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Study of the population structure of decapod crustaceans in the Pool Malebo in Kinshasa (DR Congo)

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Abstract

The study of the population structure of crustaceans was undertaken during the period from June to September 2019, in the Pool Malebo. A total of 467 individuals were collected. These specimens were divided into 3 families, 3 genera and 4 species. Several biotic indices were used to study the structure of the population on the one hand, and its diversity on the other. Gross abundance, relative frequency, species richness, diversity of Shannon-Weaver and equitability of Piélou were calculated. The evaluation of these indices in the different stations showed that there is a parallelism between them. The highest gross abundance of crustaceans in the Pool Malebo was observed in *M. sollaudiis* (224 individuals which accounted for 47.9% of the total abundance. It was followed by *C. africana*, *C. togoensis* and *Soudanautes sp*. which accounted for 145, 59 and 39 individuals respectively, i.e. 31.1%, 12.6% and 8.3 of the total catch. The distribution of crustaceans is largely influenced by the physical and chemical quality of the water (dissolved oxygen, temperature, pH, conductivity, nitrate, etc.).

Keywords: Structure; Crustaceans; Pool Malebo; DR Congo

1. Introduction

At the World Summit in Rio de Janeiro (1992), our leaders agreed to adopt a strategy for sustainable development. One of the key agreements adopted in Rio was the Convention on Biological Diversity (CBD). This is important on many levels and raises many questions about, among other things, the role of biodiversity in the functioning of ecosystems, the usefulness of all species, and the consequences of the introduction or disappearance of species. Within this biodiversity, fish, like invertebrates, seem to constitute an interesting biological model for addressing the questions posed [1].

We cannot talk about sustainable development without knowing the species. And not only in the broad sense, but also in depth, i.e. knowing their ecology, biology, life cycle, etc. Watercourses are populated not only by fish, which are at a high trophic level, but also by invertebrates such as shrimps, which are detritivores. Shrimps act as decomposers by consuming dead organisms and waste in hydrosystems.

Rivers in general and those of the Democratic Republic of Congo in particular are complex and dynamic ecosystems, characterized by relatively high biological productivity and considerable resource diversity. Their socio-economic importance can be assessed both in terms of the intensity of fishing practiced in them and the diversity of species caught

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[2]. In addition, the exploitation of crustaceans in inland waters represents a very old specific activity for which various traditional methods have been developed by fishermen.

Crustaceans are organisms belonging to the phylum Arthropod, whose bodies are covered by a chitin-protein exoskeleton called exocuticle and often impregnated with calcium carbonate. Decapod crustaceans have a prominent place in the scientific context because of their great economic importance. In addition, they provide the population with almost one third of the animal protein needed for its diet [3].

Around the world, numerous data are available on crustaceans [4, 5, 6, 7, 8, 9, 3, 10, 11, 12]. In the DRC in particular, some work has been done on this group of living beings [13, 14, 15, 16] but studies on this group in the Kinshasa region are still embryonic. Taking into account that the crustacean species are present in the Kinshasa region (Pool Malebo) and that they all cycle in freshwater, this study is based on the biology and ecology of these species in view of their possible domestication in ponds.

The overall objective of this study is to highlight the morphological characteristics of decapod crustaceans necessary to understand their way of life. This will be achieved by studying their biomorphology. More specifically, the aim is to 1) measure physicochemical variables; 2) study the diversity and abundance of crustaceans that inhabit the Pool Malebo, 3) measure morphometric parameters in order to better describe the morphology of the different species and evaluate the growth pattern of each of the species present in this part of the Congo River.

1.1. Study environment

The Pool Malebo (4°5'- 4°18'S and 15°19'- 15°32'E) is a portion of the Congo River (Figure 1) 35 km long between Maluku and Kinsuka and 23 km wide. It has an area of roughly 500km2 and the depth of the river at this level varies between 3 and 16m [17, 18].

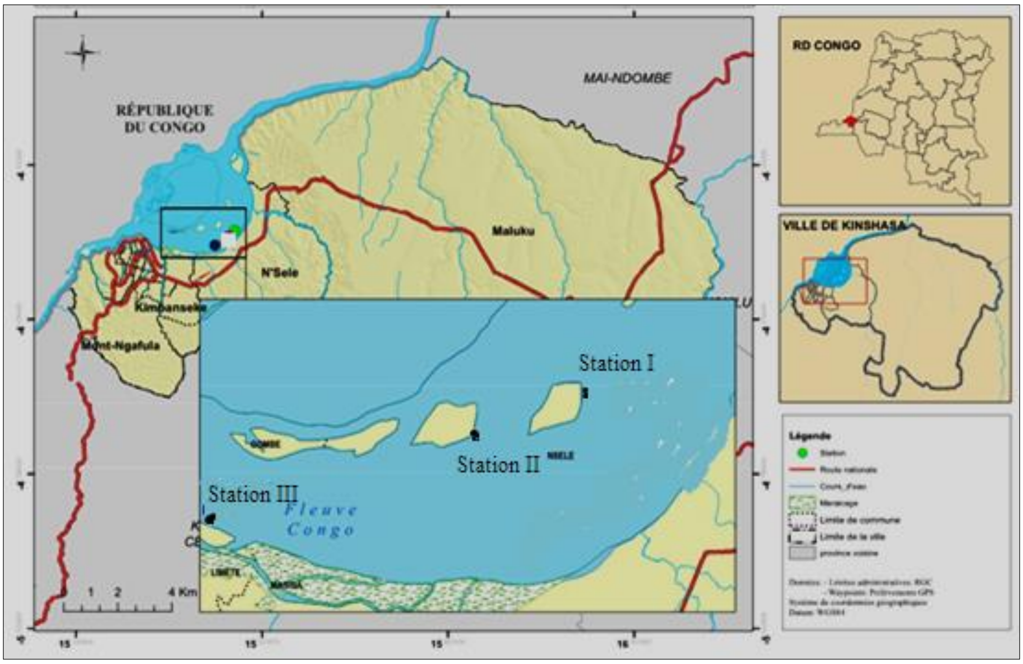

Figure 1 Localization of the study stations on the Pool Malebo of the Congo River

2. Material and methods

2.1. Measurements of physical and chemical parameters

The physical analyses of the water focused on temperature (°C), conductivity (µs/cm), turbidity (NTU) and hydrogen potential (pH). They were measured in situ using a Combo Hanna HI 98129 multiparameter analyser probe.

The chemical analyses included dissolved oxygen (mg/l), ammonia nitrogen (NH_4^+) (mg/l), nitrite (NO_2^-) (mg/l), nitrate (NO_3^-) (mg/l), phosphate (PO_4^{3-}) (mg/l), sulphate (SO_4^{2-}) (mg/l), and BOD_5 (mg/l). Apart from dissolved oxygen, which was measured *in situ* using the WTW340i/SET multiparameter probe, the other parameters were measured at the General Commissariat of Atomic Energy (CGEA/CREN-K) laboratory using the HACH DR/2400 spectrophotometer.

2.2. Measurement of biological parameters

2.2.1. Sampling and identification of crustaceans

Four hundred and sixty-seven crustaceans were sampled using the dipping technique described by [17]. This technique consists of collecting the target organisms in different microhabitats using a 400 µm mesh net. The staining of each specimen was noted before storage in pillboxes containing 10% formalin. In the laboratory, the specimens were washed with tap water and then preserved in 70% ethanol. By station, the organisms were transferred to Petri dishes, grouped according to their size and morphology for identification and enumeration under a binocular magnifying glass. After dissection, observations were made under an Ivymen light microscope. The keys and books proposed by [19, 20, 21, 22, 23] were used for the identification of crustaceans.

2.2.2. Morphometry and morphology of crustaceans

In the laboratory, measurements were made using an electronic Digital caliper (0-150 mm). The dimensions taken on the shrimps were: total body length (Lt), standard length (Ls), carapace length (Lc), rostrum length (Lr), abdomen length (La), merus length (Lm) and carpal length (Lca). The measurements taken on the crabs are: length (Lc) and width (lc) of the carapace. For meristic data, the values considered for shrimp are the number of spines on the dorsal and ventral side of the rostrum and the number of post-orbital spines. For crabs, the number of distal and proximal carpal spines are taken into account.

Morphometric parameters considered in crustaceans: a) shrimp in lateral view and b) crab in dorsal view. La: length of abdomen, Lc: length of carapace, Lr: length of rostrum, Ls: standard length, Lt: total length of body, Lm: length of merus, Lca: length of carpus.

The different lengths taken from the shrimps were related to the standard length in order to determine the different correlations that exist between the different parts of each species on the one hand and the differences between the crustacean species on the other. These ratios are:

- Lc/Ls: ratio of carapace length (cephalothorax) to standard length;
- Lr /Ls: ratio of rostrum length to standard length;
- La / Ls : ratio length of abdomen to standard length;
- Lca / Lm : ratio carpus length to merus length;
- Lc/lc : ratio length of the carapace to its width.

2.2.3. Statistical analysis of the data

Several analyses were used to study the crustacean populations of the Pool Malebo:

1° Specific richness (S)

Which corresponds to the simple counting of the number of species present in the sample;

2° Shannon Index H' [24]

Which is used in ecology as a measure of specific diversity. It is expressed by the following formula:

$$H' = -\sum_{i=1}^{S}\left(\frac{ni}{N}\right)\ln\left(\frac{ni}{N}\right)$$

Where: (S) is the total number of species present; (*ni*) the number of species i in the sample and (N) the total number. H' varies between 0 (in the case where the stand consists of only one species) and H' maximum (H'max = $\log_2$.S) in the case where all the species present are present with equivalent abundance.

3° Equitability index J' [25]

Which measures the equilibrium (or regularity) or even the equi-representation of the species in the stand in relation to a theoretical equal distribution for all species : J' = H'/Hmax

R varies between 0 (a single species dominates) and 1 (all species have the same abundance).

4°Simpson's index (1-D)

This index corresponds to the probability that two individuals drawn at random belong to the same category (species). When diversity is maximum, its value is 0, when diversity is minimum it is 1, which sometimes hinders its interpretation. It is an index independent of a distribution. To obtain more intuitive values, the diversity index represented by 1-D is used, with the maximum diversity represented by the value 1 and the minimum by zero. The index gives more weight to abundant species than to rare species. It is given by the expression:

$$\boldsymbol{D} = \sum_{i=1}^{k} \frac{\mathbf{1}}{\boldsymbol{pi}^2}$$

(Pi): proportion of the total number of individuals. This expression poses a problem in terms of the weight of abundant species, which may be difficult to collect. Hence the use of the following formula

$$\boldsymbol{D} = \mathbf{1} - \sum_{i=1}^{s} \boldsymbol{Pi}^2.$$

These different indices were calculated using Past statistical software (Paleontology statistical) version 6.1

3. Results and discussion

3.1. Physical parameters

The stationary variations of physical parameters of the Congo River in 2021 are shown in Figure 2.

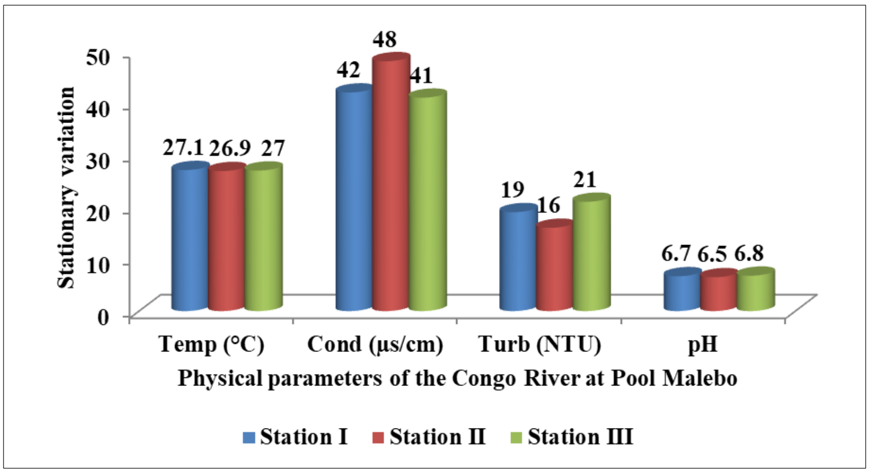

Figure 2 Stationary variations in physical parameters of the Congo River in 2021

Figure 2 shows that the average temperature values of the Congo River waters varied between 26.9°C and 27.1°C. The maximum temperature (27.1°C) was observed at station III. The minimum (26.9°C) was recorded at station II.

As regards the conductivity of the Congo River water, its values varied between 41µS/cm and 48µS/cm. The peak was reached by station II (48µs/cm) and the low value was observed at station III.

As for the turbidity of the river water, its values fluctuated between 16NTU and 21NTU. The highest value was observed at station III and the lowest at station II. The pH varied between 6.5 and 6.8. The values recorded at each station show a trend towards neutrality and indicate that the Congo River waters are very weakly acidic. The highest values were recorded at station III, while the lowest pH values were observed at station II.

3.2. Chemical parameters

The stationary variations of chemical parameters of the Congo River waters in 2021 are illustrated in Figure 3.

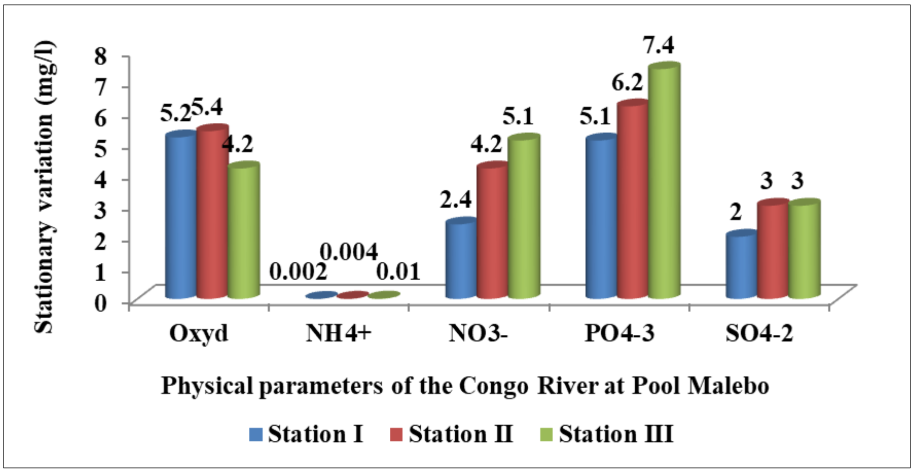

Figure 3 Stationary variations in chemical parameters of the Congo River in 2021

Figure 3 shows that the dissolved oxygen content in the river water varied between 4.2 mg/l and 5.4mg/l. The highest value (5.4mg/l) was noted at station II, while station III recorded low values (4.2mg/l).

Ammoniacal nitrogen levels fluctuated between 0.004mg/l (Station II) and 0.01 mg/l (Station III). These values increase from upstream to downstream.

The nitrate content varied longitudinally between 2.4mg/l (Station I) and 5.1mg/l (Station III). The highest concentration was recorded in station III while the lowest was recorded in station I.

The variation of phosphate content is increasing from upstream to downstream i.e. 5.1mg/l at station I and 7.4mg/l at station III.

As for the sulphate concentration, its values oscillated between 2mg/l and 3mg/l. Stations II and III recorded very high levels, while the lowest level was recorded at station I.

3.3. Crustacean population structure of the Pool Malebo by station

Table 1 Crustacean species caught in the Congo River in the Pool Malebo in 2021

Family	Species	code	Station I		Station II		station III		N'
			ni	ni/N	ni	ni/N	ni	ni/N	
Palaemonidae	*Macrobrachium sollaudii*	Masol	73	0.57	121	0.543	30	0.256	224
	Caridina africana	Carfri	39	0.31	75	0.336	31	0.265	145
Atyidae	*Caridina togoensis*	Carto	12	0.09	22	0.097	25	0.214	59
Potamidae	*Soudanonautes melii*	soume	3	0.02	5	0.022	31	0.265	39
N			127		223		117		469
S			4		4		4		

The stationary distribution of crustaceans, their gross and relative abundances in the Pool Malebo are recorded in Table 1.

Legend

N: number of individuals per station; N': number of individuals per species; S: species richness

Table 1 shows that the highest gross abundance of crustaceans in the Pool Malebo was observed at station II with 223 individuals which represented 47.55% of the total abundance. It was followed by stations I and III which respectively counted 127 individuals (i.e. 27.1%) and 117 individuals (i.e. 24.9%) of the total catch.

At station level, at station I, the species *M. sollaudiis* was the most represented with 73 individuals (57% of the total abundance). It was followed by the species *C. africana* with 39 individuals (i.e. 31%), *C. togoensis* with 12 individuals (i.e. 12%) and *Soudanautes sp*. with 3 individuals (i.e. 2%) of the total number.

At the St II station, the species *M. sollaudiis* was represented with 121 individuals (54.3% of the total number). It was followed by the species *C. africana, C. togoensis* and *Soudanautes melii.* with 75, 22 and 5 individuals, representing respectively 33.6%; 9.7% and 2.2% of the total abundance.

At the St III station, the highest abundance was observed within the species *Soudanautes* sp and *C. africana* with 30 and 25 individuals respectively (representing 25.6% and 24.1% of the total abundance).

3.4. Index analyses

The stationary index variations of crustacean populations in the Pool Malebo are illustrated in Figure 4

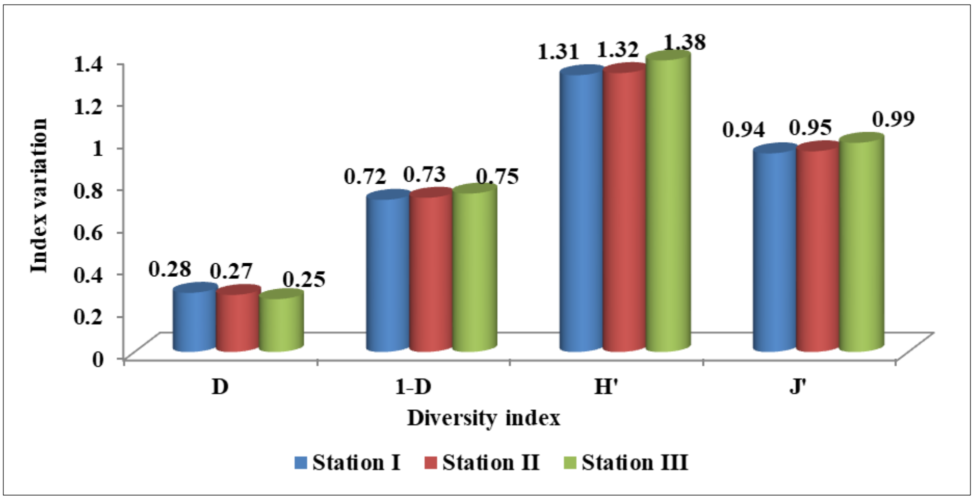

Figure 4 Variations in station indices of crustacean populations in the Pool Malebo in 2021 (D: Dominance; 1-D: Simpson Index; H': Diversity index of Shannon ;J': Equitability index)

Figure 4 shows that the highest dominance was observed at station I (0.28) and the lowest at station III (0.25).

With regard to the Simpson index, the highest value was recorded at station III (i.e. 0.75) while station I had the lowest value (i.e. 0.72).

Station III was more diverse than the others (sot 1.38) while station I was the least diverse (1.31).

The Equitability index varied between 0.94 and 0.99. The highest value of Equitability was recorded at station III with 0.99 and station I had a low value of 0.94.

3.5. Morphological characteristics of the different crustacean species

During this study, the individuals collected all belong to the order Decapoda in which the first three pairs (P1 to P3) of thoracopods or pereiopods are transformed into maxillipeds, the next five pairs (P4 to P8) being the only ones with a locomotor function. P1 is often transformed into a claw (cheliped) and is particularly developed. The periopods are generally without exopods in the adult. These individuals are divided into two suborders (Natantia and Reptantia), two infra-orders (Carididae and Brachyurae), three families (Atyidae, Paleamonidae and Potamidae), three genera (*Caridina, Macrobrachium* and *Soudanonautes*), three species of shrimp (*Caridina africana, Caridina togoensis, Macrobrachium soullaudii*) and one morphotype of crabs of the genus *Soudanonautes*.

3.5.1. Macrobrachium soullaudii.

In this species, the first two pairs of legs are dissimilar; they are terminated by a claw. The fingers are lined with small setae. Only the second pair is more developed (more powerful) with a simple, undivided carpus. The key to families of [26] classifies these individuals in the family Palaemonidae. This family includes among others: the genera *Desmocaris* , Leander and *Macrobrachium* . Furthermore, the fingers of the last three pairs of legs (P3-P5) ending with hooked claws allow them to be attached to the genus *Macrobrachium* according to [19]. In this species, the P2s are identical and slender, with fine bristles running along their length. The carpus is distinctly longer than the merus, the dactyl longer than the carpus, the rostrum shorter than the carapace. In the adult male, the claw is without tubercles other than the few proximal teeth on the dactyl and finger. Part of P2 is pubescent. The slightly convex rostrum does not reach the tip of the antennal scale. It has five to seven spines on the dorsal side and three to four spines on the ventral side; hence the rostral formula 5-7/3-4. Ovigerous females carry about twenty medium-sized eggs of 5 mm diameter glued to the pleopods. Individuals of this species are of medium size. The total length varies between 26.3 and 92.6 mm with an average of 44.1 ± 17.7 mm.

3.5.2. Caridina

Individuals of this species have periopods 1 and 2 terminated by pincers, which are inserted more or less obliquely into the distal carpal notch, the fingers being extended by a brush of setae and the mandible lacking a palp. Referring to the key to families in [19], these individuals are in the family Atyidae. This family includes a total of three genera: *Atya, Caridinopsis* and *Caridina*. Furthermore, this shrimp is small in size (10-30 mm). The claws of both pairs of periopods (P1-P2) are not split to the base and have a distinct palmar portion and a carpus that is not or only slightly indented. The digital sieve is shorter than the claws. P3 is slender with a well-developed dactyl. The rostrum is dorsally spinose; P1 with a complete carpal notch has an arthrobranchia at its base. This allows them to be attached to the genus *Caridina* [19]. In this species, the rostrum is dorsally and ventrally spinular. P1 has a complete carpal notch. P3 is highly developed and ends in the dactyl. The rostrum is shorter than the carapace with the tip of the apex pinkish; the posterior margin of the telson bears 6-8 barbed spines longer than the inner lateral spines. In males the dorsal spines of the rostrum are not limited to the same level as those of the ventral side, while in females both the dorsal and ventral spines of the rostrum are limited to the same level. The body is generally creamy white with pinkish areas. The total length varies between 7.76 and 29.61 mm with an average of 15.8 ± 3.0 mm. The standard length is longer than the rostrum, abdomen and carapace.

3.5.3. Soudanonautes melii.

The individuals are of the superfamily Branchyura, characterized by a dorso-ventrally flattened body and a transversely enlarged carapace, without an individualized protruding rostrum; the abdomen, very reduced, flattened, is folded under the cephalothorax and does not bear a caudal fan. P1 is terminated by a pincer or cheliped. According to [19], individuals with a mandibular palp with an entire terminal article adjacent to the mandible belong to the family Potamidae. Three genera are distinguished within this family: Potamonautes, Liberonautes and Soudanonautes. Furthermore, individuals with an intermediate tooth on the anterolateral margin and a second gonopod (Go 2) shorter than the first gonopod (Go 1) with a reduced terminal article are of the genus *Soudanonautes*. Thus the crabs collected in the Congo River belong to the genus *Soudanonautes*.

An ecosystem, whether aquatic or terrestrial, is characterized by a set of ecological factors. These are either abiotic or biotic. Abiotic factors include all the physico-chemical characteristics of the environment and biotic factors are all the interactions that take place between individuals of the same species or different species [27].

Indeed, it is known that ecological factors play a determining role in the number and nature of species likely to cohabit in a given ecosystem [28]. Reference [29] has shown that the distribution of aquatic fauna is largely influenced by the physical and chemical quality of the water (dissolved oxygen, temperature, pH, suspended solids, hardness, ammonia, etc. ....). And the seasonal cycle of flood patterns, duration and intensity in tropical environments are important [30]. Similarly,[31] emphasizes the role of hydrology as a structuring factor in aquatic ecology and also notes that hydrological variability resulting from the seasonal distribution of rainfall or the inter-annual variability of precipitation has important consequences on the biology of species and the dynamics of aquatic populations.

Water temperature plays an important role in the modification of chemical and physical properties as well as biological reactions [32]. In the waters of the Congo River, this parameter shows values between 26.9°C (station II) and 27.1°C (station I) (Figure 2) and does not show large variations between sampling stations and remains close to the temperature of the region [33]. They are close to those obtained by [34] who confirms that most tropical waters have a temperature of 25°C or higher. This is due to the exposure of the waters to direct solar radiation.

Reference [35] states that this is an acceptable temperature to complete the development cycle of crustaceans and in the aquarium the holding temperatures for shrimp vary for different species; these temperatures range from 15 to 30°C. However, a good compromise for the species *Macrobrachium sollaudii* is around 25°C.

The results of this study show that the average pH values of the waters of the Congo River vary between 6.5 and 6.8. The average of these values is comparable to those found on Chari at D'jamena [36]. This could be explained by the quality of humic acid-rich wastewater discharges from urban activities. The average value of 6.7 obtained at the river seems to confirm the remarks of [37] according to which, because of the buffering capacity of water, i.e. its ability to oppose any variation in its pH, it is rare, except in the case of discharges, for the pH to deviate from the 6.5-8.5 range.

The measurement of conductivity allows an overall assessment of the mineralization of the water. Figure x shows that the average conductivity values of the river water are between 41µS/cm and 48µs/cm. From these data it can be seen that the mineralization of the Congo River water is low because the measured conductivities are below 100 µs/cm).

The conductivity values measured are well below the limit value of 1000 µs/cm set by the WHO. The mean values of the measured values are slightly higher than those obtained by [38] in the Congo River (33µS/cm).

The average turbidity values of the waters at the different stations are between 16 NTU and 21 NTU (Figure 2). It follows that the waters of the Congo River are turbid. This turbidity is a function of the rapids experienced by the Congo River at Kinsuka pêcheur. This increase in turbidity is the result of rainwater runoff carrying large quantities of waste from various urban activities and the resuspension of sediments previously deposited in the river.

The pH (hydrogen potential) measures the concentration of H+ ions in water and thus reflects the balance between acids and bases on a logarithmic scale from 0 to 14. This parameter conditions a large number of physico-chemical equilibria [24]. Its values are between 6 and 7.4 in natural waters [39]. For the Congo River waters, they do not show significant variations and tend to be neutral with a minimum of 6.5 and a maximum of 6.8. These values around neutrality are most often linked to the nature of the terrain through which the water flows [33]. According to [40], most of Kinshasa's watercourses have a pH that oscillates around neutrality.

Dissolved oxygen measures the concentration of dissolved oxygen in water [41]. O2 concentrations are one of the most important water quality parameters as it is essential for aquatic life and the degradation of biodegradable pollutants allowing self-purification [33]. Oxygen in surface waters comes mainly from the atmosphere and from the photosynthetic activity of algae and aquatic plants (macrophytes). It is involved in the majority of chemical and biological processes in the aquatic environment and its average content in unpolluted surface waters is 8 mg/l.

O2 concentration varies daily and seasonally as it depends on many factors such as: atmospheric pressure, water temperature, salinity, light penetration, water agitation and nutrient availability [42]. According to [42], levels below 1 mg O_2/l indicate a state close to anaerobic, 1 to 2 mg O_2/l indicate a heavily polluted river but in a reversible way, levels of 4 to 6 mg O_2/l characterise a good quality water and levels above the natural O2 saturation level indicate an anthropisation of the environment.

The results of our study showed values between 4.2 mg/l (station III) and 5.4 mg/l (station II). In general, the dissolved oxygen content decreases with organic pollution. These values indicate that the water quality of the river at the Pool Malebo is of good ecological quality.

Naturally occurring and soluble in the soil, nitrates enter the soil and groundwater and flow into the watercourses. However, they are also synthetically added by fertilisers [39] and are a factor in the degradation of water quality.

Nitrates are generally derived from the decomposition of organic matter by bacterial oxidation of nitrites and are thus the ultimate product of nitrification [32]. Nitrate levels range from 2.4 mg/l to 5.1 mg/l. Nitrate contamination in the studied hydrosystem is linked to inputs of industrial and municipal effluents [43] and also to soil leaching. Nevertheless, its values remain below the 30 mg/l limit value set by the WHO.

The natural origins of sulphates are rainwater and the dissolution of evaporitic sedimentary rocks, in particular gypsum (CaSO4), but also pyrite (FeS) and more rarely magmatic rocks (galena, blende, pyrite) [32]. Anthropogenic origins are the combustion of hydrocarbons which leads to a significant production of sulphides and, the use of chemical fertilizers and lye [44]. The reversible transformation of sulphates into sulphides occurs through the sulphur cycle [45]. Surface waters contain highly variable levels of sulphates and their concentration is generally between 2.2 mg/l and 58 mg/l [46]. The values of this parameter in the studied waters are not very variable and have varied from upstream to downstream between 2 mg/l and 3 mg/l. These sulphate levels in the study area may be caused by urban anthropogenic activities (wastewater discharges and various effluents, etc.).

The inventory of crustaceans in the Pool Malebo revealed three genera: two shrimps (*Macrobrachium* and *Caridina*) and one crab (*Soudanonautes*). Several factors would also explain this low richness in the Pool Malebo: abiotic factors, the fishing methods used, the types of microhabitats sampled and the sampling periods [47].

The abundance of *Macrobrachium sollaudii* in the Pool Malebo could be explained by adaptation in several types of habitats (ponds, swamps, streams, rivers and estuaries [1] and can tolerate turbid, muddy waters and warm pools lacking oxygen [48].

The assessment of species richness, Shannon-Weaver index and Piélou equitability revealed that these metrics evolved in a similar way in the different study stations.

4. Conclusion

The study of the structure of the crustacean populations on the one hand and their diversity on the other showed that the Pool Malebo presents a favorable environment for crustaceans where this population can settle and develop despite the anthropic pressure that this system is experiencing. On the other hand, some microhabitats present in this zone would also be at the origin of this observed diversity.

The highest gross abundance of crustaceans in the Pool Malebo was observed in *M. sollaudiis* (224 individuals which represented 47.9% of the total abundance). It was followed by *C. africana, C. togoensis* and *Soudanautes melii*. which counted 145, 59 and 39 individuals respectively, i.e. 31.1%, 12.6% and 8.3 of the total catch.

Compliance with ethical standards

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Disclosure of conflict of interest

No conflict of interest.

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