Ecological Characterization of Invasive Alien Species and Associated Abiotic Factors of Three Islands in the Pool Malebo in Kinshasa, Democratic Republic of the Congo

Michael Tshibangu Mukendi [a], Henri Kunzi Mbale [a], Pisco Munkolo Menga [a], Masens-da-Musa Yung [a], Jean Meti Ntumba [b], Gédéon Ngiala Bongo [a*] and Félicien Luyeye Lukoki [a]

[a] *Department of Biology, Faculty of Science, University of Kinshasa, P.O.Box 190, Kinshasa XI, Kinshasa, Democratic Republic of the Congo.*
[b] *Ecole Régionale Post-Universitaire d'Aménagement et de Gestion Intégrés des Forêts et Territoires Tropicaux, University of Kinshasa, Kinshasa, Democratic Republic of the Congo.*

Authors' contributions

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

Original Research Article

ABSTRACT

Nowadays, invasive alien species are causing more and more environmental problems in several water bodies around the world, in Africa and in the Democratic Republic of the Congo. In October 2020, a floristic inventory was carried out around three islands of the Congo River (Molondo, Mipongo and Japon) at the Pool Malebo in Kinshasa. The study focused on the identification and behavior of alien species along with associated abiotic factors in the Malebo Pool of the Congo River in Kinkole, Kinshasa.

The study used a simple random sampling design to select different sites where samples were collected after a direct observation. We collected invasive species in the middle of the Congo River

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Corresponding author: E-mail: gedeonbongo@gmail.com;

and to achieve that, we used canoe depending on the location of each site. Recorded species were classified either alien species or invasive alien species according to the status in the study region. The identification of collected species was performed according to APG III. Seeing the way these species invade the environment and how they disturb the ecology of rivers, the physico-chemical characteristics of waters were measured between 8:00 am and 3:00 pm with the appropriate electronic probe for each parameter. For each parameter, the comparison between the sites was carried out using the ANOVA test with XLSTAT 2013 software.

The findings show that 19 species have been identified as invasive alien species out of which, four were dominant, namely *Echinochloa pyramidalis, Eichhornia crassipes, Salvinia molesta and Pistia stratiotes.* Considering the physico-chemical parameters, 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 the three sites. The formation of vegetation groups around these islands in the Congo River at the Pool Malebo in Kinshasa would also be justified by the influence of these parameters.

1. INTRODUCTION

In recent decades, invasive animal and plant species have become a major problem because of their environmental, economic and health effects. In the past few years, several studies [1-3] have tried to analyze relative contributions of several mechanisms to the success of the invasion. It is confirmed that this reductionist approach does not allow the understanding of this phenomenon [4]. An alien species is a species (plant, animal, microorganism), which has been introduced as a result of human activity, outside of its natural range. They are sometimes called alien or non-native species [5]. In other terms, an alien invasive species constitutes an allochthonous species of which the introduction or spread threatens the environment, economy or society, including human health. They are generally from other continents or from another region [6].

Among different routes of entry of invasive alien species are waterways (rivers, such as the Congo River), shipping, aquarium trade, pet trade, horticultural seed trade, clandestine entry of species with goods, etc. [6]. Infestations of waterways by this weedy aquatic alien plants block water access and navigation routes thus limiting marine traffic, swimming and fishing. These plants can associate with each other and form associations and plant groupings over several kilometers notably with *Echinocloa pyramidalis, Vossia cuspidata*, etc. The ecology of invasive alien species varies regionally, as do the associated abiotic factors. The eradication of invasive plant species already established over a large area is rarely feasible [7-8]. Strategies to prevent new introductions and spread of invasive plants are considered more effective [9]. Thus, understanding and predicting the invasive success of plants is one of the major concerns of invasive plant ecology. Moreover, two major questions are at the heart of research in invasion ecology: on the one hand, what are the traits of invading individuals or species? [10] and on the other hand, what characteristics of ecosystems or communities make them sensitive or resistant to invasions? [11-13].

Global progress has been insufficient for the reduction of their spread. Various international conventions and global, regional, along with national policies as well as programmes directed towards the prevention, control or the eradication of invasive alien species are being realized. However, efforts to mitigate their impacts are insufficient as well [14]. Furthermore, species invasions are likely to increase on a par with climate change along with the international trade. With the climate change issue, these invasive species would inevitably provoke changes in biodiversity and in the ecosystem services that it provides [3,15].

In fact, most cases of invasiveness can be linked to the intended or unintended consequences of economic activities and therefore economic applications are essential to understand the problem and provide more accurate and comprehensive assessments of the benefits and costs of control alternatives to increase the effectiveness and efficiency of public funding [3]. However, invasive species are increasingly recognized as having important impacts on landscapes, ecosystems and levels of

biodiversity [16]. Seeing the way these species invade the environment and how they disturb the ecology of rivers, we thought of determining some physico-chemical characteristics (abiotic factors) of these rivers in order to know if these alien species disturb or not.

The study focused on the identification and behavior of invasive alien aquatic species along with associated abiotic factors in the Pool Malebo. This research is a contribution to the ten-year strategic plan for biological diversity of the Aichi goals.

2. MATERIALS AND METHODS

2.1 Study Area

The study was carried out in the Pool Malebo at Kinkole in the following areas: Molondo, Mipongo and Japon located in Kinshasa city, in the Democratic Republic of the Congo (DRC) (Fig. 1).

This city with its low-altitude climate is characterized by a hot and humid tropical climate of AW4 type according to Köppen's classification. There is an alternation of two seasons: A dry season from June to September and a rainy season from September to May [3,17].

2.2 Study Design and Sample Collection

The study used a simple random sampling procedure in order to select different sites where samples were collected. All the study sites were located in Kinshasa city and these chosen habitats were invaded by alien species. The Pool Malebo sites (Molondo, Mipongo and Japon) are located at the eastern part of Kinshasa city. The collection was performed after a direct observation. The location of collection depended on sites, we collected invasive species in the middle of the Congo river by using canoe. Samples were collected in the morning between 8 am and 3 pm. Recorded species were classified either alien species or invasive alien species according to the status in the study region. These species named "invasive" are species that cause any apparent damage or may pose threats to native aquatic ecosystem and to the economy. The study took place in October 2020.

2.3 Methods

The identification of different species in the field was performed using specific identification keys (precisely Phylogenetic classification APG III) [18], while specimens which the identification was difficult in the field were brought to the herbarium of INERA, located at the department of Biology, Faculty of Sciences, University of Kinshasa. The study of the phytogeographical distribution is inspired from the chorological divisions recognized for tropical Africa as described in the literature [3].

2.4 Hydrological Parameters

Physico-chemical parameters constitute elements of which manifestation conditions and influences, to varying degrees affect the wetland macrophytes. From an ecological point of view, the analyzed parameters were the temperature (°C), the pH, the turbidity and the electrical conductivity, which has been measured (at 25°C) in micro-Siemens by cm (μS/cm). These physico-chemical parameters measured between 8:00 am and 3:00pm using HANNA HI98130 electronic probe brand at 10 cm depths. The turbidity was measured in ppm using a multi parameter probe (HANNA HI 98130). It reflects the quantity of dissolved solids in the water.
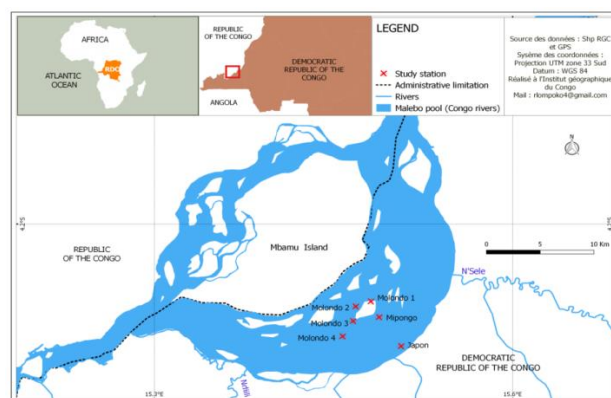

Fig. 1. Administraive map of Pool Malebo indicating different islands

2.5 Data Analysis

For each parameter, the comparison between the sites was performed using the ANOVA test (p-value ≤ 5%). With each significant difference, the variance analysis was accompanied by a multiple pairwise comparison (LSD test). The data analysis was performed using the XLSTAT 2013 software.

3. RESULTS

3.1 Floristic Inventory of Invasive Alien Species

Table 1 presents the general list of species recorded at the different sites. These species are classified in clades, orders and families according to the new phylogenetic classification system APG III [18], and the Pteridophytes determined according to Cronquist [19].

The general floristic list also includes the sites where water samples were taken for physico-chemical analyses (water, swamps, banks).

It is observed from Table 1 that Molondo island has most of identified species found in the Pool Malebo followed by Mopongo island and at last Japon island. Following species are found in the three islands namely: *Ludwigia abyssinica, Alternanthera sessilis, Ipomoea aquatic, Commelina diffusa, Eichhornia crassipes, Pistia stratiotes, Echinochloa pyramidalis, Polygonumla nigerum,* and *Salvinia molesta.*

Figures below are presenting different invasive species found in the study sites.

Table 1. Floristic inventory of invasive alien species collected in Kinshasa

Family/species	Molondo	Mipongo	Japon	Habitats
Onagraceae				
1.Ludwigia abyssinica A. Rich.	+	+	+	Swamp
2. *Ludwigia leptocarpa* (Nutt) Hara	+	+	-	Swamp
. Amaranthaceae				
3. *Alternanthera sessilis* (L.)DC	+	+	+	Water
. Convolvulaceae				
4. *Ipomoea aquatica* Forsk	+	+	+	Water
. Nymphaeaceae				
5. *Nymphaea lotus* L.	+	-	-	Water
Commelinaceae				
6. *Commelina diffusa* Burm. F	+	+	+	Swamp
Pontederiaceae				
7. *Eichhornia crassipes* (Mart) Solms	+	+	+	Water
Araceae				
8. *Pistia stratiotes* L.	+	+	+	Water
9. *Colocasia esculenta* (L) Schott	+	-	-	Swamp
Cyperaceae				
10. *Cyperus papirus* L.	-	-	+	Water, swamp
Poaceae				
11. *Echinochloa pyramidalis* (Lam) Hitch & Chase	+	+	+	Water, swamp
12. *Leersia hexandra* Sw	+	-	-	Swamp
Polygonaceae				
13. *Polygonumla nigerum* R.Br.	+	+	+	Water
Gisekiaceae				
14. *Gysekia pharnaceiodes* L.	-	+	+	Swamp
Fabaceae				
15. *Aeschynomene fluitans* L.	+	-	-	Water
16. *Aechinomum sensitiva* Swartz	-	+	+	Water
Rubiaceae				
17. *Oldenlandia affinis* (Roem.&Schult.) DC	-	+	-	Water
Selaginellaceae				

Family/species	Molondo	Mipongo	Japon	Habitats
18. *Selaginella myosorus* (Sw.) Alston. Salviniaceae	+	-	-	Water, Swamp
19. *Salvinia molesta* D.S. Mitchell	+	+	+	Water
Total	**15**	**13**	**12**	

Legend: +: presence, -: absence

(a) *Eichhornia crassipes* and *Echinocloa pyramidalis* (Japon site)   (b) *Salvinia molesta* and *Eichhornia crassipes* (Molondo site)

(c) *Eichhornia crassipes* and *Echinochloa pyramidalis* (Mipongo site)

Fig. 2. Different vegetal groupings found in different sites
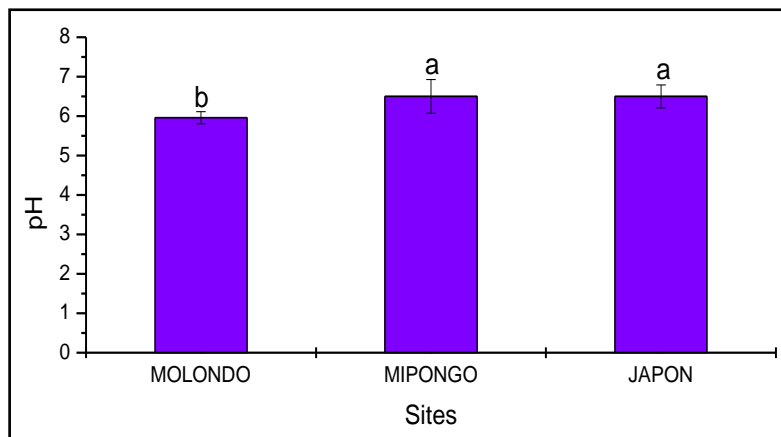

Fig. 3. Variation in pH

3.2 Hydrological Parameters

Figures below show means and standard deviations of various parameters taken from the sites surveyed in the environment where the invasive alien species are found. The means represented by the same letter means that there is no significance difference between sites.

3.2.1 pH

Fig. 3 presents the pace of pH between each site.

The ANOVA indicates that pH varies significantly among sites (F = 4.98; p = 0.026; LSD = 0.361). Indeed, the pairwise LSD test indicates that the value recorded at Molondo (5.96 ± 0.15) is significantly lower than the values recorded at the rest of the sites (Fig. 3). It should be noted that the sites with the same letters do not differ significantly in terms of water pH.

3.2.2 Temperature

Fig. 4 gives the pace of temperature.

The ANOVA indicated no significant variation in temperature among different sites (F = 0.42; p = 0.66).

3.2.3 Conductivity

Fig. 5 describes the conductivity situation.

The ANOVA shows no significant variation in conductivity between sites (F = 1.55; p = 0.25)

3.2.4 Turbidity

Fig. 6 describes the turbidity status.

The ANOVA found no significant variation in turbidity across sites (F = 2.28; p = 0.14)

3.2.5 Dissolved Oxygen

Fig. 7 describes the turbidity status.

The analysis of variance reveals a significant variation in dissolved oxygen depending on the sites (F = 12; p = 0.001; LSD = 3.65). Indeed, the LSD test shows that the highest values of dissolved oxygen are noted at Molondo (18.00 mg/l ± 2.74 mg/l), and the lowest are recorded at Japon (9.92 mg/l ± 2.22 mg/l). However, Molondo and Japon Islands have values that do not differ significantly.
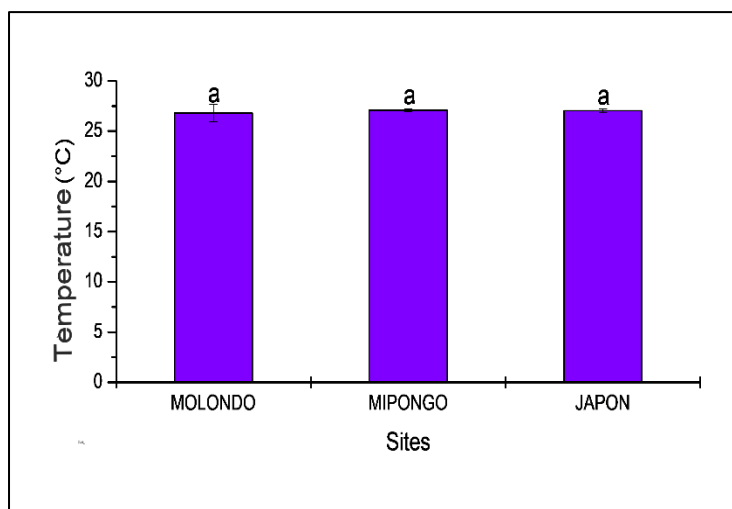
3.2.6 Salinity

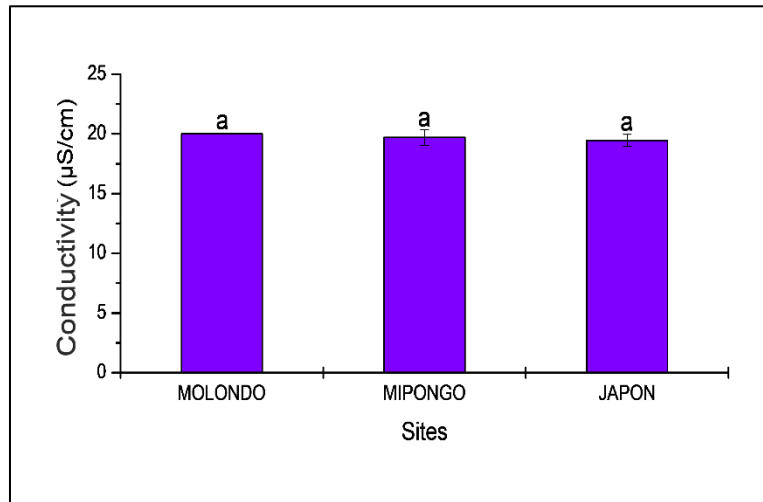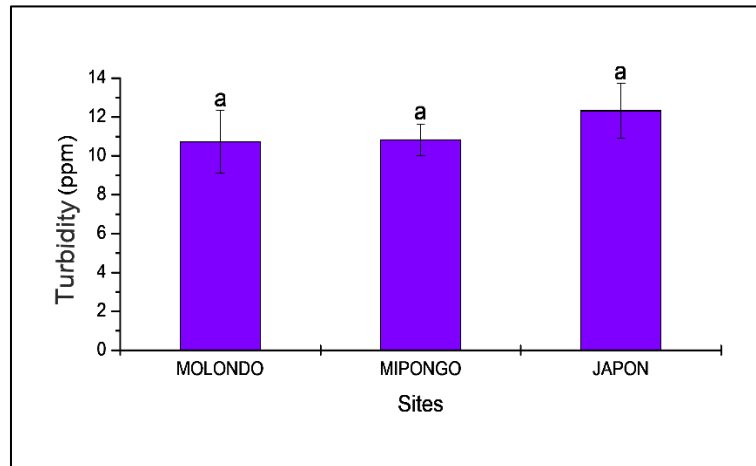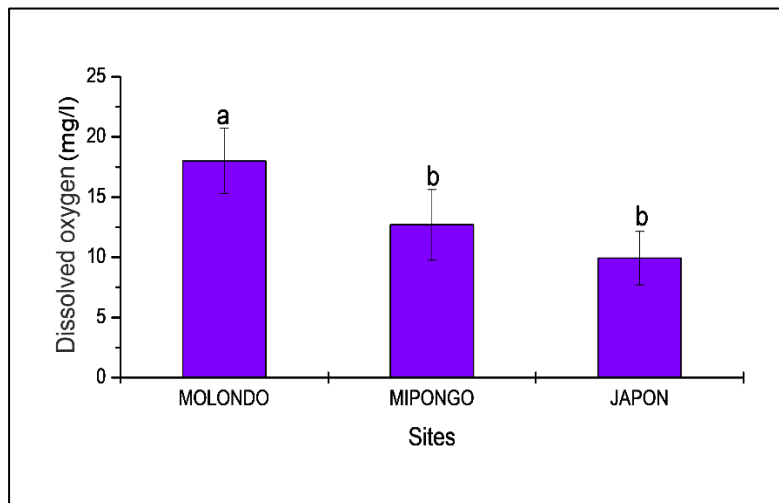The level of salinity of different sites is described in the figure below.
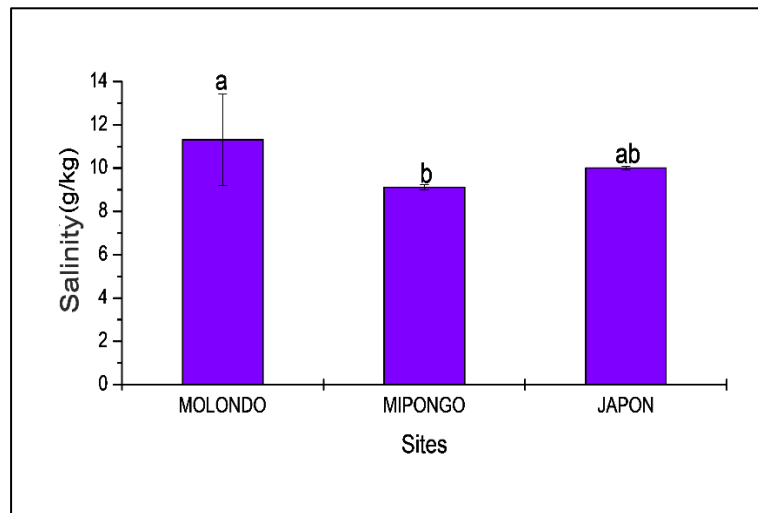

Fig. 4. Water temperature

Fig. 5. Variation in Conductivity

Fig. 6. Variation of Turbidity

Fig. 7. Variation in Dissolved Oxygen

Fig. 8. Variation in Salinity

The ANOVA reveals a significant variation in salinity according to site (F = 4.06; p = 0.04; LSD = 1.69). The LSD test shows that the highest salinity value is recorded at Molondo (11.32 g/Kg ± 2.12 g/Kg) and the lowest at Mipongo (9.12 g/Kg ± 0.13 g/Kg).However, these values are not significantly different.

4. DISCUSSION

The invasion of ecosystems by alien species is a growing threat to the delivery of ecosystem services. Invasive alien species are as a result of the ongoing and increasing human re-distribution of species to support agriculture, forestry, mariculture, horticulture and recreation as well as a by-product of accidental introductions [20]. Furthermore, aquatic vegetation forms an essential component of a lake ecosystem, influencing its physical and chemical processes as well as affecting human activities [20].

The main aim was the ecological characterization of invasive aquatic alien species in the Congo River at Pool Malebo. The findings showed that following species have been found in all the sites, namely: *Pistia stratiotes, Echinochloa pyramidalis, Polygonumla nigerum,* and *Salvinia molesta.* Yet, there is a dominance of *Echinochloa pyramidalis,* which, forms a monospecific meadow and *Eichhornia crassipes.* These species are dominant and causing several damages to the aquatic and physical environment. Rwizi [20]. reported some of the species that we have found in this study, of which *Ageratul conyzoides, Eichhornia crassipes, Ipomea carnea, Lantana camara and Salvinia molesta.*

Several authors reported the behavior of invasive alien species and more focus have been put on *Eichhornia crassipes* which, chokes water bodies and reduces biodiversity by causing anoxia and degrades water quality. *E. crassipes* (water hyacinth) is a free floating aquatic plant well known for its production abilities and the removal of pollutants from water. Its multiplication is faster than any other known freshwater plant [21]. The leaves of riparian trees, which are the natural food for the aquatic organisms, are also replaced by the less suitable leaves of the alien trees. The accumulation of leaves of invasive alien plants on river beds reduces water levels causing fish deaths and give rise to algal blooms and other poor water quality impacts. These also have impact on the recreational value of the rivers and lakes [22-24].

Several studies reported that plant invasions are a serious threat to natural and semi–natural ecosystems worldwide. In many areas, catchment-scale hydrological modifications and invasive alien plants are among the most influential agents of degradation. Significantly, biological invasions by non–native and animal species are considered as one of the greatest threats to natural ecosystem and biodiversity [23-24].

Considering hydrological parameters, the findings showed some variation in different parameters analyzed. These observations are going along with Mbale et al. [3]: The modification of water physico-chemical

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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. This invasive aquatic vegetation can change the ecosystem functions such as physical structure, community composition, biogeochemical cycling and hydrology [25]. These invasive aquatic weeds reduce water velocity substantially, impact water quality as well as provide habitat for non-native fish predators [3]. In this context, the use of biological method may help in restoring the ecology of infested water. This method needs the use of natural enemies, usually insects or pathogens which, have the ability to reduce the spread of these invasive alien species to manageable levels [26].The purpose of the biological method is not to eradicate the weed but to reduce its abundance to a level where it is no longer problematic [20].

There exists several native enemies of water hyacinth, two South American weevil beetles (*Neochetina eichhorniae* and *Neochetina bruchii*) and two water hyacinth moth species (*Niphograpta albiguttalis* and XubidaInfusella) have had effective long-term control of the water hyacinth in many countries, notably at Chivero (Zimbabwe), Lake Victoria (Kenya), Louisiana (USA), Mexico, Papua New Guinea and Benin [26].

Although the prevention, eradication and control of invasive alien species in different ecosystems present scientific, political and ethical challenges. This issue can be substantially reduced through concerted action. Awareness needs to be raised among local communities and stakeholders on the inherent dangers of invasive alien species infestations. Scientifically-based information and effective tools need to be provided to policy makers and resource managers so that well-informed decisions can be taken. Thus, management strategies, which can be made available to the decision-maker along the invasion chain, which is prevention – early detection – rapid response and lastly the eradication, control as well as the adaptation. Furthermore, cooperative programs and NGOs need to be forged among governments as well as other institutions to enable the problem to be addressed in a strategic, holistic and timely manner.

5. CONCLUSION

The invasion of these species constitutes a real challenge for ecologists, economists, social scientists, agricultural engineers, and others. Hence the need to develop and implement sound risk analysis frameworks and environmental impact assessments. As can be seen, this study has demonstrated that 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. This study is of high relevance to a country where the vegetal cover is more and more affected the introduction of alien species, which disturb the flowing of rivers.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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