# Carnivore diversity in unclassified forests on the right bank of the Aruwimi River in Democratic Republic of Congo (DRC)

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## ABSTRACT

The forests of the Congo Basin are home to a wide variety of mammals, but this diversity is under pressure from various human activities, notably hunting, agriculture and logging. In the unclassified forests on the right bank of the Aruwimi river, however, scientific knowledge of carnivores remains limited, particularly regarding their species composition, distribution and relative abundance. The aim of this study is therefore to assess the diversity of carnivores in this region by identifying the species present, analysing their distribution according to location and forest habitat type, and estimating their relative abundance based on presence indices. Carnivore diversity is analysed using ecological niche theory. This study adopts a descriptive and comparative ecological approach, based on field surveys. Surveys were carried out at four sites – Libombo, Dikwa, Bopale and Likati – in 2020, 2021, 2022 and 2025 respectively, with a survey effort of 15 days per site. Data collection combined foot patrols (reconnaissance) with surveys along linear transects. In total, 24 5-km recce routes were covered. Direct observations and indirect evidence, including tracks, droppings and food remains, were used to detect and identify species. The data were analysed using the R software package, employing proportions, chi-squared tests and correspondence analysis. The results show that the composition of carnivore communities differs significantly between sites ($\chi^2 = 42.587$; $p = 0.003547$) and between forest types ($\chi^2 = 17.332$; $p = 0.01537$). Crossarchus alexandri dominates at Bopale, Dikwa and Likati, whilst Libombo exhibits a more balanced composition, notably featuring Civettictis civetta and Lutra maculicollis. A highly significant association is also observed between species and types of presence indices ($\chi^2 = 72.131$; $p < 0.001$), demonstrating the value of combining several categories of indices to detect forest carnivores. The detection of Panthera pardus at Dikwa and Profelis aurata at Likati provides further insight into the composition of the carnivore communities studied. In conclusion, the unclassified forests on the right bank of the Aruwimi river are home to a community of carnivores whose composition varies according to location and habitat characteristics. The combination of direct observations and indirect indices constitutes a relevant approach for their inventory and monitoring, whilst maintaining habitat diversity appears important for the conservation of these communities.

**Keywords**: Aruwimi, Bas-Uélé, Carnivores, Diversity, Tshopo, Unclassified Forests

## I. INTRODUCTION

The Congo Basin is home to a wide diversity of mammals, but these communities face various threats, notably changes in land use and defauination linked to hunting (Fonteyn et al., 2023). These pressures can alter the structure and composition of forest mammal communities. Carnivores play an important role in food webs due to their interactions with prey populations and their role in the functioning of forest ecosystems. In tropical forests, the composition of carnivore communities can vary depending on habitat characteristics, resource availability and the degree of disturbance to the environment (Chades et al., 2008). Ecological niche theory also emphasises that the coexistence of species depends, in particular, on differentiation in the use of space, resources and environmental conditions (Hutchinson, 1957). Furthermore, hunting can contribute to the decline of wild mammal populations and indirectly alter the relationships between predators and their prey (Fa et al., 2003).

In the Congo Basin, several studies have examined the presence, ecology and conservation status of certain carnivores, notably the leopard (*Panthera pardus*). The work of Henschel et al. (2014) shows, in particular, that the



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leopard's choice of prey in the forests of the Congo Basin can result in an overlap with the resources exploited by hunters. Other studies have also shown that the composition of carnivore communities varies according to habitat characteristics and resource availability (Crawford et al., 2020).

In the Democratic Republic of Congo, however, the available data remain unevenly distributed across the different types of forest landscapes. Unclassified forests have been the subject of fewer wildlife studies than certain protected areas, even though they may provide habitats for various mammal species. Local knowledge can help to supplement biological inventories, but it must be cross-checked against ecological observations and appropriate identification methods (Kamgaing *et al.*, 2019). On the right bank of the Aruwimi river, scientific information regarding the composition, distribution and relative abundance of carnivores remains limited. This gap is particularly evident in the unclassified forests of Libombo, Dikwa, Bopale and Likati, where comparative data on carnivore communities remain insufficient. It therefore appears necessary to document their diversity and distribution in order to better characterise the communities present in these forest landscapes.

This study therefore aims to assess the diversity of carnivores in the unclassified forests on the right bank of the Aruwimi river in the Democratic Republic of Congo. It focuses specifically on species composition, the distribution of species across localities and forest habitat types, and their relative abundance estimated from observations and presence indices.

### 1.2 Research Objectives

i. To determine their spatial distribution across different types of forest habitats.
ii. To describe the relative abundance of carnivore species based on the presence indices observed in various study sites.

## II. LITERATURE REVIEW

### 2.1 Theoretical Review

Carnivore diversity can be analysed using ecological niche theory according to which the coexistence of species depends, in particular, on spatial differentiation, activity times and the resources used (Hutchinson, 1957). In tropical forests, the community structure also depends on the availability of prey, habitat characteristics and anthropogenic disturbances (Fonteyn *et al.*, 2023). The 'empty forest' model highlights that a seemingly intact forest cover may nevertheless suffer severe defauation as a result of hunting. This situation can alter food webs by reducing mammal populations, particularly those that serve as prey for carnivores. In the Congo Basin, hunting thus represents a significant pressure on wildlife (Fa *et al.*, 2003).

### 2.2 Empirical Review

Research carried out in the Congo Basin shows that the composition of carnivore communities varies according to habitat, available resources and the level of disturbance. The leopard (*Panthera pardus*) is one of the best-documented large carnivores, whose diet can, in particular, lead to indirect competition with hunters when both exploit the same prey. In Odzala-Kokoua National Park, studies have highlighted a historical decline in several large carnivores. However, certain forest clearings may still support their survival where food resources are sufficient (Henschel *et al.*, 2014). Recent research also shows a difference in resource use between the leopard and the African golden cat, facilitating their coexistence in the forests of the Congo. In the Democratic Republic of Congo, data remain patchier, particularly in unclassified forests (Gaston, 2000). Hunters' knowledge can supplement biological surveys by providing information on the presence and habitat use of mammals, but this must be cross-checked against ecological observations (Kamgaing *et al.*, 2019). The literature reveals a gap about the unclassified forests on the right bank of the Aruwimi. Available data on the diversity, distribution and relative abundance of carnivores in these areas remain limited. Thus, this study aims to help fill this gap.

#### 2.2.1 Composition and species diversity of carnivores

Research carried out in the forests of Central Africa has documented the diversity of carnivores and highlighted the difficulties involved in surveying them in dense forest habitats. Henschel *et al.* (2014), in Odzala-Kokoua National Park in the Republic of the Congo, studied the status of savannah carnivores using foot patrols to search for footprints and camera traps. In particular, the authors detected spotted hyenas, leopards, servals and African golden cats, whilst noting the absence of any signs of lions in the surveyed area. This study illustrates the value of combining different techniques to catalogue species and document their presence. On a broader scale, Fonteyn *et al.* (2023) compiled species lists derived from wildlife surveys and bushmeat data in order to examine the geographical structure of mammalian communities in the forests of Central Africa. Their works demonstrate the value of comparative inventories in gaining a better understanding of regional diversity. Whilst these studies serve as benchmarks for the identification of carnivores,



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they do not, on their own, enable us to determine the specific composition of the communities present in the unclassified forests of Libombo, Dikwa, Bopale and Likati.

### 2.2.2 Distribution of carnivores across different localities and habitats

Several studies have examined variations in carnivore occurrence in relation to habitat characteristics and human pressures. Henschel *et al.* (2011) studied the diet and density of the leopard (*Panthera pardus*) at four forest sites in Gabon, subject to varying levels of hunting pressure, assessed in particular on the basis of their distance from human settlements. By combining faecal analysis with camera trap data, they observed that hunting pressure increased in the vicinity of human settlements, whilst the availability of potential prey decreased. The authors also noted an increase in leopard density as the distance from human settlements increased, without detecting the species at the site closest to these settlements. More recently, a study (Gibb et al., 2019) conducted at two forest sites in the North of the Republic of the Congo, used camera traps and genetic analysis of faeces to examine the coexistence of leopards and African golden cats (*Caracal aurata*). The results indicate that both species may inhabit the same areas, whilst differences in diet help to limit competition for resources (see the study published in *Animals* in 2026). This research highlights the importance of comparing carnivores across sites and habitats whilst taking anthropogenic pressures into account. It justifies analysing the distribution of species across Libombo, Dikwa, Bopale and Likati forests, as well as across different forest types, without assuming that the observed differences necessarily result from ecological preference.

### 2.2.3 Relative abundance of species and presence indices

Indirect evidence is an important source of information for the study of forest carnivores, particularly when direct observations are difficult to obtain. Henschel *et al.* (2011) used faecal analysis and camera trap data to study the diet and population density of leopards in the forests of Gabon. This combination of methods enabled them to document the relationships between prey availability, hunting pressure and the presence of the predator. In Odzala-Kokoua National Park, Henschel *et al.* (2014) also combined on-foot tracking of footprints with camera traps to assess the presence of carnivores. This research demonstrates the value of employing multiple detection methods rather than relying on a single indicator. However, not all signs have the same probability of detection or the same duration of persistence in the environment. Consequently, their frequency must be interpreted with caution: a high number of footprints, droppings or food remains does not necessarily correspond to a high abundance of individuals (Zwerts et al., 2021). In the unclassified forests on the right bank of the Aruwimi river, the analysis of direct sightings, tracks, droppings and food remains thus enabled a comparison of the methods used to detect the species surveyed and provides a better understanding of their relative frequency at the various sites studied.

## III. METHODOLOGY

### 3.1 Research design

This study adopts a descriptive and comparative ecological approach, based on field surveys. It aims to characterise the diversity of carnivores, their spatial distribution and their relative abundance in the unclassified forests on the right bank of the Aruwimi river. The study is comparative in nature, as observations were carried out at four sites within the study villages – namely Libombo, Dikwa, Bopale and Likati – and across different types of forest habitats. This approach allowed a comparison of the composition of carnivore communities between sites and between the main types of forests studied (Schilling et al., 2022). Data were collected through direct observations and indirect evidence of animal presence.

### 3.2 Study Area

The study was conducted in the unclassified forests on the right bank of the Aruwimi river, in the Democratic Republic of Congo. Four localities were selected: Libombo and Dikwa, in the Territory of Banalia in the Tshopo province, and Bopale and Likati, in the Territories of Buta and Aketi in the Bas-Uélé province, as illustrated in Figure 1 below.



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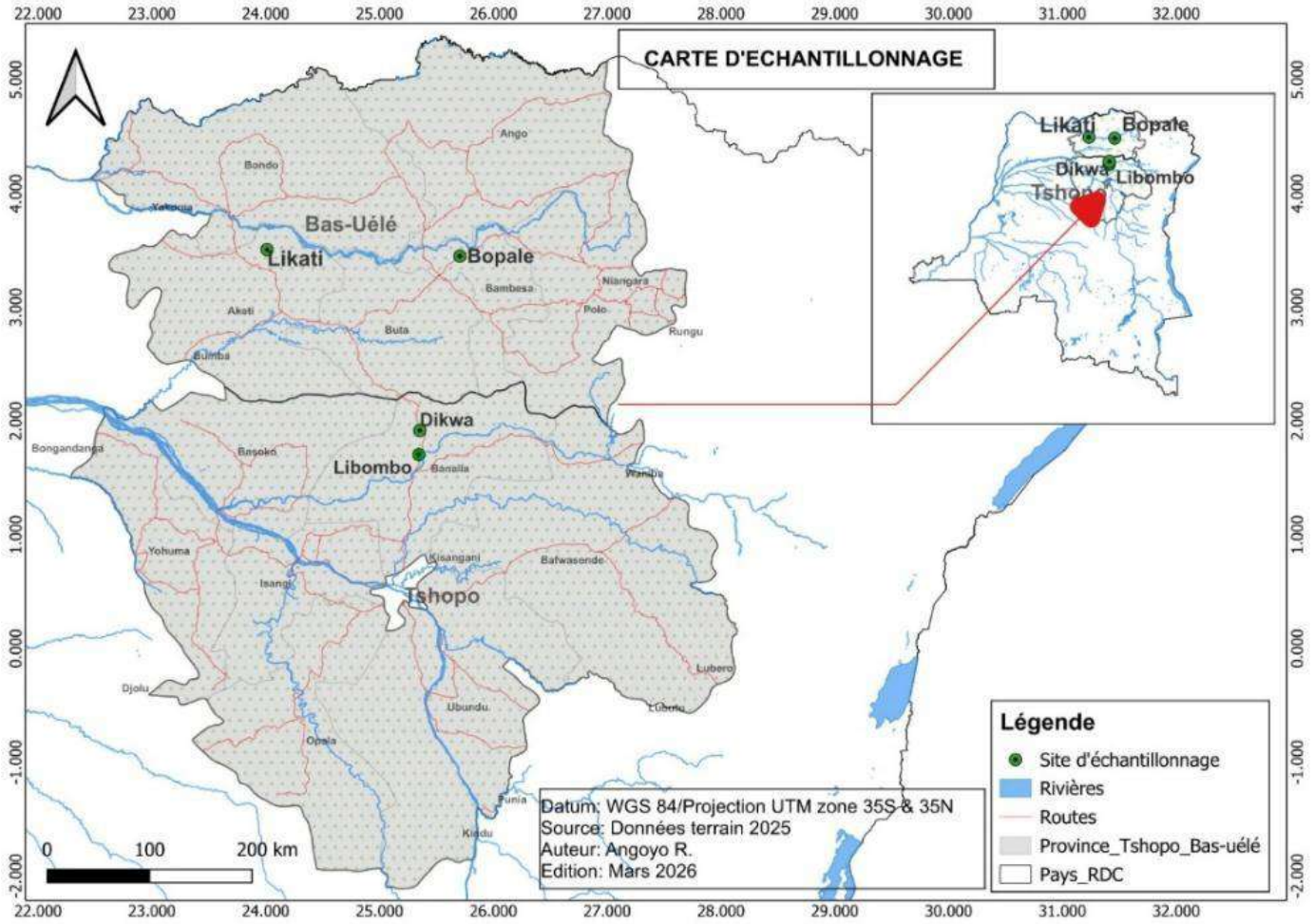



**Figure 1** *Sampling map*

The study area is located within the Congo Basin forest and comprises various types of forests, including primary and secondary forests as well as areas subject to various anthropogenic disturbances due in particular to agriculture, logging and hunting. The ecological context of this area thus allows for an examination of variations in carnivore diversity according to habitat characteristics.

### 3.3 Target population and sampling unit

The target population for the study comprises all carnivore species hosted in the unclassified forests on the right bank of the Aruwimi. The observation unit corresponds to each occurrence or sign of presence detected during the surveys. Observations focused on animals directly seen or heard, as well as on indirect signs indicating the presence of a species. These included, in particular, tracks, droppings and food remains.

### 3.4 Sampling technique and methodology

Sampling was carried out in a targeted manner, focusing on the different types of forest habitats in each of the four sites. We successively surveyed at Libombo in 2020, Dikwa in 2021, Bopale in 2022 and Likati in 2025. Each site was surveyed over a period of fifteen days. Survey routes were defined to cover the main habitat types in each site, that is, primary forests, secondary forests and disturbed areas. Along these routes, 5 kilometre transects were set. Each site comprised six transects, totalling 24 transects covered across all four sites. The routes were distributed to cover the various types of habitats to enable the search for carnivores under contrasting ecological conditions. This approach made it possible to compare their presence and distribution across the different types of habitats.

### 3.5 Sample size and sampling effort

The documented sampling effort amounted to 15 days of surveying per site, totalling 60 days across the four sites.

The field teams were accompanied by five experienced local guides, mainly hunters, who assisted in the search for and identification of signs of animal presence.



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### 3.6 Data collection methods and procedures

Data collection was based primarily on the "reconnaissance" **('recce')** method described by Walsh and White (1999), combined with surveys along linear transects. This approach involves traversing predefined routes to search for signs of carnivores in different habitats. Two categories of data were considered: direct observations, corresponding to animals observed visually or detected through their voices; indirect evidence, comprising mainly tracks, droppings and food remains. For every piece of evidence detected, the information was recorded in field forms, including the geographical coordinates, habitat type, nature of the evidence and species identification where possible. The use of indirect evidence is particularly well-suited to the study of forest carnivores, where direct observation may be limited by the density of vegetation and the elusive behaviour of the animals.

### 3.7 Equipment and species identification

The field teams used Garmin MAP 64sx and Etrex Touch 35 GPS devices, a compass, a Nikon Coolpix digital camera, data collection forms and the identification guide *Mammals of Africa* by Kingdon *et al.* (2013). Species identification was carried out on the basis of direct observations, as illustrated in Figure 2, and various signs of presence. The knowledge of local guides was used as a supplementary source and then cross-checked against the identification criteria provided by scientific guide (Zemanova, 2019). Particular attention was paid to the characteristics of the signs in order to minimise the risk of misidentification.



**Plate 1** *Profelix aurata (observed at Likati)*

### 3.8 Data analysis techniques

The data collected were organised and analysed using the R software package. The analyses focused primarily on:species richness, corresponding to the total number of carnivore species recorded; analysis of the relationship between species and types of indices; spatial distribution, examined by village and forest habitat type; a comparison of species composition between sites and forest types. Chi-square ($\chi^2$) tests were used to investigate associations between categorical variables, notably between species and villages, species and forest types, and between species and types of presence indices. A correspondence analysis (CA) was also conducted to examine the associations between carnivore species and the villages surveyed. The threshold for statistical significance was set at 5 per cent ($p < 0.05$). The results are presented as proportions, tables and graphs to facilitate comparison of species diversity and distribution.

### 3.9 Validity, reliability and credibility of the data

Data reliability was ensured by combining several identification sources. Direct and indirect observations were cross-checked against the knowledge of local guides and the identification criteria set out in the guide *Mammals of Africa*. This triangulation helped to minimise errors associated with the identification of presence indices. The ecological validity of the study also rests on the coverage of several sites and habitat types, enabling a comparison of carnivore diversity across different forest contexts. However, the report acknowledges certain methodological limitations, notably potential biases linked to species detectability and the subjectivity that may arise in the identification of certain signs.



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The combined use of direct observations, indirect signs and the knowledge of local guides was adopted to reduce these uncertainties.

### 3.10 Ethical considerations

Data collection was carried out in collaboration with local communities at the four study sites: Libombo, Dikwa, Bopale and Likati. Local guides participated in the fieldwork. As the study was primarily based on the observation of wildlife and signs of its presence, the protocol did not involve the experimental capture of animals. Information provided by local communities was used as part of the scientific collaboration and the ecological survey.

## IV. FINDINGS & DISCUSSION

### 4.1 Composition and species diversity of carnivores

Analysing the composition and species diversity of the carnivores recorded in the unclassified forests on the right bank of the Aruwimi River is a fundamental step towards understanding the structure of wildlife communities in this forest landscape (Kingdon, 2015). The results obtained highlight a statistically significant difference between the study sites, confirming that the distribution of species is not uniform but varies according to the ecological contexts and anthropogenic pressures specific to each site. This heterogeneity reflects the importance of local factors, such as resource availability, habitat configuration and the intensity of disturbances, in determining carnivore assemblages.

This section aims to describe the main trends observed, by identifying the dominant species and the specific characteristics of each site, in order to provide a solid descriptive basis for ecological interpretation. These preliminary findings pave the way for a more in-depth discussion (section 4.2), which aims to examine the mechanisms that may explain these variations, as well as their implications for species coexistence dynamics and for conservation strategies in unclassified forests of the Congo Basin.

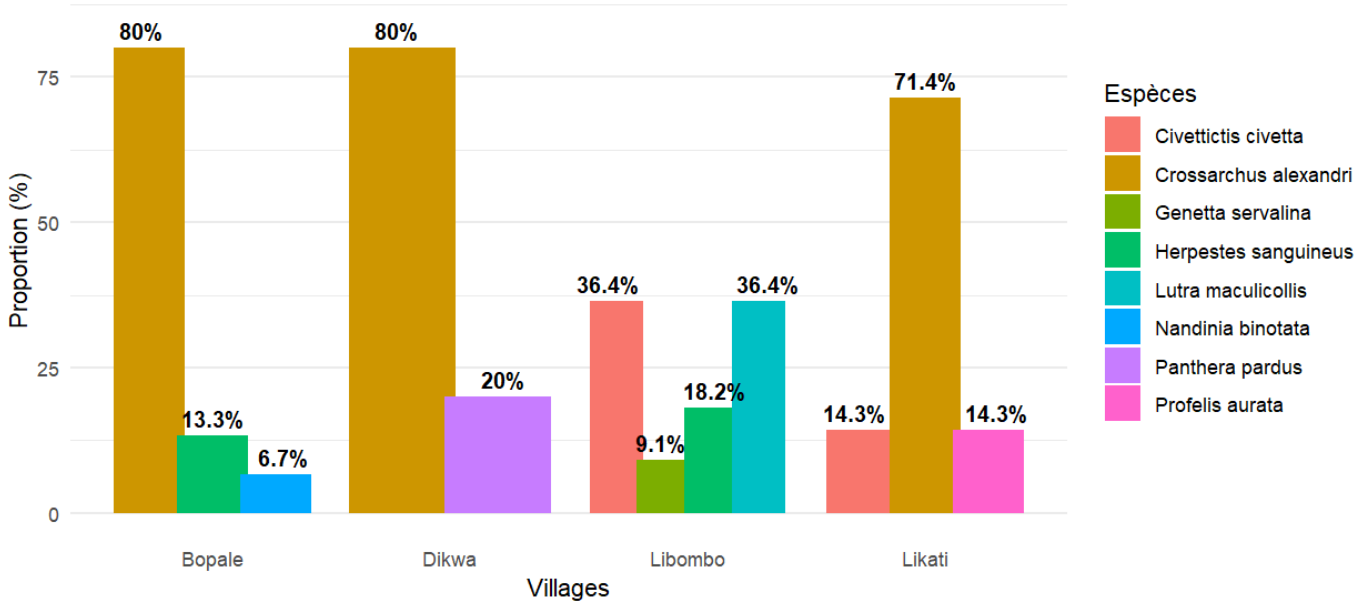



**Figure 2** *Species by village*
X-squared = 42.587, p-value = 0.003547

The survey conducted in the four study sites – Libombo, Dikwa, Bopale and Likati – revealed several species of carnivores belonging to different taxonomic groups. However, the species composition varies from one site to another, with some species being dominant in several localities. *Crossarchus alexandri* is the most common species at Bopale, Dikwa and Likati. It accounts for 80%, 80% and 71.4%, respectively according to the observations recorded in those three localities. At Libombo, by contrast, no single species accounts for more than 40% of observations. *Civettictis civetta* and *Lutra maculicollis* each account for 36.4%. *Genetta servalina* (13.3%) and *Nandinia binotata* (6.7%) are also reported at Bopale, whilst *Panthera pardus* accounts for 20% at Dikwa. At Likati, *Profelis aurata* accounts for 14.3%. These results show a differentiated species composition between the villages with a strong dominance of *C. alexandri* in three sites and a more balanced distribution at Libombo.



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### 4.2 Distribution of carnivores by village

A comparison of species distribution across the four villages reveals a statistically significant association between species and localities ($\chi^2$ = 42.587; p = 0.003547). The observed composition is therefore not uniformly distributed across the villages. Bopale, Dikwa and Likati have relatively similar profiles, characterised by a high proportion of *Crossarchus alexandri*. Libombo, by contrast, has a more diverse composition, with significant numbers of *Civettictis civetta* and *Lutra maculicollis*. Dikwa is also notable for the presence of *Panthera pardus*, whilst *Profelis aurata* is particularly abundant at Likati.

### 4.3 Distribution of carnivores by forest type

Analysing the distribution of carnivores according to forest type provides a better understanding of how ecological characteristics influence community structure. The results indicate that species composition varies significantly between primary, secondary and mixed forests, reflecting differences in community composition linked to habitat quality and the degree of disturbance. This section examines the main trends observed, highlighting the dominant species in each forest type and the implications of these variations for the ecology and conservation of carnivores.

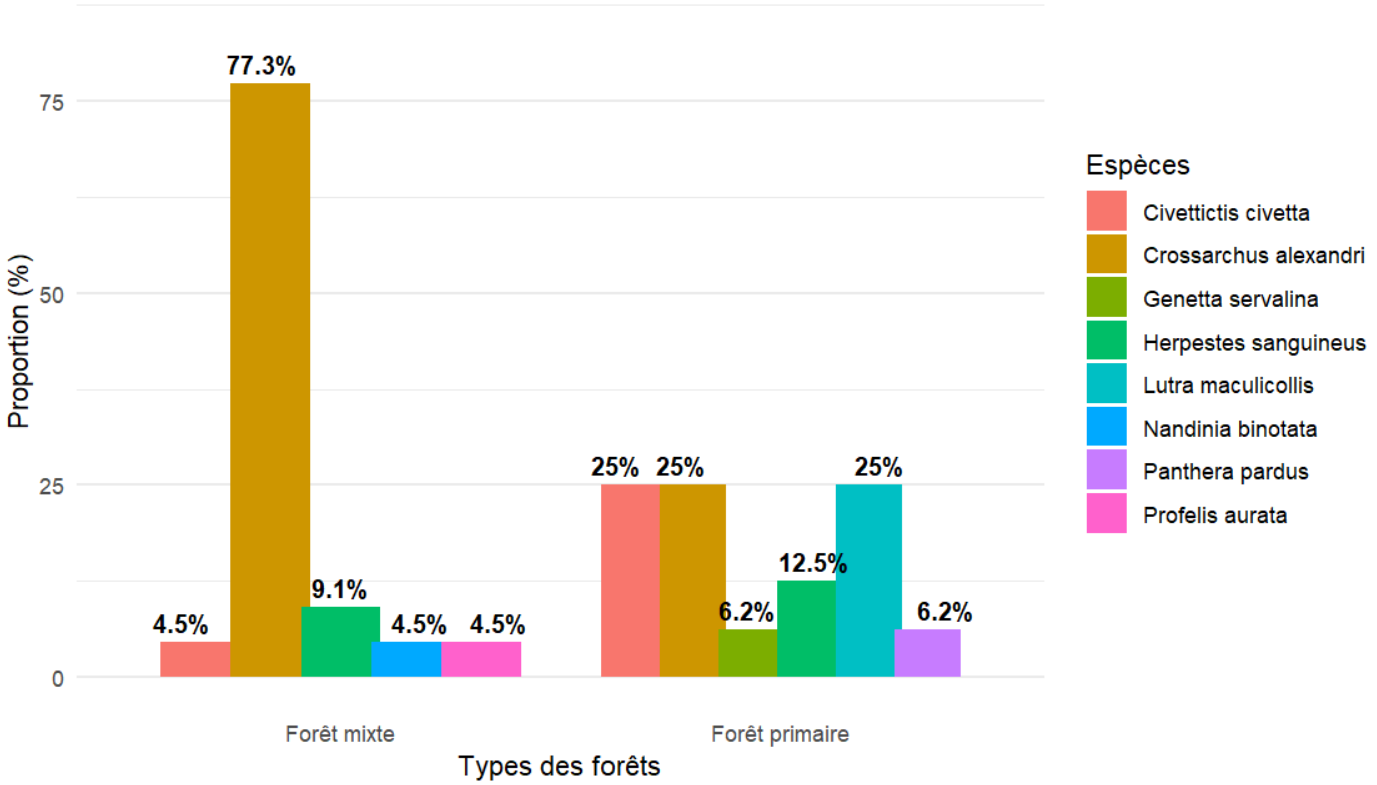



**Figure 3** *Distribution of carnivores by forest type*
X-squared = 17.332, p-value = 0.01537

The composition of carnivores also differs according to forest type. The chi-squared test indicates a statistically significant association between species and forest types ($\chi^2$ = 17.332; p = 0.01537). In the mixed forest, *Crossarchus alexandri* dominates, accounting for 77.3% of observations. *Herpestes sanguineus* accounts for 9.1% and *Civettictis civetta* for 4.5%. *Lutra maculicollis* and *Panthera pardus* were not detected in this forest type in the data presented. In the primary forest, the distribution appears more balanced: *Civettictis civetta*, *Crossarchus alexandri* and *Lutra maculicollis* each account for 25%, whilst *Panthera pardus* accounts for 6.2%. These results indicate that community structure varies according to forest types. The strong dominance of *C. alexandri* in the mixed forest could be associated with this species' greater tolerance of modified habitats. Conversely, the more balanced distribution observed in the primary forest suggests a more diversified use of this habitat by the carnivores surveyed. This interpretation must, however, be treated with caution, as species detectability and sampling effort may equally influence the observed frequencies.

### 4.4 Analysis of the relationship between species and index types

Investigating the relationship between carnivore species and the types of presence indicators is an essential methodological step in assessing the reliability and relevance of the data collected. As forest carnivores are often elusive



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and difficult to observe directly, the inclusion of indirect indicators (footprints, droppings, food remains) helps to supplement visual observations and improve the detection of species. The statistical analysis therefore aims to determine the extent to which each index category contributes to the detection of different species, and to identify significant associations that reflect ecological behaviours or detection characteristics. This section presents the results obtained and discusses their implications for the inventory and monitoring of carnivores in the unclassified forests of the Aruwimi.

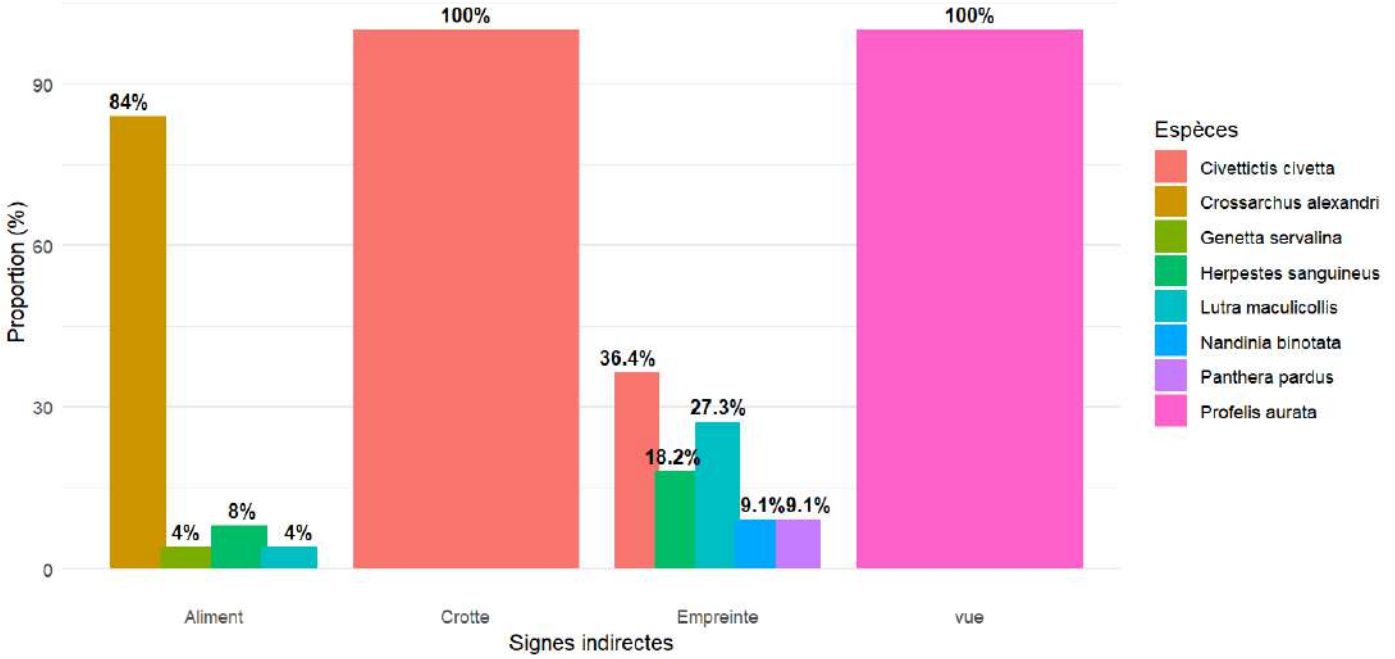



**Figure 4** *Analysis of the relationship between species and index types*
X-squared = 72.131, p-value = 1.594e-07

The relationship between species and type of evidence was assessed on the basis of the frequency of the various presence indicators detected in the field. A highly significant association was found between species and types of evidence ($\chi^2 = 72.131$; $p = 1.594 \times 10^{-7}$). The various indices therefore do not contribute equally to the detection of species. *Civettictis civetta* is mainly identified from droppings, which account for 100% of the corresponding indices in the available data. *Profelis aurata* is represented exclusively by direct observations in this sample, whilst *Crossarchus alexandri* is mainly detected from food remains, which account for 84% of its indices. Footprints also enable the detection of several species: *Civettictis civetta* accounts for 36.4% of the footprints, *Lutra maculicollis* 27.3%, *Genetta servalina* 18.2% and *Panthera pardus* 9.1%. These results show that the probability of detection varies according to the species and the nature of the trace being sought. The use of several categories of traces therefore appears more appropriate than a single type of indicator for surveying forest carnivores.

### 4.5 Degree of degradation of presence indices

Assessing the degree of deterioration of presence indices is an important methodological consideration when evaluating the reliability of data collected on forest carnivores. Indeed, the persistence or gradual disappearance of tracks, droppings and food remains determines their value as indicators of presence and directly influences estimates of the relative abundance of species. The statistical analysis carried out reveals significant differences between the categories of recent and older indices, reflecting degradation patterns specific to each type of trace. This section examines these results in order to better understand potential biases relating to detectability and to draw implications for ecological interpretation and the planning of wildlife surveys.



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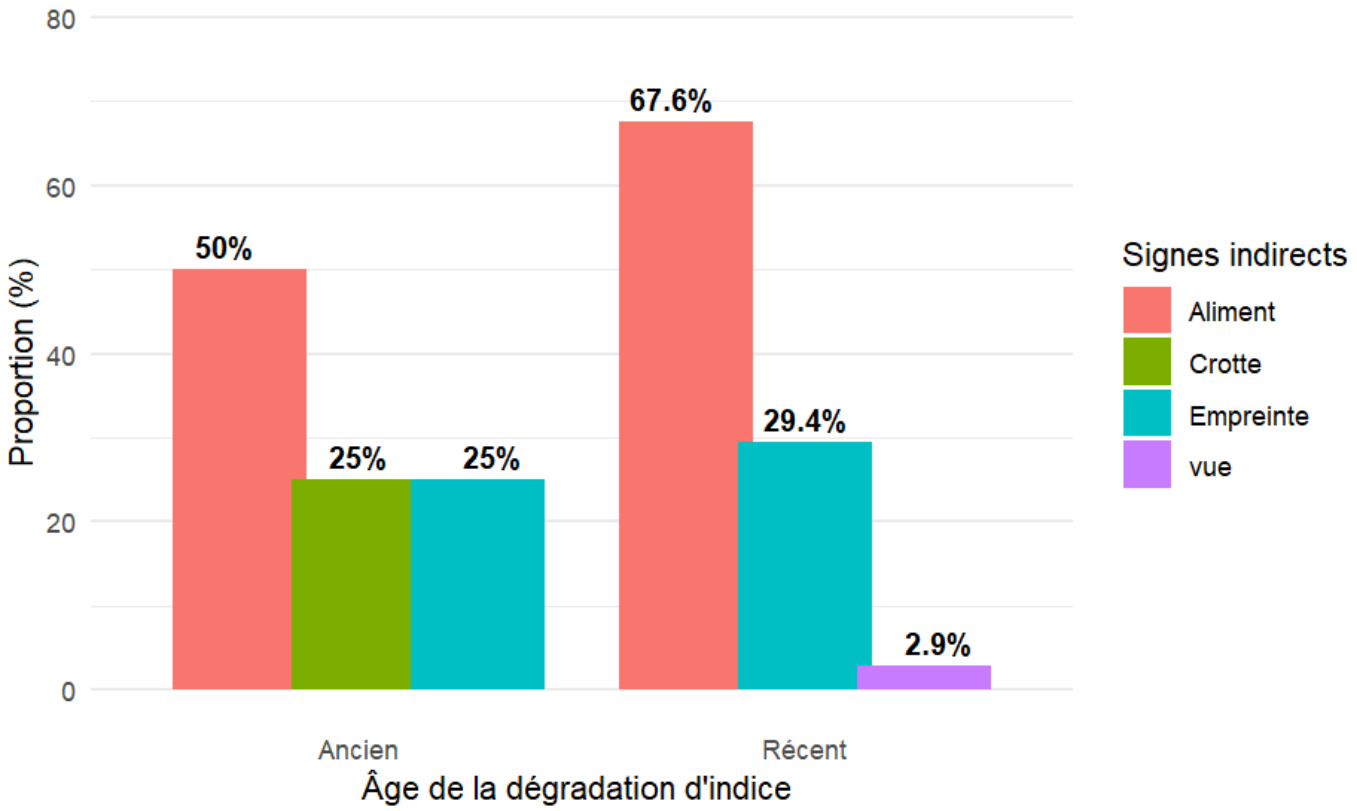



**Figure 5** *Degradation status of types of indirect indices*
X-squared = 8.8111, p-value = 0.03191

Analysis of the relationship between the nature of the evidence and its state of deterioration reveals a statistically significant association ($\chi^2 = 8.8111$; $p = 0.03191$). Among recent indices, food remains constitute the dominant category at 67.6%, followed by footprints at 29.4% and direct observations at 2.9%. Among ancient indices, they comprise (50%), droppings (25%) and footprints (25%). The decrease in the proportion of footprints between recent and ancient evidence can be explained by their gradual degradation due to environmental conditions. Conversely, the presence of droppings amongst the older traces suggests greater persistence of this type of trace. This difference in persistence must be taken into account when interpreting the frequency of traces and estimating abundance.

**4.6 Associations between species and villages: correspondence analysis**

Factor analysis of correspondences (FAC) is a useful statistical tool for examining in greater depth the relationships between carnivore species and the study sites. Whilst the $\chi^2$ test highlights the existence of significant associations, FAC enables the spatial structure of the communities to be visualised and characterised in greater detail. This multivariate approach makes it possible to identify the species that contribute most to the distinctive characteristics of each village and to highlight the similarities or differences between sites in the factor space. This section presents the results of this analysis, highlighting the clusters observed and their implications for understanding local dynamics of carnivore diversity.



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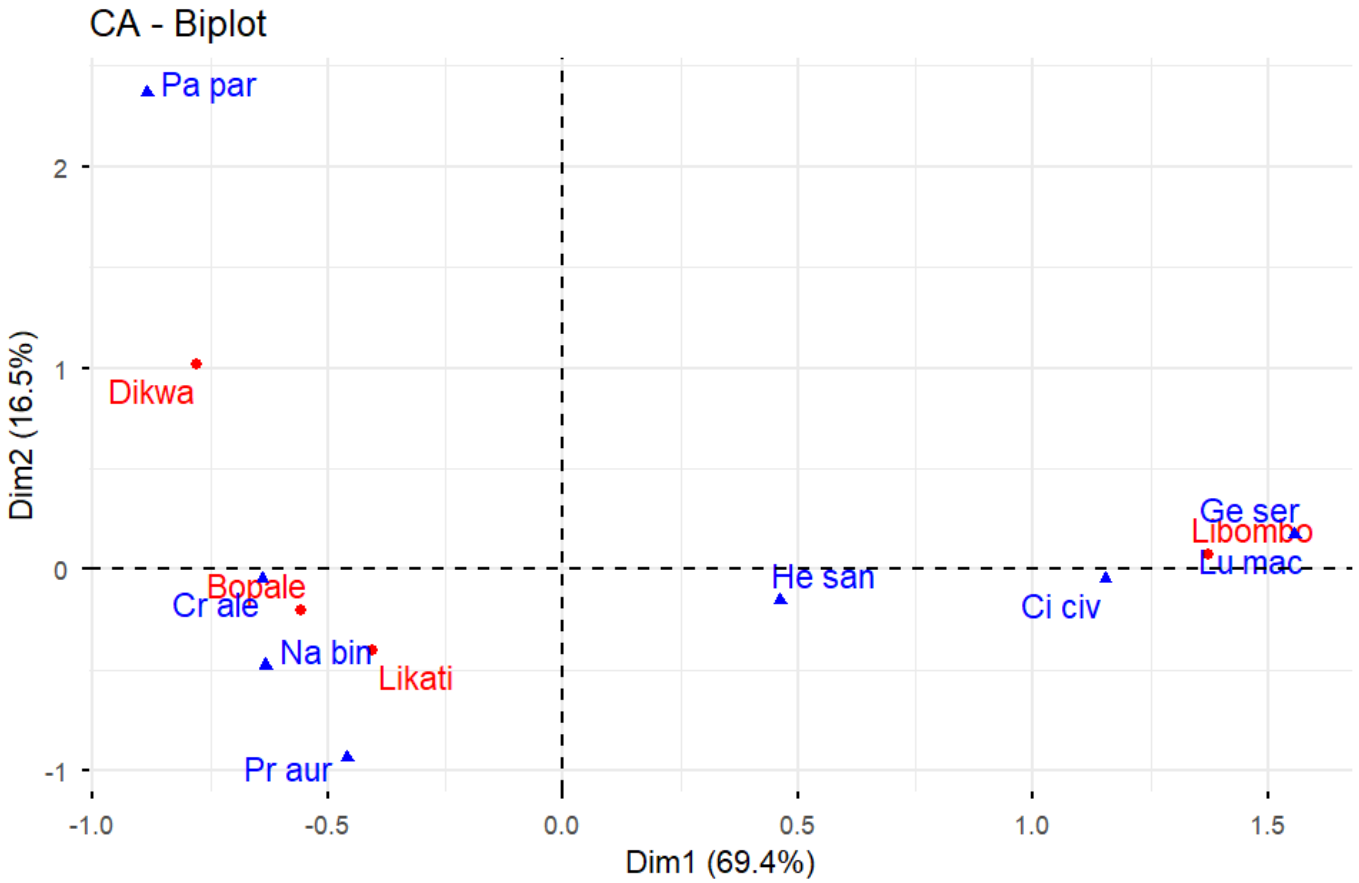



**Figure 6** *Variability in carnivore biodiversity across the study villages*

Correspondence analysis confirms the spatial pattern observed using the chi-squared test. The principal axis mainly distinguishes Libombo from Dikwa, Bopale and Likati. Libombo is associated with *Genetta servalina*, *Lutra maculicollis* and *Civettictis civetta*. Dikwa shows a particularly strong association with *Panthera pardus*. Bopale and Likati are close together in the factor space and are notably associated with *Crossarchus alexandri*, *Nandinia binotata* and *Profelis aurata*. *Herpestes sanguineus* occupies a more central position. AFC thus complements the $\chi^2$ test: whilst the latter establishes the existence of an association between species and villages, AFC makes it possible to identify the species that contribute most to the distinctive characteristics of each locality.

### 4.7 Conservation status of the species surveyed

Of the species assessed in the document, five (62.5%) are classified as Least Concern (LC), two (25%) as Vulnerable (VU) and one (12.5%) as Near Threatened (NT). *Profelis aurata* and *Panthera pardus* are listed as Vulnerable, whilst *Lutra maculicollis* is classified as Near Threatened. The presence of species in the VU and NT categories highlights the conservation importance of the forests studied. However, this status is a descriptive characteristic of the surveyed community and was not subjected to statistical testing in this study.

### 4.8 Discussion

#### 4.8.1 Composition and species diversity

The results highlight variation in the composition of carnivores across the four study sites. The $\chi^2$ test reveals a significant association between species and sites ($\chi^2 = 42.587$; $p = 0.003547$). This difference indicates that the recorded species are not distributed evenly across Libombo, Dikwa, Bopale and Likati. However, this result alone does not allow us to identify the factors responsible for this differentiation. It could be linked to several local characteristics, notably habitat structure, resource availability, anthropogenic pressure or differences in species detectability.

The dominance of *Crossarchus alexandri* at Bopale, Dikwa and Likati is one of the key features of the observed species composition. This dominance may be linked to the ability of certain mongooses to inhabit different types of environments, including modified habitats, as reported by Kingdon (2015; Ray et al., 2015). However, the data from this study do not allow us to conclude directly that this dominance results from an adaptation to disturbed environments, as the degree of disturbance and the ecological characteristics of the sites were not measured quantitatively.

At Libombo, the composition appears to be relatively more balanced amongst the recorded species. This pattern may reflect differences in local habitat conditions or in resource availability, but this interpretation should be treated



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with caution. Indeed, no direct measurements of anthropogenic pressure, habitat quality or resource availability were included in the analysis. This difference should therefore be regarded as a characteristic of the observed composition rather than as evidence of an effect of human pressure. The presence of *Panthera pardus* at Dikwa and *Profelis aurata* at Likati is also of interest from a conservation perspective. Nevertheless, their detection at a single location does not allow us to conclude that these sites necessarily constitute preferred habitats or areas of particular importance for these species. Further surveys, carried out using a standardised sampling method and possibly with the aid of camera traps, would be necessary to clarify their distribution.

**4.8.2 Variation according to forest types**

The analysis highlights a significant association between the composition of carnivores and forest types ($\chi^2$ = 17.332; p = 0.01537). Mixed forest is characterised by a high proportion of *Crossarchus alexandri*, whilst primary forest shows a more balanced distribution of the species recorded. These results show that the composition observed varies according to the categories of forest studied. However, they do not allow us to conclude that primary forest necessarily possesses greater species richness or diversity than other forest types, as the analyses presented are not based on a diversity index or a statistical comparison of species richness. It is therefore preferable to speak of differences in composition rather than to conclude that primary forest has greater diversity. The high abundance of *Crossarchus alexandri* in the mixed forest could be linked to the specific characteristics of this habitat. Some species may indeed exhibit a certain tolerance to disturbed habitats (Kingdon, 2015). However, the hypothesis that *C. alexandri* is better adapted to disturbed habitats should be regarded as a possible interpretation rather than a conclusion supported by the data from this study.

**4.8.3 Relationship between species and types of presence indices**

The $\chi^2$ test reveals a highly significant association between species and types of presence indices ($\chi^2$ = 72.131; p < 0.001). The species are therefore not detected with the same frequency using the different types of presence indices. For example, *Civettictis civetta* is mainly represented by droppings in the data under consideration, whilst *Profelis aurata* was detected solely through direct observation in this sample. *Crossarchus alexandri*, for its part, is mainly associated with food remains. This varied distribution of traces can be explained in part by species-specific characteristics, their behaviour and the conditions under which they are detected. However, the test carried out does not allow us to determine whether these differences result from the animals' behaviour, the persistence of the traces, or the probability of detection. It is therefore preferable to interpret these results as an association between species and types of traces, rather than as evidence of specific marking behaviours. The use of several categories of signs nevertheless appears relevant for inventories of forest carnivores, as certain species may be more easily detected by some types of signs than by others (Stuart & Stuart, 2013). This approach thus helps to reduce reliance on a single type of observation.

**4.8.4 Degree of deterioration of the signs**

The analysis also highlights a significant association between the types of signs and their state of degradation ($\chi^2$ = 8.8111; p = 0.03191). Recent signs consist mainly of food remains and footprints, whilst older signs include more droppings and food remains. This difference suggests that the composition of the traces observed may vary over time. However, the study does not directly measure the rate at which each type of trace disappears or degrades. It would therefore be an over-generalisation to claim, on the basis of these results alone, that droppings are more reliable indicators in the long term. Putman's (1984; Stephenson, 2020) work nevertheless highlights the value of faeces in mammal monitoring studies, which provides a point of comparison with the observations made here. The degradation of traces is thus a factor to be taken into account when interpreting presence frequencies. The differences observed could in fact be influenced both by the actual presence of the species and by the variable persistence of traces in the environment.

**4.8.5 Associations between species and sites**

Correspondence analysis complements the results of the $\chi^2$ test by highlighting associations between certain species and certain localities. Libombo is notably associated with *Genetta servalina*, *Lutra maculicollis* and *Civettictis civetta*, whilst Dikwa is more strongly associated with *Panthera pardus*. Bopale and Likati occupy relatively similar positions and are notably associated with *Crossarchus alexandri*, *Nandinia binotata* and *Profelis aurata*. These associations describe the specific characteristics of site composition, but they should not be interpreted directly as ecological preferences or species specialisation. The AFC primarily allows us to visualise the relationships between habitat types and species within the analysed data (Tilman, 1994). To demonstrate a habitat preference or ecological specialisation, additional data on habitat use, resource availability and sampling effort would be required. The more central position of *Herpestes sanguineus* in the analysis could indicate a less pronounced association with any particular



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site within the sample studied. However, this is not sufficient to classify this species as a 'generalist' within the study area. Such an interpretation would require a more detailed analysis of its habitat use.

#### 4.8.6 Implications of the results for conservation

The presence of eight species whose conservation status is documented in the data – including *Profelis aurata* and *Panthera pardus*, which are classified as Vulnerable, and *Lutra maculicollis*, which is classified as Near Threatened – is of interest for our understanding of the fauna of unclassified forests. However, the conservation status is not derived from a statistical analysis carried out in this study and should therefore be regarded as supplementary information on the species recorded.

Overall, the results show above all that carnivore communities differ in composition between sites and forest types, and that detection methods vary according to species and the type of evidence used. These observations highlight the value of continuing surveys in the unclassified forests of the Aruwimi using a standardised sampling approach. Combining direct observations, indirect evidence and, where possible, camera trapping would, in particular, enable a better characterisation of the distribution and relative abundance of species.

## V. CONCLUSION & RECOMMENDATIONS

### 5.1 Conclusion

The aim of this study was to assess carnivore diversity in the unclassified forests on the right bank of the Aruwimi river by identifying the species present, analysing their spatial distribution and estimating their relative abundance based on presence indices. The results show differences in the composition of carnivore communities between the localities and forest types studied across the four study sites, namely Libombo, Dikwa, Bopale and Likati. Species composition varies significantly between villages ($\chi^2 = 42.587$; $p = 0.003547$) and by forest type ($\chi^2 = 17.332$; $p = 0.01537$). *Crossarchus alexandri* dominates the records at Bopale, Dikwa and Likati, whilst Libombo exhibits a more balanced composition, notably featuring *Civettictis civetta* and *Lutra maculicollis*.

The distribution of species according to forest type also shows a significant difference. Primary forest exhibits a relatively more balanced composition, whilst mixed forest is strongly dominated by *Crossarchus alexandri*. These results suggest that local habitat characteristics play a role in shaping carnivore assemblages, although the available data do not allow these differences to be attributed to a single environmental factor. The study also shows that presence indices are important tools for surveying forest carnivores. The highly significant relationship between species and index types ($\chi^2 = 72.131$; $p < 0.001$) indicates that species are not detected in the same way depending on the indices used. Combining direct sightings, tracks, droppings and food remains therefore appears more appropriate than using a single type of indicator. However, the interpretation of these frequencies must take into account the varying detectability and persistence of the different indicators.

Finally, the presence of *Panthera pardus* and *Profelis aurata*, listed in the document as vulnerable species, as well as *Lutra maculicollis*, classified as Near Threatened, highlights the ec e and conservation importance of the forests studied. The results therefore support the continuation of inventories and the establishment of regular monitoring of carnivores in the unclassified forests on the right bank of the Aruwimi, with particular attention paid to habitats with a diverse species composition and to species of particular conservation interest. Further studies, based on standardised sampling efforts repeated over time, would make it possible to better distinguish between actual population fluctuations and variations linked to species detectability and the persistence of presence indices.

### 5.2 Recommendations

Stepping up the conservation of unclassified forest is recommended. The results show that these forests are home to a significant diversity of carnivores, including vulnerable and near-threatened species. We would therefore recommend that appropriate management and conservation measures be put in place, even outside protected areas.

Also, maintaining the diversity of forest habitats is suggested. The variation in species composition across different forest types highlights the importance of preserving primary, secondary and mixed forests alike, in order to ensure the coexistence of different species.

In addition, combining monitoring methods is crucial. The study showed that indirect indicators (footprints, droppings, food remains) effectively complement direct observations. We would recommend that this combined approach be maintained to improve the reliability of inventories.

Involving local communities The participation of guides and hunters was crucial in identifying signs of wildlife. Their ongoing involvement in surveys and raising awareness of conservation is essential for the sustainability of these initiatives.



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Stepping scientific research up Data on carnivores in unclassified forests remain limited. We would recommend to continue comparative surveys in other locations within the Congo Basin in order to fill the gaps and refine conservation strategies.

Taking vulnerable species into account**:** The presence of *Panthera pardus* and *Profelis aurata* (VU), as well as *Lutra maculicollis* (NT), draws particular attention. Specific monitoring and protection measures should be considered for these vulnerable species

**Declaration of Interest**

The authors declare that they do not have any known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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