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IDENTIFICATION OF INVASIVE ALIEN SPECIES AND ASSESSMENT OF ECOLOGICAL FACTORS IN THE POOL MALEBO IN KINSHASA, DEMOCRATIC REPUBLIC OF THE CONGO

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Abstract. The aim of this study was to identify invasive aquatic species and assess ecological factors in 5 islands, namely Mipongo, Japon, Kabongo, Kingabwa and Molondo.of the Pool Malebo. A floristic inventory was conducted around these sites and physico-chemical characteristics were measured in each island between 8:00am and 3:00pm using an appropriate electronic probe. The floristic affinity between sites was determined by cluster analysis using MVSP software version 4.03, after highlighting the Jaccard's coefficient based on the presence/absence of species in the different collection sites. The comparison between the sites was carried out using the ANOVA test with SPSS 25 software for physico-chemical parameters. The findings show that 24 species were identified as invasive out of which, six were dominant, namely *Eichhornia crassipes, Echinocloa pyramidalis, Pistia stratiotes, Leersia hexandra, Ludwigia abissinega*, and *Ludwigia sp*. No significant differences were observed for the temperature (F = 0.42 and p = 0.66), conductivity (F = 1.55 and p = 0.25) and turbidity (F = 2.28 and p=0.14) for the three sites. While the pH (F = 4.98; p = 0.026; LSD = 0.361), dissolved oxygen (F = 12; p = 0.001; LSD = 3.65) and salinity (F = 4.06; p = 0.04; LSD = 1.69) showed significant variation in three sites. The formation of vegetation groups around these islands in the Pool Malebo would also be justified by the influence of these parameters. The spread of invasive alien species on the surface of the river needs to draw more attention to scientists, policy makers and government in order to find a way to a good management of these species.

Keywords: Invasive species, identification, ecology, Pool Malebo.

1. Introduction

Several developing countries are facing pollution problems from various origins, and the Democratic Republic of Congo (DRC) is not an exception. According to 2016 statistics of Kinshasa city hall, every day this town produces 9000 tons of solid waste. Due to the lack of adequate sanitation, this waste is mostly dumped in waterways, streets, open sewers becoming public garbage cans or dumping grounds. This causes generalized insalubrity and poor individual and collective hygiene conditions (Gutberlet; Uddin, 2018, Ferronato; Torretta, 2019). The rivers in Kinshasa are experiencing increasingly high levels of pollution. This region is currently experiencing strong demographic growth; the industries that are being set up need a huge personnel, with obvious effects on the pollution of the rivers that cross it (Champiat et al., 1988). The

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monitoring of the water quality of these rivers is necessary because they favour the growth of invasive alien species on their surface, which disturbs the runflow of the rivers (Le Maître et al., 2015). Besides, the introduction of invasive alien plants (IAPs) is now considered to be a major cause of local extinction of native freshwater and plant species (Apedo, 2015, Rai; Singh, 2020).

In Africa, these invasive species are the cause of several problems on the water ecosystem as they constitute hazards elsewhere in the world. They interfere with the flow of rivers, canals and drains therefore they bring perturbation to the irrigation schemes which slow the drainage of water from floodplains (Chu; Karr, 2017). Furthermore, these species impede boat navigation, recreation and fishing; suppress indigenous vegetation by overgrowth and affects the light climate in the water; threaten hydroelectric power plants. These invasive aquatic species increase water losses through evapotranspiration, and entrap sediment, thus decreasing the capacity of the reservoir for water resources (Kurungundla et al., 2016). In the Democratic Republic of the Congo (DRC), there are almost no report or literature on invasive alien species in the Congo river and its effluents. Thus, there is a need of investigating on these species in order to find a good management system. The Pool Malebo is very rich in biodiversity both animal and vegetal, and it has an environment which is opened to all tributaries which flow into the Congo river. The abundance of invasive species might influence and modify its physico-chemical parameters along with its abiotic factors, which leads to the disturbances of aquatic life. The main purpose of this research was to identify invasive species in the Pool Malebo and assess abiotic factors of this affluent of Congo River.

2. Materials and Methods

2.1. Study area

This research was conducted in different islands of the Pool Malebo, which are Mipongo, Japon, Kabongo, Kingabwa and Molondo, situated at the Eastern part of Kinshasa, DRC as shown in the figure below.

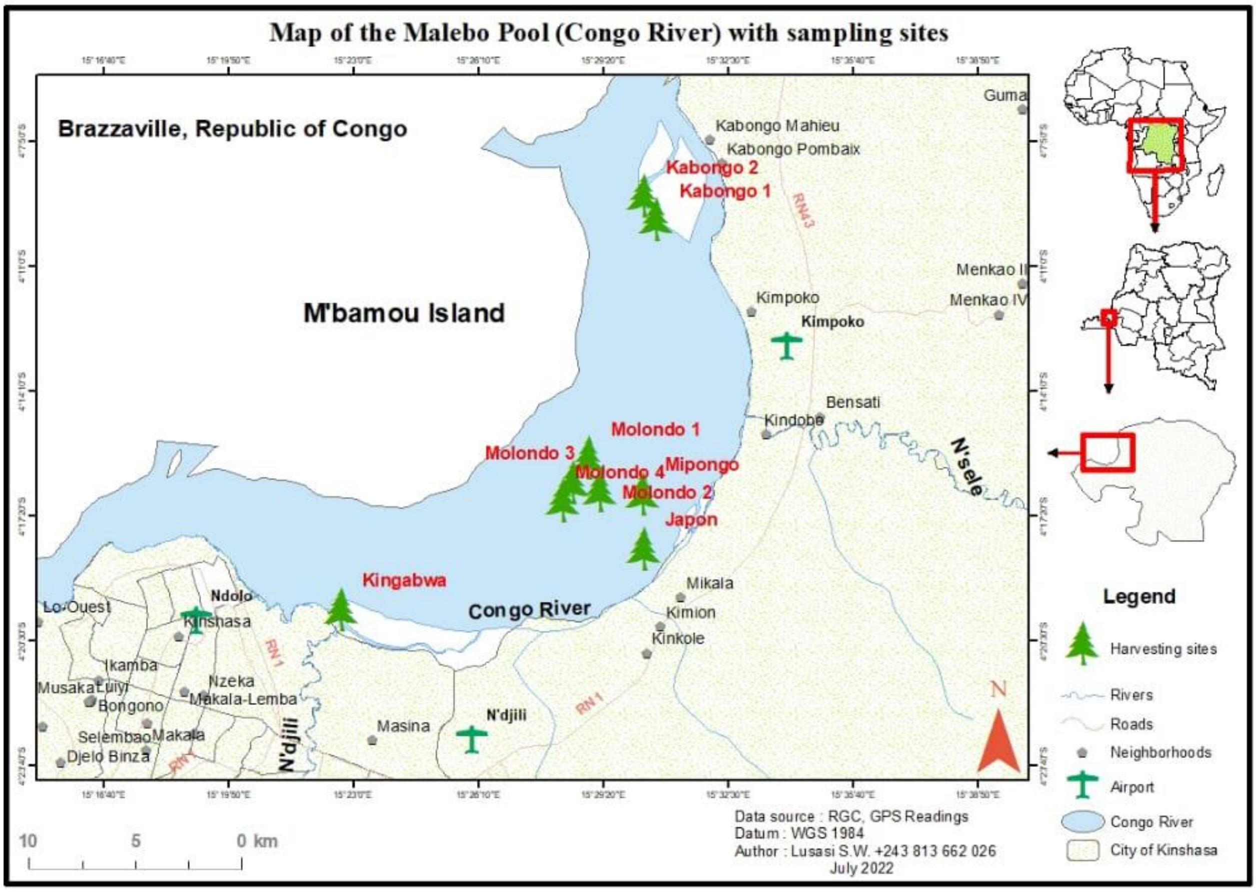

Fig. 1. Map of Pool Malebo indicating different sites

2.2. Study Design and Sample Collection

A simple random sampling procedure was used to select different sites where the sampling was realized (sample collection). It should be noted that all these sites were invaded by invasive alien species. In fact, we proceeded by a direct observation for the sample collection. Using a canoe, we were able to collect invasive species situated in the middle of the Congo River, knowing that the sample collection depends on the location of different sites. Samples were collected between 8 am and 3 pm. Identified species were listed either alien species or invasive alien species following the status of the study area. These species named "invasive" are species that cause any apparent damage or may pose threats to native aquatic ecosystem and to the economy. This research was carried out in August 2020.

The rivers in the Kinshasa region are becoming increasingly polluted. This region is currently undergoing strong demographic growth, and the industries that are being set up there call for the formation of large human settlements, with obvious effects on the pollution of the rivers that cross it (Champiat et al., 1988). Monitoring the quality of the water in these rivers is essential. In Kinshasa, the population cares little about the quality of the environment, especially the rivers that carry large quantities of domestic and industrial waste.

2.3. Methods

The identification of plants in the field was carried out by our team, and species of which the identification was difficult, were brought back to the laboratory of systematic botany and plant ecology at the department of Biology, University of Kinshasa for further analysis leading to their confirmation. The phytogeographical distribution is inspired from the chorological divisions recognized for tropical Africa as described by Mbale et al. (2019).

As there are aquatic species leading to an invasion of the aquatic ecosystem, hydrological parameters were also considered. So, hydrological parameters constitute elements of which manifestation conditions and influences at different levels the macrophytes wetland. From an ecological insight, the parameters that were used to determine the quality of rivers, were namely: temperature (°C), pH, turbidty, conductivity (µS/cm), the salinity as well as dissolved oxygen. These parameters were measured between 8 am and 3 pm using an appropriate electronic probe for each specific parameter. The turbidity was expressed in ppm using a multi-parameter probe coupled to the turbidimeter (HANNA HI 98130).

2.4. Data Analysis

The floristic affinity between surveys was determined by "cluster analysis" using the software "Multivariate Statistical Package" (MVSP) version 4.03, after highlighting the Jaccard's coefficient based on the presence/absence of species in the different collection sites, using the "Unweighted pair group method with arithmetic mean" (UPGMA). Surveys were ordered using a species/site table, and the quantitative values were subjected to a principal component analysis (PCA) using MVSP software to identify relationships between species and collection sites. For each parameter, the comparison of data between sites was performed using ANOVA and the p-value was 0.05. For each significant difference, the ANOVA was accompanied by a pairwise multiple comparison (LSD test = Least Significant Difference). Data analysis was performed using SPSS 25.

3. Results and Discussion

3.1. Floristic inventory of aquatic plants

3.1.1. Floristic analysis

The floristic analysis is presented in the figure below.

From the above figure, it emerges that 18 families are represented in all the sites, of which the family of Cyperaceae predominates (12.50 %), followed by Fabaceae and Onagraceae (8.30 %) families. The spectrum of biological type is presented here below.

The figure above indicates that Champhytes are the most predominant biological type in Pool Malebo (29.2 %).

Fig. 4 presents the spectrum of disapore type.

It is observed that sclerochores are predominant (50 %) compared to other types of diaspore.

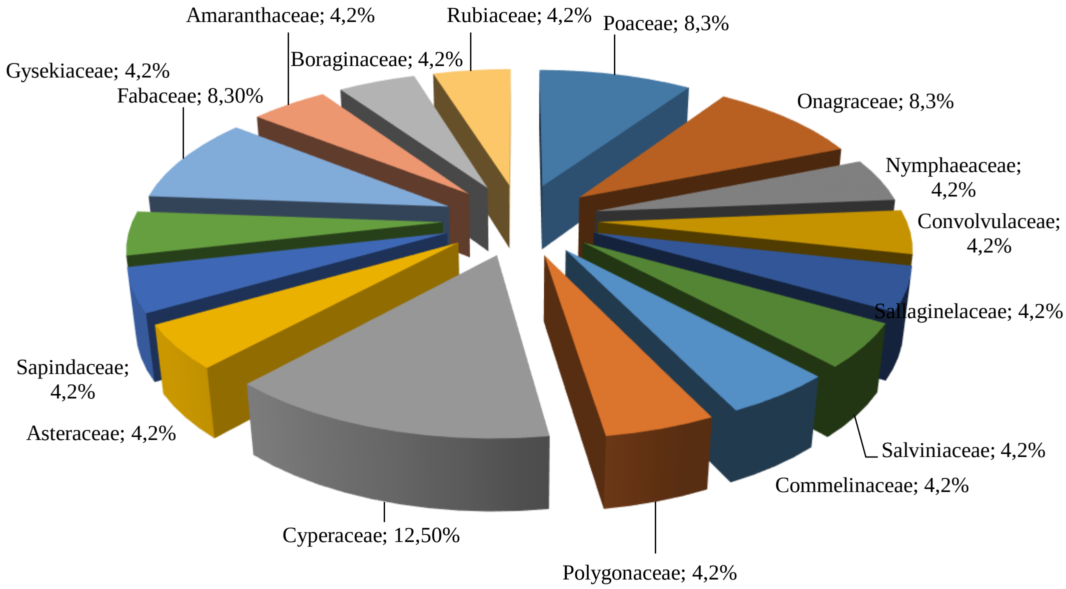

Fig. 2. Distribution of identified families in different sites

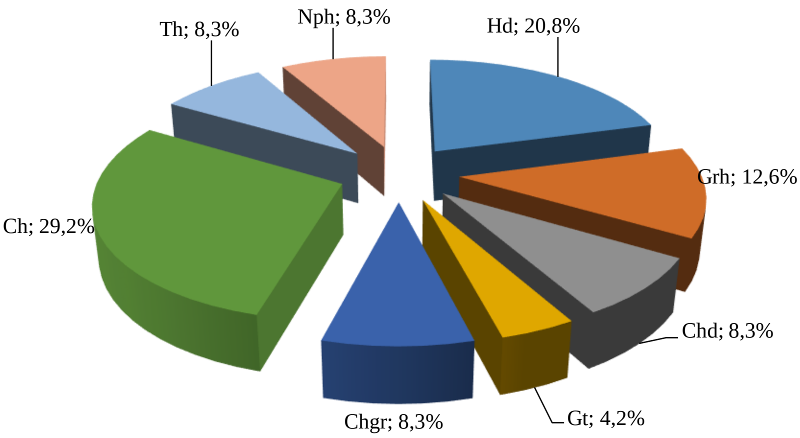

Fig. 3. Spectrum of biological type

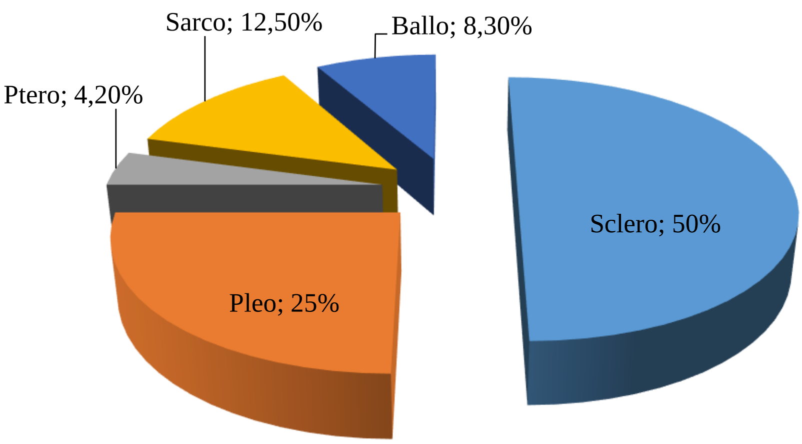

Fig. 4. Spectrum of diaspore type

3.1.2. Floristic affinity between collection sites

Fig. 5 illustrates the dendrogram resulting from the hierarchical classification of collection sites according to their floristic affinities the similarity matrix between collection sites.

From the figure above, it is observed that there is a strong floristic similarity between the Japon and Kabongo sites (J.C = 0.706), then Mipongo (J.C = 0.667). The Molondo site has an average floristic affinity with the above-mentioned sites (J.C = 0.585), while the floristic similarity is quite low between the Kingabwa and Molondo sites (J.C = 0.444).

3.1.3. Affinities between species

The affinity between species is presented in the figure below.

Based on their presence or absence, the plant species identified at each site or island were then subjected to a clustering analysis (Fig. 6) and the principal component analysis (Fig. 7) helped to identify relationships among species and between species and sites.

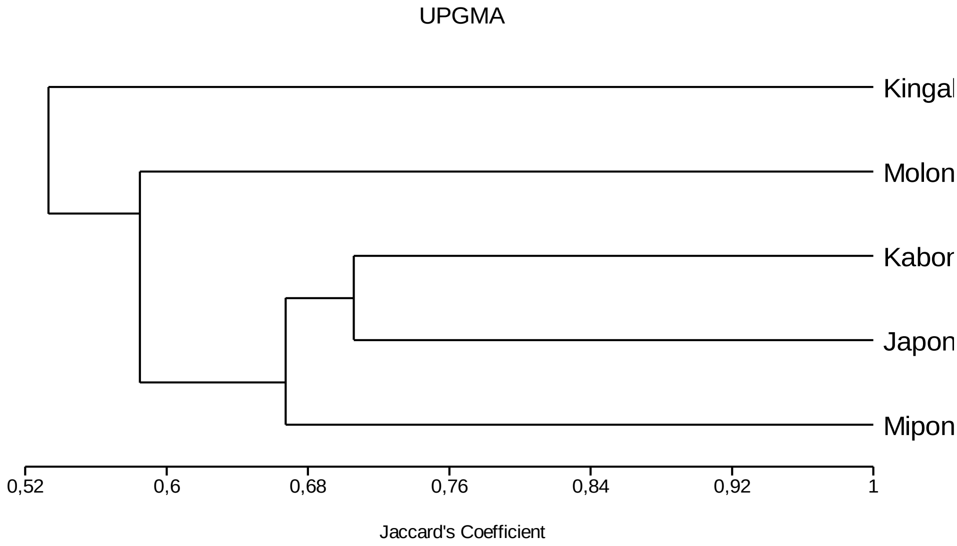

Fig. 5. Dendrogram of floristic similarity between different sites

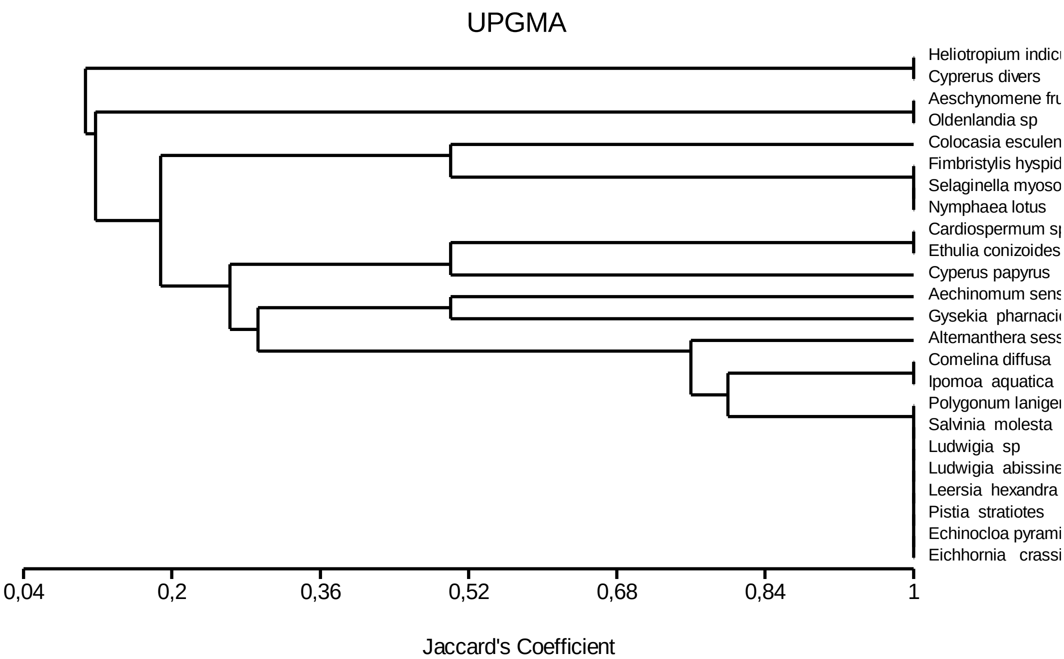

Fig. 6. Dendrogram of floristic similarity between different species

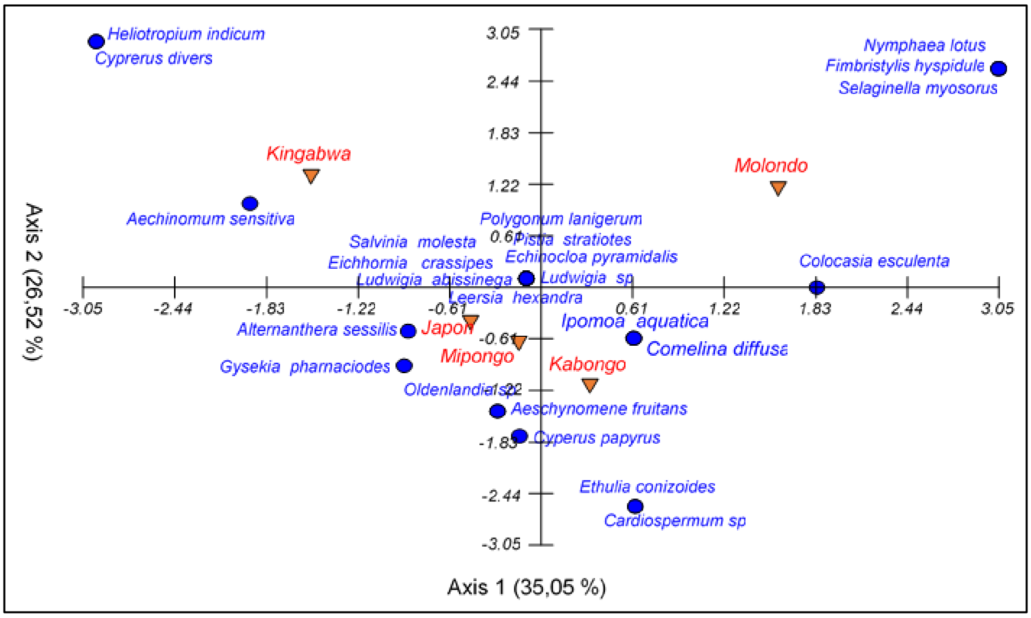

Fig. 7. Factorial design of the PCA of species distribution based on surveys

Following species are found in the five islands namely: *Ludwigia abyssinica*, *Alternanthera sessilis*, *Ipomoea aquatic*, *Commelina diffusa*, *Eichhornia crassipes*, *Pistia stratiotes*, *Echinochloa pyramidalis*, *Polygonumla nigerum*, and *Salvinia molesta*. While *Nymphaea lotus*, *Selaginella myosorus* and *Fimbristylis hyspidule* were specific to Molondo site, *Colocasia esculenta*, *Ethulia conizoides* and *Cardiospermum sp* were specific to Kabongo island (Ngamanzo), *Oldenlandia sp* and *Aeschynomene fruitans* were found only in Mipondo site and last *Heliotropium indicum* and *Cyperus* dives were specific to Kingabwa island.

3.2. Hydrological parameters

Different figures below show means and standard deviations of various parameters as measured in the environment where the invasive species are found. The means represented by the same letter shows that there is no significance difference between these sites.

a) pH

Fig. 8 below shows the variation of pH in different sites.

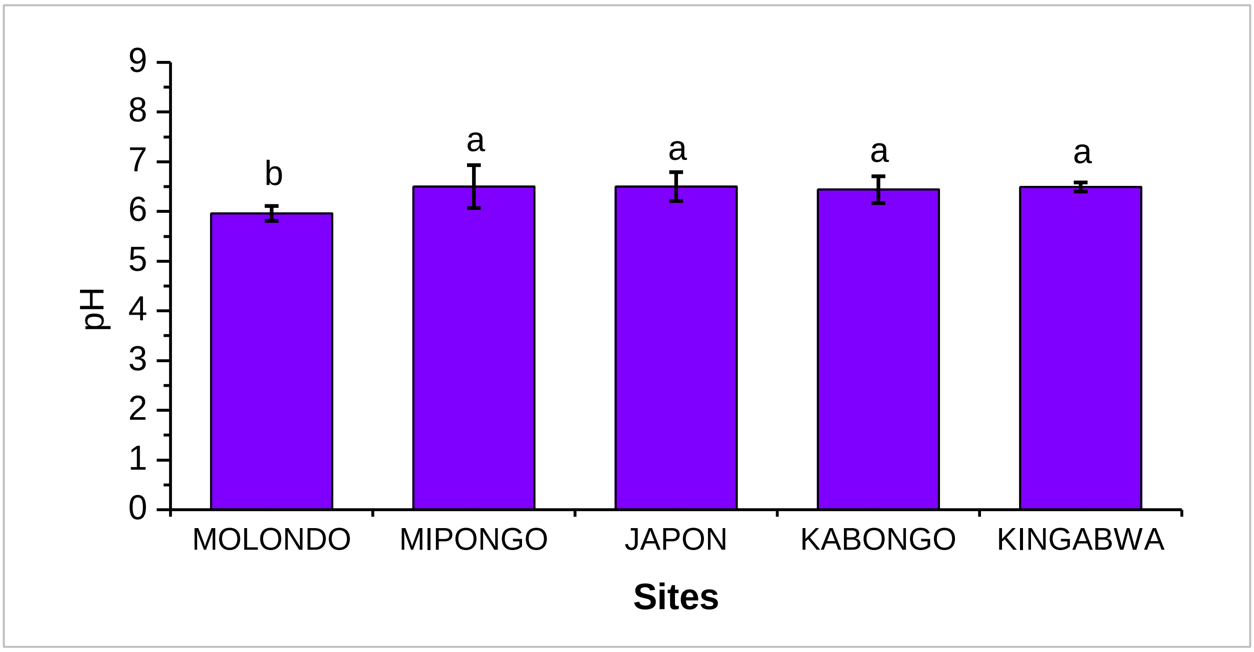

Fig. 8. Variation of pH depending on sites

The ANOVA indicates that the pH varies significantly between sites ($F = 3.70$; $p = 0.021$; LSD = 0.361). In fact, the LSD test indicates that the value recorded at Molondo (5.96 ± 0.15) is significantly low compared to the values recorded at the rest of the sites.

b) Temperature

The variation of temperature on different sites is described in the figure below.

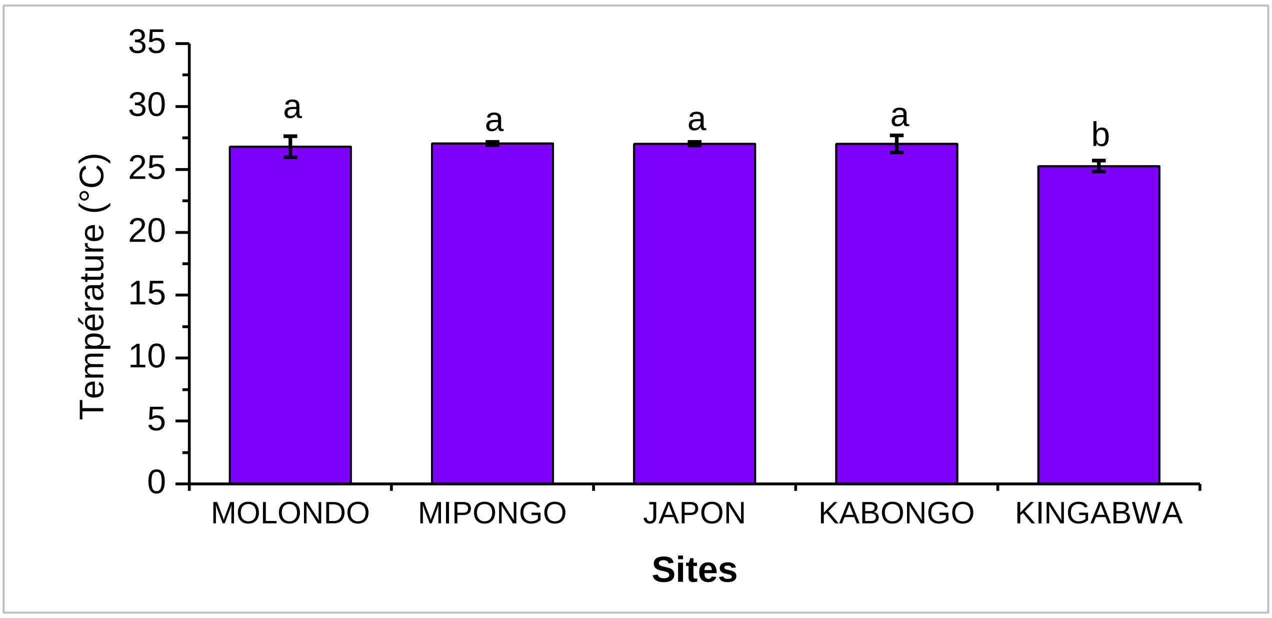

Fig. 9. Variation of temperature depending on sites

The ANOVA indicates a significant variation in temperature according to the sites ($F = 10.80$; $p < 0.001$; $LSD = 0.696$). Indeed, the LSD test indicates that the value recorded at Kingabwa (25.26 °C ± 0.43 °C) is significantly low compared to the values recorded at the rest of the sites.

c) Conductivity

The pace of turbidity is described in the figure below.

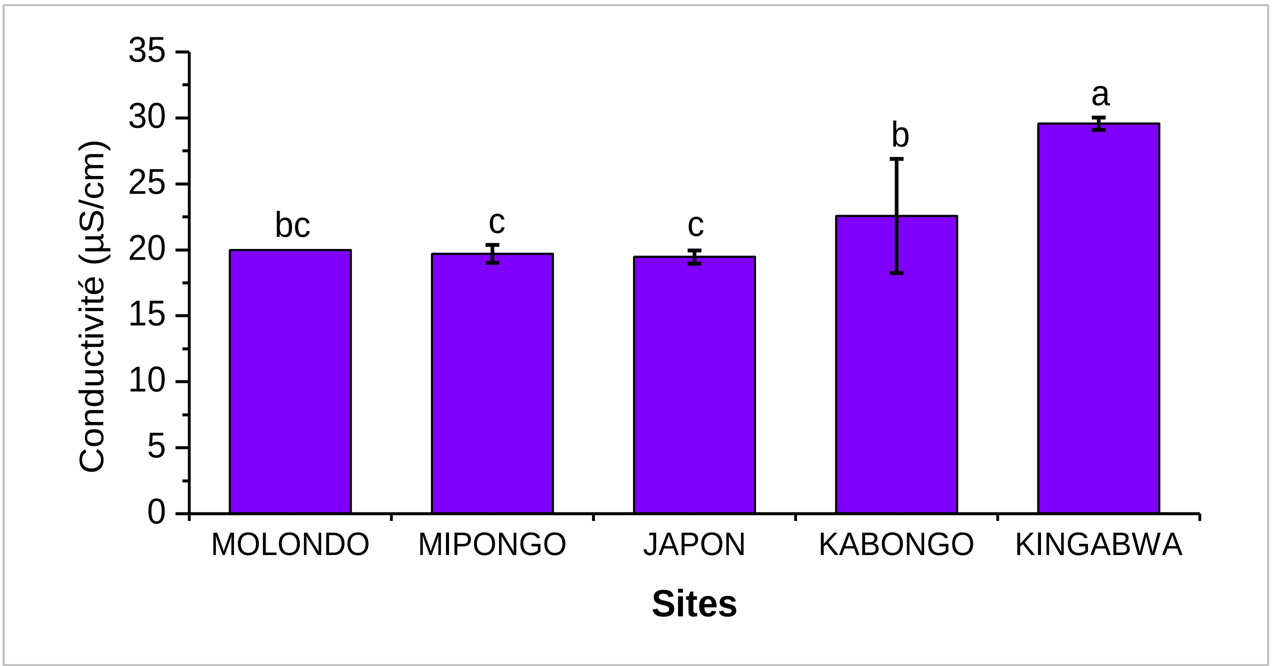

Fig. 10. Variation of conductivity depending on sites

The ANOVA indicates a significant variation in conductivity according to the sites (F = 23.10; p < 0.001; LSD = 2.618). In fact, the LSD test reveals that the highest value of conductivity is recorded at Kingabwa (29.56 µS/cm ± 0.46 µS/cm), followed by Kabongo (29 .56µS/cm ± 4.33 µS/cm). Mipongo (19.70µS/cm ± 0.67 µS/cm) and Japon (19.46µS/cm ± 0.51 µS/cm) have comparable but significantly lower values than Kingabwa and Kabongo. However, Molondo (20.00 µS/cm ± 0.00 µS/cm) has an intermediate and insignificant mean conductivity between Kabongo, on the one hand, and Mipongo and Japon, on the other.

d) Turbidity

Fig. 11 presents the variation of turbidity following sites.

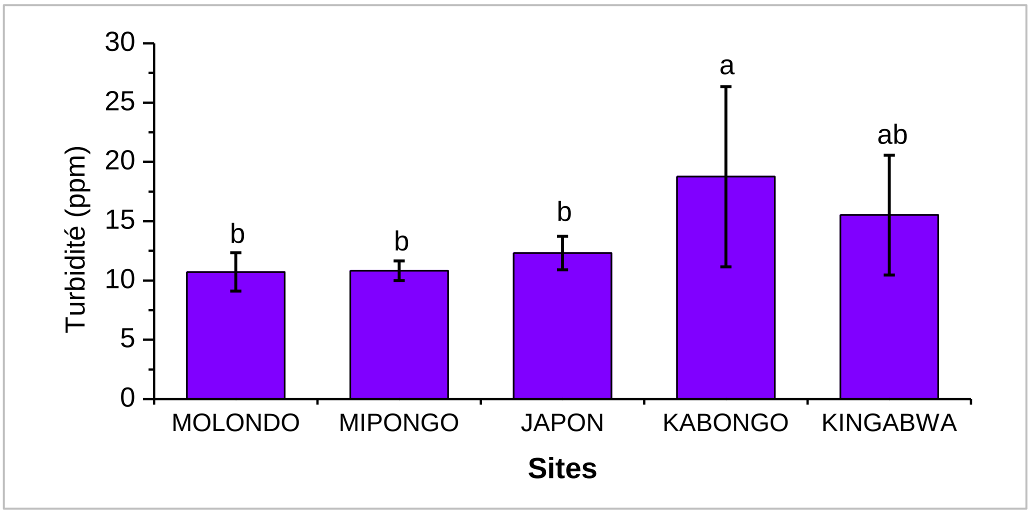

Fig. 11. Variation of turbidity depending on sites

The ANOVA reveals a significant variation in turbidity according to the sites (F = 3.39; p = 0.029; LSD = 5.550). The LSD test shows that the highest turbidity value is noted at Kabongo (18.76 ppm ± ± 7.60ppm). However, the values noted in Japon (12.32 ppm ± 1.42 ppm), Mipongo (10.82 ppm ± ± 0.82 ppm) and Molondo (10.72 ppm ± 1.61 ppm) are comparable but significantly lower than in Kabongo. And Kingabwa has a mean turbidity (15.52 ppm ± 5.04 ppm) that does not differ significantly from those recorded at the rest of the sites.

e) Dissolved oxygen

The variation of dissolved oxygen is presented in the figure below.

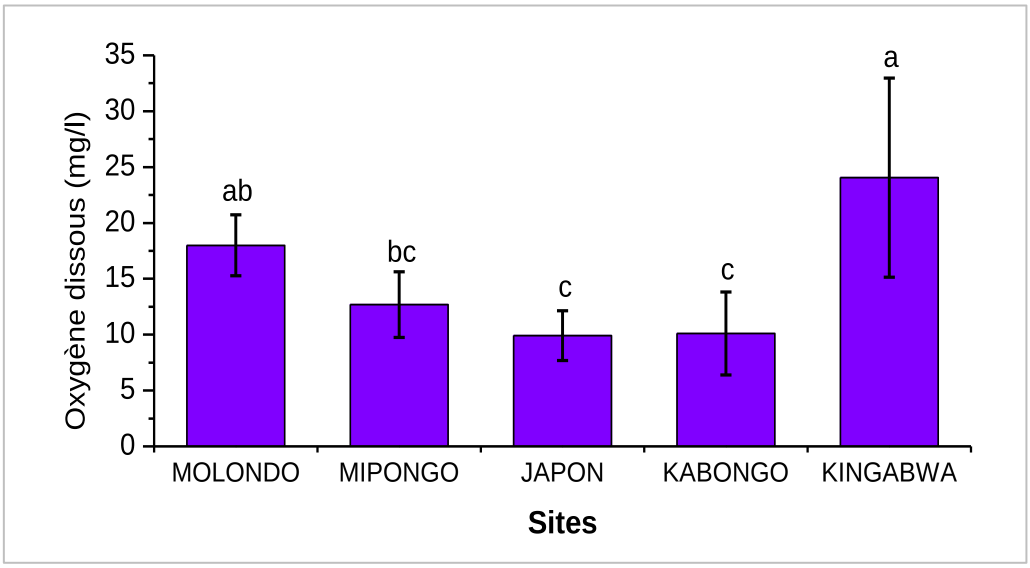

Fig. 12. Variation of dissolved oxygen depending on sites

The ANOVA reveals a significant variation in dissolved oxygen according to the sites ($F = 7.97$; $p < 0.001$; LSD = 6.309). Indeed, the LSD test shows that the highest values of dissolved oxygen are noted at Kingabwa (24.04 mg/l ± 8.91 mg/l) and Molondo (18.00 mg/l ± 2.74 mg/l), and the lowest are recorded at Mipongo (12.69 mg/l ± 2.94 mg/l), Kabongo (10.10 mg/l ± 3.72 mg/l) and Japon (9.92 mg/l ± 2.22 mg/l). However, Molondo and Mipongo have values that do not differ significantly.

f) Salinity

Fig. 13 describes the status of salinity variation in different sites.

The ANOVA reveals a significant variation of salinity according to sites ($F = 30.50$; $p < 0.001$; LSD = 1.266). Indeed, the LSD test shows that the highest salinity value is recorded in Kingabwa (14.12 g/Kg ± 0.22 g/Kg), followed by Molondo (11.32 g/Kg ± 2.12 g/Kg), Japon (10.00 g/Kg ± 0.07 g/Kg), Mipongo (9.12 g/Kg ± 0.13 g/Kg) and Kabongo (7.94 g/Kg ± 0.17 g/Kg). However, Japon and Mipongo had values that did not differ significantly.

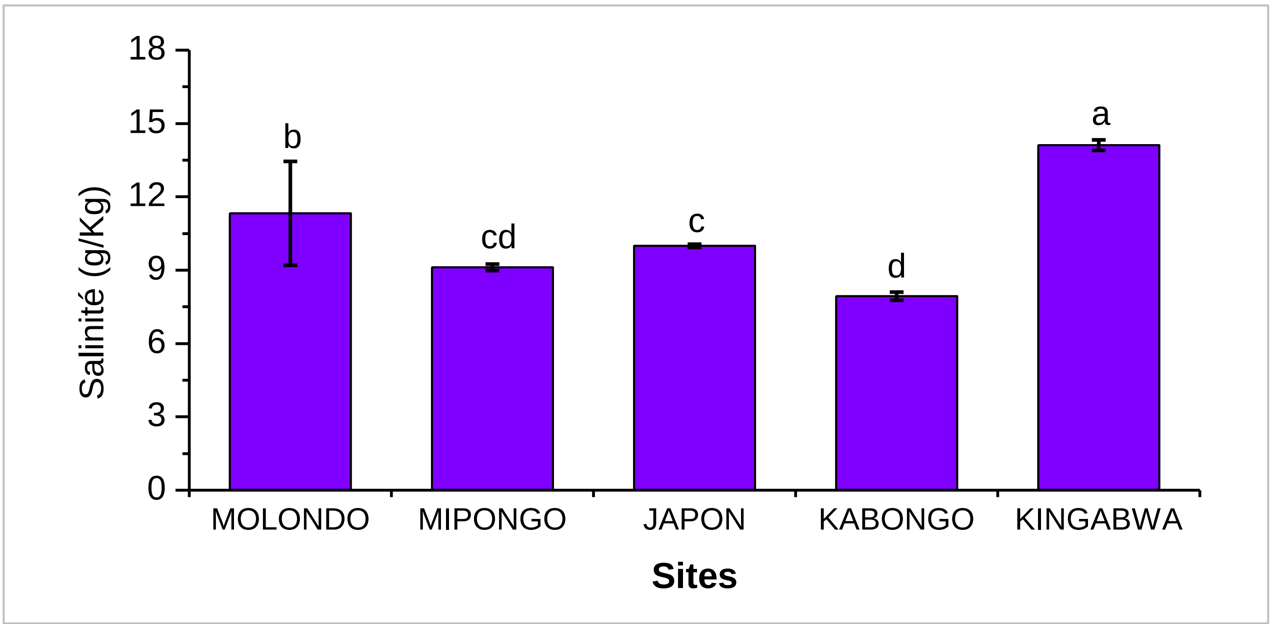

Fig. 13. Variation of salinity depending on sites

3.2. Discussion

The literature reports that plant invasions constitute a serious threat to natural and semi–natural ecosystems at a global scale. In many areas, catchment-scale hydrological modifications and invasive alien plants are among the most influential agents of degradation. In fact, biological invasions by non–native and animal species are considered as one of the greatest threats to natural ecosystem and biodiversity (Enright, 2000, Gorgens et al., 2004). They constitute the biological balance and drivers of biodiversity loss along with its hydrological parameters (Katsanevakis et al., 2014).

Following species are found in the 5 islands namely: *Ludwigia abyssinica, Alternanthera sessilis, Ipomoea aquatic*, *Commelina diffusa*, *Eichhornia crassipes*, *Pistia stratiotes*, *Echinochloa pyramidalis*, *Polygonumla nigerum*, and *Salvinia molesta*. Chamier et al. (2012) reported that several South African alien aquatic plant species are important invaders of rivers and water bodies. Among these plants, they found *Eichhornia crassipes, Pistia stratiotes, Salvinia molesta, Myriophyllum aquaticum* and *Azolla filiculoides*. These species form dense mats in aquatic ecosystem rich of nutrients, mostly as floating weeds widespread. Among the identified invasive species in the Pool Malebo we find *Eichhornia crassipes*, *Pistia stratiotes* and *Salvinia molesta*, which are known as invaders of this aquatic ecosystem (Chamier et al., 2015). While Apedo (2015) reported the identification of only one specific invasive species notably *Australian acacias*. In Bostwana, it was observed the presence of *Eichhornia crassipes*, *Salvinia molesta* Mitchell, *Pistia stratiotes* L., *Myriophyllum aquaticum* (Vell.) Verdc., and *Azolla filiculoides* Lam. as the most five invasive alien species which disturb the aquatic system and the waterflow of rivers (Kurugundla et al., 2016, Hill et al., 2020). In Namibia, the following species, notably *Salvinia molesta*, *Azolla filiculoides*, *Pistia stratiotes*, and *Myriophyllum aquaticum* have been reported to be invasive in the aquatic ecosystem. Besides, they note the absence of *Eichhornia crassipes*, so a great care must be taken to avoid its introduction and potential spread. It is arguably the worst of the five major aquatic weeds in southern Africa (Ministry of Environment, 2004). Others studies focused more on *Eichhornia crassipes* as the most invasive alien species, which leads to several disasters, despite its positive impact also as reported in the literature. In Ethiopia, it was reported that *Eichhornia crassipes* becomes the main invading weed in different water bodies and constitutes a threat and a serious one to the aquatic biodiversity of the country and different socio-economic activities of the society, and this situation calls for a urgent solution (Hailu et al., 2020). The permanent presence of these species precisely *Eichhornia crassipes* is a real proof of introduction of this species in several regions of the world especially to its tolerance in several ecological and environmental factors.

Hydrological comparison of different sites performed on different sites of Pool Malebo reveals the presence of invasive species in this aquatic ecosystem which disturb its abiotic factors. This invasion causes the spread of certain species of which *Echinochloa pyramidalis* forming mono-specific meadows and *Eichhornia crassipes*, which is the most dominant in different sites. Besides these monospecific formations, we also observed associations of species like *Eichinocloa pyramidalis* and *Eichornia crassipes*, and on the other hand *Pistia stratiotes* and *Salvinia molesta*. The introduction of exotic vegetation species to indigenous habitats has widespread implications for natural resources, including water (Hayes, 2003). The modification of water physico-chemical parameters constitutes a major threat to the survival of aquatic beings and it constitutes as well a nuisance for the environment, human health and economic development. These invasions might contribute to the change of ecosystem functions like the physical structure, biogeochemical cycling, hydrology and at last the community composition of the invaded ecosystem (Tobias et al., 2019). Their high evaporation rates as compared to indigenous species cause them to use more water than the vegetation they are replacing (Malan, Day, 2002).

As to the parameters analysed, the study shows that there is a variation on different sites for different parameters. This observation is similar to what Mbale et al. (2019, 2023) reported. The water quality issues associated with these invasions leave much to be desired. The inhibition of both water flow and diffusion of air into water can be attributed to dense mats of these weeds resulting in lower concentrations of dissolved oxygen. Lower oxygen concentrations, combined with the increased amounts of organic matter can accelerate eutrophication processes (Chamier et al., 2012).

4. Conclusion

The invasion of alien species in the aquatic ecosystem constitutes a real challenge, so there is a need to develop and implement environmental impact assessments. The awareness needs to be raised among local communities and stakeholders on the inherent dangers of these species infestations. The knowledge of ecological factors is essential for wetland development, control of exotic species that threaten native or local species, and the consequences of which are either the disappearance of native species, environmental modification, or various socio-economic impacts.

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