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RESEARCH ARTICLE

DISTRIBUTION PROFILE AND INFLUENCE OF EDAPHIC FACTORS ON THE DIVERSITY AND ABUNDANCE OF TERRESTRIAL MOLLUSCS IN THE YAPO CLASSIFIED FOREST, CÔTE D'IVOIRE

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ABSTRACT

Molluscs play an important role in the decomposition of organic matter in their environment. They are sometimes indicators of the health of their environment. Understanding their distribution profile and their link with certain soil parameters in their living environment is necessary for effective conservation policy. The aim of this study was to analyse the distribution profile of terrestrial molluscs and the correlation between them and certain edaphic parameters. To do this, sampling by direct and indirect observation using the quadrat method was used. Certain physical and chemical parameters of the soil were determined. The results revealed, in terms of trophic structure, a dominance of herbivorous molluscs (70%) over carnivores. The distribution profile of the taxa revealed that habitats without anthropogenic pressure were the richest in taxa, with 10 and 15 taxa respectively for enriched open habitats and natural closed habitats. The abundance of molluscs was positively influenced by litter thickness (R= 0.84) and soil calcium content (0.54). Taxonomic richness correlated positively with species richness (R=0.59). Although not significant, granules negatively influenced mollusc abundance. This study reveals the importance of preserving the mollusc habitat from anthropogenic disturbances in order to prevent their disappearance.

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INTRODUCTION

In tropical forest ecosystems, terrestrial molluscs are part of the soil fauna. Bachelier (1978) describes them as secondary soil fauna, while El Alami (2013) classifies them as soil macrofauna, ranging in size from 4 mm to 80 mm. Their role in the functioning of terrestrial ecosystems is well known. Indeed, they contribute to the decomposition of organic matter and the release of certain minerals, particularly carbon, magnesium, potassium and manganese in forests (Meyer *et al*., 2013). Aditionaly, they serve as food for many animal species in the trophic interaction network (Martin, 2000) and excellent bioindicators of the health of their environment (Pihan, 2001 ; Hall, 2009 ; Esteves, 2020 ; Gheoca *et al*., 2021). Several studies have shown their variability in response to climatic conditions and certain biotic and abiotic soil factors (Heiba *et al*., 2018 ; N'Dri, 2020 ; Zaidi *et al*., 2021 ; Kakar *et al*., 2023). In addition to their functional role, molluscs comprise several dietary guilds, including predators, decomposers, herbivores, omnivores and carnivores (Steger *et al*., 2017 ; Ortega-Jiménez et al., 2022 ; Donnarumma *et al*., 2018). Thus, through their presence, carnivores contribute to the regulation of their prey populations. Similarly, decomposer or detritivorous molluscs contribute to the decomposition of litter (Meyer *et al*., 2013 ; Astor, 2014), allowing organic matter and nutrients to be returned to the soil. As a result, these molluscs contribute to the stability of the forests in which they live. These functions of molluscs in forest ecosystems reflect the numerical abundance of herbivorous molluscs (Oké and Alohan, 2006 ; Oké, 2013). Furthermore, molluscs are influenced by certain biotic and abiotic factors such as air humidity, soil moisture, soil calcium content and litter thickness (Amani *et al*., 2018 ; Barrientos, 2020 ; N'Dri *et al*., 2020 ; Estevesa *et al*., 2025). Most of the world's biodiversity is found in tropical forests (Groombridge and Jenkins, 2000). However, according to Konan *et al*. (2015), African forest ecosystems, and especially those in Côte d'Ivoire, are subject to various anthropogenic disturbances. Protected areas, including the Yapo classified forest, are no exception (Konan *et al*., 2015). Among these disturbances is timber harvesting. Molluscs, due to their low mobility, are the most vulnerable to this degradation. Several studies have been conducted to develop an effective policy for conserving both plant and animal resources in this classified forest. As such, it has been the subject of several studies on flora (Konan *et al*., 2015 ; Piba *et al*., 2015 ; Bley *et al*., 2020 ; Ouattara *et al*., 2021 ; Ouattara *et al*., 2025) and molluscs (Amani *et al*., 2016a ; Amani *et al*., 2016b ; Amani *et al*., 2018). Most of the work on molluscs has focused on the pressure of collecting edible snails (Amani *et al*., 2016a), their diversity (Amani *et al*., 2016b) and their spatio-temporal variation (Amani *et al*., 2018). This study therefore aims to analyse the distribution profile of molluscs in relation to their trophic structure and certain physical and chemical parameters of the soil.

MATERIALS AND METHODS

Study site: The Yapo Classified Forest is located in southern Côte d'Ivoire, between latitudes 5° 40' 02" N and 5° 47' 32" N and longitudes 30° 57' 02" W and 40° 11' 37" W (Figure 1). It is located in the administrative region of Agnéby-Tiassa, in the sub-prefecture of Azaguié. It covers approximately 9,000 hectares. It is located 8 km north of Azaguié, 25 km south of Agboville, and 50 km northeast of Abidjan. With an average annual rainfall of 1,400 mm and an average annual temperature of 27°C, the Agboville department is characterised by four climatic seasons, including two rainy seasons and two dry seasons (SODEXAM 2010). According to Beaufort (1972), the forest floor is rich in coarse material, including quartz gravel and grit. The vegetation consists of several tree species, such as *Drypetes aylmeri, Dacryodes klaineana, Parinari glabra, Parkia bicolor, Strombosia glaucescens, Terminalia ivorensis, Dacryodes klaineana, Heritiera utilis* (Konan et al., 2015)

Biological Material: The biological material in this study consisted of the various species of molluscs sampled.

Method

Based on vegetation characteristics, the study area was subdivided into three forest types : enriched semi-open habitat (H1), natural semi-open habitat (H2) and closed habitat (H3). Habitat H1 is characterised by undergrowth and a moderately dense forest with 6.5 cm thick litter. It contains trees from reforestation. Habitat H2 is characterised by a natural forest with moderately dense undergrowth and litter with an average thickness of 4 cm. It is subject to anthropogenic disturbances from the local population. Habitat H3 is characterised by natural forest and dense canopy cover with little human intrusion and an average litter depth of 4.5 cm. Sampling was carried out by combining direct observation with the collection of soil specimens. These were taken from 18 plots measuring 2,400 m², spread throughout the forest, for direct observation and by collecting litter from 1 m² and 5 dm³ of soil to search for soil molluscs. Small molluscs collected from soil and litter samples were preserved in 70° ethanol. The specimens were identified on the basis of morphological characteristics from previous studies and identification keys (Rowson, 2009 ; Oke, 2013 ; Daget, 2003). Soil pH was determined in the laboratory by measuring soil samples taken from each quadrat using a pH meter. Soil particle size distribution and certain minerals were determined using the AFNOR NF X31-107 method and the method used by Memel (2009).

Statistical analysis: Kohonen's self-organising map algorithm (Kohonen, 2001) was used to order the surveyed plots according to species assemblages (abundance of molluscs). Kohonen's self-organising map was created using MATLAB 6.1 software. Hierarchical ascending classification analysis was used to classify the areas based on taxonomic similarities. The Mann-Whitney test was used to compare the mean values of pH, calcium and iron levels. Pearson's correlation coefficients were calculated between abiotic and biotic parameters. The significance threshold was set at 5%. These coefficients were calculated using STATISTICA 7.1 software..

RESULTS

Trophic structuring: The distribution of functional food groups indicates the dominance of herbivorous molluscs (70%) over carnivores (30%). The same is true when they are distributed according to habitat (Figure 2). The proportion of carnivores is highest in habitat H1 (32%) compared to those observed in habitats H2 (27.27%) and H3 (28%). Among herbivores, this proportion is higher in habitats H2 (72.73%) and H3 (72%) compared to habitat H1 (68%).

Distribution profile of the mollusc community: The Kohonen self-organising map was used to analyse the abundance matrix of the

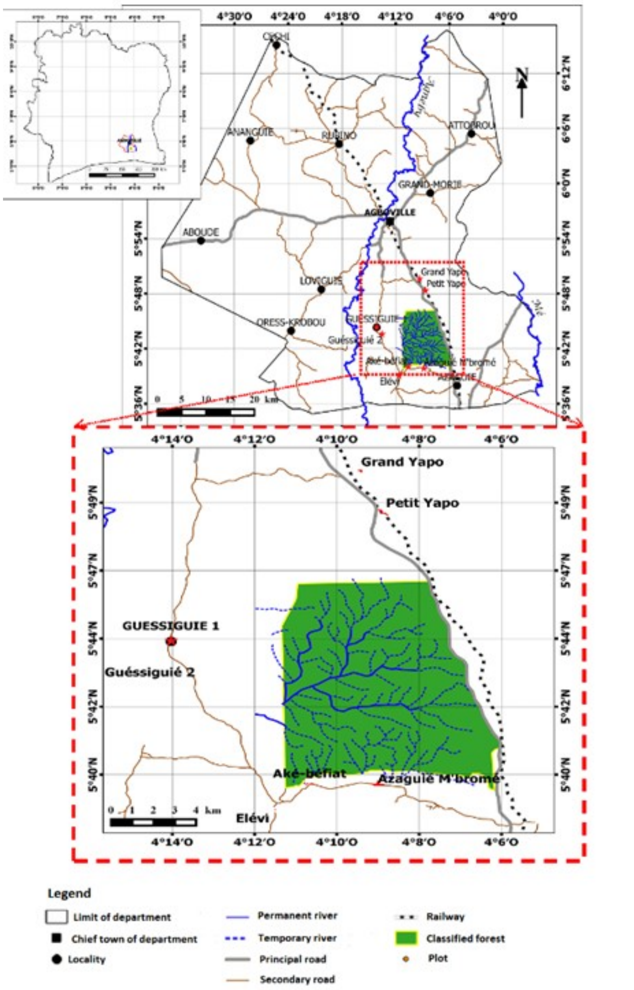

Figure 1. Location of the study site (Amani et al., 2016b modified)

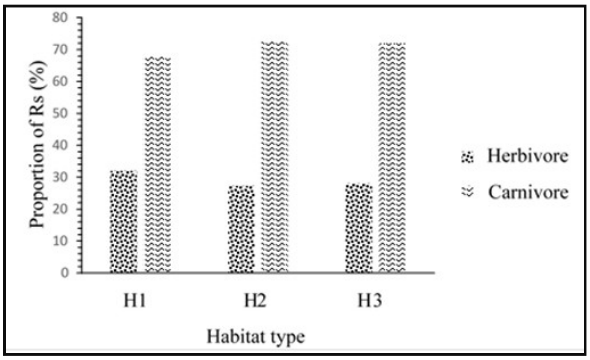

Figure 2. Proportions of the two functional food groups of gastropods sampled in habitats in the Yapo Classified Forest; H1: enriched semi-open habitat; H2: natural semi-open habitat; H3: natural closed habitat, Rs = taxonomic richness

terrestrial gastropod mollusc community in the Yapo Classified Forest. Based on the minimum values for quantification and topography errors (Table 1), a 12-cell Kohonen map (4 rows x 3 columns) was selected to project the samples. This projection provided a classification of the samples that takes into account the distribution and probability of occurrence of terrestrial gastropod molluscs in the samples. The cells of the self-organising map were classified into three groups (I to III) based on a hierarchical classification analysis using the Ward method and Euclidean distance (Figure 3). The groups are illustrated by different symbols on the Kohonen map (Figure 4). Group I, in the lower left half of the map, includes samples mainly from plots P18, P17, P11 and P15, with respective contributions of 91.67%, 83.33%, 58.33% and 58.33%. As for Group II, i is dominated by samples from plots P10, P12, P13, P14 and P16 with respective proportions of 58.33%, 75%, 50%, 75% and 58.33%.

Table 1. Kohonen map sizes and corresponding quantisation and topography errors; the selected size is shown in bold

Taille de la carte	Erreur de quantification	Erreur topographique
3 X 3	0,93	0,005
3 X 4	0,903	0,023
4 X 3	**0,896**	**0**
4 X 4	0,872	0,005
4 X 5	0,855	0,005

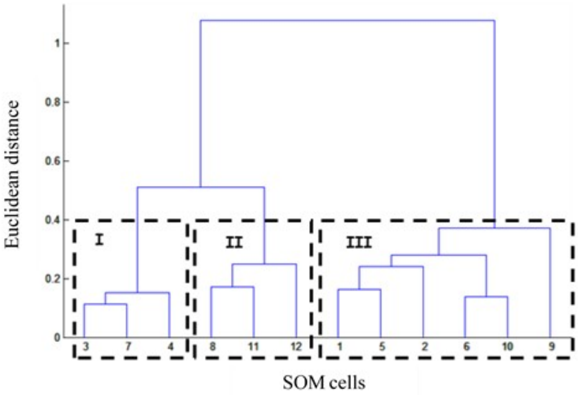

Figure 3. Hierarchical classification of SOM cells using the Ward method: I, II and III = defined groups

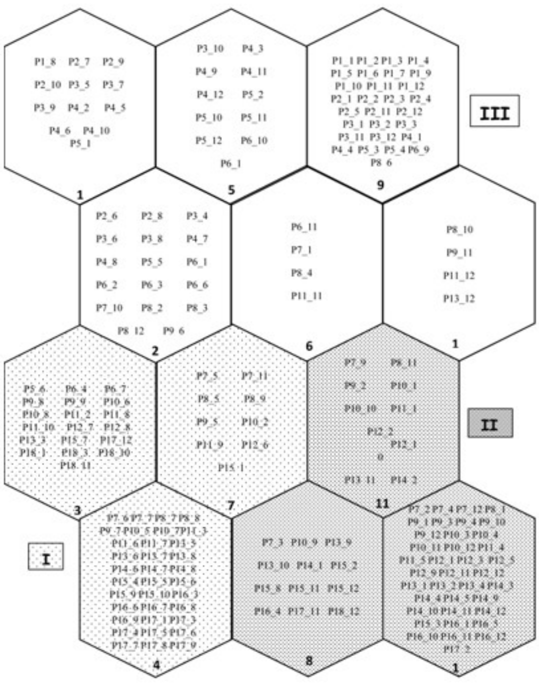

Figure 4. Distribution of samples in the SOM based on the abundance of gastropod taxa I to III = identified groups; P1 to P18 = sampled plots; index 1 to 12 = sample numbers; the Arabic numerals 1 to 12 at the base of each hexagon correspond to the numbers of the SOM cells

Group III, located in the upper half of the map, includes all samples from plots P1, P2, P3, and P4. Samples from plots P5, P6, and P8 contribute 91.67%, 83.33%, and 50% respectively. Figure 5 shows the distribution profile of each taxon in the groups defined by SOM. Analysis of Figure 6, which summarises this distribution, indicates that group III contains the most taxa (15 taxa). It is followed by group II, which contains 10 taxa. Group I contains 4 taxa.

Influence of edaphic factors: The litter depth is greater in habitat H1 (4.33 ± 1.50 cm) than in habitat H3 (3.09 ± 0.86 cm) and habitat H2 (2.93 ± 0.83 cm). The Mann-Whitney test indicates no significant difference between the litter thicknesses of the three habitats. The granulometric composition of the soils of the three habitat types is shown in Table 2. The soils of the Yapo Classified Forest are generally sandy, with 59.83% sand, 27.89% gravel and 13.70% silt and clay. The texture is therefore sandy-silty-clayey. In terms of habitats, H2 is richer in sand (70.03%) and silt and clay (22.42%) than habitats H1 (61.67% sand and 9.74% silt and clay) and H3 (47.8% sand and 8.95% silt and clay). The soils of habitat H3 have the highest proportion of granules (42.68%). The soils of habitats H1 and H2 contain 28.04% and 6.96% granules respectively.

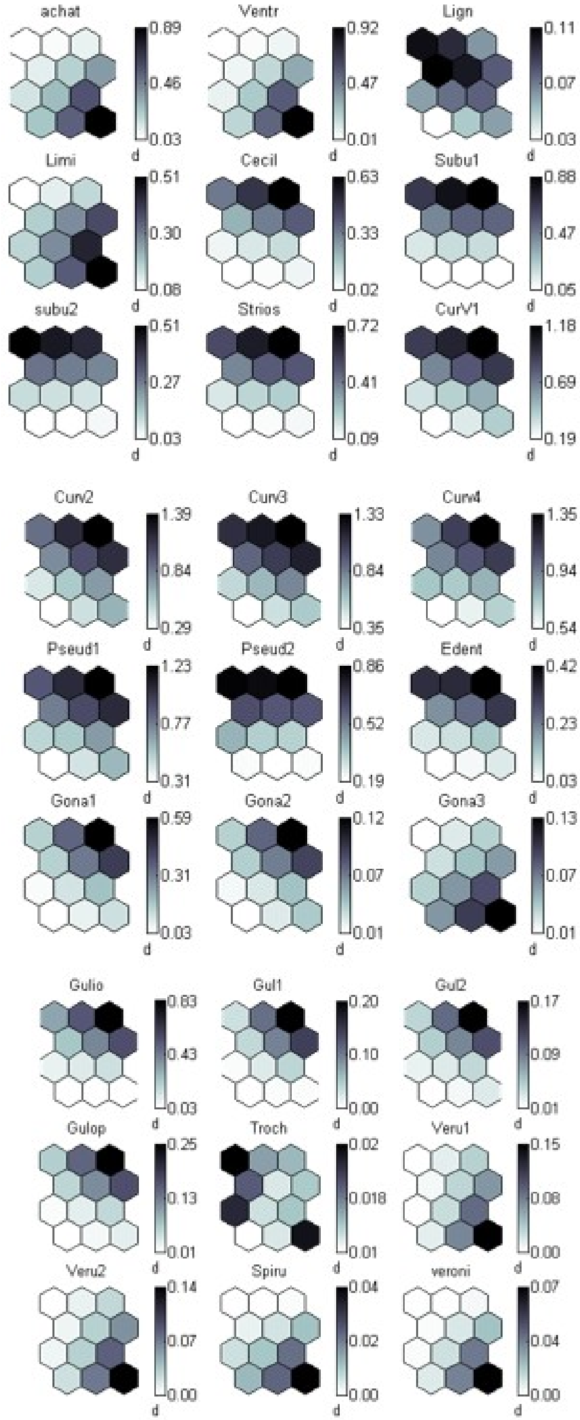

Figure 5. Distribution profile of each gastropod taxon from the sampled areas on the Kohonen map, based on abundance data ; dark colours = high abundance; light colours = low abundance or absence; d = scale, see Table II for taxon acronyms

Table 3 shows the chemical compositions of the soils in the different habitats. The soils of habitats H1 and H3 have the highest amounts of calcium and iron, with 0.032 ± 0.001 mg/kg and 0.03 ± 0.001 mg/kg for calcium and 3.52 ± 0.24 mg/kg and 3.5 ± 0.72 mg/kg for iron, respectively. For pH, all soils in the three habitats are acidic. However, the soils in habitat H2 are the most acidic, with an average pH of 4.44 ± 0.15.

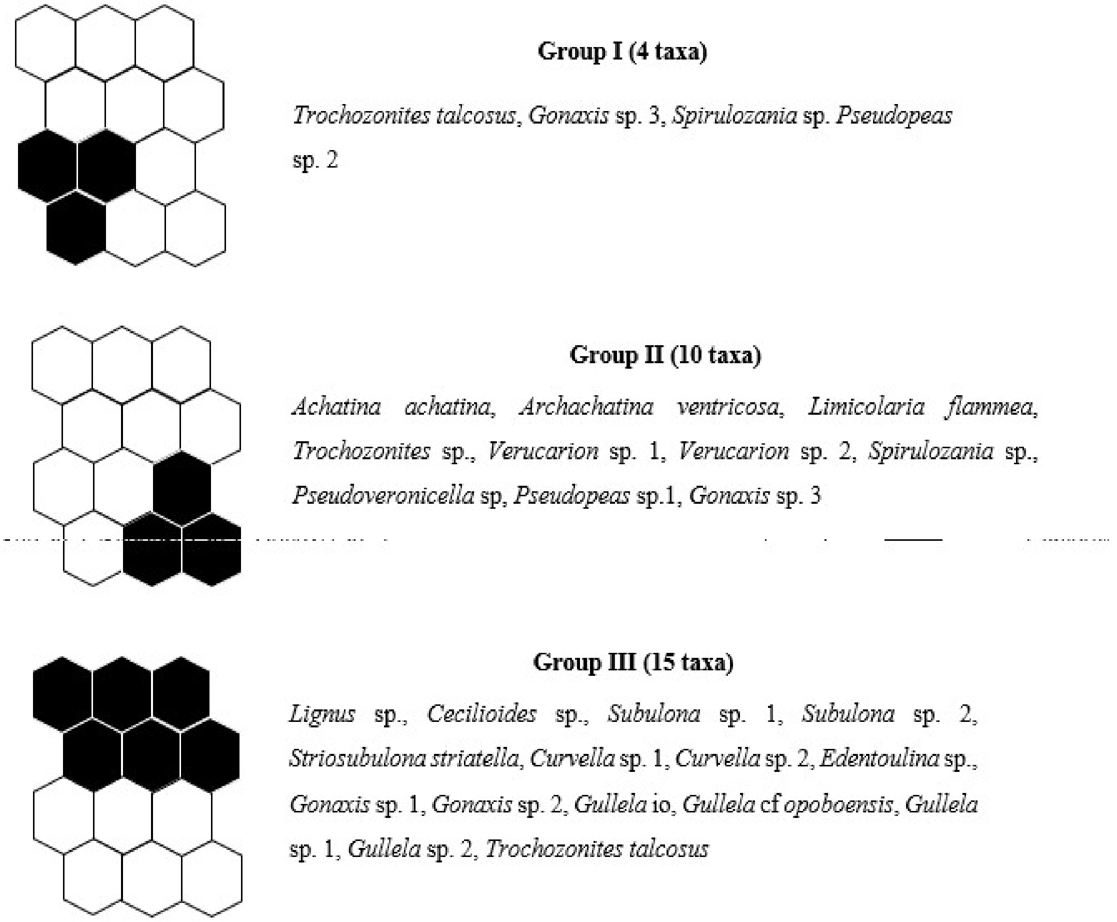

Figure 6. Distribution of gastropod taxa in the groups defined by SOM illustrated in Figure 5.

Table 2. Soil particle size distribution of the three habitat types in the Yapo Classified Forest

Désignation	Sieve mesh diameter (Ø)	Proportion of soil fractions (%)			
		Enriched semi-open habitat	Natural semi-open habitat	Closed habitat	Average
Granules (G)	Ø> 1.18	28.04	6.96	42.68	25.89 ± 17.96
Coarse sand (Cs)	0.15 <Ø <1.18	51.3	51.41	38	46.9 ± 7.71
Fine sand (Fs)	0.075 <Ø< 0.15	10.37	18.62	9.8	12.93 ± 4.93
Total sand (G + Cs)	0.075 <Ø< 0.18	61.67	70.03	47.8	59.83 ± 11.23
Limon and Clay	Ø <0.075	9.74	22.41	8.95	13.7 ± 7.55

Table 3. Chemical composition of soils in the three habitat types of the Yapo Classified Forest

Designation	Enriched semi-open habitat	Natural semi-open habitat	Closed habitat
Calcium (mg/kg)	0.032 ± 0.001	0.026 ± 0.002	0.03 ± 0.001
Iron (mg/kg)	3.52 ± 0.24	2.51 ± 0.38	3.5 ± 0.72
pH	4.46 ± 0.16	4.44 ± 0.15	4.56 ± 0.45

Table 4. Correlation between taxonomic richness, abundance and environmental parameters; significant correlations are shown in bold

Environmental parameters	Taxonomic richness		Abundance	
	r	P	r	P
Litter thickness	0.59	**	0.84	**
Ca Content	0.25	ns	0.52	*
Iron content	0.3	ns	0.35	ns
pH	0.26	ns	0.06	ns
Limon + Clay	-0.141	ns	-0.25	ns
Sand	0.07	ns	0.22	ns
Granules	0.02	ns	-0.04	ns

** : The correlation is significant at the 0.01 level; * : The correlation is significant at the 0.05 level. r : Pearson's correlation coefficient; ns : non-significant correlation

The Mann-Whitney test indicates no significant difference between the amounts of calcium, iron and pH in the different habitats. Table 4 shows the Pearson correlation coefficient values between taxonomic richness, abundance and certain edaphic factors. The taxonomic richness of terrestrial gastropod molluscs is positively and significantly influenced by litter thickness (r=0.59). Similarly, there is a positive and significant correlation between calcium content (r=0.52), litter thickness (r=0.84) and abundance. Although negative, the correlation between granule size and abundance, and between silt+clay content and taxonomic richness and abundance, is not significant.

DISCUSSION

Our results revealed a dominance of herbivorous molluscs. Molluscs are classified according to their feeding habits. Previous studies conducted by Ortega-Jiménez et al. (2022) revealed five feeding guilds composed of scavenger, detritus feeder, grazers, predators, filter feeders. Donnarumma et al 2018 indicated in their work that the molluscs sampled were dominated mainly by herbivores (51%), followed by omnivores (45.83%) and carnivores (3.17%). The same was true in the work of Oké and Alohan, 2006, as well as Oké (2013). Unlike our work, Steger et al (2017) observed a dominance of carnivorous predators among the gastropods collected in their work. This predominance of herbivores in our work confirms the theory of the preponderance of prey over predators. Some of these carnivorous molluscs, such as slugs, feed on molluscs and other soft-bodied invertebrates (Oké and Alohan, 2006). The distribution of the self-organising map indicates two categories of samples. These are samples with high taxonomic richness (groups III and II) and samples with low taxonomic richness (group I). The samples in groups III and II are mainly from habitats H1 (enriched semi-open habitat) and H3 (natural closed habitat), characterised by a relatively dense canopy, a litter layer thickness of around 5 cm, an average coarse sand content (46%) and low human disturbance. In contrast, in group I, the samples belong to the semi-open natural habitat (H2), which is heavily frequented by local populations (poachers and medicinal plant gatherers, traces of machinery left behind during commercial tree felling) and has a high proportion of coarse sand (50% to 63%). The difference would therefore be linked to the environmental conditions of the different habitats. According to Legendre and Legendre (1998), taxonomic richness depends on environmental stability. According to Memel (2009) and Douglas et al. (2013), anthropogenic disturbances play a key role in shaping the diversity and structure of terrestrial mollusc communities. The taxonomic richness of terrestrial gastropod molluscs is positively influenced by litter thickness. Similarly, calcium content and litter thickness promote an increase in abundance. Although negative, the correlation between granule size and abundance is not significant. The chemical composition of the soil is a factor influencing the abundance and species richness of molluscs. Indeed, our work has revealed a positive correlation between soil calcium content and the number of species and individuals collected. Our observations confirm the results of Heiba et al (2018) and N'Dri et al (2020), who showed a positive correlation between the abundance of terrestrial molluscs and litter thickness and calcium levels. Other authors have also demonstrated the close (positive) link between organic matter and certain mollusc species such as *B. similaris* and *Zootecus insularis* (Kakar et al., 2023). In terms of litter thickness, this correlation was very strong with abundance (0.84) and species richness (0.69). As this litter decomposes, it produces organic matter and releases minerals such as calcium, which in turn can influence the abundance of molluscs. Previous studies have shown a strong correlation (0.904) between this abiotic parameter and species richness (Zaidi et al., 2021). The calcium contained in the substrate promotes early sexual maturity and increases the number of eggs laid (Aman et al., 2023), which will have a positive impact on mollusc abundance. Thick litter would provide favourable living conditions for many microorganisms in the litter. From a nutritional point of view, this diversity of organisms provides molluscs with a varied range of food for both herbivores and carnivores. Similarly, such litter would better retain moisture, which is one of the factors in the composition of terrestrial molluscs (Svobodová and Horsák, 2025). The influence of litter thickness on terrestrial mollusc communities has also been reported by Nunes and Santos (2012). Furthermore, calcium is a component of mollusc shells. As such, it also determines their distribution and abundance. Our results corroborate those of numerous authors (Skeldon et al., 2007 ; Memel, 2009 ; Chokor and Oke, 2011). This mineral plays an important role in the formation of Achatinidae shells, egg calcification, and the quantity and size of eggs laid (Otchoumou et al., 2005, Aman et al., 2023). Although previous studies have shown that acidic environments are poorer in species (Zaidi et al 2021) and specimens than calcareous soils (Lange, 2003), there has been no significant negative correlation between taxonomic richness and pH.

CONCLUSION

The distribution profile of molluscs in the forest is influenced by the degree of anthropogenic disturbance. As for trophic structure, it was dominated by herbivores. The taxonomic richness of molluscs is positively and significantly correlated with litter thickness. Similarly, there is a positive and significant correlation between soil calcium content and mollusc abundance, and between litter thickness and abundance. Taking this information into account is important in forest management strategy.

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