

DIVERSITY OF THE COMPANION FLORA OF THE MANGROVES IN THE COASTAL NATIONAL PARKS OF CÔTE D'IVOIRE

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ABSTRACT

*Mangroves, intertidal zones ecosystems, are characterized by the presence of specific species such as mangroves. In Côte d'Ivoire, the mangrove is accompanied by a characteristic flora which remains little studied. In this study, it is subject to inventory the flora present in forest ecosystems of mangroves in Azagny National Park (ANP) and those of Ehotilé Islands National Park (EINP). The floristic compositions, diversity and structures of these different mangroves are also compared. Twenty inventory plots were placed in each mangrove in the parks studied. A floristic list of 114 companion species had been drawn up for swamps in ANP. Regarding the EINP, 171 plant species have been inventoried. The most common companion plant species in the mangroves of ANP are *Echinochloa pyramidalis*, *Culcasia angolensis*, and *Calamus deerratus*. The most frequent plant species in the EINP on the different plots are *Cercestis afzelii* (1), *Homalium lesteui* (0.85), *Baissea axillaris* (0.85). The great variation in this diversity of species from one site to another may be related to the soil diversity. The mangroves of the EINP have a greater flora richness than those of the ANP.*

KEYWORDS: Mangrove, Companion Species, Biodiversity, Azagny, Ehotilé, Côte d'Ivoire

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INTRODUCTION

Mangroves, characterized by intertidal zones, are characterized by the presence of a specific species that are mangroves. The soil is hydromorphic, anaerobic and the submerged waters are polyhaline. The salt content varies throughout the year depending on freshwater inputs (Egnankou, 1985). In this particular environment, plants acquire their survival through morpho-physiological adaptations. For Snedaker (1978), organisms embedded in mangroves are unable to survive in others. According to Egnankou (1985), mangroves contain about 60 dependent or facultative species.

In Côte d'Ivoire, mangroves are often accompanied by characteristic flora. The work of Egnankou (2010) highlighted the mangrove structures encountered in Côte d'Ivoire. There are monospecific mangroves with *Rhizophora racemosa* G. Mey. (Rhizophoraceae), mangroves with *Avicennia germinans* (L.) L. (Avicenniaceae). There are also mangroves comprising the two mangrove species; *Avicennia germinans* succeeding *Rhizophora racemosa* towards the mainland. The presence of companion species in these mangroves is very characteristic. Herbaceous formations composed mainly of *Paspalum vaginatum* Sw. (Poaceae) are generally observed in the mangroves bordering the lagoons of Fresco. In the mangroves of the Grand-Lahou region, the species *Mariscus*

ligularis (L.) Urb. (Cyperaceae), *Cyperus articulatus* L. (Cyperaceae), *Pycreus polystachos* (Rottb.) P. Beauv. var. *polystachos* (Cyperaceae), *Ethulia conyzoides* Linn. (Asteraceae), *Echinochloa pyramidalis* (Lam.) Hitchc. & Chase (Poaceae), *Sporobolus virginicus* (Linn.) Kunth (Poaceae), *Fimbristylis microcarya* F. Muell. (Cyperaceae) and *Fuirena umbellata* Rottb. (Cyperaceae) constituting the companion species observed. In terms of the composition of several mangroves reported in the Grand-Bassam and Fresco regions, we can distinguish formations of *Machaerium lunatum* (Linn.f.) Ducke (Fabaceae) and *Dalbergia ecastaphyllum* (Linn.) Taub. (Fabaceae) back-mangrove. The presence of several shrub and tree species is also reported. This is *Hibiscus tiliaceus* Linn. (Malvaceae), *Acrostichum aureum* Linn. (Adiantaceae), *Caesalpinia bonduc* (Linn.) Roxb. (Fabaceae), *Nauclea latifolia* Sm. (Rubiaceae).

The mangroves in Côte d'Ivoire are therefore accompanied by flora that remains little studied. The mangroves of the Azagny National Park and those of the Éhotilé Islands National Park have the particularity of belonging to protected areas. The influences of human activities on the structure of mangroves are therefore reduced. It is important to make an inventory of the companion flora of these mangroves in order to increase knowledge and provide a database for the conservation and sustainable use of natural resources. In this study, it will be a question of making an inventory of the companion flora present in the mangroves of the Azagny National Park and those of the Éhotilé Islands National Park. The floristic compositions, diversity and structures of these different mangroves will also be compared.

MATERIAL AND METHOD

Study Sites

The Azagny National Park is located on the east bank of the mouth of the Bandama. It lies between latitudes $5^{\circ} 9'$ and $5^{\circ} 17'$ North and longitudes $4^{\circ} 47'$ and $4^{\circ} 57'$ West. It is located for the most part in the sub-prefecture and the department of Grand-Lahou, only a portion of the park in its eastern part is located in the sub-prefecture of Jacqueline and the department of Abidjan (Gnagbo, 2015). The park is limited to the west by the Bandama river, to the south-east we have the Ebrié lagoon and to the south by the artificial Azagny canal dug in 1920 (Bouichou, 1978). Mangroves (Figure 1) and other aquatic formations line the lagoons and rivers, the banks of the Azagny canal as well as the backwaters inside the park where they can form floating mats (Lauginie, 2007). The characteristic species of the park's mangroves is *Rhizophora racemosa*.

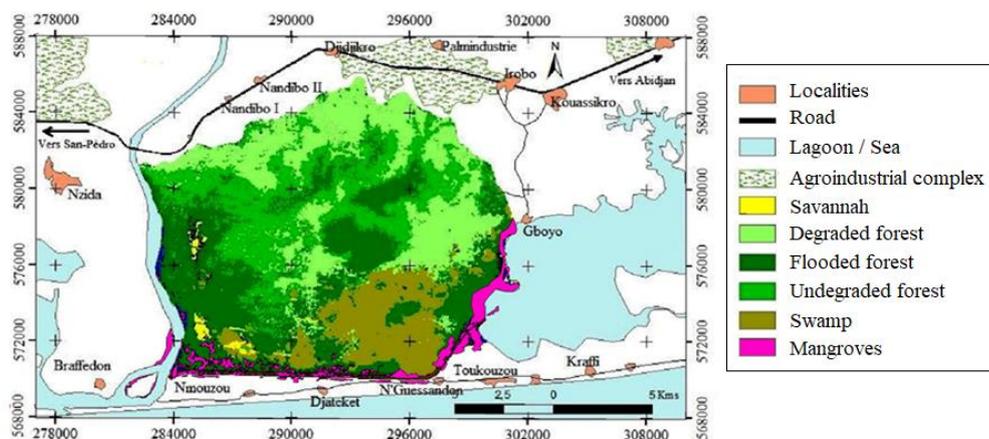


Figure 1: Vegetation of the Azagny National Park.

The Aby Lagoon Complex which contains the Éhotilé Islands National Park (EINP) is located between West longitudes 2 ° 51 'and 3 ° 21' on the one hand and North latitudes 5 ° 05 'and 5 ° 22' on the other part (Figures 2 and 3). The Éhotilé Islands National Park is located in the Aby-Sud lagoon, in the Adiaké department, in the south-east of Côte d'Ivoire. It is located between 3 ° 16'42 "and 3 ° 18'52" West longitude, and between 5 ° 9'24 "and 5 ° 11'13" North latitude. The Park is made up of six islands with a total area of 550 ha. Among these islands, five are located in the deltaic zone of Aby-Sud: Assokomonobaha (327.5 ha), Balouhaté (75 ha), Niamouan (47.5 ha), Méha (45 ha), Elouamin (22, 5 ha); and a BossonAssoun (32.5 ha), located in Tendo Lagoon, off the village of Mbrati. In the Éhotilé Islands National Park, mangroves are well developed on Balouhaté Island, where they represent most of the vegetation (Figures 2 and 3); it is also found in southwest and west of Assokomonobaha; it occupies 60% of the surface of the Meha and Elouamin islands. At Niamouin Island, it is reduced to a few feet of mangrove trees very scattered along the banks.

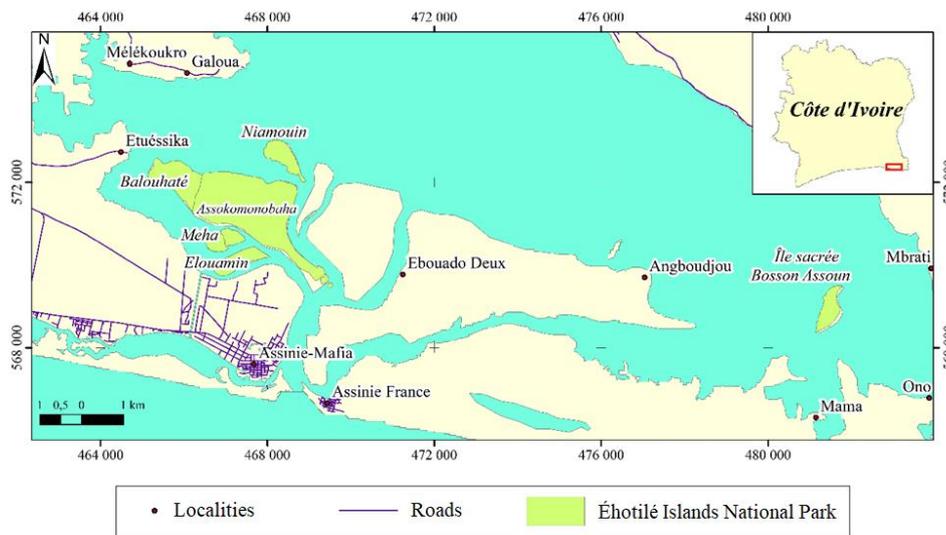


Figure 2: Location of all the Éhotilé Islands.

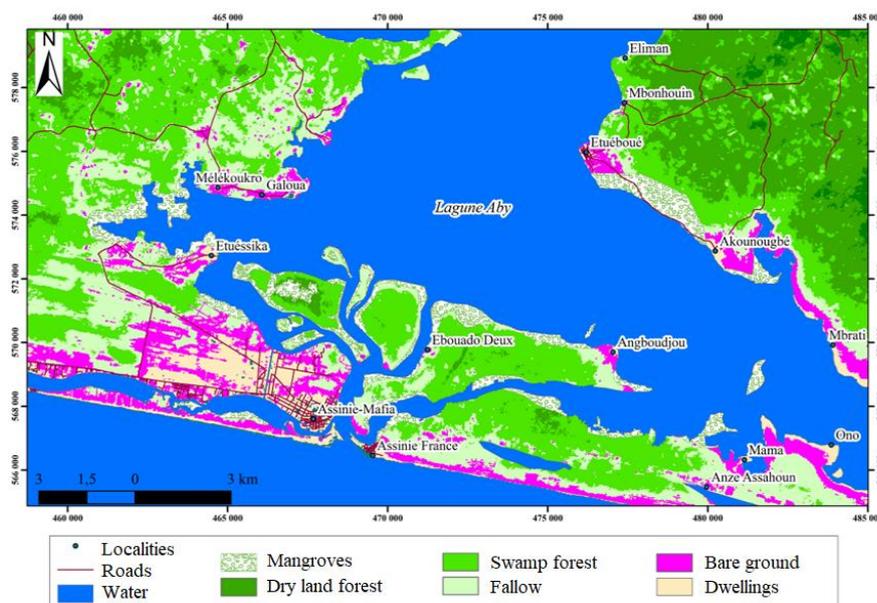


Figure 3: Vegetation of the Assinie Region Including the PNIE.

Data Collection

Data collection consisted of carrying out botanical surveys in the mangroves present in the two parks. To do this, surveys of surfaces according to the method of Duvigneaud (1983) were applied. It consisted of setting up plots in the mangroves. Each data collection plot starts from a transect topographic line according to the method of Duvigneaud (1983). A rope is stretched from the open water to the temporarily or permanently flooded banks. The transect line therefore starts from the lagoon limit of the mangrove to the limit of the intertidal zone. Then, a corridor is limited to one meter on either side of the transect line. At the end, a two-meter-wide plot is obtained from the lagoon limit of the mangrove to the terrestrial limit of the intertidal zone. All the woody plants present inside each plot were inventoried. In short, twenty surveys were carried out in the mangroves of the Azagny National Park. Twenty other records in the Ehotilé Islands National Park, more precisely on the main island which is Assokomonobaha. Subsequently, the traveling survey was carried out. It consisted of traversing the mangroves along the tracks and in hard-to-reach places to complete the list of species present at all the study sites.

Data Analysis

The raw results were subjected to two types of analysis, qualitative and quantitative. Qualitative analyzes consisted of counting the total number of species, genera and families. The list of species was established according to the Cronquist classification (1981). Quantitative diversity was assessed by calculating specific frequencies, relative densities, specific wealth, the Shannon and Weaver (1948) diversity index, the Piélou (1966) fairness index and the Simpson index in order to evaluate the floristic richness, the specific diversity and the floristic equitability of the mangroves in each park.

The specific frequency of a species is the number of plots in which this species is present out of the total number of plots inventoried. The relative density of a species is the ratio of its absolute density (that is, the number of individuals per unit area) to the total of the absolute densities of all species on the list.

Specific frequency = Number of plots on which the species is observed / Total number of plots

Relative density = Total number of individuals of species i / Sum of individuals of all inventoried species

Specific richness corresponds to the number of species (Aké-Assi, 1984). The Shannon index (H') is used to assess the heterogeneity and diversity of a biotope. It is calculated by the following formula:

$$H' = -\sum (n_i / N) \times \ln (n_i / N)$$

where n_i is the number of individuals of species i and N the total number of individuals of all species of the group considered. Diversity is low when $H' < 3$, medium if H' is between 3 and 4, then high when $H' \geq 4$ (Yédomonhan, 2009). The balance between species, which corresponds to a high value of H' , is considered to be characteristic of good biodiversity capable of being sustainably maintained (Adou Yao, 2005). The Simpson diversity index which takes into account the abundance of rare species was used. It expresses the probability that two individuals drawn at random from an infinite population belong to the same species (Simpson, 1949). It is expressed using the following formula:

$$D = \sum [n_i (n_i - 1) / N (N - 1)]$$

where n_i is the frequency of species i in the sample, N is the sum of the frequencies of all species in the sample, and D is the Simpson diversity index. The assessment of the regularity of the species in the different plots was made from the calculation of the equity index (E). This index designates the ratio between the observed diversity and the maximum

theoretical diversity of the stand. It is expressed as follows:

$$E = H' / \ln (S)$$

where S denotes the specific richness; $\ln (S)$ represents the theoretical value of the maximum diversity that can be achieved when all species are represented by the same number of individuals.

In order to compare the floristic compositions between the two mangroves, a non-metric multidimensional scale (NMDS) analysis was used taking into account the parameter of “Bray-Curtis distance” for the abundance of the species. The significance of NMDS was tested using Similarity Analysis (ANOSIM). The various statistical tests and analyzes were carried out with the PAST software version 4.03 (Hammer et al., 2001).

RESULTS

Qualitative Diversity

Botanical surveys carried out in the Azagny National Park gave a total of 113 companion species of mangroves distributed between 46 families and 84 genera. In the Éhotilé Islands National Park, the botanical survey yielded 171 plant species divided between 61 families and 141 genera (Table 1).

Table 1: Floristic Richness of Mangroves in the Parks

	Azagny	Ehotilé
Nb. Species	113	170
Nb. Genres	84	141
Nb. Families	46	61

Family spectra show the dominant families in the mangroves of each park (Figure 4). In Azagny, the most represented families are Orchidaceae (24 species or 21.24%), Araceae (10 species or 8.85%), Arecaceae (6 species or 5.31%), Euphorbiaceae (6 species or 5.31%) and Moraceae (5 species or 4.42%). In the Ehotilé Islands, the most representative families are the Fabaceae (12 species, i.e. 10.59%), the Annonaceae (9 species, i.e. 5.29%), the Rubiaceae (9 species, i.e. 5.29%), the Euphorbiaceae (8 species or 4.71%) and Moraceae (8 species or 4.71%).

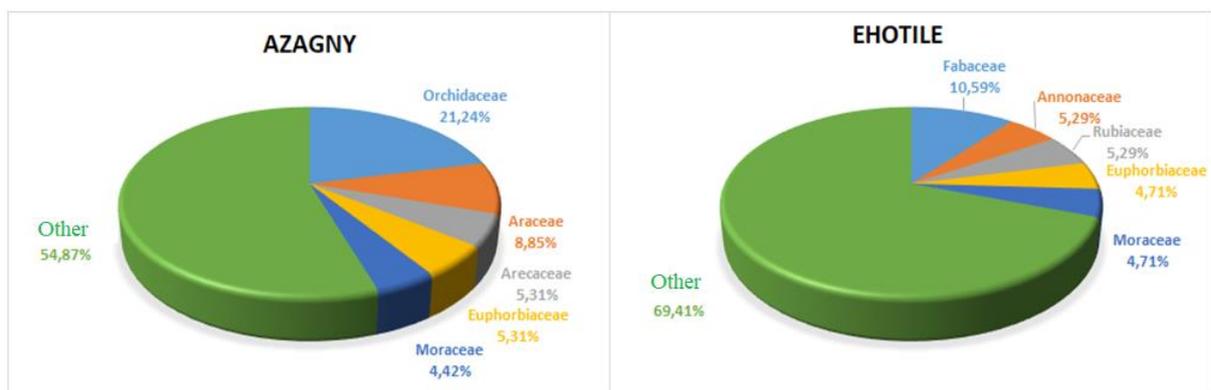


Figure 4: Spectra of the Most Representative Families in the Parks of Azagny and the Ehotilé Islands.

The most frequent companion plant species in the mangroves of Azagny National Park (ANP) are *Echinochloa pyramidalis* (1), *Culcasiaangolensis* (1), *Calamus deerratus* (0.9), *Smeathmaniapubenscens* (0.75), *Agelanthusdodoneifolius* (0.55), *Hallealedermannii* (0.5), *Tapinanthusglobiferus* (0.5), *Platyneriumstemaria* (0.5), *Raphia hookeri* (0.5). The most observed specimens on all surveys were also recorded. The highest relative densities are

Echinochloa pyramidalis (0.04), *Cercestisafzelii* (0.04), *Culcasiaangolensis* (0.03), *Acroceraszizanooides* (0.03), *Agelanthusdodoneifolius* (0.03), *Piper guineense* (0.03), *Nephrolepisbiserrata* (0.03), *Angraecumbancoense* (0.02), *Baphia nitida* (0.02).

In the Ehotilé Islands National Park (EINP), the most frequent plant species are *Cercestisafzelii* (1), *Homaliumlestui* (0.85), *Baisseaxillaris* (0.85), *Baphia nitida* (0.55), *Hymenostegiaafzelii* (0.5), *Lophiraalata* (0.5), *Tabernaemontanacrassa* (0.5). In number of individuals, the companion plant species in the PNIE mangroves with the highest relative densities are *Cercestisafzelii* (0.03), *Abrusprecatorius* (0.02), *Tabernaemontanacrassa* (0.02), *Baphia nitida* (0.02), *Calamus deerratus* (0.02), *Chassaliakolly* (0.02), *Raphia hookeri* (0.02).

Unlike the most common species, many plant species were observed only once in all of the surveys. In the ANP, species such as *Epidendrum radicans*, *Hetaeriaheterosepala*, *Keayodendronbridelioides*, *Polystachyavictoriae* and *Tridactylefusifera* have a single occurrence each. Along with the ANP, in the EINP, 12 plant species were also observed only once. These are *Dalbergia lactea*, *Diocleareflexa*, *Erythraia maritima*, *Isolonacampanulata*, *Massularia acuminata*, *Nephrolepis biserrata*, *Palisota hirsute*, *Paspalum conjugatum*, *Salacia owabiensis*, *Salacia staudtiana*, *Smilax kraussiana* and *Uvariabaumannii*.

Quantitative Diversity

Comparison of the means of species richness in the parks shows that they are different. The mangroves of the EINP are floristically richer than those of the ANP (Table II). The means of the Shannon index in the two parks are different (Table 2). The mangroves of the EINP are more diversified than those of the ANP. The means of the Simpson's index in the parks indicate that they are different (Table 2). Taking rare species into account, the mangroves of the EINP are more diversified than those of the ANP. Regarding the averages of the equity index, we note that they are statistically identical. In both parks, the species are distributed fairly. The mean values of the Pielou equitability Index are high, so there is no dominance of a species. The rarefaction shows that for the same sample effort, the curve in the ANP mangrove tends to stabilize around 110 species (Figure 5). This sampling effort seems insufficient in the mangroves of the EINP with a large number of species recorded without a stabilization trend.

Table 2: Local Diversity of Study Sites

	Specific Richness	Shannon Index	Equitability Index		Simpson Index
Azagny	25,75±4,8	3,1±0,2	0,95±0,02	0,95±0,01	
Ehotilé	34,3±5,28	3,4±0,18	0,96±0,02	0,96±0,00	
Test statistics	t=2,02 ; p-value= < 0,0001	t=2,02 ; p-value= 0,33	t=2,02 ; p-value< 0,0001	t=2,02 ; p-value< 0,0001	

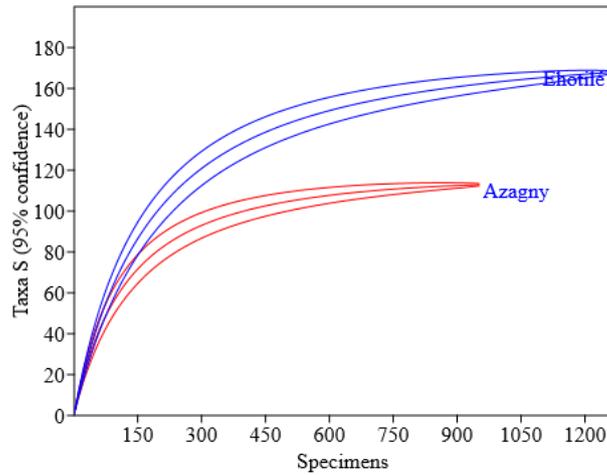


Figure 5: Rare Fraction Curves Showing the Sampling Sufficiency in Each Environment.

The NMDS graph (Figure 6) shows a clear distinction between the mangrove plant communities of the PNA and that of the PNIE ($r = 0.41$; $p < 0.0001$). However, the two national parks have 19 common plant species in mangroves. Among these, *Halleledermannii*, *Acrocerasizanioides*, *Anthocleista nobilis*, *Xylopia aethiopica*, *Chassaliakolly*, *Tabernaemontanacrassa*, *Nephrolepis biserrate*, *Rhizophora racemosa*, *Cercestisafzelii* and *Raphia hookeri* have numbers of individuals greater than 10 on the whole of the two parks.

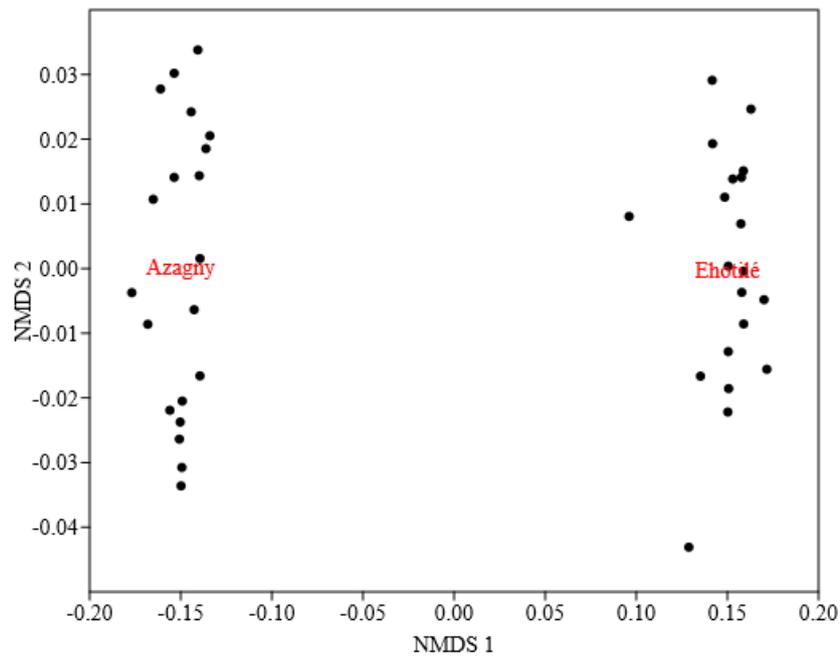


Figure 6: Graph Showing the Distribution of Inventoried Plant Communities.
(Stress: 0.2756; $r = 0.4139$; $p = 0.0001$)

DISCUSSIONS

The mangroves covered by this study belong to national parks. They are therefore protected areas. These mangroves also belong to the RAMSAR Convention list of Wetlands of International Importance (Gardner and Davidson, 2011). However, botanical records have highlighted the presence of plant species characteristic of anthropized biotopes. Indeed, several scientific studies have highlighted strong anthropogenic pressures on the mangroves of Côte d'Ivoire, including those in protected areas (Alexandre et al. ; Ablat et al., 2005; Kouamé, 2009; Ouattara et al., 2017; Abrouet et al., 2019). The high flora richness of the mangroves of the Azagny National Park and the Éhotilé Islands National Park is due to the presence of anthropized biotopes within these parks. According to Kouamé (2016), it is enough for natural and anthropized biotopes to coexist for their respective floral processions to intermingle and increase the local flora richness. According to the work of Kouamé (2009), the indicator species of the mangroves of Grand-Lahou and the Éhotilé Islands are *Echinochloa pyramidalis*, *Paspalum vaginatum*, *Cyperus articulatus*, *Mariscus ligularis*, *Sesuviumportulacastrum* and *Blutaparon vermicularis*. Monospecific *Paspalum vaginatum* lawns are observed in places between *Rhizophora racemosa* plants. In the present study, the most abundant species are *Echinochloa pyramidalis*, *Cercestisafzelii*, *Culcasiaangolensis*, *Abrusprecatorius*, *Tabernaemontanacrassa*. The work of Hupalo (2000) stratified wetlands according to hydro-geomorphological subclasses. The presence of communities of companion plant species in mangroves is influenced by local hydrological and geomorphological factors. We could therefore think that the differences observed in the plant compositions observed between the mangroves of the Azagny National Park and the Éhotilé Islands National Park could be linked to physicochemical factors determining local microclimates.

The low value of the coefficient r obtained after the NMDS graph shows that each of the mangroves has an ecological characteristic that guides the establishment of the niches of the species that inhabit them. The great variation in the diversity of species from one site to another can be linked to the edaphic diversity as demonstrated by the work of Nicolle et al. (1987). In fact, in the sectors of the Éhotilé Islands National Park, the soils are generally hydromorphic on quaternary sands or young on marine sands within places of significant accumulations of plant debris (Egnankou, 1985). The soils of the Azagny National Park area are sandy or sandy-clayey to muddy (Lauginie, 2007). In the different mangroves, species with a wide ecological range such as *Echinochloa pyramidalis*, *Chromolaena odorata*, *Anthocleista nobilis*, *Culcasiaangolensis* can be noted. It is these species which are the basis of the first level of separation of the records. They are also found in totally or partially open places and regardless of the number of strata structuring the mangrove. Among them, *Pterocarpus santalinoides* is considered by Afidégnon (1999) as a species associated with *Rhizophora racemosa* and *Avicennia germinans* in mangroves. For Kouamé et al. (2009), *Pterocarpus santalinoides* is an opportunistic plant in mangroves. The results of this study support the argument that it is more likely an opportunistic plant that is not characteristic of mangroves. *Echinochloa pyramidalis* is common and quite widespread in Africa (Mohamed et al., 2006). It is found in the Ivory Coast in dense populations on bodies of water such as Bandama, the Aby lagoon (Egnankou, 2015).

CONCLUSIONS

Data collection made it possible to draw up a floristic list of 114 companion species of swamps in Azagny National Park. Regarding the Éhotilé Islands National Park, 171 plant species have been inventoried. From the compilation of these various records, it emerges that *Echinochloa pyramidalis*, *Culcasiaangolensis*, *Calamus deerratus*, *Cercestisafzelii*, *Homaliumletestui* are the characteristic species of the mangroves of the Azagny National Park and the Éhotilé Islands National Park. There are also many plant species that appear extremely rarely in the mangroves studied.

There is little floristic similarity between the mangroves present at the two different study sites. Analysis of the NMDS graph shows a clear distinction between the floristic composition of the mangroves of the Azagny National Park and that of the Éhotilé Islands National Park. However, the two national parks have 19 common plant species in the different mangroves. For the same sample effort, the flora present in the mangroves of the Azagny National Park tends to stabilize around 110 species. This is insufficient in the mangroves of the Éhotilé Islands National Park with a greater number of species recorded without a tendency to stabilize. The mangroves of the Éhotilé Islands National Park have greater flora richness than those of the Azagny National Park.

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