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Research Article

CONSERVATION STATUS AND DISTRIBUTION OF LARGE NON-ARBOREAL MAMMALS IN TAÏ NATIONAL PARK (SOUTH-WEST, CÔTE D'IVOIRE)

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ABSTRACT

The availability of accurate information on biological diversity and spatio-temporal distribution within a protected area is essential for informed management and conservation decision-making. The Taï National Park (TNP) is a World Heritage Site and one of the best-preserved protected areas in Côte d'Ivoire. However, information on the spatial distribution and local conservation status of many animal species remains limited. In the light of this information deficit, the present study aimed to characterize the community of large non-arboreal mammals in the TNP, by camera trapping. A total of 87 camera traps were deployed within the park, following a systematic system, for 120 days. Our observations indicate the presence of 20 species of large non-arboreal mammals, divided into 13 fully protected species, three partially protected species and four species with rapid population growth, on a national scale. Eight of these species are said to be internationally threatened, according to the International Union for Conservation of Nature's Red List. This study also reveals that almost the entire surface of the park has a high diversity of large non-arboreal mammals, with particularly diverse areas such as the east of the Ecology Research Center. In view of its results, the study suggests an improvement in the biomonitoring method to adopt camera trapping.

Keywords: Endangered species, Taï National Park, Large mammals, Species richness, Camera trap.

INTRODUCTION

Tropical forests are home to a rich biodiversity, but they are among the ecosystems most subject to human devastation (Merz & Hoppe-Dominik, 1991). In tropical regions, activities such as logging and mining, agriculture, hunting, and illegal gold mining are increasing threats to wildlife (Caspary *et al.,* 2001). Côte d'Ivoire, a country located in the tropical zone of West Africa, is no exception. Indeed, the most recent statistics on forest cover indicate that the area of Ivorian forests has decreased from 16 million hectares in 1960 to 2.97 million hectares in 2020 (Cuny *et al.,* 2023). This loss of forest cover has been accompanied by a drastic loss of the population of large mammals, including the chimpanzee *Pan troglodytes verus* whose population fell by 90% between 1995 and 2007 (N'Goran *et al.,* 2013) and the forest elephant *Loxodonta cyclotis* whose population fell from 1,611 individuals in 1994 to 225 individuals in 2022 corresponding a loss of 86% (Kouakou *et al.,* 2022). To address the loss of its biodiversity, Côte d'Ivoire has established a network of protected areas (PAs), like other countries in the world (Merz & Hoppe-Dominik, 1991). Despite the efforts made to conserve PAs, they are subject to various anthropogenic pressures, including poaching, infiltration for agricultural purposes and gold panning (Barima *et al.,* 2016; Ousmane *et al.,* 2020). In spite of this situation, some PAs, such as the Taï National Park (TNP), are exception. Indeed, the TNP is now the largest forest area in Côte d'Ivoire and one of the last best-preserved forest parks in the sub-region (Chatelain *et al.,* 2001; Kolongo *et al.,* 2006). Due to its rich biodiversity, the TNP was classified as a Biosphere Reserve in 1978 and a World Heritage Site in 1982 as part of the MAB-UNESCO programme (Bousquet, 1978; Chatelain *et al.,*

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2001). The TNP remains one of the last refuges for wildlife in general and large mammals in particular.

TNP managers use the linear transect method to monitor trends in the park's animal populations. Although this method provides a general overview of the fauna, it often does not allow a difference to be made between species belonging to close taxa. Thus, in the various biomonitoring reports, the term "monkeys" is used to refer to all tailed monkeys or the term "duikers" to refer to all small antelopes belonging to the Bovidae family (Tiedoué *et al.,* 2015, 2016, 2018). Also, some species of conservation interest, but cryptic, such as the leopard *Panthera pardus* and the giant ground pangolin *Smutsia gigantea*, are very rarely observed on transects in forest environments, hence the difficulties in monitoring the evolution of their population. In view of the above, it appears that the biomonitoring method used so far provides general information, but very often does not allow for a more detailed description, at the species level, which is essential for a sustainable management strategy for the TNP.

To compensate for this deficiency and to have more information on the community of large non-arboreal mammals in the TNP, in the framework of this study, data collection was done by camera trapping. This methodology is intended to be one of the most advanced and appropriate for the study of wildlife (Meek *et al.,* 2014; Burton *et al.,* 2015; Monket *et al.,* 2022). Unlike previous methodologies such as aerial counting or radiotracking, which are costly, logistically demanding and often have ethical limitations; camera trapping, offers a less invasive alternative and potentially more ethical and economical (Meek *et al.,* 2014; Monket *et al.,* 2022). In addition, the advent of camera traps has facilitated the study of rare, cryptic, nocturnal animals, highly sensitive to human presence, using large home ranges or living in hard-to-reach habitats, such as dense tropical forests (Meek *et al.,* 2014; Trolliet *et al.,* 2014; Burton *et al.,* 2015; Monket *et al.,* 2022). The general objective of this work is to characterize the community of large non-arboreal mammals in the TNP. Specifically, the aim is to determine the species richness of large non-arboreal mammals in the TNP, to establish the conservation status of these species and produce a spatial distribution map of large non-arboreal mammals in the TNP.

MATERIALS AND METHODS

Study site

The TNP is located in the southwest of Côte d'Ivoire. It extends over three administrative regions: the Nawa region, in the east and northeast, the Cavally region, in the north and northwest, and the San-Pedro region, in the southwest and south. It is located between 5°08' and 6°24' north latitude and 6°47' and 7°25' west longitude (Figure 1). The TNP covers an area of 536,016 ha, 99.5% of which is forest (Schweter, 2004). Due to the harmonization of the management method of the TNP and the N'Zo Wildlife Reserve, the two entities are grouped under the name "Taï National Park". The relief of the TNP is made up of a fairly uniform set of hills and crisscrossed by numerous highly branched rivers (OIPR, 2014). Almost the entire park is covered by highly saturated and reworked ferralitic soils, characteristic of a hot and humid region all year round (Bousquet, 1978). The TNP is distinguished by its floristic and faunal richness (Chatelain *et al.,* 2001; Kolongo *et al.,* 2006).

Data collection

Data collection was done in accordance with the methodology explained by Kely *et al.* (2021). The trapping was done in 120 days, divided into two periods: the first period, from June 9, 2016 to August 8, 2016 and the second period from October 10, 2017 to December 9, 2017. Eighty-seven BUSHNELL Trophy Cam HD Essential E3 camera traps were deployed throughout the TNP, following a systematic system, with an equidistance of 6 km between two consecutive trapping positions. In the field, the camera traps were installed within a radius of 200 m from the theoretical position initially targeted, depending on the presence of a fruit tree, a water point or signs of the presence of large mammals. In order to avoid significantly clearing the seedlings in the field of vision and to better observe large mammals, the traps were set at a height of 1.5 m above the ground, on sufficiently robust shrubs, 10 m from the target points (Ngama *et al.,* 2018). In order to have as much information as possible on the target species, the traps were set in hybrid mode, i.e. allowing video sequences (60 seconds) to be recorded alternating with photographs. The trigger time between two successive detections was one second (1 s).

Data analysis

The data from each camera trap were recorded in a database, sorted and classified according to the different species of large non-arboreal mammals. The identification of species was done according to our own knowledge and sometimes with reference to the African Mammal Identification Guide (Kingdom, 2006). To avoid recounting the same individual dragging itself in the trap's field of vision or members of the same group (for gregarious species), we chose the independence time of 30 minutes, between two successive detections, for the same species (N'Goran *et al.,* 2020; Monket *et al.,* 2021). Thus, for the same species, two successive detections are said to be independent, when they occur in a time interval of more than 30 minutes.

Species considered to be essentially arboreal were not taken into account for this study. Thus, for the primate order, among the 12 species identified in the TNP (Chatelain *et al.,* 2001), only two recognized as semi-terrestrial (Nakashima, 2015), were taken into account. These are the mangabey *Cercocebus atys* and the West African chimpanzee *Pan troglodytes verus*. In the context of this work, most diurnal primates, most carnivores larger

than a fox or a domestic cat, artiodactyls, including duikers (Hoffmann, 2010) and all other mammals with a body weight at adulthood greater than those mentioned above were considered large mammals. For each species, we determined the absolute frequency and the frequency relative to the TNP. The absolute frequency (ni) of a species in the TNP was obtained by summing the numbers of independent detections of the species at each camera trap. The relative frequency (Fr) was obtained using the formula below:

Fr=(ni/N)×100 with **ni**: the absolute frequency of species **i**; **N**: the sum of all the absolute frequencies of the different species.

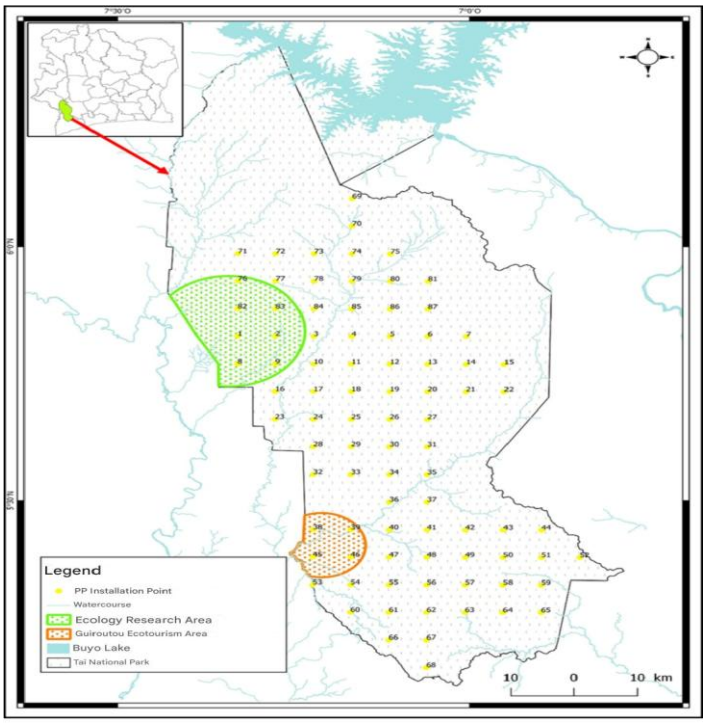

Figure 1. Location of the Taï National Park and sampling device.

The different species have been classified in the TNP according to their respective relative frequencies, according to Thiollay (1986): a species is said to be dominant (D), in a habitat, when its relative frequency is greater than 5%; regular (Re), when its relative frequency is between 1% and 5%; rare (Ra), when its relative frequency is between 0.2% and 0.9% and accidental (Ac), when its relative frequency is less than 0.2%. To determine the conservation interest of the different species of large non-arboreal mammals, their status was sought nationally and internationally. The status at the national level was determined according to Law No. 2024-364 of June 11, 2024 on wildlife management, which classifies wildlife species into four groups, namely: group I species (fully protected species), group II species (partially protected species), group III species (fast-proliferating species) and group IV species (exotic species). The international status was determined with reference to the International Union for Conservation of Nature (IUCN) Red List, version 2025-1. The calculation of the Shannon diversity index (H') at each point of camera trap installation made it possible to generate a spatial distribution map of large non-arboreal mammals at the TNP, by interpolation of the values obtained, under Qgis 3.42.3.

RESULTS AND DISCUSSION

At the end of the trapping period, data from 77 functional camera traps were taken into account in our analyses. These traps have accumulated 4309 independent observations of large non-arboreal mammals. These mammals are classified into five Orders, 11 Families, 16 Genus and 20 Species (Table 1). The order Artiodactyla is the most diverse with four families, eight genus and 13 species. Secondly, the order of Carnivora with three families, three genus and three species. In third place comes the order of Primates with two families, two genus and two species. In last place are the order of the Proboscidea and that of the Pholidota, each represented by one specie. Figure 2 below shows images of some large non-arborical mammals recorded in the TNP.

Referring to the relative frequency of species observed by camera trapping, four dominant species (D) were identified in the TNP (Table 1). These are Maxwell's duiker *Philantomba maxwellii*, with a relative frequency of 44.14%; Ogilbyi's duiker *Cephalophus ogilbyi* (25.74%), Bay Duiker *Cephalophus dorsalis* (7.77%) and Mangabey *Cercocebus atys* (5.41%). Six species are regular (Re) in the TNP, the most represented of these species is the

Jentink's duiker *Cephalophus jentinki*, with a relative frequency of 3.69%. Six species are rare (Ra) in the TNP, including the Forest Elephant *Loxodonta cyclotis* (0.86%) and the Leopard *Panthera pardus* (0.65%). Four species are accidental (Ac). These include the Giant Ground Pangolin *Smutsia gigantea* (0.09) and the Forest *Buffalo Syncerus caffer nanus* (0.05). Among the 20 species of large non-arboreal mammals observed during our work, 13 species belong to group I, fully protected species at the national level, three belong to group II, partially protected species and four belong to group III, rapidly proliferating species. Eight of these species are listed as threatened on the IUCN Red List. These are two critically endangered (CR) species, the West African chimpanzee *Pan troglodytes verus*, which is a regular species, and the Forest Elephant *Loxodonta cyclotis*, which is a rare species in the TNP, three endangered species, namely the Jentink's duiker *Cephalophus jentinki*, the Pygmy Hippopotamus *Choeropsis liberiensis* and the Giant Ground Pangolin *Smutsia gigantea*, and three vulnerable species (VU), the Mangabey *Cercocebus atys*, the Zebra duiker *Cephalophus zebra* and the Leopard *Panthera pardus*.

Table 1. List of species observed by camera trapping in the Taï National Park.

Family	Type	Species	Common name	Absolute frequency	Relative frequency (%)	Status in PNT	National status	IUCN status (2025-1)
Order : Artiodactyla								
Bovidae	Philantomba	*Philantomba maxwellii* (C.H. Smith, 1827)	Maxwell's Duiker	1,902	44.14	D	III	LC
	Cephalophus	*Cephalophus ogilbyi* (Wterhouse, 1838)	Ogilby's Duiker	1,109	25.74	D	I	LC
		Cephalophus dorsalis Gray, 1846	Bay Duiker	335	7.77	D	II	NT
		Cephalophus jentinki Thomas, 1892	Jentink's Duiker	159	3.69	Re	I	EN
		Cephalophus niger Gray, 1846	Black Duiker	91	2.11	Re	I	LC
		Cephalophus zebra Gray, 1838	Zebra Duiker	75	1.74	Re	I	VU
		Cephalophus silvicultor (Afzelius, 1815)	Yellow-backed Duiker	31	0.72	Ra	I	NT
	Tragelaphus	*Tragelaphus eurycerus* (Ogilbyi, 1837)	Bongo	25	0.58	Ra	I	NT
	Syncerus	*Syncerus caffer nanus* (Boddaert, 1785)	African Buffalo	02	0.05	Ac	II	NT
Suidae	Potamochoerus	*Potamochoerus porcus* (Linnaeus, 1758)	Red River Hog	80	1.86	Re	III	LC
	Hylochoerus	*Hylochoerus meinertzhageni* Thomas, 1904	Forest Hog	3	0.07	Ac	III	LC
Hippopotamidae	Choeropsis	*Choeropsis liberiensis* (Morton, 1849)	Pygmy Hippopotamus	105	2.44	Re	I	EN
Tragulidae	Hyemoschus	*Hyemoschus aquaticus* (Ogilby, 1841)	Water Chevrotain	14	0.32	Ra	I	LC
Ordre : Carnivora								
Viverridae	Civettictis	*Civettictis civetta* (Schreber, 1776)	African Civet	29	0.67	Ra	III	LC
Felidae	Panthera	*Panthera pardus* (Linnaeus, 1758)	Leopard	28	0,65	Ra	I	VU
Mustelinae	Mellivora	*Mellivora capensis* (Schreber, 1776)	Honey Badger	2	0.05	Ac	II	LC
Order : Primates								
Cercopithecidae	Cercocebus	*Cercocebus atys* (Audebert, 1797)	Sooty Mangabey	233	5.41	D	I	VU
Hominidae	Pan	*Pan troglodytes verus* Schwarz, 1934	Western Chimpanzee	45	1.04	Re	I	CR
Order : Proboscidea								
Elephantidae	Loxodonta	*Loxodonta cyclotis* Matschie, 1900	African Forest Elephant	37	0.86	Ra	I	CR
Order : Pholidota								
Manidae	Smutsia	*Smutsia gigantea* (Illiger, 1815)	Giant Ground Pangolin	4	0.09	Ac	I	EN
TOTAL				4309	100			

LC: Least Concern, **NT**: Near Threatened, **VU**: Vulnerable, **EN**: Endangered, **CR**: Critically Endangered.
I: Group I species, **II**: Group II species, **III**: Group III species.
D: dominant, **Re**: regular, **Ra**: Rare, **Ac**: Accidental

Figure 2. Images of some large non-arboreal mammals in Taï National Park.

(a) *Philantomba maxwellii*, **(b)** *Cercocebus atys*, **(c)** *Cephalophus ogilbyi*, **(d)** *Cephalophus niger*, **(e)** *Cephalophus silvicultor*, **(f)** *Tragelaphus eurycerus*, **(g)** *Cephalophus jentinki*, **(h)** *Cephalophus dorsalis*, **(i)** *Pan troglodytes verus* et **(j)** *Loxodonta cyclotis*

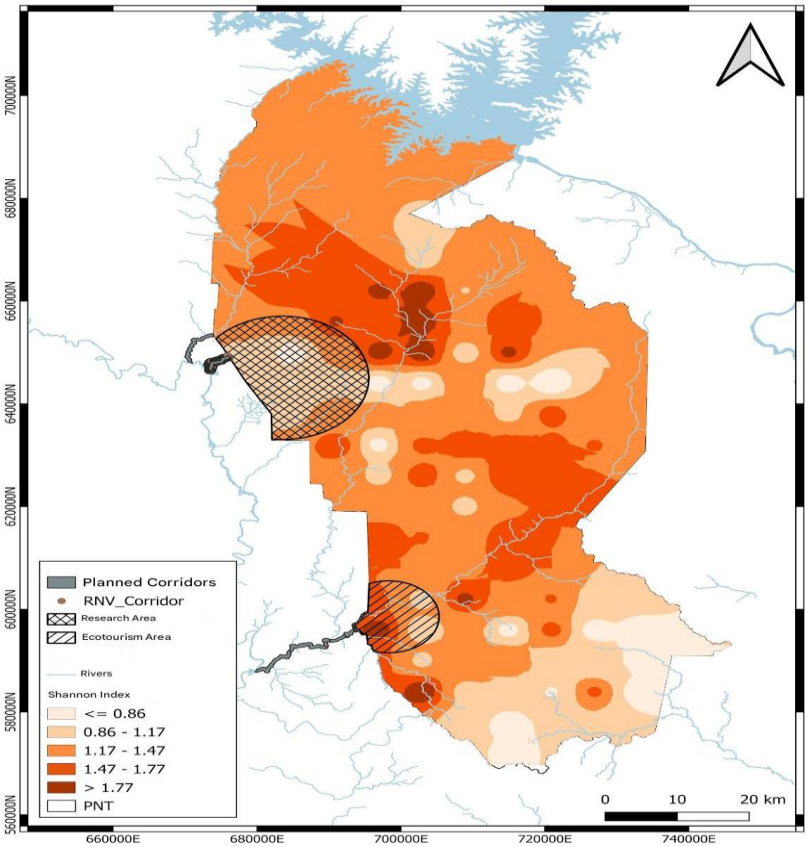

Figure 3. Spatial distribution map of large non-arboreal mammal across the Taï National Park .

The interpolation map of the large non-arborical mammals' diversity index obtained at each camera trap installation point shows that almost all of the TNP has a large non-arborical mammal diversity greater than 1.17. The areas of greatest diversity, with values in some places greater than 1.77, are located east of the Ecology Research Center (CRE), in an area heavily watered by tributaries of the Meno River and along the Hana River and its tributaries. The areas of low diversity are located within the CRE and in the southeastern part of the park. This work has made it possible to record five orders of large non-arboreal mammals: Primates, Carnivora, Pholidota, Proboscidea and Artiodactyla. The results are in agreement with those of Chatelain *et al.* (2001). This study did not reveal the presence of any species not yet described in the TNP. Thus, we can conclude that the park managers have a good knowledge of large non-arboreal mammals. For the order Artiodactyla, the four expected families were observed, namely: Suidae, Hippopotamidae, Tragulidae and Bovidae (Chatelain *et al.,* 2001). All species of the family Suidae (*Hylochoerus meinertzhageni* and *Potamochoerus porcus*), Hippotamidae (*Choeropsis liberiensis*) and Tragulidae (*Hyemoschus aquaticus*) have been observed. For the 10 species of the family Bovidae, taken into account in our study, recognized in the TNP (Chatelain *et al.,* 2001; Hoppe-Dominik *et al.,* 2011), nine were observed. Only the bushbuck *Tragelaphus scriptus*, was not observed. This absence of the bushbuck could be justified by the fact that this species is recognized as anthropophilic, i.e. better adapted to anthropogenic environments (Mathot *et al.,* 2006). While the sites we sampled, although prone to poaching (Kely *et al.,* 2021), remain relatively well preserved, with no farms or land clearing.

For Carnivora, three species were identified during our sampling. These are the Leopard Panthera pardus, the African Civet *Civettictis civetta* and the Ratel *Mellivora capensis*. Several studies have also confirmed the presence of these species in the TNP (Chatelain *et al.,* 2001; N'Goran *et al.,* 2020; WCF, 2020). For the Pholidota, only the Giant Ground Pangolin *Smutsia gigantea* has been observed. The two other species likely to be encountered in the TNP, namely the White-bellied Pangolin *Phataginus tricuspis*, and the Black-bellied Pangolin *Phataginus tetradactyla*, were not observed during our work. These unobserved species would be preferentially arboreal.

Maxwell's Duiker *Philantomba maxwellii* is the most abundant species in the TNP, and this finding is consistent with Newing (1994) and Hoppe-Dominik *et al.* (2011) who showed that Maxwell's Duiker *Philantomba maxwellii*

abundance was approximately nine times higher than that of other duikers. This observation would be justified by the resilience of this species to poaching pressures (Hoppe-Dominik *et al.,* 2011), the main pressure that threatens the TNP (UNEP, 2015). Our results reveal that the Ogilby's Duiker *Cephalophus ogilbyi* is relatively more abundant than the Bay Duiker *Cephalophus dorsalis* in the TNP. These results are consistent with those obtained by the WCF (2020), following camera trapping, and are in contradiction with those obtained during the various phases of biomonitoring which reveal that the Bay Duiker *Cephalophus dorsalis* is more abundant in the TNP than the Ogilby's Duiker *Cephalophus ogilbyi* (Tiedoué *et al.,* 2015, 2016, 2018). For example, for phases 11 and 12 of biomonitoring, the Bay Duiker *Cephalophus dorsalis* has a kilometric index of abundance of 0.029 and 0.049 individuals/km, respectively, while those of the Ogilby's Duiker *Cephalophus ogilbyi* are, over the same periods, 0.010 and 0.004 individuals/km. This difference with our results and those of other studies that have used camera traps could be linked to the fact that the agents in charge of biomonitoring confuse the Bay Duiker *Cephalophus dorsalis* with the Ogilby's Duiker *Cephalophus ogilbyi*. Indeed, these two species have very similar morphological traits. However, the species observed in the forest, during the movements of the biomonitoring teams, are most often on the run, making it difficult to characterize them. In addition, biomonitoring data for these two species would be inaccurate, as the Bay Duiker *Cephalophus dorsalis* is a nocturnal species in the TNP, as opposed to the diurnal Ogilby's Duiker *Cephalophus ogilbyi* (N'Goran *et al.,* 2020; WCF, 2020). Therefore, a high frequency of observation of the Bay Duiker *Cephalophus dorsalis* during the day would be problematic.

Amongst the 20 species of large non-arborical mammals observed in the TNP, eight are classified as having a “Special Status" on the IUCN Red List. This importance of species with a "special status" in the TNP attests to the central role of this park in the conservation of biodiversity in Côte d'Ivoire. It is therefore right that the TNP is defined as a biodiversity hotspot (Kolongo *et al.,* 2006). The interpolation of the diversity indices obtained at each camera trap installation point shows that the diversity of large non-arborical mammals remains high over almost the entire TNP. This observation corroborates those of the WCF (2020) which show that it is possible to observe between 10 and 22 species of large mammals over most of the park. It also happens that the areas richest in large mammals seem to coincide with the preferential distribution areas of the Forest Elephant *Loxodonta cyclotis* in the TNP obtained by Kely (2020) and Kely *et al.* (2021). This observation could be explained by the fact that through its action on the environment, the Elephant would promote the living conditions of other animal species. Indeed, the Elephant opens passages in closed vegetation, thus creating passages for other animals. It digs practical and favourable water holes for other herbivores (Bouché, 2012; Maisels *et al.,* 2013). In addition, the contribution of the Elephant to the regeneration of the flora is largely supported (Alexandre, 1978; Kouamé *et al.,* 2010; McConkey *et al.,* 2018; Berzaghi *et al.,* 2019). Thus, many animal species finding the food resources essential to their lives would share the habitat with this species. Also, the habitat of the Elephant in the TNP corresponds to the least disturbed and very wellpreserved sites (Boafo & Nandjui, 2011; Kely *et al.,* 2021). Such a habitat is a preferred refuge for large wildlife. Indeed, previous studies had shown that the distribution of the Elephant in the TNP was conditioned by the same factors as those of other large mammals, including the chimpanzee *Pan troglodytes verus*, the pygmy hippopotamus *Choeropsis liberiensis*, all duikers and the tailed monkeys (Boafo & Nandjui, 2011; Campbell *et al.,* 2011; Hoppe-Dominik *et al.,* 2011; N'Goran *et al.,* 2012; Bogui *et al.,* 2016; Diarrassouba *et al.,* 2019; Kely *et al.,* 2021; Monket *et al.,* 2022).

CONCLUSION

This work confirmed the presence of 20 species of large non-arboreal mammals in the TNP, belonging to 16 genus, 11 families and five orders. At the park level, four of these species are dominant, six are regular, six are rare and four as accidental. Of these species observed, 13 are fully protected, three are partially protected and four are said to be rapidly proliferating, at the national level. Internationally, eight of these species are said to be threatened. The areas east of the CRE and along the Hana River are the most diverse, while those located southeast and in the heart of the CRE are the least diverse in terms of large non-arboreal mammals. This study by camera trapping allowed to have more detailed data on the large non-arborical mammals of the TNP, unlike the linear transect method used for biomonitoring. Thus, we suggest that managers use camera trapping during biomonitoring, in order to have a more accurate mapping of wildlife in time and space.

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CONFLICT OF INTERESTS

The authors declare no conflict of interest

ETHICS APPROVAL

Not applicable

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AI TOOL DECLARATION

The authors declares that no AI and related tools are used to write the scientific content of this manuscript.

DATA AVAILABILITY

Data will be available on request

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