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Contribution to the Knowledge of Freshwater Shrimps (*Crustacea, Decapoda*) and Their Spatial Distribution in the Malebo Pool (Congo River), R.D Congo

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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Original Research Article

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ABSTRACT

Background and Objective: Crustaceans play a considerable role in the ecological process of aquatic ecosystems, acting at different trophic levels as herbivores, detritivores, predators and prey and constitute an important source of animal protein for humans and livestock. This study investigated the diversity of shrimp from the left bank of the Malebo Pool in the Congo River.
Study Area: Five sampling campaigns were organized from July 2020 to August 2021 in six sites (Ngamanzo 1, Ngamanzo 2, Kinkole 1, Kinkole 2, Kinsuka 1 and Kinsuka 2) in the Malebo Pool, the terminal part of the middle Congo River.
Methods: Shrimp samples were collected using dip nets and creels during the experimental fisheries. Physical parameters were measured monthly in situ at six sites. Chemical parameters

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were assessed using an ultraviolet atomic spectrophotometer. Systematic identification of shrimp was done using appropriate systematic identification keys. The structure of the shrimp populations was studied using several ecological indices.

Results: A total of 1422 shrimp specimens were sampled. These individuals belonged to three different species (Caridina africana Macrobrachium dux and Macrobrachium sollaudii), two genera (Caridina and Macrobrachium) and two families (Atyidae and Palaemonidae). Shanon and Weaver's diversity index values ranged from 0 to 1.3 indicating that the shrimp fauna is not diverse in Malebo Pool. These species are better represented at Ngamanzo 1, Ngamanzo 2 and Kinkole 2. Redundancy analysis (RDA) showed that environmental variables such as dissolved oxygen level, conductivity, water temperature, transparency, water flow velocity, plant debris, aquatic plants and canopy strongly influence taxonomic diversity across sites.

Conclusion: The results obtained showed that the shrimp fauna is rich and diversified in the studied part of the Malebo Pool in the Congo River and, these organisms are essential in maintaining the ecological balance in this aquatic ecosystem.

Keywords: Decapod crustaceans; malebo pool; specific diversity; spatial distribution and systematic inventory.

1. INTRODUCTION

Crustaceans constitute a highly diverse order of macroinvertebrates that have colonized freshwater, marine, and lacustrine aquatic environments [1]. They contribute significantly to the diet and economy of households. They play a considerable role in the ecological process of aquatic ecosystems, acting at different trophic levels as herbivores, detritivores, predators and prey [2] and constitute an important source of animal protein for humans and livestock [3].

Thus, their role in controlling aquatic community structuring is not negligible [4,5]. In addition, shrimp of the family *Atyidae* and *Palaemonidae* are an important resource for artisanal fisheries in some parts of the world [6,7,8,9].

According to Ganghe [10], 2000 species of shrimp belonging to 20 marine-influenced families have been described worldwide. In freshwater, two families (*Atyidae* and *Palaemonidae*) with several species are reported [10]. Some species of the Palaemonidae family can reach large sizes and are therefore important resources for artisanal fisheries and aquaculture [5].

In the city-province of Kinshasa in the Democratic Republic of Congo, the Malebo Pool plays an important role in maintaining the natural balance and the supply of fishery resources through artisanal fishing. In this period of population increase and increasing pressure on resources leading to the disappearance of fishery products [11], it is important to know the biogenetic stock in order to initiate ecological studies that could lead to the domestication of some of them. Therefore, the objective of this study is to inventory the shrimp infested in the Pool Malebo region (Congo River) in the Democratic Republic of Congo.

2. STUDY ENVIRONMENT, MATERIAL AND METHODS

2.1 Environment

The study was conducted in the Malebo Pool (Fig. 1), the terminal part of the middle Congo River. Formerly called Stanley Pool, Malebo Pool (4°05' and 4°20' S latitude, 15°19' and 15°32' E longitude and average altitude 272 m) is located between the locality of Maluku upstream and the Kinsuka rapids downstream [12]. The Pool forms a body of water about 35 km long and 25 km wide, its surface area is ±500 km² [13].

The Malebo Pool is a large flooded lake corresponding to the widening of the Congo River between Kinshasa and Brazzaville. Both cities are built on the alluvial plains of this pool. It is dotted with numerous islands and innumerable sandbanks [14].

Mbamu Island, with an area of approximately 180 km², is at the center of the pool; it is entirely part of the Republic of Congo and forms the border with the Democratic Republic of Congo at its eastern limit. The waters of the Malebo Pool are shallow, ranging from 5 to 14 meters deep [15]. Its maximum flood flow is 63,000 m3/second between October and May; and low water of 22,000 m3/second between June and September [16]. An alluvial plain, floodable and included

between the N'djili and N'sele rivers: tributaries of the Malebo Pool in its southeastern part, is largely swampy and its altitude does not exceed 280 m [11].

The climate of Malebo Pool is Aw4 according to the Köppen classification system [16] with a rainy season that extends from mid-September to mid-June and a dry season from mid-June to mid-September. It is a hot and humid tropical climate, Sudano-Guinean, with an average daily temperature of over 18°C. In the city of Kinshasa, the Pool is surrounded by the municipalities of Mont-Ngafula to the west and Maluku to the east and crosses the municipalities of Gombe, Barumbu, Limete, Masina and N'sele [15].

2.2 Biological Material

The biological material used in this study consists of 1422 shrimp specimens sampled in the Malebo Pool from July 2020 to August 2021.

2.3 Methods

2.3.1 Measurement of environmental variables

Physico-chemical parameters were measured monthly in situ at six sites. Water temperature (°C), pH, conductivity (µS/cm), and turbidity (ppm) were measured using a Hanna Combo/Ec multiparameter probe No. HI 98129. Dissolved oxygen was measured using a Sper Scientifique multiparameter. A Secchi disk (30 cm diameter painted white-black) and a graduated bar (in centimeters) were used to estimate, respectively, the transparency and depth of the water column. The average canopy closure rate as well as the nature of the substrate (sand-gravel mix, mud, plant debris) were visually estimated in percent for each site according to the method of Rios & Bailey [17]; Djiriéoulou et al., [2]. Assessment of chemical parameters (nitrate, calcium, magnesium, and chlorine) was performed using an ultraviolet atomic spectrophotometer.

2.3.2 Shrimp sampling and identification

Shrimp specimens were sampled during five fishing trips between July 2020 and August 2021 using a dip net with a length of 1.62 m, width of 1.3 m, depth of 2.60 m, and mesh size of 1 mm, and creels made of wooden frames and vines. The trap was set down each time in the evening and lifted very early in the morning. The collected specimens were kept in jars containing 4% formalin for fixation before identification in the laboratory.

In the laboratory, the specimens were washed with tap water and then preserved in 70° ethanol. The systematic identification of shrimps was done using the determination keys proposed by Konan [5]; De Man [18]; Holtuis [19]; Monod [20]; Mongindo [21]; Kankonda [22]; Tachet et al., [23].

2.3.3 Shrimp population structure and data analysis

The structure of the shrimp populations was studied using taxonomic richness and relative abundance. Thus, several indices were calculated. These were:

- **Specific richness (S):** it refers to the number of species present in a given ecosystem [24]) ;
- **Relative abundance:** Relative abundance provides information on the importance of each taxon in relation to the total number of taxa present. It corresponds to the ratio of the number of individuals of the same species to the total number of individuals of all species combined [25]. ni/Nx100, where ni is the number of individuals of taxon i and N is the total number of individuals in the sample;
- **Jaccard Similarity Index:** J'=Tc/(T1+T2-TC) . Where, Tc: number of taxa common to stations 1 and 2; T1 and T2 are the number of taxa present at stations 1 and 2 respectively. This index varies from 0 to 1. A qualitative study based on the presence or absence of species in the different samples, allows to compare the stations taken two by two [26];
- **Shannon and Weaver index:** this is a measure of the species composition of an ecosystem, in terms of the number of species and their respective abundance [26]. It is calculated from the faunal lists obtained according to the following formula: H'; Where, i varies from 1 to S, ni: number of taxon i; N: total number and H': Shannon and Weaver Diversity Index. In nature, the value of H' is between 0.5 (very low diversity) and 4.5 (in the case of large samples of complex communities);
- **Pielou's equitability index:** this index measures the equitability (or equi-repartition) of the species in the stand in relation to a theoretical equal distribution

for all species. It is obtained by the formula: EQ=H'/log2S. The key of Dajos [25], was used to classify species: constant species (% Occ ≥50%), accessory species (25% < % Occ < 50%) and accidental species (% Occ ≤ 25%). Of the incidental species, those with % Occ < 5%, are rare species.

2.3.4 Static data analysis and processing

The data from the different observations were encoded on the Excel 2013 spreadsheet. To identify the difference in the variation between the mean values of the physico-chemical parameters, the analysis of variance with a classification criterion (ANOVA 1) [27] accompanied by Fisher's LSD (Least Significant Difference) test [28] was used at the 95% confidence interval.

The Principal Component Analysis (PCA), which is a descriptive and exploratory method whose aim is to extract the information contained in a table of data in the most synthetic way possible, was also used. It is a technique that allows an arrangement of ecological entities along bi- or multidimensional axes based on data related to the specific composition [29]. The application of a PCA follows three steps:

- The development of a database ;
- Checking the normality of the distribution of the variables and, if necessary, transforming it ;
- Performing the analysis itself.

The main purpose of PCA is to simplify and condense a set of data into a diagram in which the ecological entities are represented by points. Note that the matrix has the stations (sites) in rows and the parameters in columns. On the graphical representation resulting from a PCA, the points that are close correspond to ecological entities with similar characteristics. On the other hand, points that are far away correspond to different ecological entities for the variables concerned. The interpretation of such a representation is based on the axes that express the greatest variability. These are the eigenvalues. In this study, we used PCA to compare data on variations in shrimp populations according to physical, physicochemical and chemical parameters. These analyses were performed with Past (Paleontological Statistics, version 2.16) software [30].

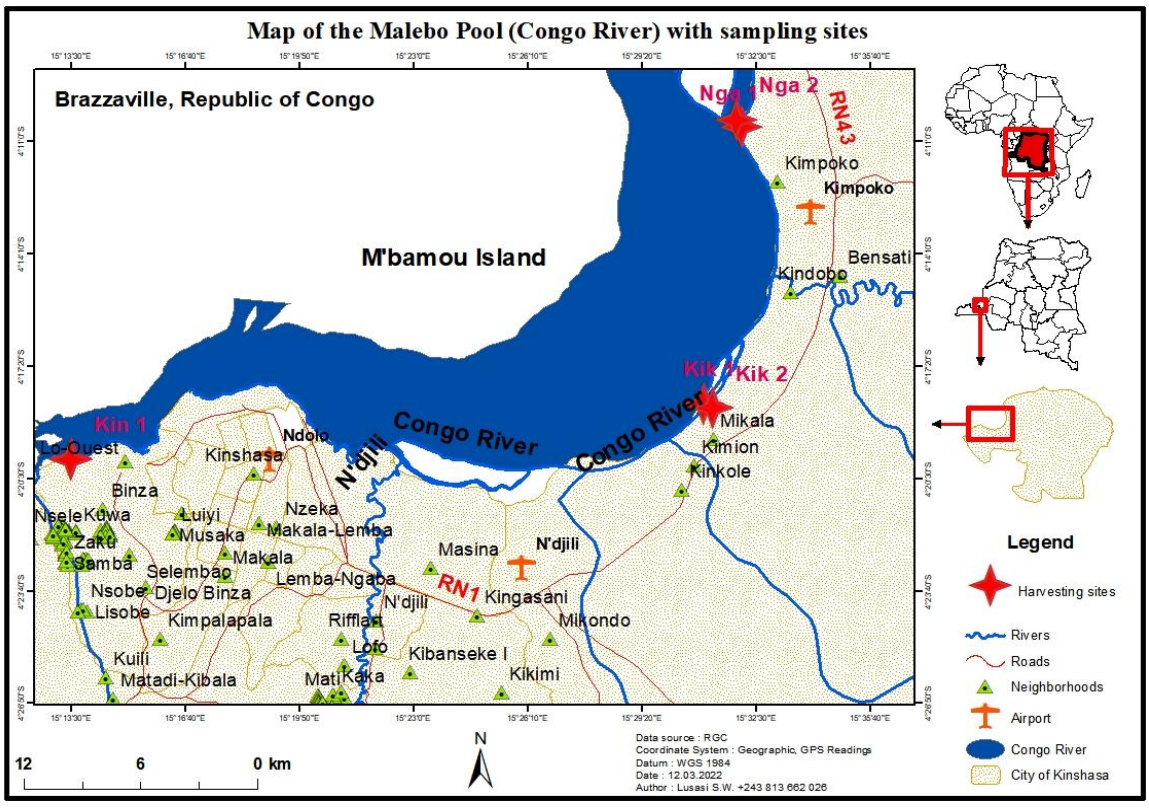

Fig. 1. Map of the Malebo Pool showing shrimp sampling sites

This software is designed for simultaneous processing of environmental and biological data. The presentation of results in the form of a diagram, where the relative positions of the environmental variables and the species studied are represented by arrows, makes it possible to specify their relationships. The length of the arrow in the ordination reflects the importance of the environmental variable. Also, the direction shows how the environmental variable is correlated to the various axes. The angle between the arrows indicates the correlations between the variables, with the location of species relative to the arrows revealing the environmental preferences of the species [31,32,33,34].

Mapping of study stations was generated using ArcGIS 10.8 software using geographic coordinates (latitude and longitude) collected in the field with a Gamin Etrex GPS.

3. RESULTS

3.1 Shrimp Fauna Identified in Pool Malebo

The freshwater shrimp fauna identified in the left bank of the Malebo Pool in the Congo River is shown in Table 1.

One thousand four hundred and twenty-two (1422) shrimp were sampled at six selected sites in the Malebo Pool between July 2020 and August 2021. These shrimp belong to the order *Decapoda*, the infra-order *Caridea*, two families (*Atyidae* and *Palaemonidae*), two genera (*Caridina* and *Macrobrachium*) and three species (*Caridina africana*, *Macrobrachium sollaudii* and *M. dux*).

3.1.1 Relative abundance of the shrimp families surveyed

Shrimps belonging to the families *Atyidae* and *Palaemonidae* represent the same proportion of relative abundance, i.e. 50% respectively (Fig. 2).

3.1.2 Relative abundance of genera

Shrimp grouped in the genus *Macrobrachium* are the most abundant with 66.7% than those of the genus *Caridina* with 33.3% (Fig. 3).

3.1.3 Numerical frequency of species

It appears from the results shown in Fig. 4 that *Caridina africana* is the shrimp that presents a high number of individuals (735 specimens) followed by *Macrobrachium dux* (623 specimens) and *M. sollaudii* (64 individuals).

Table 1. Freshwater shrimp fauna identified in the Malebo Pool (Congo River)

Orders	Infra-Order	Families	Genus	Species
Décapode	*Caridea*	*Atyidae* *Palaemonidae*	*Caridina* *Macrobrachium*	*C. africana* *M. sollaudii* *M. dux*
1	**1**	**2**	**2**	**3**

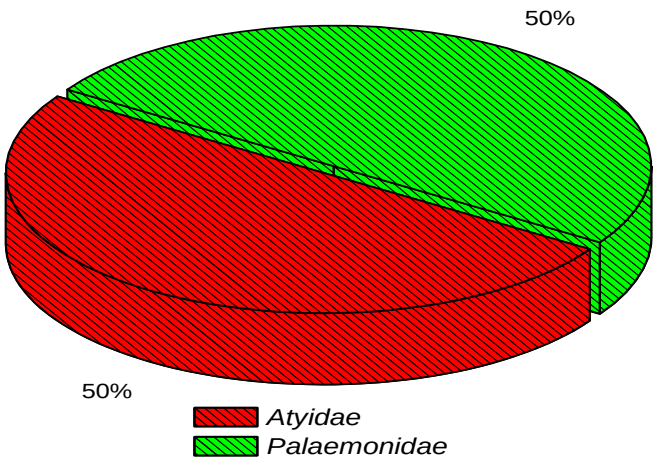

Fig. 2. Relative abundance (%) of shrimp families inventoried

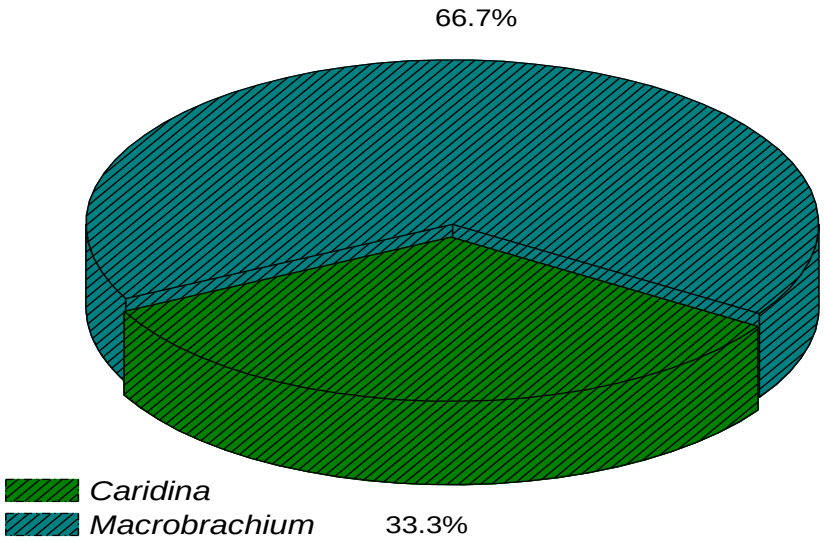

Fig. 3. Relative abundance (%) of the genera of the shrimp inventoried

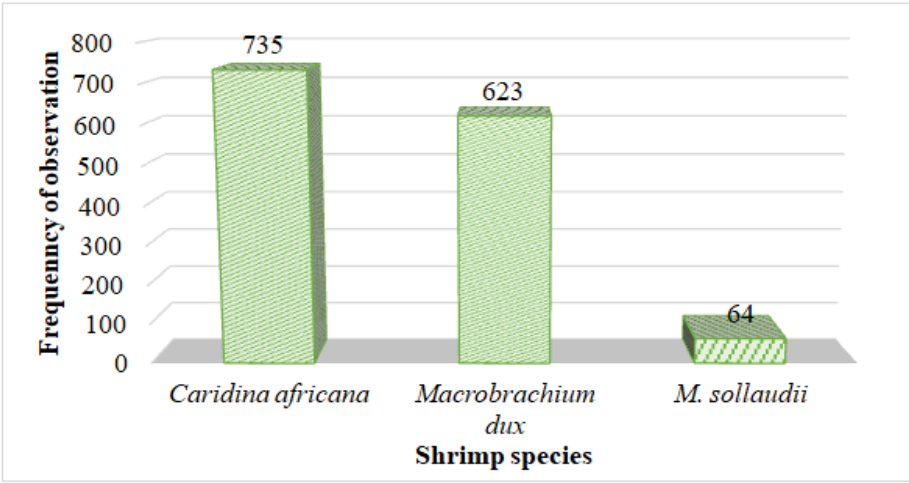

Fig. 4. Numerical frequency of shrimp species surveyed

3.2 Distribution of Shrimp Species in the Malebo Pool

The distribution of three shrimp species identified in the Malebo Pool (Congo River) according to the sampling stations (Ngamanzo, Kinkole and Kinsuka) in this study is shown in Table 2.

Table 2. Distribution of shrimp according to stations

Sites	Total number of individuals sampled		
	Caridina africana	***Macrobrachium sollaudii***	***Macrobrachium dux***
Ngamanzo 1	52	16	44
Ngamanzo 2	438	33	234
Kinkole 1	0	6	4
Kinkole 2	56	9	341
Kinsuka 1	0	0	0
Kinsuka 2	189	0	0

Caridina africana is the shrimp recorded in all three sampling stations and captured in abundance with 735 specimens or 51.7% (Fig. 5). *Macrobrachium dux* with 623 individuals or 43.8% and *M. sollaudii* with 64 individuals or 4.5% are caught in two stations (Ngamanzo and Kinkole) and are absent in Kinsuka.

3.3 Index Evaluation of Shrimp Diversity

The different values of the diversity indices applied to the shrimp data inventoried in the six sampling sites of the Malebo Pool in the Congo River are shown in Table 3.

The Shannon-Weaver diversity index values calculated range from 0 to 1.001 indicating that the shrimp fauna of Malebo Pool is not very diverse. The Ngamanzo 1 site is the richest (H' = 1.001) and Kinsuka is the least diverse. As for the equitability index, values ranged from 0 to 97% indicating that the shrimp fauna is not equitably distributed in all the surveyed sites. Individuals collected at the Kinsuka 1 (D = 0.971) and Ngamanzo 1 (D = 0.9114) sites are evenly distributed. The number of individuals varies from 1 to 704. The Ngamanzo 2 site had a high number of specimens (704 individuals) followed by the Kinkole 2 site (406 individuals).

3.4 Jaccard's Similarity Index

The similarity matrix established from Jaccard's similarity index between the stands calculated for the six sites studied is shown in Table 4.

The results in the table show that the stands show some relative variability in the similarity of their taxonomic compositions. All the stations show less than 33% similarity. No similarity was observed between the Ngamanzo 2 and Kinsuka 1, Kinkole 1 and Kinsuka 1, Kinkole 2 and Kinsuka 1 and Kinsuka 1 and Kinsuka 2 sites.

3.5 Vegetation Inventoried at Shrimp Sampling Sites

The plant species identified at the different sites and their percentage of coverage are listed in Table 5.

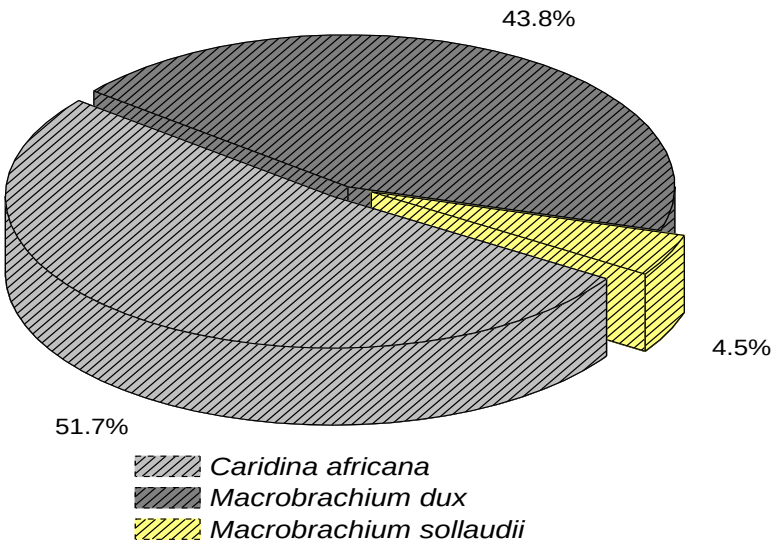

Fig. 5. Percentage change in catch of shrimp species in the Malebo Pool (Congo River)

Table 3. Values of diversity indices calculated on the shrimp fauna of the Malebo Pool

Diversity indices	Sampling sites					
	Ngam 1	Ngam 2	Kink 1	Kink 2	Kins 1	Kins 2
Number of taxa	3	3	2	3	1	1
Number of individuals	112	704	10	406	1	189
Shannon_H	1.001	0.8047	0.673	0.5042	0	0
Equitability_J	0.9114	0.7324	0.971	0.459	0	0

Legend : *Ngam 1 = Ngamanzo 1, Ngam 2 = Ngamanzo 2, Kink 1 = Kinkole 1, Kink 2 = Kinkole 2, Kins 1 = Kinsuka 1 and Kins 2 = Kinsuka 2*

Table 4. Similarity matrix between the stands of the six study sites in the Malebo Pool

Harvesting sites	Sites de récolte					
	Ngam 1	Ngam 2	Kink 1	Kink 2	Kins 1	Kins 2
Ngamanzo 1	1	33	25	33	20	28
Ngamanzo 2		1	28	33	**0**	20
Kinkole 1			1	28	**0**	25
Kinkole 2				1	**0**	20
Kinsuka 1					1	**0**
Kinsuka 2						1

Legend : *Ngam 1 = Ngamanzo 1, Ngam 2 = Ngamanzo 2, Kink 1 = Kinkole 1, Kink 2 = Kinkole 2, Kins 1 = Kinsuka 1 and Kins 2 = Kinsuka 2*

Table 5. Distribution of plant species (% cover) by shrimp sampling site

Plant species	Code	Shrimp sampling sites					
		Kins 1	Kins 2	Kink1	Kink2	Nga1	Nga 2
Echinochloa pyramidalis	Ec.py	0	75	65	25	40	55
Eichornia crassipes	Ei.cr	0	10	9	66	14	32
Ludwigia abyssisica	Lu.ab	0	0	2.5	5	3	5
Pistia stratiotes	Pi.st	0	0	2.5	0	3	3
Salvinia nymphellula	Sa.ny	0	0	2.5	0	3	2
Polygonum lanigenum	Po.la	0	0	5	1	2	3
Ledermaniella sp	Le.sp	100	10	0	0	0	0
Alternanthera sessilis	Al.se	0	2.5	0	0	0	0
Panicum rupens	Pa.ru	0	2.5	0	0	35	0
Ipomoea aquatica	Ip.aq	0	0	3.5	3	0	0
Nymphea lotus	Ny.lo	0	0	5	0	0	0
Aechinomene cristata	Ae.cr	0	0	5	0	0	0

Twelve plant species including Echinochloa pyramidalis, Ludwigia abyssisica, Salvinia nymphellula, Panicum rupens, Ipomoea aquatica and Aechinomene cristata were identified in the different study sites in the Malebo Pool (Congo River).

3.6 Environmental Variables

Twelve environmental variables were measured at each shrimp sampling site. The mean values of these physico-chemical parameters for each site are presented in Table 6.

In general, the Congo River waters in the Malebo Pool show a slight variation in abiotic variables from one study station to the next. The highest dissolved oxygen content (7.2±0.2 mg/L) is found at Ngamanzo 1 and Kinsuka 2 and the lowest value is observed at Kinsuka 1 (5.9±0.6 mg/L). Flow velocity is low (0.11±0.01 m/sec) at Kinkole 1 and higher at Kinsuka 2 (0.39±0.03 m/sec) and Kinsuka 1 (0.28±0.01 m/sec). The water is less turbid and has conductivity values between 12.4±0.2 ppm (Ngamanzo 2) and 13.4±0.5 ppm (Ngamanzo 2). The depth at the shrimp sampling points varied between 1.2±0.4 m (Kinkole 1) and 1.6±0.3 m (Ngamanzo 1). The waters remained warm with mean temperatures ranging from 26.85±0.05 °C (Kinsuka 1) to 27.6±0.1 °C (Kinkole 1). The hydrogen potential remained slightly acidic across the different sites. Ions in solution were weakly dissolved, with the highest average conductivity (32.4±0.1 µS/cm) recorded at Ngamanzo 2 and the lowest value (29.05±0.15 µS/cm) recorded at Kinsuka 1.

3.7 Substrate Composition at Shrimp Sampling Sites

The particle size analysis classified the bottom substrates at the shrimp sampling sites into rock, sand, plant debris and mud (Fig. 6). The Kinsuka 1 and Kinsuka 2 sites are dominated by rock while the Kinkole 1, Kinkole 2, Ngamanzo 1 and Ngamanzo 2 sites are dominated by sand.

3.8 Relationship between Environmental Variables and Shrimp Species in Malebo Pool

The Canonical Correspondence Analysis applied to the data on shrimp species and abiotic

variables can be explained by the first two axes. Axis 1 explains 88.4% of variability and axis 2 (11.59%) (Fig. 7). Axis 1 (eigenvalues 0.011057) is positively correlated with Kinsuka 1, Kinsuka 2 and Ngamanzo 1 sites. These sites are also correlated with *Caridina africana* and *Macrobrachium sollaudii* and with water current velocity, turbidity, water column depth, pH and conductivity. Axis 2, eigenvalue (0.00145) is positively correlated with *C. africana*, *M. dux* and turbidity, dissolved oxygen, depth, temperature as well as chlorine and calcium ions.

Table 6. Mean values of physico-chemical parameters measured at six sampling sites in Malebo Pool

Parameters	Sampling sites					
	Kins 1	**Kins2**	**Kink 1**	**Kink 2**	**Ngam 1**	**Ngam 2**
O_2 (mg/L)	5,9±0,6	7,19±0,2	6,2±0 ,00	6,3±0,1	6±0,2	7,2±0,2
F = 2,73 ; p = 0,1265 ; LSD = 1.2235						
Vit (m/sec)	0,28±0,01	0,39±0,03	0,11±0,01	0,14±0,02	0,25±0,04	0,27±0,02
F = 17,8 ; p = 0,0015 ; LSD = 0,0836						
Transp (cm)	43,5±2,55	48,9±0,2	52,9±0,9	53,4±0,9	52,8±1,45	52,4±0,8
F = 7,90 ; p = 0,0129 ; LSD = 4,6652						
Turb (ppm)	13,3±0,1	12,4±0,5	12,7±0,1	12,7±0,3	13,4±0,5	12,4±0,2
F = 1,81 ; p = 0,2453 ; LSD = 1.1390						
Prof (m)	1,5±0,1	1,4±0,1	1,2±0,4	1,4±0,1	1,6±0,3	1,45±0,225
F = 0,32 ; p = 0,8844 ; LSD = 0,8123						
pH	6, 2±0,1	6,3±0,1	6,03±0,01	6,1±0,2	6,2±0,2	6,3±0,1
F = 0,63 ; p = 0,6838 ; LSD = 0,4688						
Cond (µS/cm)	29,05±0,15	30,4±0,95	29,3±0,2	29,9±0,2	29,1±0,1	32,4±0,1
F = 8,83 ; p = 0,0098 ; LSD = 1,4303						
T° (°C)	26,85±0,05	27,25±0,15	27,6±0,1	27,05±0,05	27,3±0,2	27,4±0,5
F = 1,27 ; p = 0,3838 ; LSD = 0,8085						
$N0_3^-$ (mg/L)	0,02±0,01	0,05±0,01	0,01±0,00	0,02±0,00	0,02±0,00	0,04±0,01
F = 4,53 ; p = 0,0466 ; LSD = 0,0245						
Ca^{++} (mg/L)	0,99±0,005	0,95±0,05	0,61±0,00	0,57±0,02	0,9±0,1	0,53±0,04
F = 17,5 ; p = 0,0016 ; LSD = 0,1729						
Mg^{++} (mg/L)	1,3±0,1	1,58±0,05	1,5±0,3	1,35±0,05	1,36±0,05	1,35±0,05
F = 0,55 ; p = 0,7387 ; LSD = 0,4685						
Cl^- (mg/L)	1,2±0,1	1,16±0,04	1,19±0,00	1,23±0,01	1,08±0,02	1,02±0,01
F = 3,01 ; p = 0,1060 ; LSD = 0,1562						

Legend : *O_2 = Dissolved oxygen, Vit = Flow velocity, Transp = Transparency, Turb = Turbidity, Prof = Depth, Cond = Conductivity, T° = Temperature, Ngam 1 = Ngamanzo 1, Ngam 2 = Ngamanzo 2, Kink 1 = Kinkole 1, Kink 2 = Kinkole 2, Kins 1 = Kinsuka 1 and Kins 2 = Kinsuka 2*

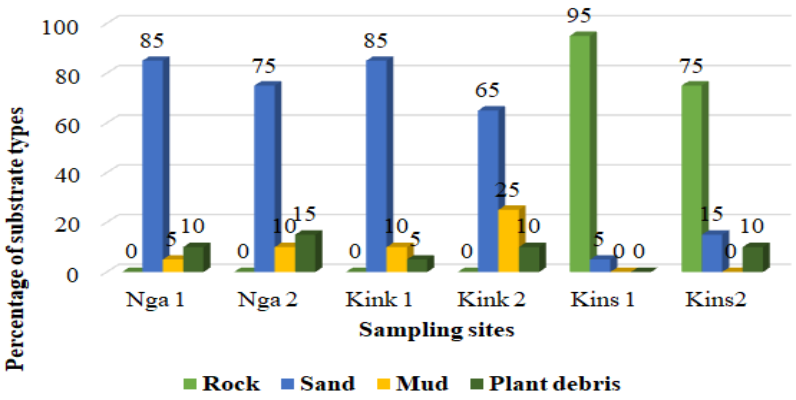

Fig. 6. Composition (%) of bottom substrates in the sampling sites

Legend : *Kins 1 = Kinsuka 1, Kins 2 = Kinsuka 2, Kink 1 = Kinkole 1, Kink 2 = Kinkole 2, Ngam 1 = Ngamanzo 1 and Ngam 2 = Ngamanzo 2*

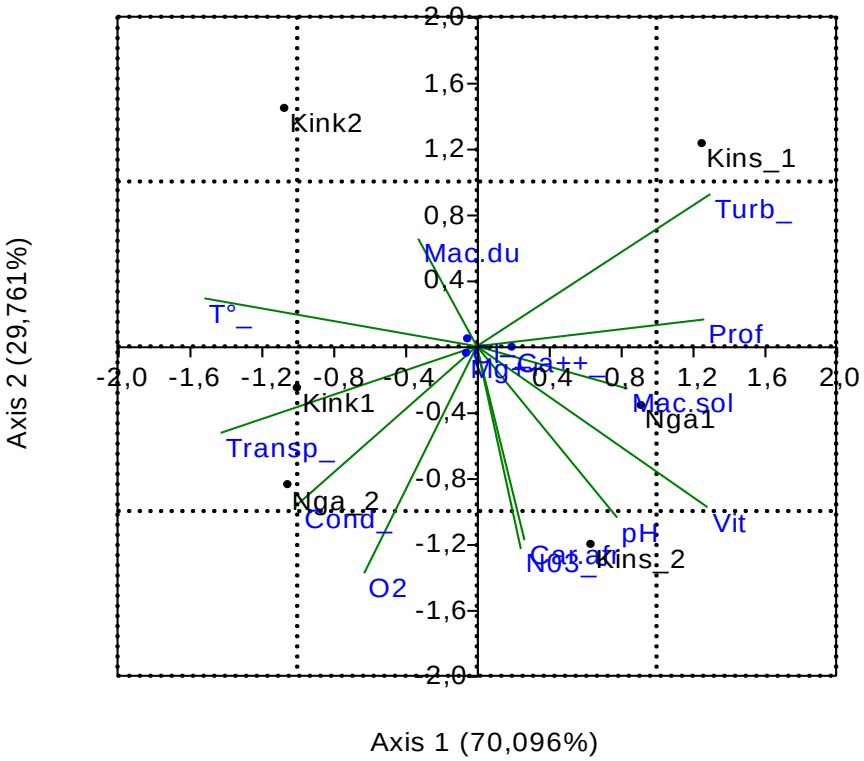

Fig. 7. Plot of the ordination of 6 sampling sites, 3 shrimp species and 12 environmental variables on the first two axes produced by canonical correspondence analysis

Legend : *T° = Temperature, Transp = Transparency, Cond = Conductivity, O_2 = Dissolved oxygen, Mac_du = Macrobrachium dux, Mac_sol = Macrobrachium sollaudii, Car_afr = Caridina africana, Mg^{++} = Magnesium, Ca^{++} = Calcium, pH = Hydrogen potential, Vit = Flow velocity, Prof = Depth, Turb = Turbidity and NO_3^- = Nitrate*

3.9 Relationship between Shrimp Fauna, Flora, Environmental Variables and Sites

The results of the Canonical Correspondence Analysis (CCA) applied to the data (species-sites-environmental variables-vegetation) of three shrimp species, 12 plant species, 12 environmental variables and 6 sites are visualized in Fig. 8. The contribution of the first axis is 53.62% and the second axis is 43.31%. Axis 1 (eigenvalue (ʎ=0.27114) is characterized by vegetation composed of *Eichornia crassipes*, *Alternanthera sessilis*, *Ludwigia abyssisica*, *Alternanthera sessilis* in Kinsuka 2 and Kinkole 2 sites and are associated with *Macrobrachium dux*, *M. sollaudii* and *Caridina africana* species. Axis 2 is associated with the Kinkole 1, Kinkole 2 and Kinsuka 1 sites as well as dissolved oxygen, pH, conductivity and water column depth. The *M. dux* species is also positively correlated to this axis and to the physico-chemical characteristics mentioned. The eigenvalues associated with the Monte Carlo test allowed the statistical selection ($p<0.05$) of aquatic vegetation to the variables underlying the distribution of shrimp species.

4. DISCUSSION

The different samplings carried out in the Malebo Pool (Congo River) allowed the collection of 1422 specimens of shrimps grouped in 3 species. These taxa were grouped into two freshwater families (Atyidae and Palaemonidae). These families were each represented by a genus (*Caridina* and *Macrobrachium* respectively). The genus *Caridina* was represented by a single species (*Caridina africana*) while the genus *Macrobrachium* was represented by two species (*Macrobrachium dux* and *M. sollaudii*). From the relative abundance point of view, the shrimps of the genus *Macronchium* were the most abundant with 66.7% than those of the genus *Caridina* with 33.3%. Individuals belonging to the species *Caridina africana* were more collected (735 specimens) than those of *Macronchium dux* (623 specimens) and *M. sollaudii* (64 individuals). These observations are close to those noted

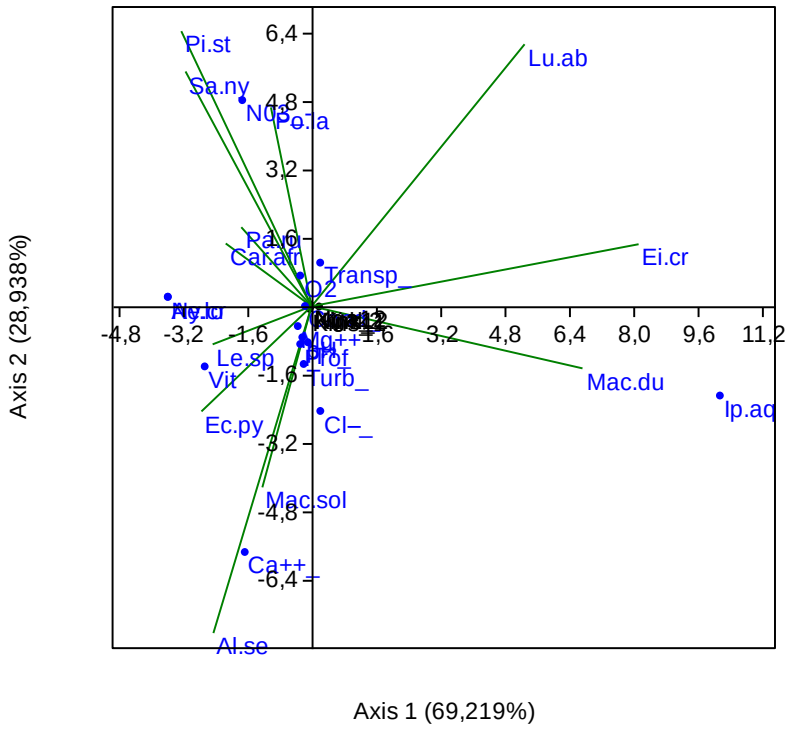

Fig. 8. Plot of the ordination of 3 shrimp species and 12 environmental variables, 12 plant species and 6 sites on the first two axes produced by Canonical Correspondence Analysis

Legend : *T° = Temperature, Transp = Transparency, Cond = Conductivity, O_2 = Dissolved oxygen, Mac_du = Macrobrachium dux, Mac_sol = Macrobrachium sollaudii, Car_afr = Caridina africana, Mg^{++} = Magnesium, Ca^{++} = Calcium, pH = Hydrogen potential, Vit = Flow velocity, Prof = Depth, Turb = Turbidity, NO_3^- = Nitrate, Ec. py = Echinochloa pyramidalis, Ei.cr = Eichornia crassipes, Lu.ab = Ludwigia abyssisica, Pi.st = Pistia stratiotes, Sa.ny = Salvinia nymphellula, Po.la = Polygonum lanigenum, Le. sp = Ledermaniella sp, Al.se = Alternanthera sessilis, Pa.ru = Panicum rupens, Ip.aq = Ipomoea aquatica, Ny.lo = Nymphea lotus and Ae.cr = Aechinomene cristata*

Agadjihouede [3]; [35]. The species *M. dux* was recorded by Agadjihouede [3] in the Grand Popo Lagoon in Benin, but is close to *M. macrobrachion*. Ajeagah et al. [35] also reported the presence of some *Macrobrachium* shrimp in a forest stream in Cameroon. However, these results are different from those of Corredor [36]; [37] who respectively found 6 and 7 species in Côte d'Ivoire. Several reasons could explain differences in specific compositions: the harvesting instruments and methodology used, the environmental characteristics of the biotopes sampled, the sampling periods and the migration of species [6]. According to Kouamélan et al., [37], the variability of the habitats surveyed and the sampling periods could also explain the specific differences observed between these different ecosystems. The large study areas offer a diversity of habitats to exploit [38].

The distribution of the three shrimp species differed among the sites. *Caridina africana* was counted in all three sampling stations and captured at 51.7%. *Macronchium dux* with 43.8% of captures and *M. sollaudii* with 4.5% of captures were absent at the Kinsuka station and sampled at two other stations; Ngamanzo and Kinkole. The type of substrate (rocky), flow velocity and vegetation characteristic of the Kinsuka site would have influenced the spatial distribution of the shrimp identified. According to Poupin [39] the majority of freshwater shrimp prefer calm environments with sandy-muddy sediment and decaying plants. This is the case with the Ngamanzo and Kinkole sites. As for the diversity indices, it was found that the specific richness of shrimp varies from one site to another. The Shannon-Weaver diversity index values showed that the shrimp fauna in Malebo Pool is not very diverse. The Ngamanzo 1 site was the richest (H' = 1.001) than the others with low richness in the Kinsuka site. The specific richness as well as the similarity observed in the Ngamanzo and Kinsuka sites would be related to the favorable feeding conditions (availability of food) in these sites. According to Allozounhoue

[40], shrimp of the genus *Macrobrachium* are omnivorous-detritivorous and feed in the wild on natural aquatic productivity where there is an abundance of plant debris, zooplankton, and microscopic fauna living on the bottom.

Analysis of the correlation between the diversity of shrimp surveyed, abiotic characteristics and characteristic vegetation at each sampling site showed that pH, dissolved oxygen level, conductivity, total dissolved solids level, water temperature, transparency, water flow velocity and aquatic plants are the environmental characteristics that influence species diversity, abundance and distribution. *Macrobrachium dux* prefers well oxygenated, cool water with low current and low conductivity. These same trends were also observed for shrimp in the Banco River [41] and in four small rivers in southeastern Côte d'Ivoire [42].

5. CONCLUSION

The objective of this study was to inventory shrimp infested in the Malebo Pool (Congo River) region of the Democratic Republic of Congo. Shrimp specimens were sampled between July 2020 and August 2021 using a dip net of 1.62 m length, 1.3 m width, 2.60 m depth and 1 mm mesh and creels made of wooden frames and lianas.

The results obtained showed that three species of freshwater shrimp (Caridina africana, *Macrobrachium dux* and *M. sollaudii*) grouped in two genera (*Caridina* and *Macrobrachium*) and two families (*Atyidae* and *Palaemonidae*) were identified. From the point of view of relative abundance, shrimps of the genus *Macronchium* were more abundant with 66.7% than those of the genus *Caridina* with 33.3%. Individuals belonging to the species *Caridina africana* were more collected (735 specimens) than those of *M. dux* (623 specimens) and *M. sollaudii* (64 individuals). *Caridina africana* was recorded at all three sampling stations and captured at 51.7% and appeared to be the most abundant and widely distributed species in Malebo Pool. Dissolved oxygen levels, water transparency, and the presence of a canopy of aquatic plants influence the abundance and distribution of different shrimp species in Malebo Pool. The results obtained showed that the shrimp fauna is rich and diversified in the studied part of the Malebo Pool in the Congo River and, these organisms are essential in maintaining the ecological balance in this aquatic ecosystem.

DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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