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Original Article

Does Nypa Palm Affect Floristic Composition of the Mangroves of the Wouri Estuary?

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Abstract *- Mangroves are essential ecosystems for the environment and are home to a particular biological diversity. They face many constraints, in particular, that of the invasion of exotic species such as Nypa fruticans. The research aim consisted of the characterization of Nipa palm traits in the Wouri estuary. The study was carried out in five points located in the main and secondary streams of the Wouri River. Floristic statements were inside twenty-five plots of 10 m x 10 m, and structural parameters such as the number of individuals, and DBH, with equidistance of 20m, were installed in five sites. The results showed that Nipa palm has an occurrence of 60 % in the studied sites. The higher density was obtained inAkwa-nord with 1309 individuals.ha^{-1}. The number of leaves significantly differed between the sampling points (K= 6.91; p= 0.03); Youpwe was the site with the higher number. Stalk width also differed significantly between the sites, from 25.2 cm in Essengue to 47.3 cm in Youpwe. Factor analysis revealed more matures and adults in Youpwe, juvenile plants in Essengue, and seedlings in Akwa-nord. This work showed that Youpwe would represent the oldest site and would have been the focus of the propagation of Nypa fruticans in the Wouri estuary.*

Keywords *- Estuaries, Floristic statements, Invasive species, Nypa fruticans, Spatial patterns.*

1. Introduction

Nipa palm was introduced into West Africa in 1906, and since then, it has been well established, co-existing with native mangroves (Kodji et al. 2011). It is now a major invasive species and a threat to coastal areas in the Niger Delta. This is because the palms have suppressed the growth of mangroves and other coastal species with their explosive population growth (Numbere 2018). Nypa palm is a native species of Indo-Pacific mangrove block that was intentionally introduced in Nigeria and the Gulf of Guinea to check erosion and for aesthetic value (Moudingo et al. 2015; Numbere and Moudingo, 2023). The palms had adapted to the environment and had become a major threat to the native mangroves. In Cameroon, the Nypa palm grows betweeen tidel fresh and mesohaline water of Rio del Rey and Cameroon estuaries (Ajonina 2008; Humphrey and Gordon 2012). Mangroves typically include evergreen trees or shrubs, as well as ferns and palms, which normally grow in or near intertidal zones in the tropics and subtropics. They are among the most productive ecosystems and constitute a renewable natural resource (Ajonina et al., 2009). The colonization of mangroves by Nypa palm has considerable ecological implications. With its dense monospecific stands, this species is out-competing the indigenous mangrove vegetation in the colonization of space. This opportunism is exacerbated by the fact that much of the mangrove forests of Nigeria and Cameroon are being felled to provide fuel wood for smoking fish for commercial sale. The resulting exposed mudflats are ideal colonization areas for Nypa, and the indigenous mangroves cannot re-colonize the areas (Sunderland and Morakino 2002). The rapid and spectacular occupation of the Cameroonian coasts by *Nypa fructicans* dates from the 1970s, after it had successfully colonized the coasts of neighboring Nigeria. But now, it is a well-established species in the Cameroonian mangroves (Numbere and Moudingo, 2023). In Cameroon, unlike other native species whose statuses are already well studied, there are very few details concerning empirical research on the revelation of the status of *N. fruticans* (Tening et al. 2013). Areas with high commercial activity, such as the Wouri estuary, can cause Nypa to rapidly expand into the surrounding mangroves, thereby accelerating the process of mangrove denaturation. In addition, information (MINPDED 2012) on non-native or invasive species is scarce in Cameroon. This study aims to determine the spatial distribution of *N. fruticans* in the mangroves of the Wouri estuary.

2. Material and Methods

2.1. Study Area

The city of Douala belongs to the Littoral region of Cameroon, with the coordinates range between 04°00'262 North latitude and 09°40'486 East longitude. The region's climate belongs to the equatorial domain of a particular or Cameroonian type and is influenced by the Atlantic Ocean

and Mount Cameroon (Din et al. 2017). It is characterized by an average annual rainfall of 4000 mm per year. If precipitation is distributed throughout the year, the wet season (June, July, August) records up to 80% of annual rainfall, while the dry months (December, January and February) only total about 150 mm, a high temperature and low amplitude around 26.7°C and high humidity throughout the year with a maximum close to 100 % (Din et al. 2008; Zogning et al. 2013).

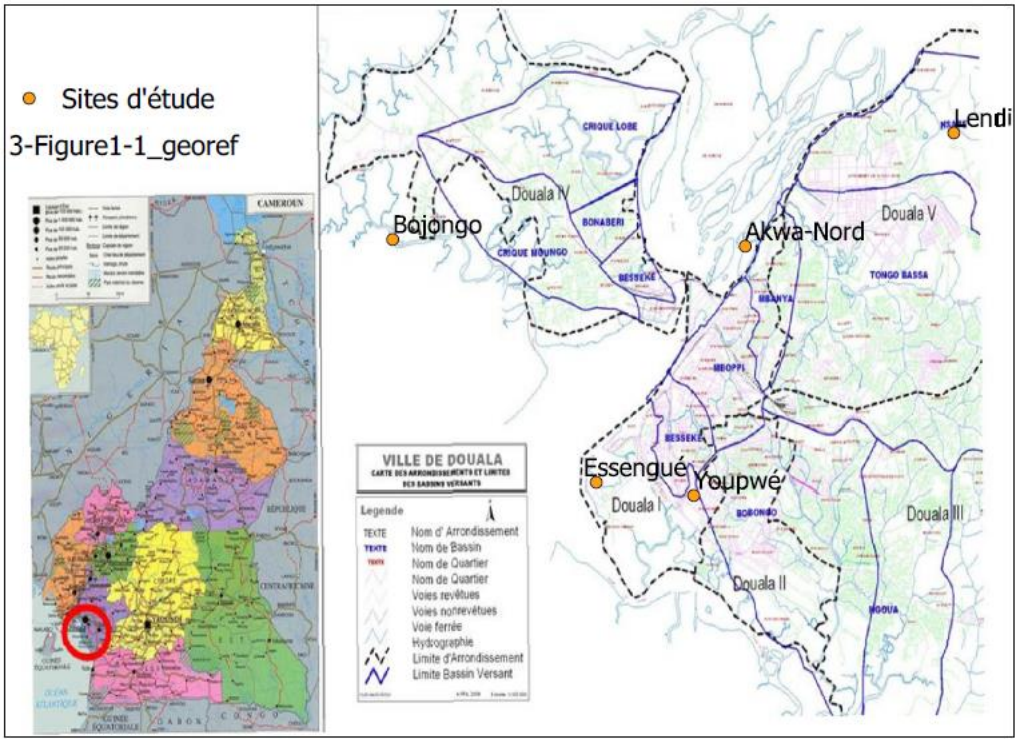

Fig. 1 Cameroon estuary mangrove map (Modified Din et al. 2008)

2.2. Setting Up Statements

Individuals of *N. fruticans* were sampled in five sites along the Wouri estuary, with their specific characteristics. In the main Wouri stream, we made two sample points. The upper sample point was fixed in the Akwa-nord quarter (UMS), which is a river port between Douala and the neighboring islands. The lower point was at Essengue Quarter (LMS), which is close to the Port Authority of Douala, and is influenced by the movements of the commercial ships.

Table 1. Location and description of sampled points

N°	Name of locality	Location	Description
1	**Akwa-nord**	Center of the mainstream	Riverport
2	**Bojongo**	Upper secondary stream	Low fishing activity
3	**Essengue**	South of the mainstream	Port activity area
4	**Lendi**	North of mainstream	Low activity
5	**Youpwe**	Lower secondary stream	High fishing activity

Source: The Author

We also investigate secondary streams of the study area: the first was the upper secondary stream of Lendi quarter (USS), in which low anthropogenic activity was recorded; The western secondary stream of Bojongo quarter (WSS), with a low fishing activity; The Lower secondary stream of Yopwe (LSS), characterized by higher fishing activity, and a big fish market. All of these characteristics are resumed in Table 1.

2.3. Floristic Statements

In each study site, five parcels of 10m x 10m were plotted with an equidistance of 5m, according to the point-frame method (Ciucci et al., 2004). All the woody species with a DBH $\geq$ 10 cm were sampled, and the names of species were found using the identifications keys of specialized manuals. Unidentified specimens were carried to the National Herbarium of Cameroon for further identification. The following diversity indexes were calculated after the sampling. The Shannon Weaver index was calculated using the formula:

$$H' = -\Sigma^{s}_{i=1} Pi \, Log_2 (Pi)$$

P_i = ni/N. ni, the number of individuals of the species i, and N, the total number of species encountered in the plot.

The Equitability of Pielou was obtained with the formula: J'=H'/H'max; H'max = Log_2 (S) with S, the number of species of a sampled area.

The density of the Nypa palm was obtained by manually counting individuals in a plot and determining the number of individuals per surface unit. The diameters of individuals were measured based on the stalks due to the early ramification of the plant. The number of alive leaves was obtained by manual counting, and the maturity of an individual was determined by the development stages method (Rozainah and Aslezaeim 2010). These authors established four growing levels of Nypa palm, such as seedlings, juveniles, adults and mature.

2.4. Data Analysis

Kruskal-Wallis non-parametric test was used to compare the number of leaves and basal areas between the sample points. A Correspondance Analysis based on the presence of the development stages in the sample points was performed to represent the association between Nypa palm's development stages and the sites.

3. Results

3.1. Nypa's Occupation Sites

After the prospections, we saw Nypa palm individuals occurring in three of the five selected study sites: the Upper and Lower mainstream and the Lower secondary stream. Essengue, and Youpwe. These sites are located in the central part of the Wouri estuary. Peripheral sites like Bojongo and Lendy were empty of Nypa individuals.

3.2. Nypa individual's Traits in the Sites

The greater Nipa palm density was obtained in Akwa-nord (1309 individuals/ha), followed by Essengue (1291 individuals/ha), and Youpwe (1255 individuals/ha). The number of leaves was significantly different between the sampling points (K= 6.91; p= 0.03); Youpwe recorded the greater number of leaves (9509 leaves/ha), while Essengue showed 8982 leaves/ha, and Akwa-nord the lowest number of leaves (7982 leaves/ha). The average stalk width was significantly greater in Youpwe (47.3±32.8 cm), followed by Akwa-nord (33.8±36.8 cm); Essengue recorded the lowest diameters, with a mean of 25.2±30.7 cm (Table 2).

3.3. Nypa's Development Stages

In Akwa-nord, seedlings and adults were the most represented development stages with densities respectively of 527 individuals/ha and 490 individuals/ha. They were followed by juveniles (273 individuals/ha) and matures (18 individuals/ha). In Essengue, the dominant development stage was adults (582 individuals/ha) and juveniles (473 individuals/ha). They were followed by seedlings (218 individuals/ha).

In the sample point of Youpwe, adults were the most represented development stage with a density of 745 individuals/ha, followed by juveniles (272 individuals/ha), seedlings (200 individuals/ha), and matures with 36 individuals/ha (Table 3).

Table 2. Nypa palm traits in the study area

Parameters	Sampled points	Total	Average ± SD (ha^{-1})	k	p-value
Density (individuals.ha^{-1})	Akwa-nord	1309	-	-	-
	Essengue	1291	-		
	Youpwe	1255	-		
Number of leaves	Akwa-nord	8982	38.48±6.1	6.91	0.03*
	Essengue	7982	50.26±7.0		
	Youpwe	9509	78.54±7.6		
Stalk diameter/width (cm)	Akwa-nord	-	33.8±38.6	15.39	0.000***
	Essengue	-	25.2±30.7		
	Youpwe	-	47.3±32.8		
Level of signification p < 0.05. (*) significant ; (**) very significant; (***) very high significant					

Source: The Author

Correspondance Analysis showed three types of association between *N. fruticans* development stages and the sites. The first association grouped adults and matures with Youpwe; the second association was between juveniles and Essengue; and the third association was between seedlings and Akwa-nord (Figure 2).

3.4. Specific Richness of the Sites

A total of 28 species belonging to 26 genus and 19 families have been identified in the mangroves of the Wouri estuary. We found Acanthaceae and Fabaceae as the families with the higher number of species (four species each). On the plant species inventoried, we found eight mangrove native species, and twenty non-native species, meaning the degradation of the mangroves of the estuary. In the sampled points, a total of 13 species were found in Essengue, followed by 11 and 10 species, respectively, in Lendi and Bojongo. Essengue and Akwa-nord came lastly with four species, respectively (Table 4).

Table 3. Abundance of Nypa's development stages in the sample points

Development stages	Sample points			
	Akwa-nord	Essengue	Youpwe	Overall
Seedlings	29	12	11	52
Juveniles	15	26	15	56
Adults	27	32	41	100
Matures	1	1	2	4
Overall	72	71	69	212

Source: The Author

Table 4. List of species inventoried in the study area

Families	Species	Mangrove status	Sample points				
			Akwa-nord	Bojongo	Essengue	Lendi	Youpwe
Acanthaceae	*Avicennia germinans*	Native	-	-	+	-	-
	Rhizophora racemosa	Native	+	+	+	-	+
	Rhizophora mangle	Native	-	-	-	+	-
	Rhizophora harrisonii	Native	-	+	-	-	-
Araceae	*Cyrtosperma senegalensis*	Non Native	-	-	-	+	-
Arecaceae	*Elaeis guineensis*	Non Native	-	+	-	+	-
	Nypa fruticans	Native	+	-	+	-	+
	Raphia Hookerii	Non-Native	-	+	-	+	-
Asteraceae	*Chromolaena odorata*	Non Native	-	-	-	+	-
Calophyllaceae	*Calophyllum inophyllum*	Non Native	-	+	-	-	-
Combretaceae	*Laguncularia racemosa*	Native	-	-	-	-	+
	Conocarpus erectus	Native	-	+	-	-	-
Commelinaceae	*Commelina benghalensis*	Non Native	-	-	-	-	+
Cyperaceae	*Pycreus mundtii*	Non Native	-	+	-	+	-
Euphorbiaceae	*Alchornea cordifolia*	Non-Native	-	-	-	+	-
	Ricinus communis	Non-Native	-	-	-	-	+
Fabaceae	*Cynometra mannii*	Non Native	-	+	-	-	+
	Dalbergia ecastaphyllum	Native	-	-	-	+	+
	Desmodium adscendens	Non-Native	-	-	-	-	+
	Drepanocarpus lunatus	Native	-	-	-	-	+
Malvaceae	*Hibiscus tiliaceus*	Native	-	-	-	-	+
Mimosaceae	*Carapa procera*	Non Native	-	-	-	+	-
	Mimosa sp.	Non-Native	-	-	-	-	+
Pandanaceae	*Pandanus heterocarpus*	Non Native	+	+	-	-	-
Poaceae	*Acroceras zizanioides*	Non Native	-	-	-	-	+
Polypodiaceae	*Acrostichum aureum*	Native	-	+	-	+	+
Pontederiaceae	*Eichhornia crassipes*	Non Native	+	-	-	-	-
Rubiaceae	*Hallea stipulosa*	Non Native	-	-	-	+	-

(+) Present; (-) Absent

Source: The Author

Table 5. Diversity indexes of sites with Nypa and without Nypa

Indexes	with Nypa				without Nypa		
	Akwa-nord	Essengue	Youpwe	overall	Bojongo	Lendi	overall
S	4	3	13	6.67	10	11	10.5
H'	1.68	1.29	2.95	1.97	3.4	2.95	3.04

Source: The Author

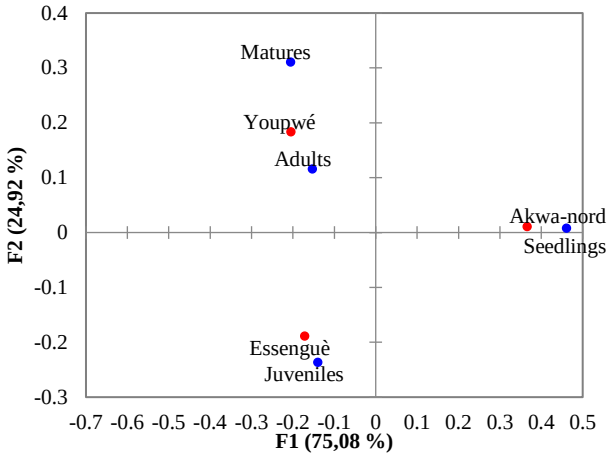

Fig. 2 Correspondance analysis map between Nypa's development stages and sites

The comparison of species richness between sites with Nypa palm and without Nypa palm showed a greater value in the site without Nypa palm. The same observation was made for the Shannon-Weaver index, which showed a value of 3,04 bits in the sites without Nypa palm (Table 5). More specifically, the plots with Nypa and without Nypa recorded the same number of native mangrove species. Indeed, we found six native mangrove species in both sites, such as *Acrostichum aureum, Aveicennia germinans, Dalbergia ecastaphylum, Drepanocarpus lunatus, Rhizophora racemosa, Laguncularia racemosa* for the sites with Nypa. For those without Nypa, there was *Conocarpus erectus, Hibiscus tiliaceus, Rhizophora harrisonii, R. racemosa, R. mangle, and Pycreus mundtii*. Note, however, here that, a change in the level of the floristic composition. Indeed, only one species of Rhizophora was inventoried in the sites with Nypa, against three species in the sites without Nypa.

4. Discussion

4.1. Nypa's Propagation in the Estuary

Nypa was recorded at three of the five sites sampled. This means that its spread is not yet optimal in the Wouri estuary. Indeed, invasive species have a strong capacity to adapt and expand in their new geographical areas (Latombe et al. 2017). The sites in which Nypa has been recorded are located near the mouth of the Wouri River; it is, therefore, to be expected that it will spread to the peripheral areas of the estuary. This species has been characterized as a well-established form in the mangroves of the Wouri estuary and was already found in previous studies (Essome et al. 2017; Emane et al. 2021; Numbere and Moudingo 2023). The sites where Nypa has been observed are areas with high anthropogenic activities. The presence of Nypa in the secondary stream of Youpwe would be due to the movements of fishing boats, which could transport the floating diaspores from the open sea towards the coast. This proliferation of Nipa leads in the long term to reduce the surface occupied by the native species of the mangrove. In Niger state, mangroves have shrunk by 12% while Nipa has increased by 60% (Nwobi et al. 2020). Its installation and development depend directly on several factors: tidal movements, coastal topography and the quality of the substrate (MINEPDED 2017). Urbanization is a key anthropogenic factor that drives the growth of invasive palms. Indeed, palms have more affinity for disturbed than undisturbed soil. Urbanization in this context is the replacement of mangrove forests with urban centres, which promotes the spread of palms by changing the soil quality (Numbere 2019). Wang et al. (2016) also thought that Human activities lead to waste deposits in mangrove swamps that could accumulate and alter swampy soil, which is favorable for nipa growth. The results revealed more non-native mangrove species than the natives in the Wouri estuary.

4.2. Development of Nypa Palm in the Mangroves

Nypa palm showed a high density in the study area. Nevertheless, this density was lower than 6400 trees.ha-1 found in Carey Island, Malaysia (Rozainah and Aslezaeim 2010). Nipa is considered a 'single stand' species. Nipa also has a higher population density compared to other mangrove species because it grows in clusters and tends to create large colonies (Tsuji et al., 2011). Nipa is categorized as fast-growing species and is commonly found along the riverside (Middeljans 2014). Lestary and Noor'an (2019) are considered a "single strand" species. This species is also considered to threaten other mangrove species and might cause a decline in biodiversity in the mangrove ecosystem. However, further research is required to find out the effect of nipa occurrence on other mangrove species (Middeljans 2014). Compared to undisturbed or low levels of disturbance areas, the population density of Nypa fruticans in the study area tended to be significantly lower (Ashton and Macintosh 2002; Kasawani et al. 2007; Middeljans 2014). Adults were the most represented development stage, followed by juveniles and seedlings. This result agreed with the work of Rozainah and Aslezaeim (2010), who found that 67% of adults in the mangroves of Malaysia. These authors showed that seed dispersal and installation of young plants on the substract are the key factors of the distribution of Nypa in the mangroves. Other major drivers of invasive (non-native) species are climatic, land use, habit characteristics and socioeconomic factors (Bellard et al. 2016).

4.3. Impact of Nypa Palm on Mangrove Diversity

Floristic diversity in the study area decreases with the presence of Nypa. However, no significant impact on the number of native mangrove species was observed, while a decrease in post-pioneer species in sites at Nypa was observed. This could reflect a slowdown in the evolution of mangroves. The competition between the roots of Nypa and those of the mangroves would slow down the accretion process responsible for the mangroves' expansion. Mangroves of the Niger Delta also face a competition between Nypa and Rhizophora in terms of species distribution and abundance (Numbere 2018). The presence of Nypa in the mangroves of the Wouri estuary can also be an opportunity for local people. Indeed, some utilizations of mature leaves, young leaves and fruits of Nypa by the population were recorded in many studies (Moudingo et al. 2020; Tsuji et al. 2011).

5. Conclusion

The spread of Nypa continues in the Wouri estuary, where it is preferentially in the main channel. The spatial distribution of Nypa's development stages in the Wouri estuary indicates areas with high human activity, as Nypa's pools in the continental part of the estuary. Analysis of the diversity indexes suggests that Nypa would lead to a reduction in species richness and a modification of the floristic composition in the sites where it is installed. A management plan must be put in place to control the spread of Nypa in the Wouri estuary.

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