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Macrobenthic biodiversity of Afrotropical wetlands: the swamps of Kisangani (Tshopo, DRC)

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Abstract
Tropical wetlands are not only among the most vital ecosystems in the world, containing unique aquatic and terrestrial communities with high biodiversity but also severely under threat due to anthropogenic activities. Kisangani is one of those places that need inversion. This study aimed at assessing macrobenthic biodiversity occurring in the Kisangani swamps to represent Afrotropical wetlands to facilitate conservation of the freshwater invertebrates. Benthic macroinvertebrates were collected from Camp Bauma, Konga-Konga, Dechaux and Scolasticat swamps in Kisangani, Democratic Republic of Congo (DRC). A total of 47 families of macroinvertebrates were found, comprising of twelve Coleoptera, eight Diptera, seven Heteroptera, six Trichoptera, five Odonata, two Decapoda, two Gastropoda one Ephemeroptera, one Plecoptera, one Dictyoptera, one Haplotaxina, and one Lumbriculida. Coleoptera was the most dominant group with 24.95 % of all individuals collected, followed by Odonata and Gastropoda with 18.36 % and 13.9 %, respectively. The family richness across the localities was not significantly different ($\chi^2 = 0.0742$, $p = 785379$). These findings augment previous research on wetlands that despite their usefulness, wetland ecosystems are under serious degradation threat, and therefore sustainable environmental management plans are needed to countereffect the rapidly growing cities like Kisangani.

Keywords: Tropical wetlands, freshwater invertebrates, diversity, conservation, kisangani

1. Introduction

Tropical wetlands, due to their shallowness, warm temperature, abundant light and high nutrient content, are among the most vital ecosystems in the world, containing unique aquatic and terrestrial communities with high biodiversity [1]. Most significantly, as everyone tends to develop a system that produces more food per unit of surface area, the productive environments, as tropical wetlands, have become the place of traditional agriculture. As a consequence, these agricultural activities force wetlands in their destruction. Whereas this tendency has to be inverted taking into account of the different context: pollution, reduction of animals and plants species as well as flooding in repetition, all those factors must lead to replacing the questions of the environment protection and water management to the centre of preoccupations [2].

Kisangani is one of those places that need inversion. The geographical position of Kisangani, consisting of a relief characterized by the united plateau with weak slant and terraces and all year round rainfall, favours the formation of several swamps. These swamps are categorized into small and big according to their utility. Small ones are primarily used for subsistence agricultural activities, and relatively big swamps are used in two folds: (i) trees with high water transpiration rates are planted to increase house building ground and (ii) construction of poorly maintained fishponds. As a consequence, these anthropogenic activities dehydrate and reduces soil fertility of the swamps, and potentially causing the extinction of an unadapted fauna and flora of these environments [3, 4]. Unfortunately, Kisangani swamps have not been well studied. Generally, there is no inventory data as well as IUCN conservation status of fauna occurring in those wet environments.

Albeit the Congo River basin is among the most recognized global hotspots of aquatic biodiversity in Africa, this productive freshwater ecosystem remains poorly explored. As a result, the knowledge of macrozoobenthos compositions in the Congo basin is fragmentary. Being part of the Congo river basin, the biodiversity of the swamps of Kisangani is not well understood.

This fact is worrying because there are two significant dangers which threaten freshwater invertebrate fauna in the Kisangani swamps. Firstly, the habitat is under threat from various factors such as global climate change and human activities, namely deforestation, mining, untreated wastewaters and the growth of industrialization to the shores in the area [5]. Moreover, the lack of conservation laws due to non-appreciation by the governments and indigenous communities [6] may endanger species. With this regard, the knowledge of this unique diversity becomes more than a necessity for better conservation.

We perceived our goal as assessing macrobenthic biodiversity occurring in the Kisangani swamps to represent Afrotropical wetlands to facilitate conservation of the freshwater invertebrates. The present paper, therefore, reports the diversity of freshwater invertebrates in Kisangani swamps.

2. Materials and methods

Kisangani, formally the Stanleyville, is the capital city of the Tshopo province and the third biggest city in the DRC. The city is also the largest among the cities situated in the tropical woodlands of the Congo. It is lies between 0°31′0′′N and 25°12′0′′E and is famous for its waterfalls called Boyoma falls; the seven-arched falls located south of the city. Kisangani spreads on a surface of 1910 km² and is characterized by a relief dominated by the United plateau with weak slant and terraces. Kisangani delights in an equatorial climate with four seasons of which two small seasons of rain, and two dry seasons [7].

Benthic macroinvertebrates were collected from Camp Bauma, Konga-Konga, Dechaux and Scolasticat, swamps in Kisangani (Figure 1). These swamps were chosen because Konga-Konga and Dechaux swamps are closest to the human residence and Camp Bauma and Scolasticat are some distance to the residential area.
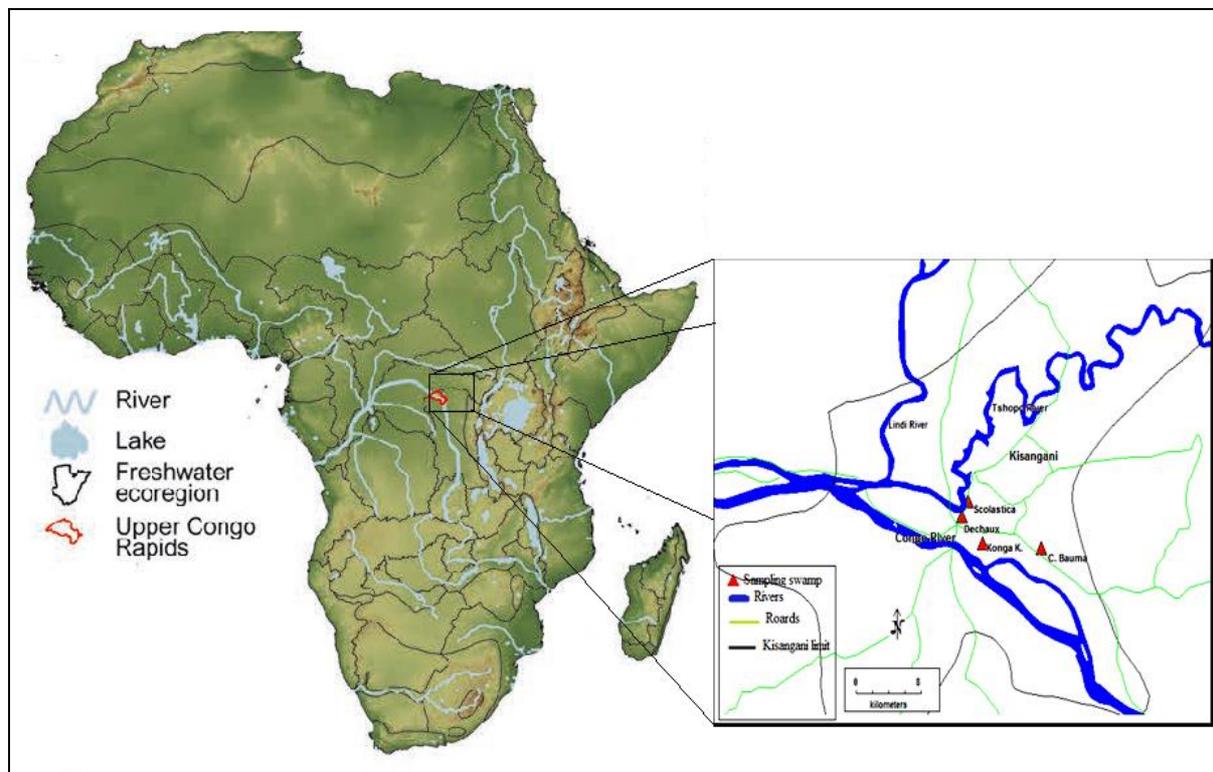

Fig 1: Study area. Plot showing (a) topographic map with superimposed African freshwater ecoregions (Abell et al., 2008) [8] and the position of the Upper Congo Rapids ecoregion, (b) the four sampling swamps in Kisangani city.

Macrozoobenthos were collected using a scoop net with a diameter of 20 cm and a mesh size of 1 mm. The scoop net was attached to a long handle, placed on the swamp bed. The method was to scrape the swamp bed and to agitate the substrate in front of the net by simple kicks and steps. Moreover, we used a handheld kitchen sieve with a diameter of 20 cm and a mesh size of 2 mm in areas of leaf litter and other plant debris to collect benthic invertebrates specimens. Besides, smaller rocks, stones, and macrophytes were taken out from the swamp and visually to search macroinvertebrates. All the samples from a sampling point was spilled in a bucket, and the net was rinsed by river water into the bucket. The sorting was done manually using forceps, specimens were separated according to taxonomic groups and were transferred in plastic containers filled with 80% ethanol. All the samples was stored in the Hydrobiological and Aquaculture Laboratory of the Faculty of Sciences of the University of Kisangani.

Invertebrates were determined up to family level in most cases using the nomenclature of Brown (1980) [9]; Tachet *et al.* (1980 and 2010) [10, 11]; Levêque (1981) [12]; OMS (1982) [13]; Brown (1994) [14]; Day & De Moor (2002) [15]; De Moor & Day (2002) [16]; Gerber & Gabriel (2002) [17]; De Moor *et al.* (2003) [18]; Day *et al.* (2001b) [19]; Stals & De Moor (2007) [20]. The number of individuals of each taxon and the number of specimens at each sampling site was counted.

2.1 Statistics analysis

To quantify the biodiversity of the swamps, we used the Shannon-Weaver, the Simpson and the Equitability indices of diversities (performed by Past3) to explain the differences in macroinvertebrate diversity in the four swamps.

Additionally, to determine the distribution of species and the composition of assemblages we assessed the importance of

recorded environmental variables by fitting them on an ordination plot. The non-metric multidimensional scaling (NMDS) using Euclidian distances based on presence/absence matrix was applying to explore the ecological similarities between families and assemblage and to show the variables that explain most of the variability in assemblage composition. We used the function Envfit in the Vegan package of the statistical software R [22] to know which environmentalvariables affected the assemblage composition in swamps of Kisangani.

3. Results

A total of 47 families of macroinvertebrates were collected in the four swamps in Kisangani, namely Camp Bauma, Konga-

Konga, Dechaux and Scolasticat, from December 2015 to June 2016. They comprised of twelve Coleoptera, eight Diptera, seven Heteroptera, six Trichoptera, five Odonata, two Decapoda, two Gastropoda one Ephemeroptera, one Plecoptera, one Dictyoptera, one Haplotaxina, and one Lumbriculida (Table 1). Coleoptera constituted the dominant group with 24.95 % of all (125) individuals collected. Odonata and Gastropoda were next with 18.36 and 13.9 %, respectively. Followed by Diptera (9.7%), Heteroptera (8.7%), Trichoptera (7.7%), and Decapoda (7.38%). Uncommon groups were Ephemeroptera (3.39%), Haplotaxina (1.99%), Dictyoptera (1.79%), Plecoptera (1.39%), and Lumbriculida (0.39%).

Table 1: Macrozoobenthos species occurring in the four sampling swamps, species presence, and absence. SW1= Camp Bauma, SW2= Konga-Konga, SW3= Dechaux, SW4= Scolasticat,

Order	Family	SW1	SW2	SW3	SW4
Odonata	Aeschnidae	1	1	1	1
	Calopterygidae	1	1	1	1
	Gomphidae	1	1	1	1
	Corduliidae	1	0	1	0
	Coenagrionidae	1	1	1	1
Coleoptera	Elmidae	1	1	0	1
	Hydrophilidae	1	1	1	1
	Haliplidae	0	1	0	1
	Georyscidae	1	0	0	0
	Gyrinidae	1	1	1	1
	Dystiscidae	1	1	1	1
	Eubriidae	1	0	0	0
	Helodidae	0	1	0	1
	Dryopidae	1	1	1	1
	Coyridae	0	0	1	0
	Hydrochidae	0	1	0	0
	Hygrobiidae	0	1	0	0
Diptera	Athericidae	1	1	0	1
	Tipulidae	1	1	1	1
	Empididae	1	0	1	1
	Simuliidae	0	1	0	0
	Chironomidae	0	1	1	0
	Limoniidae	1	0	0	1
	Culucidae	1	0	0	1
	Psychodidae	0	1	0	0
Heteroptera	Mesoveliidae	1	1	1	1
	Veliidae	1	1	1	1
	Nepidae	0	1	0	0
	Notonectidae	0	1	0	0
	Naucoridae	0	1	0	0
	Gerridae	1	1	1	1
	Corixidae	0	1	0	1
Trichoptera	Philopotamidae	1	1	1	1
	Ecnomidae	0	0	1	1
	Psychomyidae	0	1	1	1
	Hydropsychidae	1	1	1	0
	Colanoceratidae	0	0	1	0
	Gamoceratidae	1	0	0	0
Ephemeroptera	Heptageniidae	1	0	1	1
Plecoptera	Perlidae	1	0	1	1
Dictyoptera	Blattidae	1	1	0	0
Decapoda	Atyidae	1	0	1	1
	Potamonautidae	1	1	1	0
Gastropoda	Thiaridae	1	0	1	0
	Ampullariidae	1	0	1	0
Haplotaxina	Lumbricidae	0	1	1	1
Lumbriculida	Lumbriculidae	0	1	0	0
Total 12	47	30	32	28	27

The families of Thiaridae and Ampullaridae had the highest relative abundance, respectively 7.3 % and 6.5%; and the family of Eubriidae had the lowest individual caught (0.19%) (see fig.2). The Konga- Konga swamp had the high family richness (32), followed by the Camp Bauma swamp, Dechaux swamp, and Scolasticat swamp, respectively 30, 28, and 27 families caught (tab.1). The family richness across the localities was not significantly different (The chi-square statistic = 0.0742, p-value = 0.785).
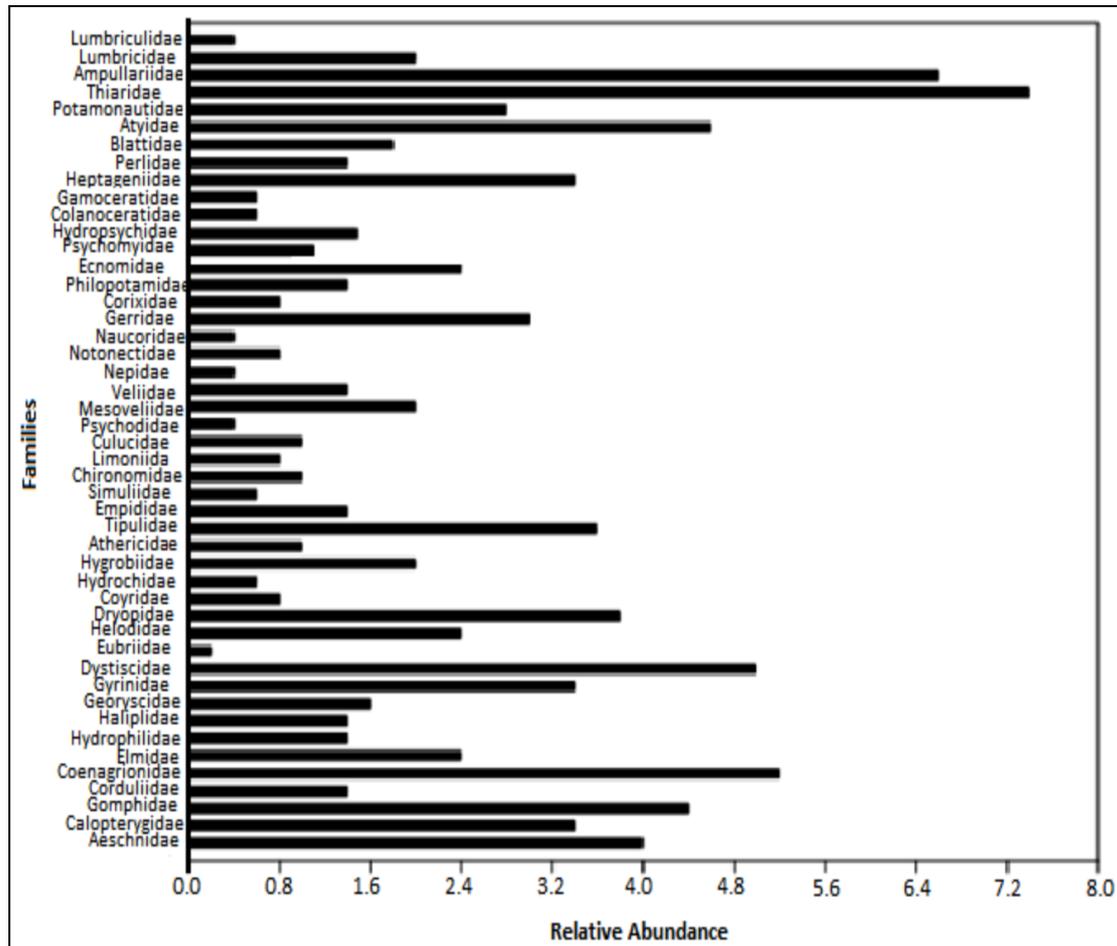

Fig 2: Relative abundance (%) of benthic invertebrates collected in four swamps of Kisangani

The Shannon index was highest in Konga- Konga swamp (3.24), followed by Camp Bauma, Scolasticat, and Dechaux swamps, with scores of 3.095, 3.061 and 3.02, respectively. The Simpson and Equitability indices showed the values less than 1. A t-test on the biodiversity indices showed that means are not different in Simpson, Shannon and Equitability indices (p-value = 1) (see table 2).

Table 2: The diversity index of the four swamps. SW1= Camp Bauma, SW2= Konga- Konga, SW3= Dechaux, SW4= Scolasticat

	Simpson_1-D	Shannon_H	Equitability_J
SW1	0.9413	3.095	0.9014
SW2	0.9488	3.24	0.9349
SW3	0.9351	3.02	0.9063
SW4	0.9444	3.061	0.9288
P-values	1	1	1

4. Discussions

The benthic invertebrates fauna of swamps of Kisangani, as shown by our results, is mainly dominated by the group of insects (76.24 % of caught invertebrates). It is, in general, a taxonomic composition typical of the tropical freshwater system, where the benthic insect represents about 95% of macroinvertebrates [23, 24], and the African freshwaters in particular [25-29].

Nevertheless, the observed results confirm the negative impact of the urbanization on the swamps of Kisangani, as shown by the low percentages (12.5%) of Ephemeroptera, Plecoptera, and Trichoptera families (EPT) of all the caught insects. These findings corroborate Carlisle *et al*. (2007) [30] that the EPT families decrease with the urbanization of the hydrographic basins. A recent publication by Wembo *et al*. (2018) [31] on the mollusc communities of the central Congo River, also showed that the rapid growth of the town of Kisangani has significant environmental impacts due to increased human activities. As a consequence, it leads to changes in the overall faunal composition of the area. Moreover, Thieme *et al*. (2005) [5] reported that anthropogenic pressure resulting from deforestation, mining and untreated wastewater plays a vital role in the faunal composition in Central Africa rivers.

Unique assemblages of plants and animals may inhabit the permanent swamps with extraordinary adaptations despite the extreme conditions imposed by the dense swamp environment [32]. As a result, invertebrate species diversity is particularly high in many wetlands because of the high number of available microhabitats within-wetland complexes [33]. The biodiversity of Kisangani swamps as revealed by the Shannon index was high and showed values superior to 3 in the four sampling swamps. The Simpson index shows how uniformly

families were represented within a sampling area and the Equitability index indicates a similarity the families occurring in the four swamps. Wetland ecosystems are perceived as among the most productive habitats worldwide. They support innumerable biological diversity by providing the water and nutrients for primary productivity; which consequently sustains many plants and animals species viz. invertebrate, fish, amphibians, reptiles birds and mammals [1]. Nonetheless, they are among the most threatened ecosystem [34] as, for example in Kisangani, they are drained dry for the house construction and in most of the cases, they contain malnourished fishponds. Long and short-term dedicated conservation strategies should be established to preserve the macroinvertebrates fauna of the swamps of Kisangani.

Many other factors are involved in regulating the occurrence and distribution of swamp-dwelling invertebrates. The most important ones are the physicochemical parameters of water [35, 36], the effects of altitude and seasonality [37] as well as the substratum and vegetation [38, 39].
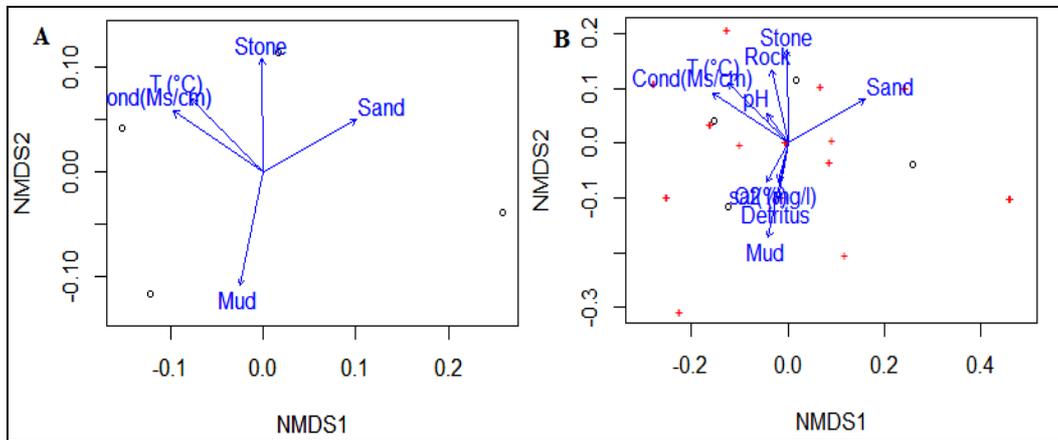

Fig 3: Non-metric multidimensional scaling (NMDS) of (a) sampling sites and (b) families showing the variables that explain most of the variability in assemblage composition.

Table 3: Variables affecting the assemblage composition in swamps of Kisangani

	R^2	Pr(>r)
T (°C)	0.9906	0.375
Cond (Ms/cm)	0.9877	0.08333.
pH	0.7228	0.70833
O2 (mg/L)	0.1751	0.95833
SatO2 (%)	0.2488	0.95833
Rock	1	0.04167 *
Stone	0.8064	0.41667
Sand	0.8561	0.25
Mud	0.7105	0.66667
Detritus	0.9751	0.20833

The findings of the present study also showed that local environmental factors, particularly those associated with the substrate (rocks, sand and stones) and physicochemical characteristics (conductivity, temperature and pH) significantly correlated with the macrozoobenthos community composition (fig.3A and B), confirm above authors. Besides, the investigated species assemblages' composition was heavily influenced by the variables like rock substrate and conductivity (Fig. 3A and B; Table 3), which usually have a considerable impact on species diversity.

5. Conclusion
Although the benthic invertebrates fauna of Kisangani swamps is mainly dominated by insects, it is a typical taxonomic composition of the most tropical freshwater system. However, the low percentage of the EPT families (Ephemeroptera, Plecoptera, and Trichoptera) is an indication that the growth of Kisangani city has negative impacts on the surrounding wetlands. Based on these findings, it cannot be overstated that many wetlands surrounding human settlements call for immediate action. Since wetland ecosystems have essential functions globally, sustainable environmental management plans are needed to buffer the rapidly growing cities like Kisangani.

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