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Research Article

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Influence of wetland physicochemical conditions on hydrophyte ecology in Banco National Park, Côte d'Ivoire

GNAGBO Anthelme*[1], EGNANKOU Wadja Mathieu[2], KAMELAN Tanoh Marius[2], GOSSAN Valdez Mordochée[2], ADOU YAO Constant Yves[2]

[1]Department of Agroforestry, Jean Lorougnon Guédé University, Daloa, Côte d'Ivoire
[2]Department of Biosciences, Félix Houphouët-Boigny University, Abidjan, Côte d'Ivoire
*Corresponding author: *agnagbo@gmail.com*

Abstract

Banco National Park, located in the heart of the city of Abidjan in Côte d'Ivoire, is home to an exceptional diversity of hydromorphic wetlands, including marshes, ponds and rivers. These ecosystems play a crucial role in preserving biodiversity and regulating local ecosystems, by providing habitats for a wide variety of hydrophytic plants. This study aimed to explore the distribution of hydrophytes according to the physicochemical characteristics of the park's hydromorphic biotopes. The floristic inventory identified 22 species of hydrophytes, including 20 in marshes, 16 in ponds and 12 in rivers. *Nymphaea lotus* has the highest frequency of occurrence (0.65), followed by *Cyperus papyrus* (0.45) and *Typha domingensis* (0.43). The marshes are home to plants such as *Sacciolepis africana* and *Utricularia foliosa,* while the rivers are dominated by *Nymphaea lotus* and *Ceratophyllum demersum*. Analysis of physicochemical parameters reveals significant differences between environments. Temperature, conductivity, pH and dissolved oxygen strongly influence species distribution. Rivers, with higher conductivity and oxygen levels, favor submerged hydrophytes. In contrast, marshes, characterized by oxygen-poor waters, harbor plants tolerant to hypoxic conditions. In ponds, floating plants predominate, taking advantage of calm water conditions and shallow depth. These results highlight the importance of ecological features in hydrophyte distribution and demonstrate the need to preserve the wetlands of Banco National Park against increasing anthropogenic pressures, to ensure the sustainability of their unique biodiversity and ecosystem functions.

Keywords : Aquatic plants, hydrosystems, biodiversity, wetlands, Banco National Park

Introduction

Wetlands are complex ecosystems, characterized by high biological diversity and productivity. They play a key role in regulating water flows, filtering pollutants and sequestering carbon, while serving as habitat for many plant and animal species. In Côte d'Ivoire, wetlands cover approximately 2% of the national area, and are widely distributed along the coastline, in lagoons, and within tropical forests (Egnankou et al., 2021) However, these ecosystems, like forests, are subject to increasing anthropogenic pressures, including urbanization, deforestation and pollution (Egnankou et al., 2023) .

Forest wetlands play a fundamental role in preserving biodiversity and regulating ecosystems. They are characterized by the presence of specific vegetation, adapted to conditions of permanent or temporary humidity and are often areas of high biological productivity. The Banco National Park, located in the heart of the city of Abidjan in Côte d'Ivoire, is one of the last vestiges of dense humid forests in the region. This park is not only a reservoir of biodiversity, but it also shelters a diversity of wetlands that play a major ecological role (Chatelain et al., 2011) .

The park covers an area of 3,474 hectares and is mainly composed of dense evergreen rainforests. However, the ecological diversity of the park also includes several types of plant formations, such as swamp forests, riparian forests, and secondary forests (Aké-Assi, 2002) . These different types of forests are influenced by the topographic, hydrological and edaphic variations of the park (Zoro Bi et al., 2003) .

One of the specificities of the Banco National Park is the presence of various types of wetlands. These wetlands are characterized by temporary or permanent water saturation, creating conditions conducive to the development of certain hydrophilic plant species. Among the types of wetlands observed, we can cite marshes, riparian zones, and small seasonal bodies of water that are home to particular flora (Kouamé, 2014) . Thus, understanding the ecological dynamics within these wetlands is crucial for their conservation, especially since these habitats are often threatened by human activities and climate change. The study is particularly interested in the distribution of plant species according to hydrological and edaphic conditions, as well as their role in regulating humid forest ecosystems.

Material and method

Data collection

The plots were selected in a stratified random manner to ensure representation of the different microtopographies of the hydromorphic environment. These were the edges of the water bodies, permanently or temporarily flooded areas of the Banco National Park (Figure 1). Survey plots on 1 m² quadrats were placed in the submerged aquatic areas (Chambers et al., 2008) . The physicochemical characteristics of the quadrats such as transparency, conductivity, pH, temperature, dissolved oxygen were measured in situ between 7 a.m. and 9 a.m. (Sculthorpe, 1967) To measure the current speed at each station of the hydrosystems, a five-meter portion along the watercourse was delimited. Using a stopwatch, the time taken for a half-full bottle to travel the five meters was recorded 3 times. Each quadra survey is coupled with a botanical inventory on a 5-meter path, on emerged land, from the limit of the water body of the hydromorphic zone. In each plot 5 meters long and 2 meters wide, defined from the path, all plant species were listed. The hydromorphic zones identified are rivers, ponds and marshes. In each of these biotopes, 20 quadras and 20 botanical surveys were carried out.

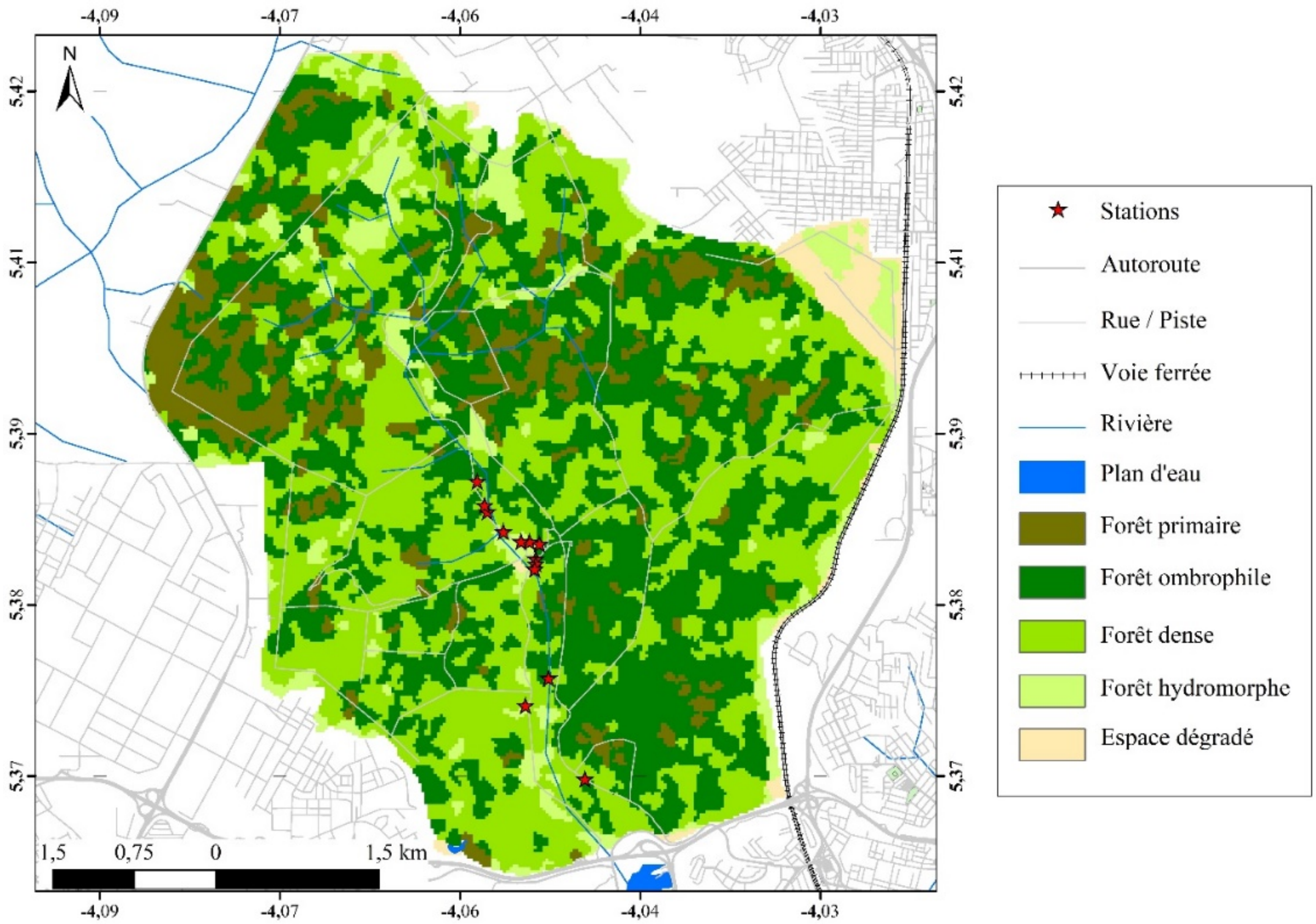

Figure 1: Presentation of the Banco National Park

Data analysis

All hydrophytic plants were identified and their relative frequencies calculated based on the number of quadrats in which they appear. For each species, its abundance-dominance is estimated using the modified Braun-Blanquet scale (Duvigneaud, 1983) , which assigns a score from 1 to 5 based on the species' coverage in the plot.

The physicochemical parameters of the hydromorphic zones characterized as Rivers, Ponds and Marshes were compared. After checking the normality in the data distribution, an analysis of variance was carried out to compare the variations in the physicochemical parameters according to the different hydromorphic environments. A factorial correspondence analysis was also used to understand the structure of the relationships between the hydrophytes and the identified biotopes (Barthes and Larini, 2022) This method made it possible to cross-reference the environmental and physicochemical characteristics of the different hydromorphic zones with the presence of hydrophytes.

Results

In all the floristic inventories, 22 floristic species were identified. In the marshes, 20 hydrophytic plants were identified. In the ponds, there are 16 hydrophytes present, while 12 hydrophytic plants are observed on the rivers and river banks. In all the collections in the hydromorphic areas of the Banco National Park, *Nymphaea lotus* has the highest frequency of occurrence with a value of 0.65. It is followed by *Cyperus papyrus* (0.45), *Typha domingensis* (0.43) and *Sacciolepis africana* (0.42). The other species are observed in less than a third of the data collection quadras.

Only marshes and rivers have species that are strictly limited to their habitats. Marshes are home to 5 exclusive species, namely *Sacciolepis africana, Cyperus papyrus, Typha domingensis, Nymphaea maculata* and *Utricularia foliosa.* As for rivers, 5 other species are observed only in these habitats. These are *Nymphaea lotus, Ceratophyllum demersum, Podostemaceae* spp., *Aeschynomene indica* and *Nymphaea maculata.*
The different hydrophyte species, depending on their abundance, are distributed according to the ecological characteristics specific to each wetland. In the marshes, *Sacciolepis africana* and *Cyperus papyrus* are particularly dominant, suggesting that these plants thrive in waterlogged soil conditions. In ponds, floating aquatic plants such as *Azolla pinnata* and *Pistia Stratiotes* dominate, reflecting calm water conditions. Rivers are dominated by *Nymphaea lotus* and *Ceratophyllum demersum,* which adapt well to more dynamic aquatic environments with good water circulation.

Plants with cover levels greater than 50% on the modified Braun-Blanquet scale were considered. *Typha domingensis* is characteristic of marshes with coverage greater than 50% on all collections made in these biotopes. *Typha domingensis* is also observed in 6 quadras in the ponds of the Banco National Park. *Nymphaea lotus* is present in the collection plots along the rivers with coverage levels greater than 50%. It is a species weakly observed in 4 quadras in the ponds. *Cyperus papyrus* is characteristic of the marshes where it covers more than 50% of the sampled quadras. It is also present in 7 quadras carried out in the ponds.

The graph of the correspondence analysis presents hydrophyte species as specific to certain habitats (Figure 2). The distribution of hydrophytes in the hydromorphic environments of the Banco National Park varies according to the types of biotopes. In the ponds, floating plants dominate, with species such as Lemna minor, Eichhornia crassipes, Pistia stratiotes, and Azolla africana. Other aquatic species such as Nymphaea pubescens and Azolla pinnata are also present. On the other hand, in rivers, submerged plants such as Ceratophyllum demersum coexist with floating species such as Salvinia molesta and rooted plants such as Podostemaceae and Nymphaea lotus. Marshes are mainly home to species of the Cyperaceae family, such as Cyperus papyrus, Typha domingensis, and Cyperus articulatus. Species adapted to saturated soils, such as Sacciolepis africana and Rhynchospora corymbosa, also thrive there. Philydrum lanuginosum and Utricularia foliosa contribute to the diversity of this environment. Thus, each biotope presents a specific composition of hydrophytes, influenced by the hydrological and ecological conditions of these environments.

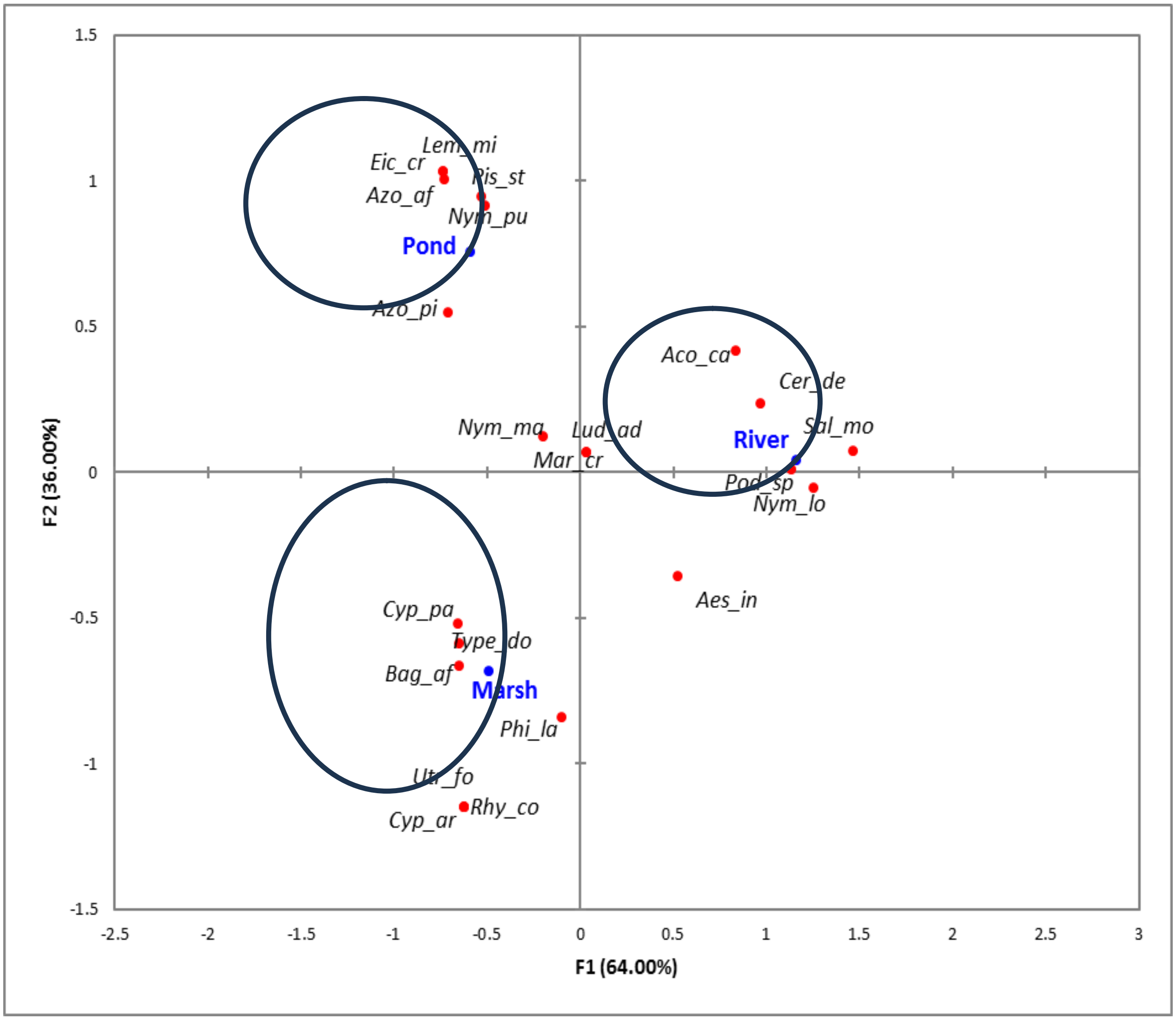

Figure 2: Graph of the distribution of hydrophytes following the hydromorphic zones

Legend : Aco_ca (*Acorus calamus)*, Aes_in (*Aeschynomene indica)*, Azo_af (*Azolla africana)*, Azo_pi (*Azolla pinnata)*, Cer_de (*Ceratophyllum demersum)*, Cyp_ar (*Cyperus articulatus)*, Cyp_pa (*Cyperus papyrus)*, Eic_cr (*Eichhornia crassipes)*, Lem_mi (*Lemna minor)*, Lud_ad (*Ludwigia adscendens)*, Mar_cr (*Marsilea crenata)*, Nym_lo (*Nymphaea lotus)*, Nym_ma (*Nymphaea maculata)*, Nym_pu (*Nymphaea pubescens)*, Phi_la (*Philydrum lanuginosum)*, Pis_st (*Pistia stratiotes)*, Pod_sp (*Podostemaceae sp.*), Rhy_co (*Rhynchospora corymbosis)*, Sac_af (*Sacciolepis africana)*, Sal_mo (*Salvinia molesta)*, Typ_do (*Typha domingensis)*, Utr_fo (*Utricularia leafy)*

The analysis of the physicochemical parameters of the hydromorphic biotopes of the Banco forest highlights significant differences (Table 1). The water temperature varies slightly between the three biotopes. The river has a significantly higher temperature (26.09±0.21°C) compared to the marsh (25.31±0.23°C) and the pond (25.29±0.15°C). This difference could be related to the rapid movement of water in the river, favoring greater exposure to heat. Regarding salinity, the marsh has a higher concentration of dissolved salts (0.16±0.08‰), while the pond (0.03±00‰) and the river (0.04±0.01‰) have significantly lower levels.

Resistivity follows an inverse trend to conductivity, with a significantly higher value in the marsh (22.69±3.08 Ω·m), followed by the pond (15.94±0.12 Ω·m) and the river (12.05±0.75 Ω·m). Conductivity, on the other hand, is higher in the river (82.5±6.59 µS/cm) than in the pond (61.35±0.58 µS/cm) and the marsh (42.06±3.97 µS/cm). This difference reflects the higher concentration of dissolved solids in the river (TDS: 41.41±3.24 mg/l), compared to the marsh (21.60±2.16 mg/l) and the pond (30.48±0.80 mg/l).

The pH also shows significant variations between biotopes. The pond has a slightly alkaline pH (8.14±0.13), while the marsh is neutral to slightly alkaline (7.62±0.07) and the river more acidic (6.31±0.21). These pH differences may be associated with the dynamics of organic matter inputs and microbial activity. The dissolved oxygen (DO) concentration is significantly higher in the river (4.21±1.39 mg/l), favored by water movement. In contrast, the marshes (1.78±0.87 mg/l) and ponds (0.24±0.04 mg/l) have much lower oxygen levels, indicating hypoxic or even anoxic conditions in these biotopes.

Water depth varies considerably between the three biotopes, with the river being significantly deeper (0.69±0.11 m) than the marsh (0.20±0.02 m) and pond (0.16±0.01 m). This has consequences for other parameters such as transparency, which is higher in the river (25.16±4.47 cm) compared to the marshes (15.19±0.31 cm) and ponds (15.04±0.02 cm), probably due to the lower deposition of suspended matter in moving water.

Finally, the water velocity in the river (0.64±0.12 m/s) is significantly faster than in the marsh (0.10±0.03 m/s) and the pond (0.02±0.01 m/s). This flow dynamic contributes to the better aeration of the river and its ability to transport dissolved substances, unlike the stagnant waters of marshes and ponds.

Table 1: Physicochemical characteristics of hydromorphic environments in the Banco National Park

Physicochemical parameters	**Marsh**	**Pond**	**River**
T(°C)	25.31±0.23 ^{b}	25.29±0.15 ^{b}	26.09±0.21 ^{a}
Salinity	0.16±0.08 ^{a}	0.03±00 ^{b}	0.04±0.01 ^{b}
Resistivity	22.69±3.08 ^{a}	15.94±0.12 ^{b}	12.05±0.75 ^{c}
pH	7.62±0.07 ^{a}	8.14±0.13 ^{b}	6.31±0.21 ^{c}
OD (mg/l)	1.78±0.87 ^{a}	0.24±0.04 ^{b}	4.21±1.39 ^{c}
Depth (m)	0.20±0.02 ^{a}	0.16±0.01 ^{b}	0.69±0.11 ^{c}
Transparency (cm)	15.19±0.31 ^{b}	15.04±0.02 ^{b}	25.16±4.47 ^{a}
TDS	21.60±2.16 ^{c}	30.48±0.80 ^{b}	41.41±3.24 ^{a}
Conductivity	42.06±3.97 ^{c}	61.35±0.58 ^{b}	82.5±6.59 ^{a}
Speed (m/s)	0.10±0.03 ^{b}	0.02±0.01 ^{c}	0.64±0.12 ^{a}

Discussion

The floristic diversity of the hydromorphic areas, with 22 species identified, reflects the ecological richness of the park. The predominance of certain hydrophytes such as *Nymphaea lotus* and *Cyperus papyrus* highlights the importance of these plants in soil stabilization and regulation of wetland ecosystems (Dutartre, 2004) . The stagnant water conditions in the ponds favor floating hydrophytes such as *Azolla pinnata* in accordance with the work of Chambers *et al.* (2008) on the dominance of floating plants in calm waters.

Water temperatures vary significantly between biotopes, with a higher value in rivers (26.09°C) compared to marshes (25.31°C) and ponds (25.29°C). This difference, related to water velocity and exposure to solar radiation, favors the presence of species such as *Nymphaea lotus* in rivers, which tolerate higher temperatures and more dynamic environments (Chambers *et al*, 2008) . Rivers, with higher dissolved oxygen concentrations (4.21 mg/l), harbor submerged species such as *Ceratophyllum demersum* and

Nymphaea lotus, which require better aeration to thrive (Gumbricht, 1993) . In contrast, low oxygen concentrations in marshes (1.78 mg/l) and ponds (0.24 mg/l) reflect hypoxic or even anoxic conditions, favoring the growth of more tolerant species such as *Typha domingensis* and *Cyperus papyrus,* which are able to survive in oxygen-poor environments (Odada et al., 2019) .

Water conductivity, which reflects the concentration of dissolved ions, is significantly higher in rivers (82.5 µS/cm), followed by ponds (61.35 µS/cm) and marshes (42.06 µS/cm). This variability influences the distribution of hydrophytes. Rivers that host species such as *Podostemaceae sp* and *Nymphaea lotus* are adapted to more nutrient-rich aquatic conditions and higher conductivity (Cook, 1996) . In contrast, marshes and ponds are dominated by plants such as *Pistia stratiotes* and *Azolla pinnata* which prefer calmer environments and lower ionic concentrations (Teugels and Leveque, 2006)

The higher values of dissolved solids observed in rivers (41.41 mg/l) indicate an increased capacity to transport dissolved substances, favoring the proliferation of *Nymphaea lotus,* a species that takes advantage of the abundance of nutrients in dynamic environments (Sculthorpe, 1967) . In contrast, marshes, with lower TDS levels (21.60 mg/l), favor hydrophytic species such as *Sacciolepis africana,* adapted to soils less rich in nutrients.

Rivers, with a slightly acidic pH (6.31), are suitable for plants such as *Ceratophyllum demersum,* which grow well in these slightly acidic conditions (Gumbricht, 1993) . In contrast, marshes have a more neutral pH (7.62), favoring the growth of species such as *Typha domingensis* and *Cyperus papyrus,* which are better adapted to more alkaline soils (Kouadio et al., 2017) . In ponds, the slightly alkaline pH (8.14) could explain the dominance of floating hydrophytes such as *Pistia stratiotes* and *Azolla pinnata,* which thrive in environments where organic decomposition contributes to increased alkalinity (Mitsch and Gosselink, 2000) .

Furthermore, the relatively low salinity of ponds (0.03‰) and rivers (0.04‰), compared to marshes (0.16‰), reflects the impact of water stagnation and the accumulation of dissolved salts in marshes. This accumulation favors the proliferation of specific species such as *Sacciolepis africana* and *Utricularia foliosa,* which are more tolerant of slightly more saline conditions, unlike river and pond species which prefer low salinity environments (Odada *et al.,* 2019) .

The significantly greater depth of rivers (0.69 m) provides ideal ecological niches for submerged and rooted hydrophytes such as *Nymphaea lotus* and Podostemaceae, which require continuous water currents and depth to thrive (Cook, 1996) . In contrast, the shallow depth of marshes (0.20 m) and ponds (0.16 m) favours floating plants such as *Lemna minor* and *Pistia stratiotes,* which thrive in shallow waters where they can readily absorb light and dissolved nutrients (Sculthorpe, 1967) .

Water transparency, which is significantly higher in rivers (25.16 cm) compared to marshes (15.19 cm) and ponds (15.04 cm), reflects less sedimentation in fast-flowing rivers, thus allowing submerged species such as *Ceratophyllum demersum* to better capture the light necessary for photosynthesis (Mitsch and Gosselink, 2000) . On the other hand, the low transparency in marshes and ponds, linked to the presence of suspended matter, favors floating and emergent species such as *Cyperus papyrus* and *Typha domingensis,* which do not need high transparency conditions for their development (Hamad, 2023) .

These results highlight the need to maintain the ecological integrity of hydromorphic environments in order to preserve their biodiversity, as highlighted by Egnankou *et al.* (2021) and Kouadio *et al.* (2017) in their studies on sustainable wetland management in Côte d'Ivoire.

Conclusion

The study conducted in the Banco National Park highlights the diversity of hydrophytes and their specific distribution according to the physicochemical characteristics of the hydromorphic biotopes. Of the 22 species identified, marshes are home to the greatest diversity with 20 species, followed by ponds and rivers. Species such as *Nymphaea lotus, Cyperus papyrus* and *Typha domingensis* dominate in terms of frequency of occurrence, illustrating their ability to adapt to the particular conditions of each biotope. Marshes and rivers are also home to species endemic to these habitats, which demonstrates the ecological specialization of hydrophytes in these environments.

Differences in temperature, conductivity, pH, dissolved oxygen concentration, and depth directly influence species distribution. Rivers, with higher conductivity and dissolved oxygen, favor submerged species such as *Ceratophyllum demersum.* In contrast, marshes, characterized by stagnant, oxygen-poor water, are home to plants tolerant of anoxic conditions, such as *Typha domingensis.* Ponds, on the other hand, with their shallow depth and slightly alkaline pH, are dominated by floating hydrophytes such as *Azolla pinnata.*

These results highlight the importance of specific ecological conditions in structuring wetland plant communities and the need to protect these fragile ecosystems against increasing anthropogenic pressures. The conservation of wetlands, such as those in Banco National Park, is crucial to preserve their biodiversity and their role in regulating local ecosystems.

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