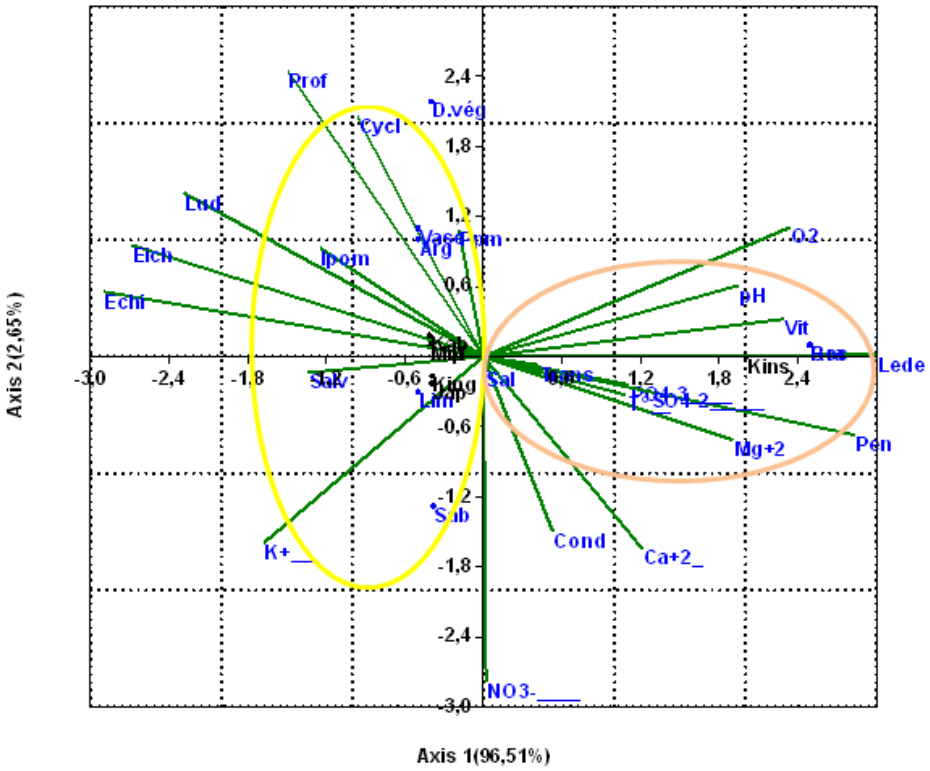

Figure 2. Canonical correspondence analysis plot of environmental features and *Marcusenius* fishing stations at Malebo Pool.
sch: M. schilthuisiae, sta: M. stanleyanus mo: M. monteiri, *ma: M. macrolepidotus, gr: M. greshoffii, moor: M. moorii, fus: M. fuscus, Cycl: Cyclosorus gongylodes, Lud: Ludwigia, Ech: Echinocloa pyramidalis, Eich: Eichhornia crassipes, Ipo: Ipomoea aquatic, Led: Ledermanniella tenuissima, Pen: Pennisetum.* T°: Temperature, pH: hydrogen potential, cond: electrical conductivity, Ppm: particles in suspension, Trans: transparency, Oxy: dissolved oxygen, K^+: potassium, Ca^{2+}: calcium, Mg^{2+}: magnesium, PO_4^{3-}: phosphate, NO^{3-}: nitrate, SO_4^{-2}: sulphate, Prof: depth, Vit: water current speed, Veg: plant debris, Sab: sand, Lim: silt, Arg: clay, Grav: gravel, Roc: rock, Sal: salinity, Kab: Kabongo, Kins: Kinsuka, Jap: Japon, Mo: Molondo, Mip: Mipongo.

This station is characterized by high water velocity (0.45 $m.s^{-1}$), favouring water mixing and very good oxygenation. The greatest depths were recorded in Kabongo, Molondo and Mipongo. Shallow depths were recorded in Kinkole, Kingabwa and Kinsuka. These depths impacted the distribution of specimens in the different fishing stations. Small specimens were caught at shallow depths while large specimens at high depths. Water current speed is undoubtedly one of the essential features underlying the plant and animal population distribution (Mahamba et al., 2017).

Habitat features

The five stations located upstream and in the middle of the pool are characterized by weak water current, plant formations with predominantly *Echinocloa pyramidalis* and *Eichhornia crassipes*; and substrates consisting of silt, plant debris, clay and silt. Distinctively, Kinsuka station has high-water current, plant formation with predominantly *Penisetum* and *Ledermanniella*; a rocky, gravelly and sandy substrate. The nature of this substrate was also observed by Pwema et al. (2011). Vegetation plays an important ecological role in the formation of micro-habitats, substrate modification and maintenance of physico-chemical features. These micro-habitats are resources for invertebrate development, the main food for Mormyridae fishes (Tessier et al., 2016) and Mahamba et al., 2017).

Distribution of *Marcusenius* in Malebo Pool habitats

Concerning the distribution of the seven *Marcusenius* spp in the pool, results showed that they are not uniform. This

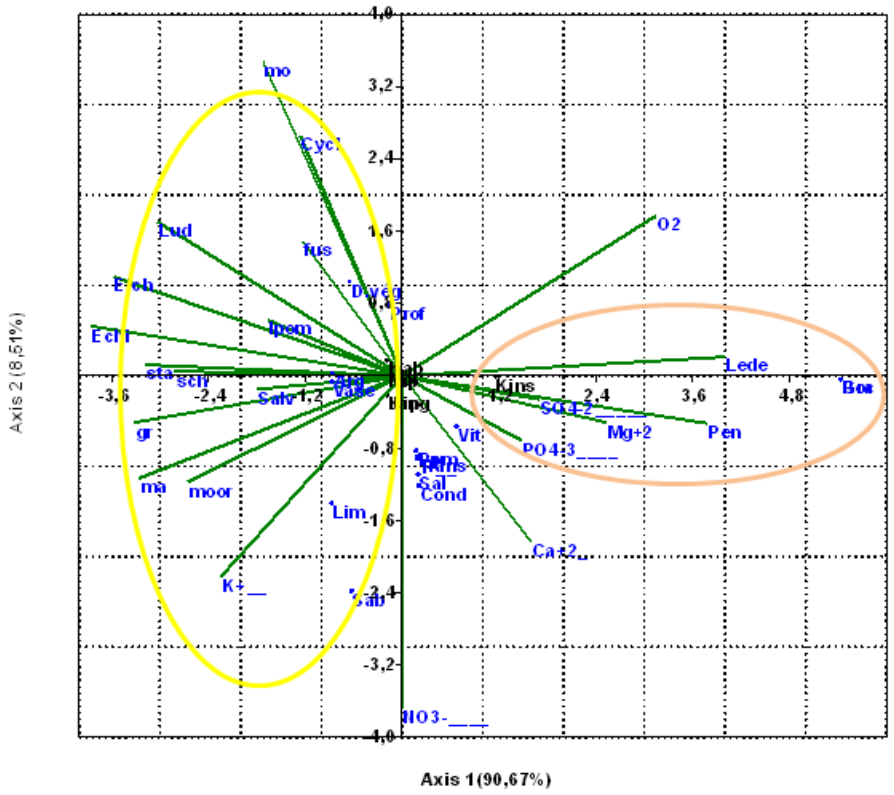

Figure 3. Canonical correspondence analysis plot of environmental features, fishing stations and *Marcusenius* presence at Malebo Pool.
sch: M. schilthuisiae, sta: M. stanleyanus mo: M. monteiri, *ma: M. macrolepidotus, gr: M. greshoffii, moor: M. moorii, fus: M. fuscus, Cycl: Cyclosorus gongylodes, Lud: Ludwigia, Ech: Echinocloa pyramidalis, Eich: Eichhornia crassipes, Ipo: Ipomoea aquatic, Led: Ledermanniella tenuissima, Pen: Pennisetum.* T°: Temperature, pH: hydrogen potential, cond: electrical conductivity, Ppm: particles in suspension, Trans: transparency, Oxy: dissolved oxygen, K^+: potassium, Ca^{2+}: calcium, Mg^{2+}: magnesium, PO_4^{3-}: phosphate, NO^{3-}: nitrate, SO_4^{-2}: sulphate, Prof: depth, Vit: water current speed, Veg: plant debris, Sab: sand, Lim: silt, Arg: clay, Grav: gravel, Roc: rock, Sal: salinity, Kab: Kabongo, Kins: Kinsuka, Jap: Japon, Mo: Molondo, Mip: Mipongo.

seems to be influenced by environmental features that characterize each site. Hence, according to these features, Malebo Pool ecosystem is subdivided into two sub-systems:

1. The lentic environment which includes Kabongo, Kinkole, Kingabwa, Mipongo and Molondo stations. This sub-system is characterized by weak water currents, muddy substrate, less sand and clay, and vegetation dominated by *Echinocloa* and *Eichhornia*. The nature of the bottom substrates impacts the distribution of plant formations which characterizes each station; it depends on these habitats and constitutes essential food resources for *Marcusenius* spp. *Marcusenius* prefer and live in this lentic subsystem of Malebo Pool. These stations are also characterised by dark waters with low transparency and mud with plant debris. These results agree with those of Stiassny et al. (2007) and Decru et al. (2019) that Mormyridae are nocturnal and generally live in dark, muddy, turbid waters.
2. The lotic environment located downstream of Malebo Pool includes Kinsuka station. It is characterized by high-water velocity, rocky substrate associated with poor flora. These features are probably the basis for the scarcity of *Marcusenius* species in the lotic subsystem of Kinsuka.

Marcusenius can thrive in a variety of environments (lakes, rivers, streams) with a preference for the lotic environment from which they originate (Hopkins, 1986); these environments provide the necessary habitat and food resources for their survival. In Malebo Pool, the lotic environment (Kinsuka site) is made up of habitats where

the substrate does not favour the development of vegetation under which prey can grow. That is why these fishes live in specific types of environment.

Conclusion

The analysis of the correlation between the characteristic environmental features of the six fishing stations in Malebo Pool and the seven species of fish of the genus *Marcusenius* investigated showed that the six fishing stations are divided into two groups based on the similarity of the environmental features analysed. These two groups differ from one another by the nature of substrate, characteristics of plant formations and speed of water current. These distinctive features affect the distribution and abundance of the seven *Marcusenius* species found in Malebo Pool.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interest.

REFERENCES

Adjibade KN, Adite A, Arame H, Chikou A, Abou Y (2020). Aspects of life-history strategy of *Marcusenius senegalensis* (Pisces: Osteoglossiformes: Mormyridae; Steindachner, 1870) from Niger River in Northern Benin. International Journal of Forest, Animal and Fisheries Research 4(1):1-13.

Amira S, Alioua Z, Harchouche K (2019). Gonadal development and fecundity of bogue Boops boops (Linnaeus, 1758) (Sparidae) on the central Algerian coast. Turkish Journal of Zoology 43(1):12-29.

Carvalho RA, Tejerina-Garro FL (2015). Environmental and spatial processes: what controls the functional structure of fish assemblages in tropical rivers and headwater streams? Ecology of Freshwater Fish 24(2):317-328.

Decru E, Moelants T, De Gelas K, Vreven E, Verheyen E, Snoeks J (2016). Taxonomic challenges in freshwater fishes: A mismatch between morphology and DNA barcoding in fish of the north-eastern part of the Congo basin. Molecular Ecology Resources 16(1):342-352.

Decru E, Sullivan P, Vreven E (2019). *Marcusenius wamuinii* (Teleostei: Mormyridae), a new elephant fish from the Mangrove national park, Democratic Republic of Congo. Ichthyological Exploration of Freshwaters 29(3):223-237.

Djidohokpin G, Sossoukpe E, Bokossa HK, Tamesse JL, Fiogbe ED (2017). Spatial and Seasonal Characterization of the Physico-Chemical Quality of the Water of the Tovè River in the Southern Benin (West Africa). International Journal of Pure and Applied Bioscience 5(3):23-36.

Kisekelwa T, Boden G, Snoeks J, Vreven E (2016). *Marcusenius kaninginii* a new species of elephant fish from the Lowa River basin, Democratic Republic of the Congo (Osteoglossiformes : Mormyridae). Ichtyological Explorations of Fresh waters 26(4):341-352.

Kramer LB, Van der Bank FH, Wink M (2016). *Marcusenius desertus* sp. nov.(Teleostei: Mormyridae), a mormyrid fish from the Namib desert. African Journal of Aquatic Science 41(1):1-18.

Lévêque C, Paugy D (2006). Les poisons des eaux continentales africaines: Diversité, écologie, utilisation par l'homme), IRD, Paris P 564.

Maake PA, Gon O, Swartz ER (2014). Descriptions of three new species of *Marcusenius* Gill, 1862 (Teleostei: Mormyridae) from South Africa and Mozambique. Zootaxa 3780(3):455-480.

Mahamba BR, Ndjaki NJ, Kankonda BA, Ulyelali-Patho J, Micha JC (2017). Caractérisation et écologie des peuplements des Mormyridae dans la réserve de Yoko (Kisangani, RD Congo). International Journal of Biological and Chemical Sciences 11(3):967-999.

Mahamba BR, Kangela KV, Kankonda BA, Ulyel APJ, Micha JC (2018). Etude des peuplements ichtyologiques des rivières Yoko et Biaro (Réserve de Yoko, Province Tshopo, RD Congo). Revue Scientifique et Technique Forêt et Environnement du Bassin du Congo-RIFFEAC 11:49-65.

Carvalho RA, Tejerina-Garro FL (2015). Environmental and spatial processes: what controls the functional structure of fish assemblages in tropical rivers and headwater streams? Ecology of Freshwater Fish 24(2):317-328.

Manda BK, Snoeks J, Manda AC, Vreven E (2018). Hidden species diversity in *Raiamas salmolucius (Teleostei: Cyprinidae) f*rom the Congo basin: two new species based on morphometric evidence. Ichthyological Exploration of Freshwaters/IEF 1066:1-19.

Mbadu ZV (2010). Diversité des espèces du genre *Distichodus* du Pool Malebo (Fleuve Congo) et mécanismes d'exploitation de leurs niches trophiques. Thèse de Docteur en Sciences, Université de Kinshasa, Faculté des Sciences, Kinshasa-RD. Congo 352 p.

Mucina L, Bültmann H, Dierben K, Theurillat JP, Raus T, Čarni A, Tichý L (2016). Vegetation of Europe: hierarchical floristic classification system of vascular plant, bryophyte, lichen, and algal communities. Applied Vegetation Science 19:3-264.

Mulaji C, Disa-Disa P, Kibal I, Culot M (2016). Diagnostic de l'état agro pédologique des sols acides de la province de Kinshasa en république démocratique du Congo (RDC). Comptes Rendus Chimie 19(7):820-826.

Ndinga ABM, Kiamfu VP, Swana WL, Eyul'anki DM, Bibuya SIN (2021). Diversité Ichtyologique de la Forêt Marécageuse Inondée du Réseau Hydrographique du Lac Tumba sur l'Axe Routier Mbandaka-CREF Mabali à Bikoro, Province de l'Equateur (RD Congo). International Journal of Progressive Sciences and Technologies 25(2):156-168.

Pwema Kiamfu V, Mbomba Bekeli N, Pigneur LM, Takoy Lomema, Micha JC (2011). Environmental variables structuring *Labeo* species (Pisces, Cyprinidae) in Malebo Pool, Congo River. International Journal of Biological and Chemical Sciences 5(2):507-514.

Seraphin KZ, Lassina D, Mexmin KK, Mamadou O, Allassane O (2022). Reproductive biology of the main fish species in lakes Taabo, Kossou and Faé (Côte d'Ivoire) with a view to rational fishing. International Journal of Fisheries and Aquatic Studies 10(1):46-55.

Stiassny MLJ, Teugels GG, Hospins CD (2007). Poissons d'eaux douces et saumâtres de basse Guinée, Ouest de l'Afrique centrale. IRD: Paris.

Tembeni JM, Mbomba B, Micha JC, Mbadu V (2019). Spatio-temporal structure of fish communities Mochokidae (Ostariophysi, Siluriformes) in the Malebo Pool, Congo River (Democratic Republic of the Congo). African Journal of Aquatic Science 44(4):377-388.

Tessier A, Descloux S, Lae R, Cottet M, Guedant P, Guillard J (2016). Fish assemblages in large tropical reservoirs: overview of fish population monitoring methods. Reviews in Fisheries Science and Aquaculture 24(2):160-177.

Tshijik JCK, Akaibe D, Micha JC, Pwema VK (2016). Comparative analysis of taxonomic diversity and ecological quality of the water of Lukunga and Mangengenge Rivers in Kinshasa International Journal of Innovation and Applied Studies 16(2):260.

Zango P, Tomedi MTE, Efole TE, Tiogue CT, Nguenga D, Kamanke SMK, Tchoumboue J (2016). Performances de reproduction du poisson chat endogène du Cameroun Clarias jaensis (Boulenger, 1909) en milieu contrôlé. International Journal of Biological and Chemical Sciences 10(2):533-542.