Research Article

# Ecological Diversity, Structure and Exploitation of Rattan Stands According to a Disturbance Gradient Around the Nkoltang Forest, Estuary Province of Gabon

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**This study was carried out in three areas of the peri-urban forest of the locality of Nkoltang, located 30 km from Libreville in Gabon. The purpose was to assess the abundance, species distribution, regeneration, and exploitation status of the different rattan species in three areas of the Nkoltang forest. The diversity and floristic abundance of rattan stands were determined from the botanical identification of the individuals. The enumeration of the different stages of development and the mortality rates made it possible to understand the structure of the stands and the state of regeneration of the resource. The abundance of cut stems made it possible to characterize the operating pressure. The results reveal that 683 rattan stems belonging to 7 species and 3 genera of rattan were inventoried in the study area. The distribution of specific abundances does not vary across forest areas. The structure of the stands shows a widespread abundance of green and vigorous stems and a low presence of mature stems. The moderately disturbed forest area supports the most diverse and abundant regeneration of rattan stands. Mining intensity is higher in the low-disturbance environment and lower in the high-disturbance environment. However, the results obtained reveal that artisanal exploitation of peri-urban forests does not seem to have any adverse effects on the abundance, structuring, and regeneration of rattan stands. Local populations seem to have a low impact on the resource.**

 doi.org/10.32388/N7OJNL 

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## Introduction

Various species of rattan palms (family Arecaceae, subfamily Calamoideae) exist and represent an important component of the vegetation of primary and secondary forests in Southeast Asia. More than 600 species of rattan palms have already been inventoried, belonging to 13 genera (Dransfield *et al*., 2008) and representing about one-fifth of all palm species known in tropical forest regions (Uhl and Dransfield, 1987).

Indonesia, one of the countries in Southeast Asia, has more than 300 species of rattan (Bastian, 2013), and the harvesting and export of rattan account for more than 80-90% of total global production (FAO, 2011). The exploitation of rattan stands has the potential to shape the structure of the tropical rainforest (Richards, 1996) because of the disturbances created in the understory as a result of their removal in the wild and the consequent loss of habitat (Siebert, 2001), particularly in the absence of effective approaches to sustainable management of the resource (e.g., rattan silviculture).

In Asian countries, the diversity of rattan species is well known to the scientific community. The available studies assessed the distribution, structure, and composition of rattan species along an elevation gradient. These studies suggest that rattan species diversity tends to vary across forest types, elevation gradients (Hamid and Suratman, 2010), and gradients of disturbance or degradation in Southeast Asia. The highest distribution of rattan species is found in lowland forests where there is little seasonal water scarcity and a hot and humid climate (Hamid and Suatman, 2010; Nagabhatla *et al*., 2007). In relation to the disturbance gradient and habitat loss, Latiff (2011) and Masum *et al*. (2017) noted that much of the lowland dipterocarp forests in Malaysia have already been exploited for rapid industrial and economic development (Masum et *al*., 2017b).

The forest disturbances thus created open up the canopy through selective logging activity. In addition, these disturbances can also stimulate the regeneration of rattan species with a heliophilic character. This is true for some taxa such as *Oncocalamus*, which is often considered to be the first colonizers of heavily disturbed areas. On the other hand, *Calamus deërratus G. Mann & H. Wendl.* often grows in permanently or seasonally flooded forests or swamps, while other species, such as *Laccosperma secundiflorum (P.Beauv.) Küntze* and *Laccosperma laeve (G. Mann & H. Wendl.) Kuntze*, are very shade-tolerant and prefer to grow under the forest canopy.

Among the few studies that have assessed the diversity, population distribution, and dynamics of rattan stands in the forests of Southwest Asia is that of Watanabe and Suzuki (2008), which found in four forest types in Borneo and Java (representing six plots of 4.82 ha in total) that there was a significant positive correlation between rattan stands and trees in the diversity of rattan plants, and that the correlation decreased for mixed dipterocarp forests (for rattans with the Shannon-Wiener diversity index, H′ = 2.87-3.34) to alluvial forests (1.96), lowland forests (1.43), and peat marsh forests (1.34). The density of rattan stems (ha-1) decreased from the low mountain (5,997), mixed dipterocarp (598-992), alluvium (592), to peat marsh forests (162).

Similarly, Ruppert *et al.* (2017) found that rattan (family *Calamoideae*) was more abundant in all marsh patches. However, rattan diversity (H′) was highest in the dipterocarp plot (D: H′ (2011)1,79; H′ (2013)1,84) in the Segari Melintang Forest Reserve (Peninsular Malaysia). The Bray-Curtis indices of rattan abundance with the highest similarity in the swamp during the years 2011 and 2013 were: parcel BC (2011) 0.484, BC (2013) 0.262).

In the Guinea-Congo forests of Central Africa, a variety of rattan species is also found and has the highest level of endemism among rattan species. The rattan species of the genus: *Eremospatha,* Laccosperma *and Oncocalamus*, are considered endemic and therefore restricted to this forest (Vorontsova *et al* ., 2016). Approximately twenty-two (22) rattan species have already been inventoried in the West and Central African regions so far (Sunderland, 2001; 2012), of which 19 species are found only in Cameroon (Gonmadje *et al*., 2018).

Compared to Asian countries, the diversity of rattans in the Guinea-Congo forests of Central Africa is very low. Rattan can grow in a variety of conditions, and its growth rate varies depending on species, environmental conditions, and management strategies (Razali *et al*., 1992; Sunderland, 2001; Sunderland *et al*., 2012; Titi and Prameswari, 2018; Gonmadje *et al*., 2018).

Rattan species are found in a wide range of environments. This is the case for the species *L. secundiflorum* and *Eremospatha macrocarpa (G. Mann & H. Wendl.) H. Wendl.* from Liberia to Angola. On the contrary, *C. deërratus* is widely distributed and is found in The Gambia, Kenya, and southern Zambia. The majority of rattan species are found naturally in sparsely exploited tropical forests (sparsely open canopy) and are early colonizers of humid tropical environments and are part of the satisfaction of various uses. Many urban and rural populations use the internal stems as a source of food and income, and the trade in rattan species is approximately US$10 million per year in Central Africa alone (Sunderland *et al*., 2008).

In the Guinea-Congo forests of Central Africa, studies on the distribution and dynamics of rattan species along a gradient of forest disturbance or degradation are rare. Among the few studies, we can mention that of Nfornkah *et al*. (2021), which contributed to the inventory of five important commercial rattan species: *E. macrocarpa, C. deerratus*, *L. Secundiflorum*, *Laccosperma robustum (Burret) J.Dransf.*, and *Eremospatha wendlandiana Dammer ex Becc., E. macrocarpa* , which are found in all agroecological zones (AEZs) of Cameroon. Indeed, the species *C. deerratus* was found in EAAs 2 and 5, while L. secundiflorum *and L. robustum* were found in EAAs 3, 4, and 5. In contrast, *E. wendlandiana* was found only in AEZ 4. This means that the growth of certain rattan species is adapted to certain specific habitats/environments. They also found that the current state of conservation of commercial rattan has a Least Concern (LC) status. The availability of *E. macrocarpa* in all areas indicates its high adaptation to habitats/environments. However, the problem of other rattan species tends to increase in the study area.

Gabon, one of the rich countries in the Guinea-Congo forests of Central Africa in terms of biodiversity, also has various species of rattan that are used to satisfy various needs. The terminal bud of rattan stems is widely harvested and consumed, especially by populations in southwestern Gabon (Yembi, 2000). Two landmark studies have highlighted the importance of the rattan value chain (Chabot, 1997) and the market value of non-timber forest products (including rattan) in markets around Libreville, the capital of Gabon (Yembi, 2000). The first study showed that a large quantity of rattan is harvested and transported to supply the urban population and rattan-making workshops around the city of Libreville. The second study showed that small-diameter rattan canes of the *E. macrocarpa* species are widely used for basket making and that large-diameter canes of the *L. secundiflorum* species are used as a structure in the manufacture of rattan furniture. The commercial harvesting of rattan for valorization in the rattan industry is very lucrative for those involved in this industry. However, the development of this activity threatens the sustainability of the resource (Chabot, 1997, Yembi, 2000), especially in the absence of sustainable management practices.

Despite the commercial importance of rattan species, there is very little knowledge about the ecological diversity, distribution, abundance, and composition of rattan along a gradient of disturbance or degradation. The scarcity of the resource on the outskirts of the city of Libreville has already been acutely felt, and the axis of exploitation of rattan stands has shifted sharply from the urbanized areas of the city of Libreville to the sparsely urbanized areas on the outskirts of the city, particularly around the forest of the Nkoltang region, where the exploitation and marketing of rattan stands has recently boomed.

 doi.org/10.32388/N7OJNL 

Thus, this paper is a contribution to the knowledge of the exploitation and health status of rattan species according to a gradient of disturbance around the surrounding forests of the Nkoltang area. Specifically, it aims to compare in the different rattan exploitation areas: i) the diversity, the composition of stands, and the abundance of stems, **ii**) the cutting and regeneration dynamics of stands, and iii) the vegetative state of stands.

## Presentation of The Study Area

This study was conducted in the locality of Nkoltang, located about 30 km from the city of Libreville (0°21′00″ N and 9°40′60″ S), the capital of Gabon. Nkoltang belongs to the second district of the commune of Ntoum (Aboghe, 2020).

The climate of this region is equatorial, characterized by the double alternation of dry seasons (from mid-December to mid-March, then from mid-June to mid-September) and rainy seasons (from mid-March to mid-June, then from mid-September to mid-December). The average annual temperature is 26.2°C, with a low of 25°C in July and a maximum of 32°C in April (Koumba *et al*., 2018). The average annual rainfall is around 1800 to 2716 mm, with a humidity of 98%. The heaviest rainfall (400 mm) is recorded between October and November and then from March to May (Koumba *et al*., 2018; Ondh-obame, 2020).

The vegetation of the environment is anthropogenic. The herbaceous layer is marked by the invasion *of Chromolaena odorata* (L.) R.M. King & H. Rob., an exotic species indicator of disturbed environments (Naidoo and Naidoo, 2023). The woody flora is dominated by *Aucoumea klaineana* Pierre, *Dactylofera sp*., *Anthocleista schweinfurthii* Gilg, *Pterocarpsus spp*., and colonizing species of disturbed forests such as *Musanga cecropioides* R.Br. and *Ceiba pentandra* (L.) Gaertn.

## Choice of Study Sites

Rattan, a species of NTFP, is heavily used by many urban and rural populations as a source of food, income, and handicrafts. The highest authorities of the country are committed to developing the value chains of this type of NTFP with high added value. However, policymakers and researchers lack knowledge about the ecological diversity of this type of NTFP, its distribution, exploitation status (growth), and health along a disturbance gradient, particularly around the forests of Nkoltang (Estuary province in Gabon), where exploitation of the resource has increased sharply over the past 10 years.

Surveys were carried out at three sites along the environmental disturbance gradient (Figure 1). The zero point of the disturbance gradient in the Nkoltang Forest was delineated from the buffer zone of the Akanda Protected Area.

**The undisturbed habitat** was represented by a secondary mature forest, located about a 25 km walk from the Nkoltang district (00°20′918″N; 009°39′141″E) in the buffer zone of Akanda National Park. In this environment, heliophilic species such as *Musanga cecropioides* R.Br. gradually disappear to make way for sciaphilous species such as *Pterocarpsus spp (Padouk), Aucoumea klaineana* Pierre. Human activity is regulated by the regulations of the eco-guards in charge of the management of the park.

**The moderately disturbed environment** was represented by a forested area located about a 4-kilometer walk from the buffer zone of Akanda National Park (00°21,570″N; 009°39,380″E). This forest is home to old fallow land that is more than 11 years old (Maloumbi, 2007). The middle floristic background is mainly composed of pioneer species such as *Musanga cecropioides* R.Br., *Anthocleista schweinfurthii* Gilg, and *Ceiba pentandra* (L.) Gaertn. etc.

**The highly disturbed environment** was represented by a forest area located more than 6 km (on foot) from the buffer zone of Akanda National Park (00°21,236″N; 009°39,420″E). The vegetation is characterized by the presence of old fallow land about 4 years before the crops are replanted. The flora is herbaceous and dominated by *Aframomum spp., Costus spp*., seeds of heliophilic trees such as *Musanga cecropioides* R.Br., *Macaranga spinosa* Müll.Arg., *Harungana madagascariensis* Lam. ex Poir, etc.

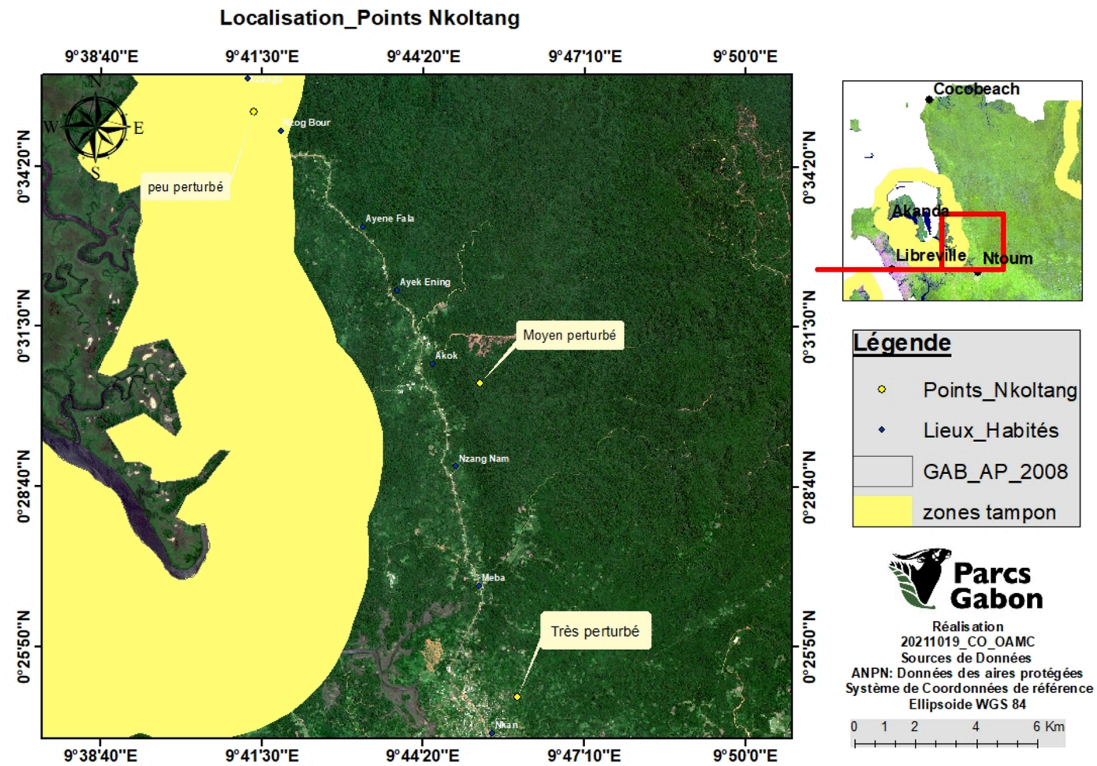


**Figure 1.** Rattan stand area in Nkoltang

## Data Collection Methodology

Data on the distribution, growth, and health of the different rattan stands were collected over a period of three months (February to April 2017). In each environment, three square plots (100m x 100m) were arranged along a transect of five (05) hundred meters. The regular equidistance between the plots was 100m to ensure the representativeness of the inventory area (Kouassi *et al*., 2009; Gerville-réache and Couallier, 2011). The transects were parallel to each other and perpendicular to the general orientation of the river system. This made it possible to better take into account the ecological variability of the environment (Doucet, 2003).

The sampling of the different tufts of rattan was carried out step by step. Each clump was labelled, numbered using tape, and georeferenced with a Garmin 7 Series GPS to prevent re-ironing. The identification of rattan species was carried out using the determination keys set up by many authors (Couvreur and Niangadouma, 2016; Kamga *et al*., 2018 and 2019; Helmstetter *et al*., 2020; Kamga *et al*., 2020). In addition, the different species were photographed using a Canon EOS 4000D camera with an 18-

megapixel resolution. For species that were difficult to identify in the field, samples of stems and sheets were collected for verification and correction at the National Herbarium of Gabon. The size and regeneration of the different stands were quantified by counting mature stems, seedlings, and buds within the clumps (Chabot 1997; Yembi, 2000; Delbón *et al.* , 2017 ; Agbani *et al*., 2018 ; Deguene, 2020). Harvesting pressure was assessed by the number of stems cut from each clump (Agbani *et al*., 2018 ; Deguene, 2020). In addition, the vegetative state of each clump was determined from the percentage of stem desiccation by following the coding indices in the following table (Iponga *et al*., 2008).

| Classes | Distribution of stem maturity |
|---|---|
| **[0 - 20[** | The stem is totally green (good condition) 100% |
| **[20 - 40[** | The stem is partially green or 75% green |
| **[40 - 60[** | The stem is half green or 50% dry |
| **[60 - 100]** | The stem is 75% dry or totally dried out |

**Table 1. C**lass for determining the vegetative state of rattan stems

## Data Analysis and Processing

All the information collected during the inventories was processed via Excel 2007 for presentation in the form of tables, histograms, percentages, and averages. The statistical processing was carried out on Ri386 version 3.4.0. The data were subjected to the graphical normality test.

According to a disturbance gradient (Low-disturbance, Highly Disturbed, and Highly Disturbed), the following parameters were compared: ecological diversity, composition, distribution, farm status (growth), and health according to a Tukey multiple comparison test when the null hypothesis was rejected at the 5% level (p*<0.05). The normality of the data was tested beforehand.*


doi.org/10.32388/N7OJNL

## Results

### *Distribution of abundance of rattan stems according to the environments surveyed*

A total of 683 rattan stems belonging to 7 species and 3 genera of rattan were inventoried in the three (3) environments surveyed. Stem abundance varies with habitat (Figure 2). Indeed, the highest number of rattan stems was recorded in the undisturbed environment (41%) with 282 stems encountered. The other two environments, i.e., very disturbed and moderately disturbed, had rattan abundance percentages of 31% (214 stems) and 28% (187 stems), respectively. However, one-way analysis of variance revealed that there was no significant difference in rattan stem abundances in the 3 different media ($p<0.05$).

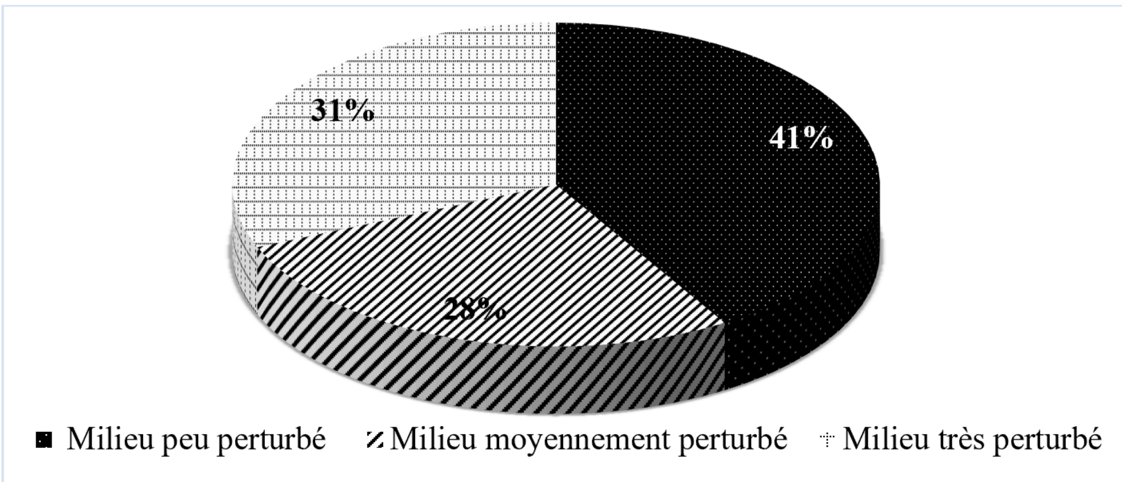


**Figure 2.** Proportion of rattan stems according to the environments surveyed

### *Distribution of abundance of rattan species as a function of habitats*

The study of the specific abundances of rattan stems reveals that the proportions of the different species vary according to the environments surveyed (Figure 3). A total of 7 rattan species have been identified in all three inventoried habitats, namely: *Oncocalamus macrospathus* (Burret, Notizbl.), *Laccosperma secundiflorum* (P.Beauv.), *Eremospatha haullevilleana* (De Wild), *Oncocalamus mannii* (H.Wendl.), *Laccosperma opacum* (G.Mann & H.Wendl.), *Eremospatha macrocarpa* (G.Mann & H.Wendl.) and *Laccosperma robustum* (Burret) J.Dransf.Tags: *E. macrocarpa* was found only in the highly disturbed habitat.

 doi.org/10.32388/N7OJNL 

In all the habitats surveyed, *O. macrospathus* and *L. opacum* were the most abundant (Figure 3). In low and highly disturbed habitats, these species accounted for 57% (160 and 121) and 25% (70 and 53) of the stems surveyed, respectively. On the other hand, in the moderately disturbed environment, each of these two species represented respectively 31% (58) and 32% (60) of the stems surveyed.

These species were followed by *E. haullevilleana* and O. mannii, *which* accounted for 11% and 5% (30 and 14) of the stems surveyed in the undisturbed environment, 20.85% (39 stems) and 12.29% (23 stems) of those in the moderately disturbed environment, and 8.41% and 5.14% of those in the highly disturbed environment.

The species *L. secundiflorum*, *L. robustum*, and *E. macrocarpa* were the least abundant, with percentages of less than 3% of the stems inventoried in the three environments surveyed.

One-way analysis of variance reveals that the specific abundances of rattan stems show a significant difference between the undisturbed environment and the other two compartments ($P < 0.05$).

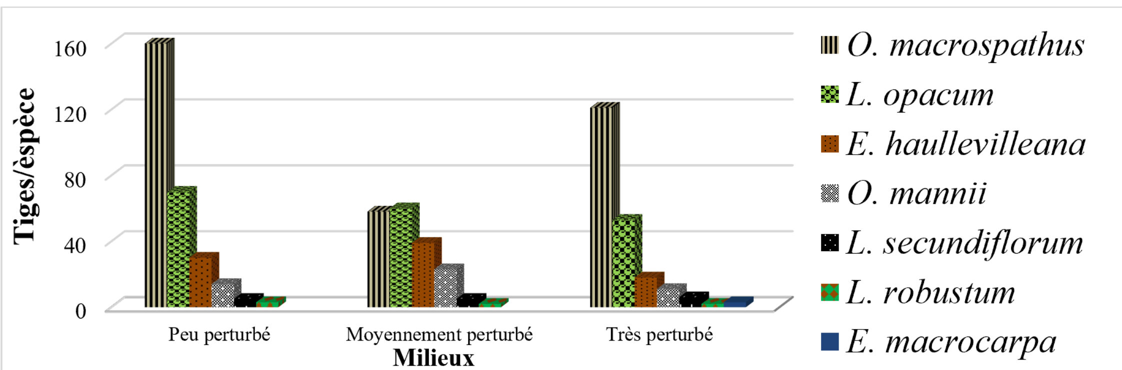


**Figure 3.** Abundance of different rattan species according to environments

## *Rattan Cutting Pressure Level in Different Media*

A total of 82 cut rattan stems were observed in the study area, and the cutting pressure varies depending on the habitat surveyed (Table 2). Indeed, the highest number of cuts was recorded in low- and moderately disturbed areas. In these two compartments, the cutting pressure levels were 44% (36 stems cut) and 35% (26 stems cut). On the other hand, the lowest cutting pressure was recorded in the highly disturbed environment, i.e., 21% (17 stems cut).


doi.org/10.32388/N7OJNL

| Environments | Number of stems cut |
|---|---|
| **Undisturbed** | 36 |
| **Moderately disturbed** | 29 |
| **Very disturbed** | 17 |
| **Total** | **82** |

**Table 2.** Abundance of rattan stems cut according to the environment

In addition, the cutting pressure of the stems does not appear to vary between species in different habitats (Figure 4). **In the undisturbed environment**, the most cut species were *E. haullevilleana 28% (10 stems) and* O. macrospathus *25% (*9 stems). These species are followed by L. *opacum, L. secundiflorum, and* O. mannii *which account for 17% (6* ), 17% (6), and 10% (4) respectively of the cut stem population. The least cut species in the undisturbed environment was *L. robustum*, 3% (1 stem cut).

**In the moderately disturbed habitat, the** most cut species were *L. opacum* 48% (14 stems) and *O. macrospathus* 31% (9 stems). *L. secundiflorum and L. robustum* were lightly cut with 14% (4 stems) and 7% (2 stems) respectively of the middle cut stock. In this environment, *E. haullevilleana* and *O. mannii* were not cut.

**In the highly disturbed environment,** the most prized species was *O. macrospathus* with 59% (10 stems) of the middle cut stock, followed by *L. opacum* and *L. secundiflorum* with each 18% (3) of the cutting workforce. The least cut species in this environment was *O. mannii* (6% or 1 cut stem). On the other hand, the *L. robustum, E. haullevilleana*, and *E. macrocarpa* have not been cut. The ANOVA test at the 5% threshold showed that there was no significant difference in the specific distribution of cut stems according to the environments surveyed.

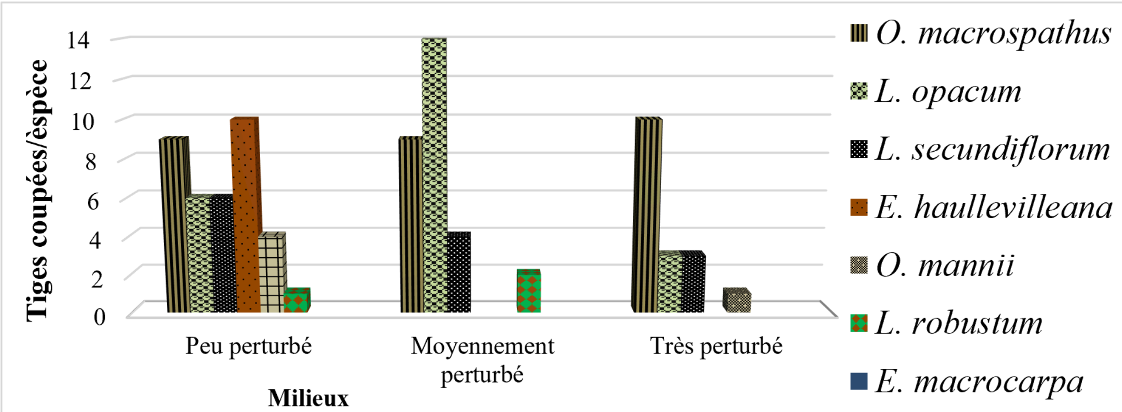


**Figure 4.** Abundance of stems cut by species and habitats

*Regeneration of rattan stands in different environments*

In the study area, the regeneration of rattan stands is characterized by 95 seedlings, 69 buds, and 04 pods. The distribution of the different stages of regeneration of young plants varies according to the environments surveyed (Table 3). Indeed, the regeneration of plants from the moderately disturbed environment was the strongest. There were 52 seedlings, 23 buds, and 04 pods. On the other hand, the regeneration of plants in low- and high-disturbance environments was average, with 21 and 22 seedlings and 23 and 26 buds, respectively.

| Environments | Seedlings | Buds | Pods | Total |
|---|---|---|---|---|
| **Undisturbed** | 21 | 23 | 0 | 44 |
| **Moderately disturbed** | 52 | 20 | 4 | 76 |
| **Very disturbed** | 22 | 26 | 0 | 48 |
| **Total** | **95** | **69** | **4** | **168** |

**Table 3.** Abundance of rattan life stages as a function of media

In addition, in the study area, the regeneration of seedlings varies according to species and environments (Figure 5). Indeed, the species whose regeneration of young plants was common to all habitats were *L.*

*opacum,* E. haullevilleana*, O. mannii*, and *O. macrospathus.* The differential species were L. *robustum and* L. secundiflorum*, which regenerate only in the moderately* disturbed environment, and *E. macrocarpa*, which was present only in the highly disturbed environment.

On the other hand, in the moderately disturbed environment, the species that regenerated best were *L. opacum* and *E. haullevilleana.* These two species, each with 22 seedlings, accounted for 58% of the number of regeneration stands in the area. The other species, namely, O. *mannii and O*. macrospathus *16% (12) each,* L. secundiflorum *8% (6), and* L. robustum *2% (2), showed low regeneration rates of young plants.*

In low and high disturbance habitats, stand-specific regeneration was moderate to low, and *O. macrospathus* was the best regenerating species. This species accounted for 48% (21) and 54% (26) of the number of young plants, respectively. The species that showed poor regeneration of seedlings in these two habitats were, respectively, *L. opacum 16% (07) and 10% (05),* E. haullevilleana 25% (11) and 16% (8), and *O. mannii* 11% (05) and 14% *(07)* of the seedlings. The species *E. macrocarpa* regenerated only in the highly disturbed environment with a rate of 4% of the young plants present.

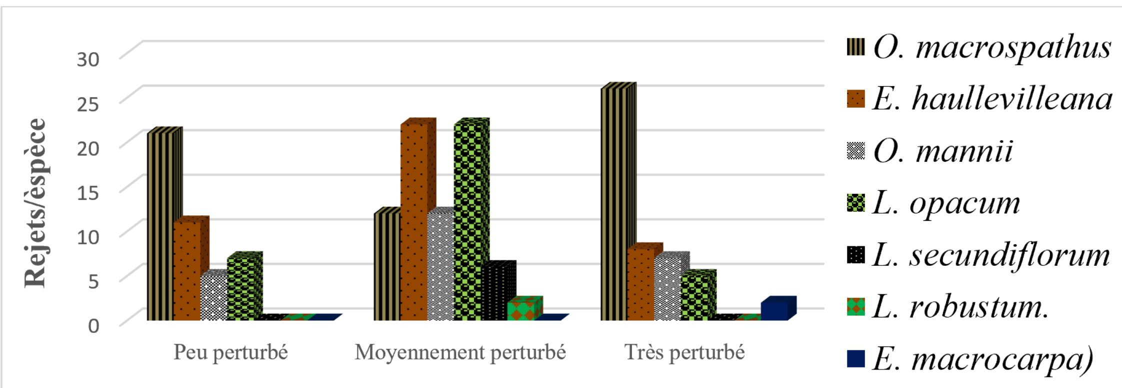


**Figure 5.** Specific abundances of rattan regeneration as a function of the environment

## *Vegetative state of rattan stands in different habitats*

The percentage of stem desiccation was used as an indicator of the state of dieback of the clumps of the different rattan stands (Table 4). In the different environments surveyed, 5 classes of vegetative states of the stems were listed, namely: [0 - 20[ the stems are totally green (good health); [20 - 40[ the stems are mostly green; [40 - 60] the stems are half green; and [60 - 100] the stems are very dry or totally dried out. The analysis of these results reveals that the different rattan stands are healthy. Their vegetative state in the different environments surveyed is on average 82% totally green to essentially green. In addition, on

 doi.org/10.32388/N7OJNL 

average, 15% of the stems in these environments are green in halves. Desiccated stands accounted for only about 3% of the stems in each habitat.

| **Environments** | **Vegetative state classes** | | | | |
|---|---|---|---|---|---|
| | **[0-20[** | **[20-40[** | **[40-60[** | **[60-100]** | **Total** |
| **Undisturbed** | **102** | 64 | 35 | 7 | **208** |
| **Moderately disturbed** | 73 | **79** | 18 | 4 | **174** |
| **Very disturbed** | **74** | 65 | 32 | 3 | **174** |
| **Total** | **249** | **208** | **85** | **14** | **556** |

**Table 4.** Dieback rate of rattan stems in different media

In addition, the distribution of specific stem abundance in the different classes of vegetative states varies according to the environment. In the undisturbed environment, the vegetative state of 208 stems belonging to 06 species and 03 genera of rattan was recorded (Table 5). Analysis of the state of dieback of the stems of these different taxa reveals that about 80% of rattan stems found in this environment are green. This percentage is composed respectively of: 38% O. *macrospathus (47 totally green stems and 33 mainly green stems), 23% L.* opacum (28 totally green stems and 19 mainly green stems), 9% E. *haullevilleana* (11 totally green stems and 7 mainly green stems), 6% O. mannii *(8 totally green stems and 5 mainly green stems),* 2% L. *secundiflorum* (5 totally green stems), and 1% *L. robustum* (3 totally green stems).


doi.org/10.32388/N7OJNL

| Vegetative state classes | Cash | | | | | | |
|---|---|---|---|---|---|---|---|
| | *O. macrospathus* | *L. opacum* | *E. haullevilleana* | *O. mannii* | *L. secundiflorum* | *L. robustum* | **Total** |
| **[0-20[** | 47 | 28 | 11 | 8 | 5 | 3 | **102** |
| **[20-40[** | 33 | 19 | 7 | 5 | -- | -- | **64** |
| **[40-60[** | 22 | 6 | 7 | -- | -- | -- | **35** |
| **[60-100]** | 4 | 2 | -- | 1 | -- | -- | **7** |
| **Total** | **106** | **55** | **25** | **14** | **5** | **3** | **208** |

**Table 5.** Specific dieback rates of rattan stems in the undisturbed environment

In the moderately disturbed environment, 174 stems belonging to 06 species and 03 genera of rattan were recorded (Table 6). Analysis of the vegetative state of the stems identified shows that 87% of the individuals in the environment are green. This percentage is composed of *30% L. opacum* (20 totally green stems and 32 mostly green stems), 26% O. macrospathus *(28 totally green stems and 18 mostly green stems), 14% E. haullevilleana* (10 totally green stems and 15 mostly green stems), 13% O. mannii *(8 totally green stems and 14* mostly *green stems),* 3% L. *secundiflorum* (5 totally green stems) and 1% *L. robustum* (2 totally green stems).


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| Vegetative State Classes | Cash | | | | | | |
|---|---|---|---|---|---|---|---|
| | ***L. opacum*** | ***O. macrospathus*** | ***E. haullevilleana*** | ***O. mannii*** | ***L. secundiflorum*** | ***L. robustum*** | **Total** |
| **[0-20[** | 20 | 28 | 10 | 8 | 5 | 2 | **73** |
| **[20-40[** | 32 | 18 | 15 | 14 | -- | -- | **79** |
| **[40-60[** | 1 | 7 | 9 | 1 | -- | -- | **18** |
| **[60-100]** | 3 | | 1 | | -- | -- | **4** |
| **Total** | **56** | **53** | **35** | **23** | **5** | **2** | **174** |

**Table 6.** Specific dieback rates of rattan stems in the moderately disturbed environment

Also, the stems recorded in the highly disturbed environment were made up of 174 individuals belonging to 06 species and 03 genera of rattan (Table 7). The vegetative state of 80% of the stems of the various species recorded is green. This percentage is composed respectively of: 37% O. *macrospathus (30 totally green stems and 34 mostly green stems), 22% L.* opacum (19 totally green stems and 20 mostly green stems), 10% E. *haullevilleana* (9 totally green stems and 8 mostly green stems), 5% O. mannii *(6 totally green stems and 2 mostly green stems),* 3% L. *secundiflorum (5 totally green stems and 1 mostly green stem), 2%* E. macrocarpa (3 totally green stems*) and 1%* L. robustum *(2 totally green stems).*

| Vegetative state classes | Cash | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | *O. macrospathus* | *L. opacum* | *E. haullevilleana* | *O. mannii* | *L. secundiflorum* | *E. macrocarpa* | *L. robustum* | **Total** |
| **[0-20[** | 30 | 19 | 9 | 6 | 5 | 3 | 2 | 74 |
| **[20-40[** | 34 | 20 | 8 | 2 | 1 | -- | -- | 65 |
| **[40-60[** | 18 | 10 | 1 | 3 | -- | -- | -- | 32 |
| **[60-100]** | 1 | 2 | -- | -- | -- | -- | -- | 3 |
| **Total** | **83** | **51** | **18** | **11** | **6** | **3** | **2** | **174** |

**Table 7.** Specific dieback rates of rattan stems in the highly disturbed environment

## Discussion

This study identified seven (7) species of rattan that are distributed differently depending on the environment. In addition, the methodology used for the morphological characterization of rattan stems provided reliable information on the distribution of abundances, exploitation pressure, regeneration, and vegetative state of rattan stands in peri-urban areas in Gabon. This information is of great use to the authorities in charge of the management of Non-Timber Forest Products in Gabon. It can be used as a decision-making tool for the development of policies for the sustainable use of rattans in forest environments. However, this study did not provide any basic information on the diameter of the stems of the different rattan species. Such information could have contributed to the development of regulations specific to the exploitability diameters of the stems of the different species of rattan in the wild. In addition, further studies should provide this information.

### *Abundances of rattan stands as a function of habitats*

A total of 683 rattan stems belonging to 7 rattan species and 3 genera were inventoried in the study area. These results indicate that the Nkoltang region has all African genera except the genus Calamus. In Africa, there are approximately sixteen (16) species of rattan, grouped into four (04) genera. The taxa Laccosperma, Eremospatha. and Oncocalamus are considered endemic to this continent with a morphology that is clearly different from those of Asia. The genus Calamus, on the other hand, is home to more than 370 species distributed in Asia, of which only one (*C. deërratu*) is found in southern and eastern Africa with a heterogeneous distribution (Uhl and Dransfiield, 1987; Sunderland, 2001; Sinmenou, 2019). Nevertheless, the gender diversity observed in our work is related to the location of the study site in the dense moist evergreen forests of the Guinea-Congo band (Fongnzossie *et al*., 2019). It should be remembered, however, that it cannot be claimed to be exhaustive because prospecting remains inadequate. In addition, the species richness of the rattan stands surveyed is similar to that obtained by Defo (2005) in southern Cameroon. This author identified eight (08) species belonging to four (04) genera. These are: *L. secundiflorum*, *E. macrocarpa*, *E. wendlandiana*, *O. mannii*, *C. deëratus*, *E. hookeri*, *L. opacum* and *E. sp*,. The taxonomic differences observed between our two studies could be explained by the low sampling effort during our surveys and the methods of species identification. Indeed, there are some similarities between rattan species. As part of our study, botanical identifications were made with the help of local guides and later confirmed in the laboratory from photographs and a few specimens collected in the field. The quality of the images and the absence of a botanist in the field certainly did not minimize the margin of error related to morphological similarities, especially between the so-called small rattan species such as *E. haullevilleana* and *O. mannii*. According to Dransfield (2007), Kamga *et al*., (2018 and 2019) and Helmstetter *et al*., (2020), these similarities lead to confusion in the ethnobotanical identification of different species by local populations.

Also, the distribution of the abundance of rattan stems in the different environments surveyed shows non-significant differences. These results indicate that the logging activities of the Nkoltang populations do not alter the abundance of rattan stems in the three forest areas. Yet, the work of Defo (2005) in Cameroon has shown an overexploitation of rattans in the forests closest to the villages to the detriment of the most distant ones. According to this author, the short distance to be travelled is a factor that favours the high intensity of exploitation of the resource. However, in our study, the forests closest to the village have relatively the same abundance distributions as the most distant ones. The analysis of specific abundances reveals that two species of rattan, namely, *O. macrospathus* and *L. opacum* , are always the most abundant. These two species represent more than 60% of the stems identified in each surveyed environment. They are tracked by species *E. haullevilleana* and *O. mannii*, which are poorly represented (about 10% of the stems) in each environment. Species *L. secundiflorum* (2%) and *L. robustum* (1%) are still very poorly represented in each environment. On the other hand, *E. macrocarpa* was represented only in a very small proportion in the highly disturbed environment. This distribution of specific abundance could be explained by the ecological niche theory. Indeed, according to Hutchinson (1957), the so-called realized ecological niche associates the physiological performance of each species with environmental constraints by including biotic interactions (parasitism, predation, competition, but also facilitation and symbioticism) with other species in the environment. This results in a range in which the abundance distribution of certain species such as *O. macrospathus* and *L. opacum* is dominant and coexists with less competitive ones that are poorly represented (Hengeveld and Haeck, 1982; Sagarin and Gaines, 2002). In addition, these two species (*O. macrospathus* and *L. opacum*) grow spontaneously in dense tropical forests and colonize windthrow early. These highly heliophilic species respond well to a limited reduction in forest cover (Nzooh-Dongmo *et al*., 1999; Sunderland, 2007). According to Sunderland (2007), forest disturbances caused by logging activities contribute to forest regeneration. In these secondary forests, they play the role of pioneer species that colonize heavily disturbed forest areas. In the different environments surveyed, *O. macrospathus* and *L. opacum* are commonly found along logging roads and skidding trails where they occupy the lower layer of the canopy (Sunderland and Profizi 2002).

In addition, the low presence of *E. haullevilleana* may be related to the fact that the natural habitat of this species is periodically flooded land (Walker and Sillans 1995). Individuals found in the environment are located on the banks of rivers. On the other hand, *O. mannii, L. secundiflorum* and *L. robustum* are species with a strong heliophilic temperament. According to Nzooh-Dongmo et *al*. (1999), they have difficulty tolerating hydromorphic substrates. The low abundance of these three species could be explained by the fact that they are preferentially found in primary forests where large windthrows constitute their natural habitat. In the specific case of *L. secundiflorum*, plants very rarely grow in secondary forests (Brink et *al*. 2012). *E. macrocarpa*, on the other hand, is less light-demanding and tolerant of low amounts of soil water. It seems to have a preference for the highly disturbed environment. Nevertheless, its absence or presence may be related to errors in botanical identification. Further surveys should be able to confirm the preferred habitat of this species.

### *Vegetative state and regeneration of rattan stands*

Our results on the vegetative state of rattan stems reveal that the different rattan stands in the study area are healthy. Indeed, their vegetative state in the different environments surveyed is made up, on average, of 82% of totally green to essentially green stems. Using the condition of the stem is a good indicator to show the health and age of rattan stands. According to the work of Défo (2005), the identification of mature stems is based on the intensity of skin drying out on a large part of the stem or the absence of


doi.org/10.32388/N7OJNL

spines on the basal part of spiny species. Also, our results suggest that the vigorous green stems, belonging to classes [0-20[ and [20-40[, represent the youngest and most abundant rattan tufts. On the other hand, the [40-60[ (15%) and [60-100] (3%) classes are the least abundant. The latter represent mature individuals with stems that are respectively half-dried out and totally dried out. The low abundance of mature stems is related to the fact that cutters select mature stems based on the size, length, and especially the appearance of the skin. According to the work of Defo (2005), the rattan clones are constantly visited by the cutters, who also remove all the mature stems from the clones as much as possible. The cutting of stems at short intervals, the cutting of immature or inmature stems, and the removal of all mature individuals of the clones explain the low presence of the clones in the clumps and in the rattan population. At the specific level, the abundance distribution of stem vegetative classes does not vary in different habitats. All species are essentially green. However, *L. secundiflorum* and *L. robustum* do not have a mature stem. In addition, when comparing the results obtained on the regeneration of the stands in relation to those obtained on the vegetative state of rattan stems, it can be seen that the age structure of the rattan stands in the Nkoltang area is stable. The greenest and youngest stems are the most abundant, while the suckers and dried stems are the fewest. This perception is based on an indicator that corresponds to the ratio of the number of young (but vigorous) plants to the number of adult plants that have not yet reached senescence (Alladatin, 2011). When this index is significantly higher than one, the rattan stand has a good capacity to renew.

Analysis of the results on the regeneration of rattan stands indicates that the stems encountered in the moderately disturbed environment have the best regeneration. All 6 species identified in the environment regenerate. In addition, the species that regenerate best are *L. opacum* and *E. haullevilleana.* In this environment, other species have average regeneration. These results appear to support the hypothesis formulated by Connell (1978) on intermediate disturbance of ecological environments (Wilkinson 1999, Baker 2016). According to this assumption, maximum diversity is obtained for an intermediate frequency and size of disturbances. In addition, after rare or low-intensity disturbance, species diversity may decline due to the exclusion of lower competitive species from the community (Connell 1978). This explains why in weakly disturbed and highly disturbed environments, respectively 4/6 and 5/7 of the species present in each of the environments regenerate. In these environments, species regeneration follows the logic of preferential ecological niches. The species that regenerate best are the most abundant in each environment. On the other hand, an intermediate disturbance rate (intermediate intensity or intermediate frequency) seems to make it possible to regenerate rattan species with different life strategies. This would maximize the diversity of rattan regeneration in the medium. Indeed, Connell's work in 1978 showed that moderately disturbed environments are home to greater species diversity and show strong regeneration linked to species with a high capacity for resilience or dependent on the disturbed environment. This work corroborates the results of our study, which revealed that all species identified in the moderately disturbed environment regenerated (6/6). Also, according to several authors, for a medium level of disturbance, the environment provides a greater range of environmental resources and is a source of opportunities for the colonization, reproduction, and survival of different rattan stands (Loucks, 1970; Grime, 1973; Bazzaz, 1975; Kuuluvainen *et al*., 2002). At the specific level, unlike the other two environments, this could explain why the species that regenerate best are L. *opacum, E. haullevilleana* and *L. secundiflorum, respectively.*

### *Cutting pressure of different rattan stands*

The analysis of the data obtained on the pressure of the cuts made it possible to determine the most exploited rattan species according to the environments. Interpretation of these data suggests that in the study area, the cutting pressure decreases with increasing disturbance level. Despite the proximity of the highly disturbed environment, located about 2 km from the village of Nkan, the cutting pressure is low. However, this environment is home to large stands of rattan. On the other hand, in the undisturbed environment, which is located about 25 km from the village, the pressure is high. This result shows that the cutting pressure does not depend on the distance travelled by the collectors in the forest environment. However, Defo's work in 2005 showed that among the explanatory factors for the overexploitation of rattan stands in Cameroon were the distance travelled and the difficulties of access to the resource. According to the author's results, rattan stands located at short distances from the villages were the most exploited.

In addition, throughout the study area, *O. macrospathus* and *L. opacum* are the most cut species. Also, in terms of frequency, these two species, associated with *L. secundiflorum*, were cut in all three media. This seems to indicate that *O. macrospathus* and *L. opacum* are the species most used by the local population. Our results do not corroborate those obtained by Nzooh-Dongmo *et al.* (1999), which identified nine (9) species of rattan in the Dja Biosphere Reserve in Cameroon, four of which are regularly used by the population. These are: *L. secundiflorum, E. macrocarpa*, *O. mannii* and *Calamus deërratus*. This difference could be due to the fact that the preferential exploitation of one or more rattan species is linked to the uses and cultural importance of rattan among local populations (Kamga and *ly*., 2020).

In addition, the cutting pressure varies depending on the environment. Indeed, in the undisturbed environment, the most cut species were *E. haullevilleana and O. macrospathus.* In moderately disturbed and highly disturbed habitats, the most exploited species are the most abundant in the environment. Species collected by local populations in these habitats were *O. macrospathus, L. opacum.* Also, in these environments, some species, although present in low abundance, have not been cut. Indeed, 4/6 and 4/7 species present were cut, respectively, in moderately disturbed and highly disturbed environments.

However, it is important to note that there can be no claim of unsustainable exploitation of rattans in the study area. In view of the abundance of green and vigorous stems and the regeneration of more than half of the species present in each environment, it appears that the exploitation of this resource in the N'Koltang area could be ecologically acceptable. Based on the work of Peters (1997), rattans are a biologically sensitive resource as the exploitation of the plant is targeted at the extraction of the main stem. Central African rattans are generally multicaulous species and multiply sexually and by budding (Kouassi et al., 2009). Harvesting the main stem, which is usually the most mature, does not necessarily result in the death of the plant or the disappearance of the clone. All the more so since the work of Siebert (2001) on the reproductive strategy of rattans has shown that harvesting mature stems seems to stimulate the production of new twigs. According to this author, a repeated harvest of *L. secundiflorum* and *E. macrocarpa* for eleven years of exploitation in the forests of Côte d'Ivoire had a beneficial effect on the regeneration of the resource and the stability of the stands. These results suggest that the sustainable exploitation of this resource depends on a biological balance between the intensity of removal and the rate of stem regeneration.

## Conclusion

This study allowed us to acquire knowledge on the abundance distribution, exploitation pressure, regeneration, and vegetative state of rattan stands following a gradient of disturbance of peri-urban forests in the Nkoltang region of Gabon. This study allowed us to highlight the presence of seven (7) species of rattan that are exploited differently. In addition, the results obtained reveal that artisanal exploitation of peri-urban forests does not seem to have any adverse effects on the abundance and regeneration of rattan stands. Indeed, despite the proximity of these forests to the urban environment, local populations seem to have a low impact on the resource. Therefore, the methodology used in this study could serve as a basis for further work aimed at providing more information needed for the development of sustainable management policies for NTFPs in Gabon.

## Acknowledgements

This work was carried out with the support of the mapping service of the National Agency of National Parks of Gabon. We would like to thank Mr. Bèn-pharès MBEGA NZENGUE, Professor Christophe Roland ZINGA KOUMBA, and Miss Fatimata SAWADOGO for their comments and suggestions on the manuscript.

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## Declarations


**Funding:** Financé par l'Institut de Recherche en Ecologie Tropical du Centre National de Recherches Scientifiques et Technologiques (IRET-CENARES) du Gabon

**Potential competing interests:** No potential competing interests to declare.