Ecological characterization of habitats of three insect species prized by populations in Kinshasa (DR. Congo)

Célestin Adeito Mavunda[1, 2, 3, 4*], Madjouma Kanda[2], Fousséni Folega[2], Demirel Maza-Esso Bawa[2, 5], Marra Dourma[2] and Koffi Akpagana[2]

[1]Regional Center of Excellence on Sustainable Cities in Africa (CERViDA-DOUNEDON), University of Lomé, 1 BP 1515 Lome 1-Togo
[2]Laboratory of Botany and Plant Ecology, University of Lomé, 1 BP 1515 Lome 1-Togo
[3]Higher Institute of Agronomic Studies of Bengamisa, Renewable Natural Resources Management Section, B.P 202 Kisangani, DR. Congo
[4]Laboratory of Ecology and Forest Management, Faculty of Sciences of the University of Kisangani, B.P 2012 Kisangani, DR. Congo
[5]University of Belgrade, Faculty of Biology, Institute of Botany and Botanical Garden "Jevremovac" Takovska 43, 11000 Belgrade, Serbia
*****Correspondence: celestin.adeito@yahoo.fr or celestin.adeitomavunda@cervida-togo.org

Abstract

Vegetation is a potential habitat for biodiversity. To manage it sustainably, it is essential to characterize its diametric and spatial structure. The purpose of this study is to ecologically analyze the habitats where *Brachytrupes membranaceus, Cirina Forda*, and *Gonibrasia jamesonii*, the insect species with the greatest consumption in Kinshasa, are found.

An inventory of caterpillar host trees was carried out around mother plants (*M. laurentii*: dbh ≥ 90 cm and *A. auriculiformis*: dbh ≥ 40 cm) in 24 plots of 2500 m^2 in wooded stands. The circumference, x and y coordinates of each tree with dbh ≥ 10 cm were recorded; and soil physico-chemical parameters were measured in situ in relation to the presence of *B.membranaceus*.

The results show that the diametric structures of the tree stems in all the stands studied are generally inverted "J", with small irregularities in the [40-50] and [20-30] classes in planted Millettia and natural Millettia forests (p-value= 2.6) respectively. An average of 342.1, 94.0 and 107.0 trees/ha (p-value = 0.4) were inventoried in the *Acacia* plantations, the *Milletia* planted forest and the *Milletia* natural forest respectively, showing a random and/or aggregated distribution according to the stand categories compared and, an average basal area of 6.93, 12.58 and 5.39 m^2/ha (p-value= 0.5). The soil is neutral (6.8) with a moisture content of 10.46%, a temperature of 32.6°C, a depth of 46.86 cm and a blackish/brownish color.

This finding provides vital information for planning management itineraries and orienting the use of peri-urban ecosystems in a more sustainable way. This study is in line to contribute to Sustainable Development Goals 2 and 15 by 2030.

Keywords: Characterization, peri-urban ecosystem, natural habitat, diametric, spatial structure, Kinshasa.

1. Introduction

Peri-urban forest ecosystems are habitats for numerous animal species, and are still preferred sites and refuges of great biodiversity throughout the planet (Asimonyio, 2015; Ngbolua et al., 2015). Unfortunately, in recent decades, due to demographic pressure and uncontrolled urbanization in cities (Béhé et al., 2020; Mavunda et al., 2022) these ecosystems have been degraded (Boulanger et al., 2020). For example, by 2030, over 5 billion people will be living in large cities (UN, 2015). Since 2009 (and for the first time in human history), there are more people living in cities than in rural areas (Change, 2014). To achieve sustainable cities, urban planning therefore remains a major challenge in terms of integrating the ecosystem services offered by urban and peri-urban ecosystems into the well-being of city dwellers.

Today, with the resurgence of numerous security, climatic, health, food, social, economic and environmental challenges, many governments, NGOs and civil society organizations (CSOs) are increasingly concerned with the preservation of biodiversity and the integrated and sustainable management of natural resources (Guillaume, 2020; Strouk, 2022). Among these resources, flora and fauna play a fundamental role, both in terms of their contribution to ecosystem functioning and their socio-economic importance.

Consequently, certain species of edible insects underpin recreational and economic activities with significant spin-offs (Bertrand & Potvin, 2003; Mbella, 2022). The characterization of their habitats is therefore essential for rational and sustainable management. Like other urban and peri-urban plant ecosystems in certain countries, those in the Democratic Republic of Congo (DRC), home to around half of the Congo Basin's forests, are experiencing the same situation, which is compromising the survival of many emblematic species important for biodiversity conservation (Asimonyio, 2015; Ngbolua et al., 2015). In this particular case, the structure of these plant ecosystems would influence intra- and interspecific diversity. To this end, a better understanding of the characteristics of peri-urban ecosystems in the DRC would be important. In addition, tree population structures are generally poorly understood, as most multinational companies do not exploit timber on the basis of species ecological data (Katusi, 2015; Mavunda et al., 2018). Yet valuing these precious species is essential, as it is the best guarantee for the long-term maintenance of large forest massifs that guarantee various ecosystem services (Badjaré et al., 2018; Debroux, 1998; Gillet et al., 2016; Méral & Pesche, 2016).

Despite their diversity, their economic and dietary importance, and the potential they hold, there has been little development of these resources. This is due to a lack of knowledge about them, even though they are highly prized by consumers and farmers. It is therefore essential to master these resources, as they provide habitats for most insects. In the same context, several authors mention the woody species on which these insects feed (caterpillars) in their inventories of useful plants in the region, without mentioning their ecological function as host trees (Dudu et al., 2002; Ghersallah Mohamed-El-Amine, 2023; Lisingo et al., 2010). The destruction of these trees, considered as natural habitats for biodiversity, would lead to the probable disappearance of certain species.

In Kinshasa, *G. jamesonii* (Butler), *C. forda* (Westwood) and *B. membranaceus* (Drury) (Appendix A) represent the three insect species collected from peri-urban ecosystems, highly prized for household consumption and catering units. The ecological characteristics of these ecosystems remain poorly known. However, the availability of vegetation (density and/or biomass) as a primary food source for several insect species is correlated with the availability and/or abundance of insects in these ecosystems. (Kifukieto et al., 2020). Thus, aren't inventories of host trees one of the most important sources of data for characterizing woodland stands, an indispensable tool for sustainable management and resource conservation (Katusi, 2015; Mavunda et al., 2018; Nshimba, 2008) ? It is in this context that the present study aims to contribute to the characterization of the natural habitats of *B. membranaceus*, *C. forda* and *G. jamesonii*, which are the most widely consumed insect species in Kinshasa. Specifically, the aim is to: (i) determine the demographic structure of caterpillar host trees (*M. laurentii* and *A. auriculiformis*) in woodland formations in peri-urban ecosystems in the city of Kinshasa; (ii) characterize the spatial distribution of these caterpillar host trees; (iii) characterize soil physicochemical parameters (potential cricket habitat).

2. Materials and Methods

Three sites, including an *Acacia* plantation in the commune of Maluku (Mont Ngata, Kingawa and Mbakana districts); the Lac Ma Vallée forest concession (*Millettia* natural forest) in the commune of Mont Ngafula; and Kimwenza-Marensa (*Millettia* planted and natural forest) in the commune of Mont Ngafula (red circles-Figure 1) were identified for this study.

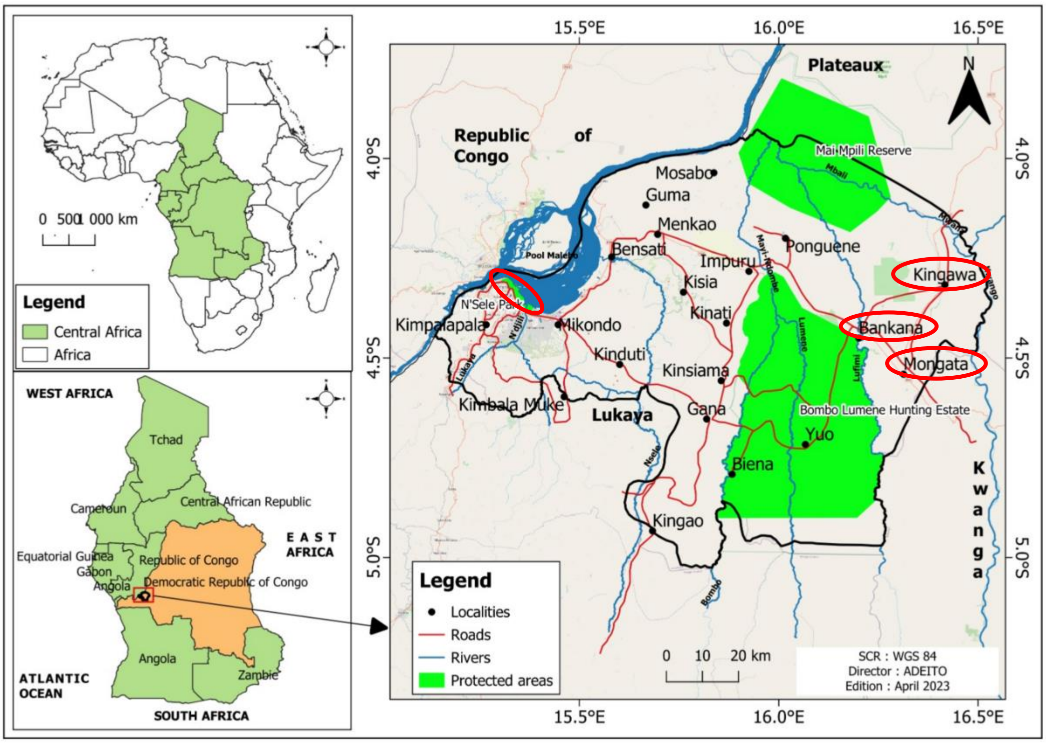

Figure 1. Location of plant formations inventoried in Kinshasa (red circles) and situation in Central Africa.

All are located in Kinshasa, which covers an area of 9 965 km^2 (De Saint Moulin & Kalombo, 2005; Vermeulen et al., 2011), along the southern bank of the "Pool Malebo", and forms a huge crescent covering a flat, low-lying surface with an average altitude of around 300 m. Located between latitudes 4° and 5° South and between longitudes 15° and 16°32' East. Kinshasa is bounded (Fig. 1) to the east by the provinces of Mai-Ndombe, Kwilu and Kwango; to the west and north by the Congo River, forming the natural border with the Republic of Congo; and to the south by the province of Kongo Central (Mavunda et al., 2022).

During inventories of caterpillar host trees including *A. auriculiformis* (pour *G. jamesonii*) and *M. laurentii* (for *C. forda*), the circumference was taken on tree stems at dbh ≥ 10 cm in 24 plots of 2500 m² including 8 in each of the formations (Acacia plantations, *Millettia* planted forests and *Millettia* natural forests) specifying the positioning for each tree stem by x and y coordinates (Figure 2). These inventories were carried out with reference to a mother plant at dbh ≥ 80 cm in the center of the plot for *Millettia* formations; and on the basis of heterogeneity for *Acacia* plantations.

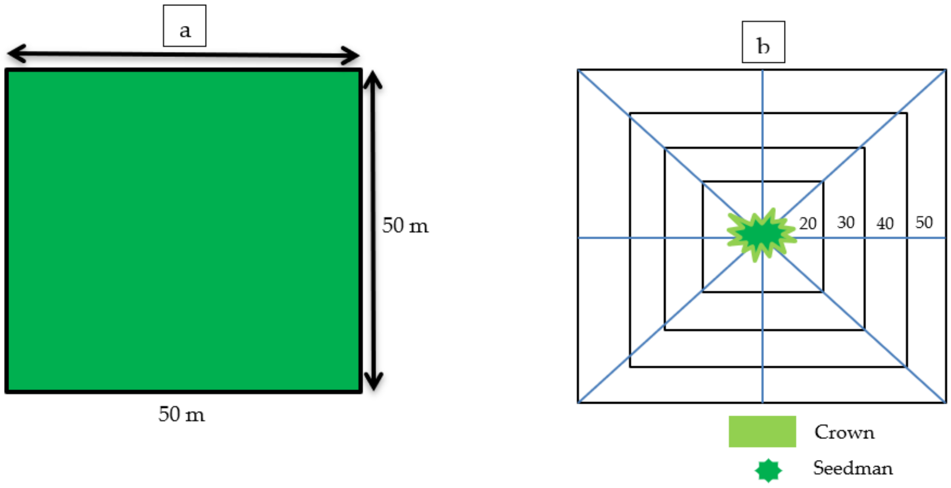

Figure 2. Experimental inventory of caterpillar host trees ((a) = *A. auriculiformis* and (b) = *M. laurentii*)).

Various criteria were taken into account when selecting these mother plants (in the case of *M. laurentii*). On the one hand, it was necessary to have tree stems that had sufficiently fruited and were at least 75 m from other trees. On the other hand, the distance to be covered, the inherent difficulties of the environment and the topography also limited our choice. Basal area was calculated for each tree stem per plot and then per plant formation. This was calculated using the following formula (G):

$$G = \frac{\pi}{4}D^2$$ (Deleuze et al., 2014; Gounot, 1969)

Where G represents basal area and D, diameter at 1.30 m above ground level.

Structural parameters (density, basal area, biomass, height and x and y position) were calculated and expressed by the box plot. Using R 3.6.3 software, the spatial characterization of caterpillars host tree stems were performed by Ripley's K(r) function, and the different tree categories (small, medium and large) by Ripley's $K_{12}(r)$ function (Lefort et al., 2013; Ripley, 1981; Walter, 2006). It is worth pointing out that small trees are those at 10 cm ≤ dbh < 30 cm; medium trees at 30 cm ≤ dbh < 50 cm and large trees at dbh ≥ 50 cm. Ripley's method (Lefort et al., 2013; Ripley, 1981; Walter, 2006) is based on the number of points "semis of points": the set of tree stems or trees in a formation or any objects counted at a certain distance or distance class:

$$K(r) = \lambda^{-1}E(r)$$

In the case of a fish distribution of a population, the expected value of K(r) is $K(r) = л r^2$. If $K(r) < л r^2$, the points are spaced apart and the distribution is regular. If K

(r) > л r^2, the distribution is contagious (aggregative) and if K (r) = л r^2, the distribution is random. K(r) is interpreted with the population intensity λ, with for the dot seed $\lambda = n/A$. In other words, the grey area of the graph represents the confidence interval at the α = 5% threshold. If the curve passes above the confidence interval, the distribution is aggregative, while if it passes below, it is regular. But if it passes within the confidence interval, it is random.

To do this, Ripley's K_{12} function is used to check for interaction between small, medium and large trees within the study formations, where the grey area represents the confidence interval at the α = 5% threshold. When the K_{12} (r) curve exceeds the upper limit of the confidence envelope, the aggregation of the dot clusters becomes significant; there is contagion or clustering between the two categories. On the contrary, when the K_{12}(r) curve exceeds the lower limit of the confidence envelope, the points are distanced and the distribution of seedlings is significantly regular. This regularity is usually interpreted as an effect of competition, or repulsion, between individuals. On the other hand, when the K_{12}(r) curve falls within the confidence envelope, there is no contagion, i.e. small individuals are independent of large ones (Asimonyio, 2015).

Forty points were sampled in-situ to analyze the soil's physicochemical parameters, using a pH meter to measure pH and humidity, a thermometer to measure temperature, a ruler to measure depth, a color catalog to determine soil color and a GPS to record the geographical coordinates of each collection point. These points were selected on the basis of the presence of at least one individual of *B. membranaceus*. These data were used to characterize the soil as a habitat for *B. membranaceus*, through correlation analyses of the parameters measured using R 3.6.3 software.

The coefficient of determination (r^2) was calculated to assess the degree of correlation between the structural parameters of the plant formations studied, and the physicochemical parameters of the soil in relation to the biotopes studied.

3. Results

3.1Structure of the peri-urban woodland formations studied

In general, the diameter structure of *Millettia* and Acacia (Appendix B) trees shows an "inverted J" shape, with the number of trees decreasing with increasing diameter classes in the formations studied (*Acacia* plantation, *Millettia* planted forest and *Millettia* natural forest), but only with small shifts at the fourth class (*Millettia* planted forest) and second class (*Millettia* natural forest) (p-value = 2.6). This distribution of tree stems by diameter class shows a higher number of small diameter classes for Acacia plantations ([10-20]) and intermediate classes for planted ([40-50]) and natural *Millettia* forests ([20-30]) (Figure3) with p-value

= 2.6 with threshold $\alpha = 0.05$. It is constant that p-value > 0.05%, which there is no significant difference between diametric structures within the stands under study.

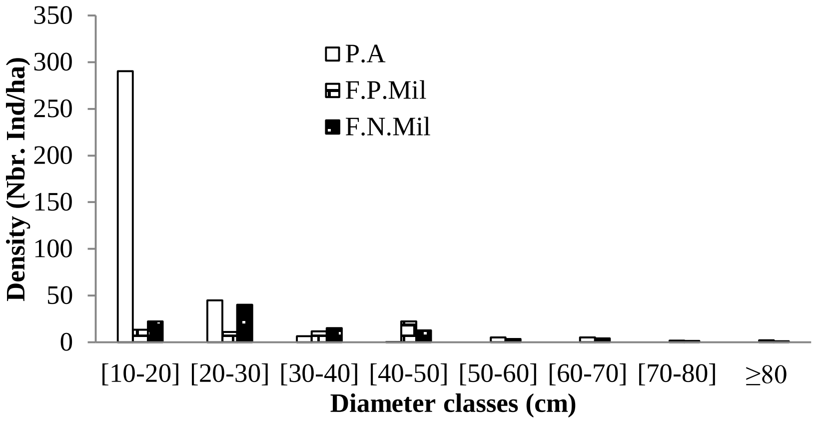

Figure 3. Variation in the number of *A. auriculiformis* (P.A) and *M. laurentii* (F.N.Mil and F.P.Mil) tree stems according to diameter class.

Legend. P.A: *Acacia* Plantation, F.N.Mil: *Millettia* natural forests*;* F.P.Mil: *Millettia* planted forests

The mean densities and basal areas obtained in our different plant formations were 342.1 trees/ha ±68.7, 94 trees/ha ±34.4 and 107 trees/ha ±29.38 and 6.93 m^2/ha ±0.3, 12.58 m^2/ha ±5.2 and 5.39 m^2/ha ±6.6 respectively in *Acacia* plantations, *Millettia* planted forests and *Millettia* natural forests. The differences in density and basal area were not significant between the different formations (W = 0.933, p-value = 0.435 for density, W = 0.938, p-value = 0.513 for basal area). Figures 4 show the dispersion of density and basal area values respectively. From these figures, it can be seen that there is variability in density and basal area within plots of the same formation and from one formation to another in the study area.

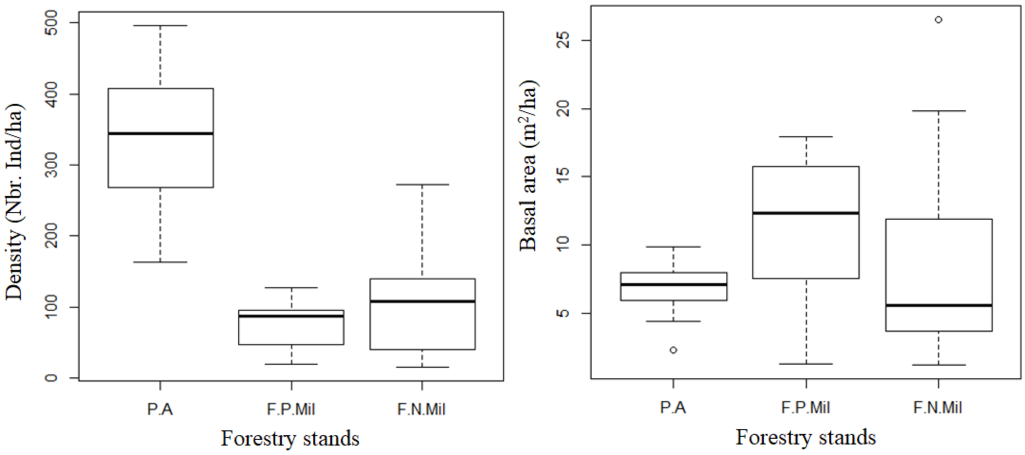

Figure 4. Dispersion of density (left) and basal area (right) values for each of the formations studied.

Legend. P.A: *Acacia* Plantation, F.N.Mil: *Millettia* natural forests*;* F.P.Mil: *Millettia* planted forests

3.2 Spatial characterization and clustering of caterpillar host trees

a. Spatial characterization of caterpillar host trees

Within the entire analysis area of planted (Figure 5a) and natural *Millettia* (Fig. 5b) forests, individuals are distributed in an aggregative way. Despite this aggregative repair in planted *Millettia* forests, there is a concentration of large trees in the south-western part of the forest plot, medium trees in the southern part and small trees in the southern and eastern part. In natural *Millettia* forests, large trees are concentrated in the center, while medium and small trees are distributed throughout the forest plot. This aggregative distribution for these two formations is the expression of the dispersion of individual trees of different categories (large trees, medium trees and small trees).

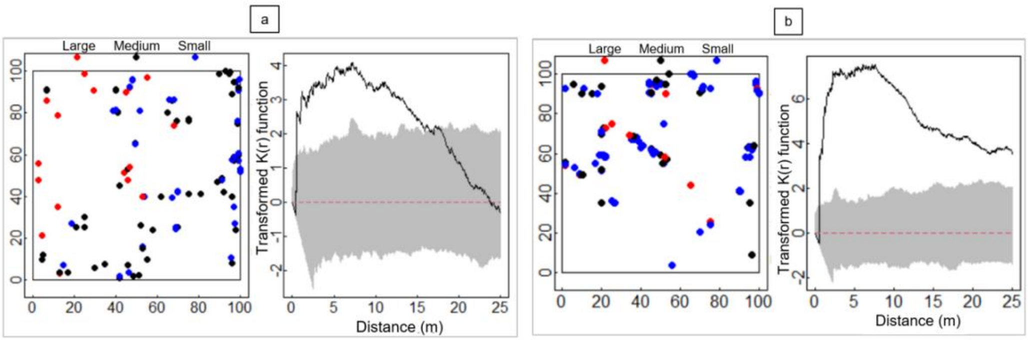

Figure 5. Spatial characterization of *M. laurentii* individuals ((FPMil (a) and FNMil (b)).

b. Grouping of individuals

A. auriculiformis and *M. laurentii* individuals from different categories were compared in pairs to observe whether they grouped together or were independent. Medium trees were compared with small trees, large trees with small trees, medium trees with small trees and large trees with medium trees. The results show an aggregative distribution between medium and small trees in the Acacia plantation (Figure 6). This aggregated distribution is the result of the concentration of small tree individuals around medium individuals and also the clustering of small tree individuals around themselves.

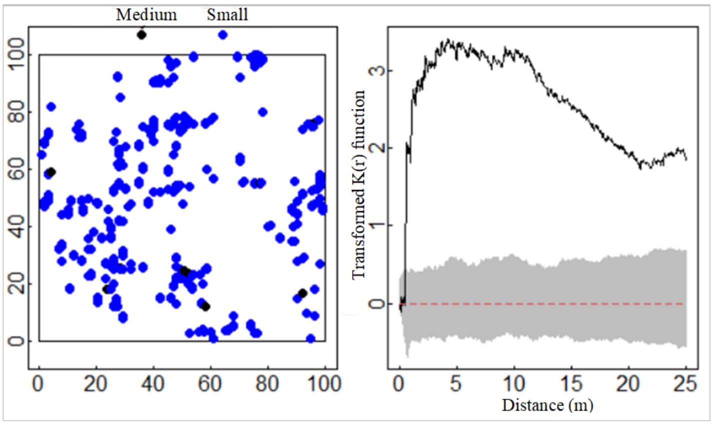

Figure 6. Transformed Ripley intertype K(r) function between medium and small trees in the P.A.

The distribution is random between large and small trees, medium and small trees, and large and medium trees in the forest planted with *Millettia*. Regardless of this random distribution, large trees are more concentrated in the west and medium diameter trees in the east (Figure 7a). Between medium and small trees, individuals are distributed throughout the plot (Figure 7b). Between large and medium trees, large trees are concentrated in the western part of the plot, while medium trees are concentrated in the eastern and southern parts (Figure 7c).

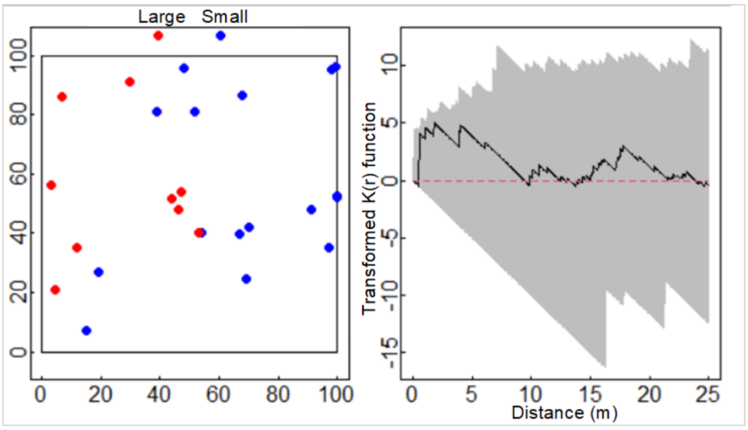

Figure 7a. Transformed Ripley intertype K(r) function between small and large trees in F.P.Mil.

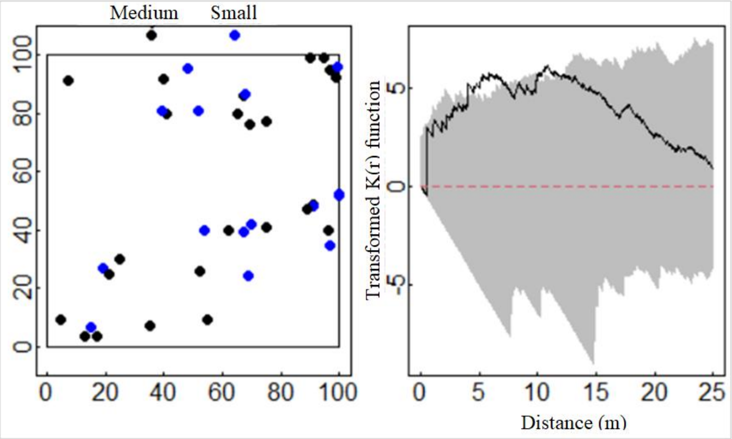

Figure 7b. Transformed Ripley intertype K(r) function between small and medium trees in F.P.Mil.

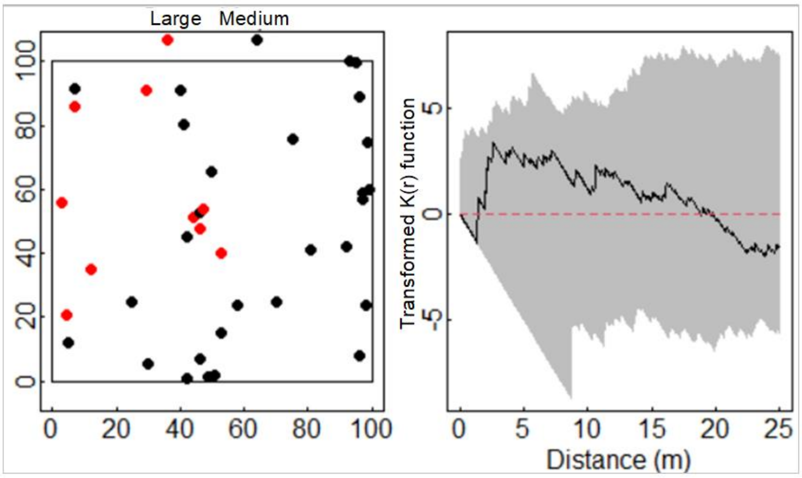

Figure 7c. Transformed Ripley intertype K(r) function between large and medium and large trees in the F.P.Mil.

The distribution is aggregative between large and small trees, medium and small trees and; random between large and medium trees in natural *Millettia* forests (Figure 8a, b and c). This aggregative distribution between large and small trees is expressed by a concentration of small-tree individuals over the entire plot area, while large trees are found only in the northern part of the plot. In relation to medium-sized and small trees, there is a random distribution for individuals of all categories, which thus form aggregates among themselves. Between large and medium trees, the random distribution is a true random distribution of individuals of all categories, as all individuals are individually randomly distributed.

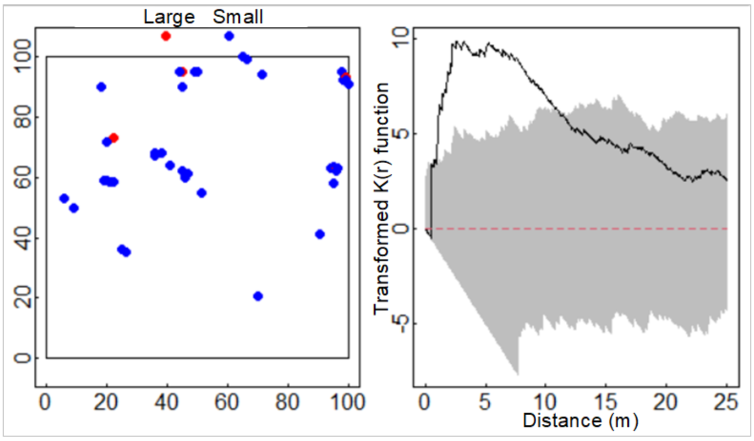

Figure 8a. Transformed Ripley intertype K(r) function between large and small trees in the F.N.Mil.

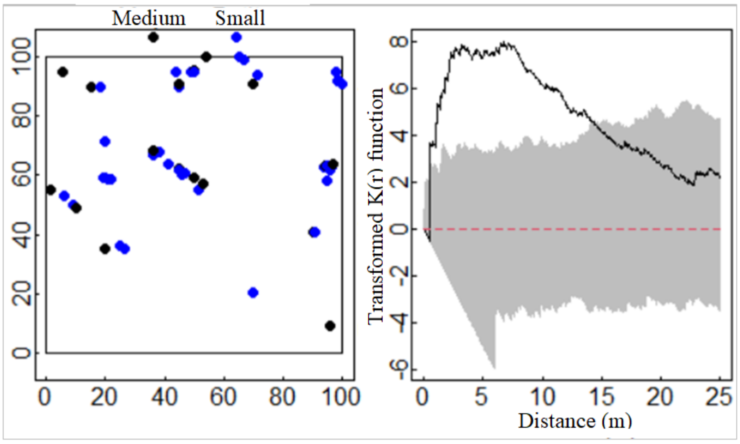

Figure 8b. Transformed Ripley intertype K(r) function between medium and small trees in the F.N.Mil.

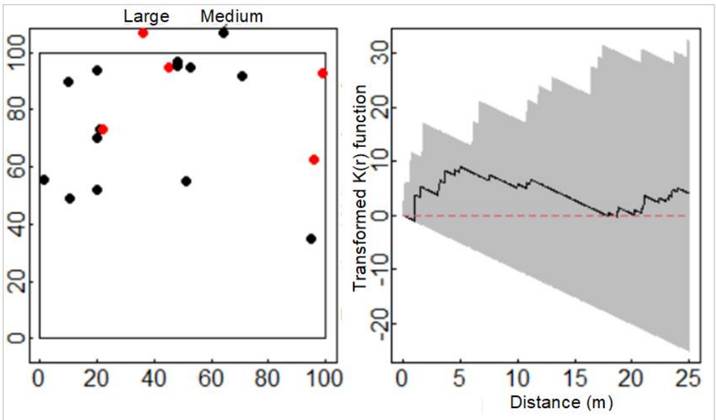

Figure 8c. Transformed Ripley intertype K(r) function between large and medium trees in the F.N.Mil.

3.3 Soil characterization: Cricket habitat (B. membranaceus)

Results show a dominance of cricket densities in the field (18 individuals) over other biotopes (grassy formation, ruderal formation and bare soil). Statistically, there was no significant difference between the densities of *B. membranaceus* individuals in the different biotopes studied (W = 0.84, p-value = 0.09).The mean particle size composition of the samples at the sites varied from one biotope to another (Table. 1). However, whatever the depth considered, pH did not vary significantly and remained almost acidic (< 7), a normal value for tropical soil. Similarly, humidity values are similar, with slight differences depending on the biotope.

Table 1. Average particle size composition of soil samples in the four biotopes explored in Kinshasa.

Composition of soil samples per biotope explored							
Biotopes	**Depth (cm)**	**% clay**	**% silt**	**% sand**	**pH**	**T°**	**% Hum.**
Field	48,06	12,54	5,98	81,48	6,78	32,73	9,57
Grassy Formation	47,59	10,05	3,98	85,52	6,7	32,55	12,45
Ruderal Formation	49,3	8,01	4,01	87,98	6,78	33,02	9,9
Bare soil	42,46	5,34	3,09	91,57	6,76	32,54	10,73

Legend. T°= Temperature Hum. = Humidity

Figure 9a shows that temperature decreases slightly according to depth in all biotopes (Bare soil, Field, Grassy formation, Ruderal formation). The correlation is strongly negative in the ruderal formation (r^2=0.893, p=0.015) and weakly negative in the grassy formation (r^2=0.101 and p=0.443).The highest temperature was observed in the ruderal formation (33.02°C) and the lowest in the bare soil (32.54°C); while the greatest depth was observed in the ruderal formation (49.3 cm) and the lowest in the bare soil (42.6 cm). With an average temperature of 32.71°C and an average depth of 46.85 cm.

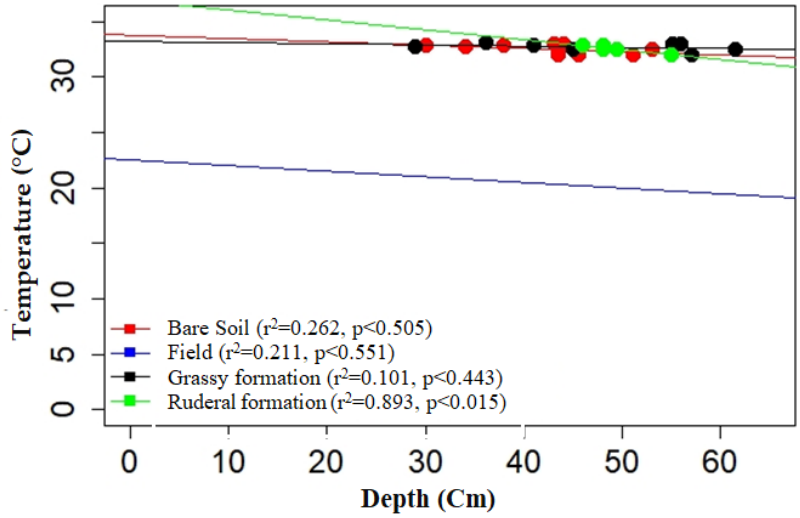

Figure 9a. Correlation between temperature and soil depth.

In all biotopes, pH remains constant, with small fluctuations within a biotope and between biotopes (Figure 9b). The correlation between depth and pH is strongly negative in the ruderal formation ($r^2=0.962$, $p=0.003$) and weakly negative in the grassy formation ($r^2=0.010$ and $p=0.809$).The highest pH values were observed in the ruderal formation (6.78) and the crop (6.78), and the lowest in the grassland formation (6.7).

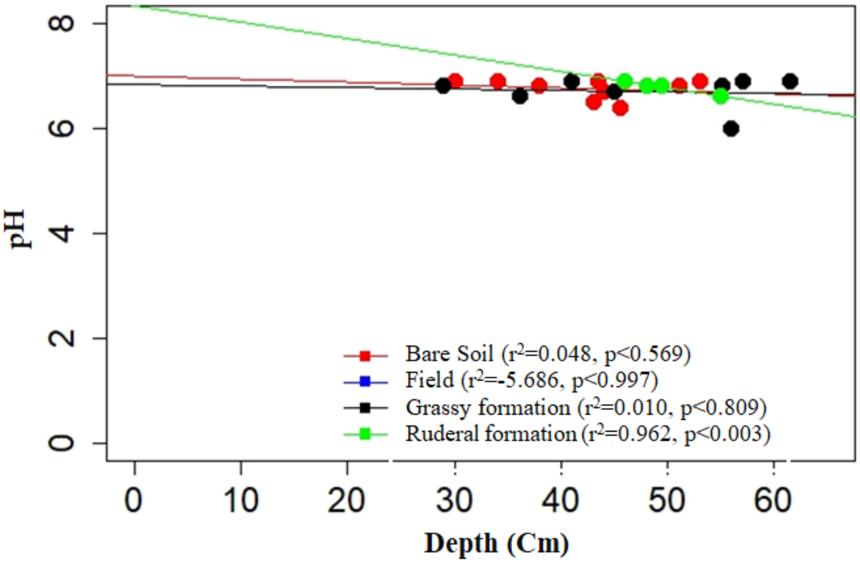

Figure 9b. Correlation between pH and soil depth.

The figure below shows a correlation between pH and average soil moisture at sample points considered as potential cricket habitat. The average pH of all biotopes decreases with increasing moisture content (Figure 9c). The correlation is strongly negative in the ruderal formation ($r^2=0.999$, $p<0.05$) and weakly negative in the bare soil ($r^2=0.885$ and $p<0.05$). The highest pH values are observed in the ruderal formation (6.78) and the crop (6.78), and the lowest in the grassland formation (6.7); while the highest humidity is observed in the grassland formation (12.45 cm) and the lowest in the crop (9.57 cm).

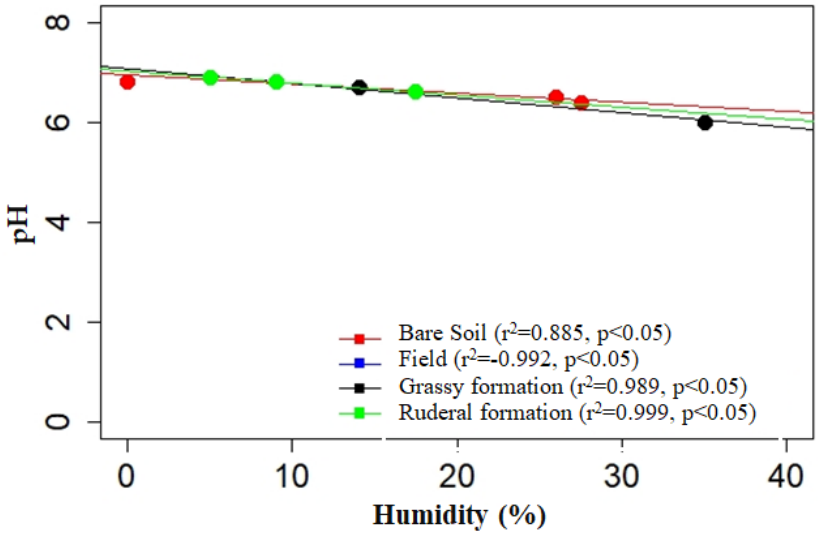

Figure 9c. Correlation between pH and humidity

4. Discussion

4.1 Demographic structure of caterpillar host trees

The results of this study show that the distribution of tree stems by diameter class is higher in the low diameter class for *Acacia* plantations ([10-20]) and intermediate classes for planted ([40-50]) and natural *Millettia* forests ([20-30]). There is no significant difference between the diametric structures within the formations under study (p-value = 2.6). Structurally, however, there was a difference. This structural difference is due to the difference in floristic composition and age between the formations studied. Several researchers have studied the diametric structure of tropical forests (Mavunda et al., 2018; Nshimba, 2008). They conclude that the diametric distributions of all the trees in a stand, for all species, show common characteristics. This means that the number of tree stems per diameter class decreases in almost the same way as one moves successively from smaller to larger diameter classes. Thus, there is a relationship between the numbers of trees in two immediately adjacent classes. According to (Mangambu et al., 2013; Mavunda et al., 2018) in unmodified tropical rainforests, the number of tree stems per diameter class decreases with increasing tree diameter. Lomalisa et al., (2022) ; Mavunda et al. (2018) observed an "inverted J" curve for *G. thompsonii* in the Yoko and Yangambi reserve. These results are not entirely consistent with those of the study. This difference may be due to the evolutionary phase of the plant formations in comparison, but also to the various anthropic pressures exerted on the formations under study as a result of their proximity to the town. Comparing the diametric structure within the three plant formations under study, we found that p-value > 0.05, meaning that there was no significant difference between the diametric structures within these formations.

The average density of tree stems inventoried within the study formations is higher in Acacia plantations (342.1 trees/ha) than in *Millettia* formations (94 trees/ha and 107 trees/ha respectively in *Millettia* planted forests and *Millettia* natural forests). This difference in density between the *Acacia* and *Millettia* plantations is due to the difference in the proportion of human intervention in the formations studied, but also and above all to the availability of light in the *Acacia* plantation (a factor that favors tree growth). Similar studies have respectively obtained 12 plants/ha in the Yangambi reserve over 5 ha (Mavunda et al., 2018) and 5 plants/ha in the permanent block in the Yoko reserve (Katusi, 2015). This difference between the results of the present study and those of the researchers cited above may be due to the choice of location for our inventory devices (installed on less rugged terrain) and also to a tendency towards monodominance of the species studied in the formations (*Acacia auriculiformis* or *Millettia laurentii*).

The basal areas found are 6.93 m²/ha, 12.58 m²/ha and 5.39 m²/ha respectively in *Acacia* plantations, *Millettia* planted forests and *Millettia* natural forests. This similarity in values (W = 0.82589, p-value = 0.56) is thought to be due to the low growth (in diameter) of tree stems in *Acacia* plantations as a result of the high density, compared with the high dbh of tree stems in *Millettia* formations. Katusi (2015); Mavunda et al. (2018) obtained 1.08 m²/ha, 0.37 m²/ha and 0.36 m²/ha respectively. Unlike Ripley, (1981), they obtained a higher value (4.67 m²/ha) than previous authors, but lower than those of the present study. The low basal area of the previous studies compared with the present study may be due to their low tree stem densities.These results allow us to confirm the hypothesis that there is a difference between the structural parameters of the woodland formations under study (*Acacia* plantation, *Millettia* planted forest and *Millettia* natural forest).

4.2 Spatial distributions of caterpillar host trees in peri-urban ecosystems

The spatial distribution of caterpillar host trees (Millettia and Acacia) in plant formations in the city of Kinshasa is globally aggregative or random depending on the formation and categories of trees grouped together for a formation. Specifically, it is random between large and small trees, medium and small trees, and large and medium trees in the *Millettia* planted forest; aggregative between large and small trees, medium and small trees and, random between large and medium trees in the *Millettia* natural forest. Using Ripley's K_{12} function, the result of this study shows that small and medium-sized trees are dependent on large trees in the planted forest, but independent in the natural forest. This independence of different tree categories (small, medium and large) in the *Millettia* planted forest would be due to similar anthropogenic actions (siting, proximity of formations to settlements...) and the dependence of different tree categories around large trees in the natural forest would be due to the stability of the formation (tendency towards a mature and less disturbed forest). These results corroborate the findings of several studies which have highlighted the predominance of species with a random or aggregative distribution in tropical forests(Chao et al., 2007; Lomalisa et al., 2022; Mavunda et al., 2018). In fact, the extent or spatial scale of a species could influence the observation of its spatial distribution, depending on whether it is small or large (Dungan et al., 2002). These results support the hypothesis that the spatial distribution of tree individuals depends on the stage of evolution of the ecosystem studied (Mavunda et al., 2018).

4.3 Influence of soil physicochemical parameters on cricket density and distribution

Overall, correlations were negative between density and biotope, temperature and depth, pH and depth, and pH and humidity. This similarity of results in different biotopes may be due to the crickets' preference for relatively identical climatic factors, but also to the small distance between the different biotopes studied. However, whatever the biotope considered, soil pH did not vary significantly and always remained acidic (≥ 7), a normal value for a tropical soil. Similarly for humidity, the results of this study resemble those of (Kifukieto et al., 2020) at the Kisantu botanical garden in the province of Central Kongo in the DRC. This resemblance in results is due to the proximity of the study areas (see pedogenesis), resulting in a close relationship between edaphic and climatic factors

According to the results of the present study, cricket density decreases with the evolutionary dynamics of biotopes (i.e. from bare soil to ruderal formation). This result contradicts that of which states that vegetation density can influence the number of tree stems, species richness and community diversity, insofar as species are more or less well adapted to different types of formation. Our results corroborate not those of (Kifukieto et al., 2020) who found a positive correlation between the abundance of termites (insects that also live in the soil, like crickets) and the proportion of resources and nutrients available in the soil, rather than the proportion of vegetation in the environment. This difference between the results of the present study and those of (Pauwels et al., 2000) and (Kifukieto et al., 2020) is due to the absence of consideration of anthopized environments (bare soil and field) and the influence of anthropogenic factors on soil fauna density and diversity in the study of (Pauwels et al., 2000). This result rejects the hypothesis of (Pauwels et al., 2000) stipulated above, but confirms the hypothesis that the density and distribution of biodiversity depends on available environmental conditions (environmental factors and food resources).

5. Conclusions

Characterization of the habitats of three of the most widely consumed insect species in Kinshasa led to characterization of the diametric and spatial structure of *A. auriculiformis* tree stems as a host tree for *G. jamesonii* in the *Acacia* plantation, of *M. laurentii* tree stems as a host tree for *C. forda* in the *Milletia* planted forest and *Milletia* natural forest, and of the soil as a habitat for *B. membranaceus* (cricket). The diametric structures of all the above caterpillar host trees are in the form of an "inverted J", with some irregularities observed in classes two (02) and four (04) in *Millettia* natural forest and *Millettia* planted forest respectively.

The spatial distribution of caterpillar host trees (*Millettia* and *Acacia*) in vegetation formations (*Acacia* plantation, *Millettia* planted forest, and natural *Millettia* forest) in Kinshasa is either aggregated or random, depending on the type of formations under study and the categories of trees in coupling. For the soil as a habitat for *B. membranaceus*, negative correlations are observed in the ruderal formation between the physicochemical soil parameters considered as potential cricket habitat (temperature-depth, pH-depth and pH-humidity).

The results of this study provides vital information for planning management itineraries and orienting the use of peri-urban ecosystems in Kinshasa, in a more sustainable way, in order to guarantee the sustainability of these ecosystems for the well-being of the local community.

This study has a distinctive feature: it seeks a more or less clear link between the ecological characteristics of ecosystems and the production of edible insect species in peri-urban environments. The examination of diametric and spatial structures of wooded stands in peri-urban areas is of great importance in the fields of forestry and forest ecology. These analyses provide crucial information about the composition, growth, health, and dynamics of forest populations. Through this study, it is possible to anticipate future yields in wood and other forest resources, which is essential for sustainable forest management planning.

In summary, the dissemination of specific information from this research to the general public constitutes a source of crucial data for sustainable forest management, biodiversity conservation, climate change mitigation, and forestry activity planning.

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Authors' contributions

Conceptualization, C.A.M. and M.D.; methodology, C.A.M. and F.F.; software, M.K. and D.M.-e.B.; formal analysis, C.A.M.; investigation, C.A.M.; data curation, C.A.M.; writing original draft preparation, C.A.M.; writing review and editing, C.A.M., D.M.-e.B. and K.A. All authors have read and agreed to the published version of the manuscript.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Abbreviations

CERViDA-DOUNEDON: Regional Center of Excellence on Sustainable Cities in Africa
IDA: International Development Association
DRC/DR. Congo: Democratic Republic of Congo
F.N.Mil: Natural *Millettia* Forest
F.P.Mil: Planted *Millettia* Forest
TG: Togo
SDGs: Sustainable Development Goals
UN: United Nations
NGOs: Non-Governmental Organization
CSOs: Civil Society Organizations

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Appendix A: Photos of the three most commonly consumed insect species in Kinshasa

Figure A1 : *G. jamesonii*

Figure A2: *C. forda*

Figure A3: *B. membranaceus*

Appendix B and C: Photos of caterpillar host trees studied

Figure B1 : Leafy branch/*A. auriculiformis*

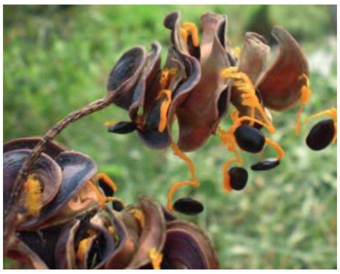

Figure B2 : Infruitscence /*A. auriculiformis*

Figure B3 : Tree stem/*A. auriculiformis*

Figure C1 : Leaf and leaflets /*M. laurentii*

Figure C2 : Inflorescence /*M. laurentii*

Figure C3 : Tree stem /*M. laurentii*