THE WESTERN CHIMPANZEE (*PAN TROGLODYTES VERUS*) IN THE ANTENNA ZONE (NIOKOLO KOBA NATIONAL PARK, SENEGAL): NESTING ECOLOGY AND SYMPATRICS WITH OTHER MAMMALS

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Abstract. The western chimpanzee (*Pan troglodytes verus*) is "Critically Endangered" due to a gradual decrease of its population and a continuous degradation of their habitats. Niokolo Koba National Park is considered an important biodiversity area in West Africa and has high conservation value for western chimpanzees. However, Niokolo Koba National Park has been inscribed on the World Heritage list as being in Danger since 2007 due to anthropogenic factors. Over the last 40 years, only sporadic and short-term studies on the ecology and behavior of chimpanzees in the park have occurred. For this reason, we studied the nesting ecology of a putative chimpanzee community in the Antenna zone. We also identified sympatric medium and large mammals using a camera trap. Chimpanzees mostly used *Hexalobus monopetalus* for nesting, followed by *Pterocarpus erinaceus*. Nest heights in the Antenna zone were lower than they are in Assirik, and outside the park at Fongoli and Diaguiri sites despite the presence of potential predators in the park. Predator presence influences nesting height behavior. These data deepen our knowledge about chimpanzees in Senegal, and are useful for the management plan of the park and will contribute to an action plan for their conservation there.
Keywords: *great apes, protected area, nest behavior, large wild mammals, Senegal*

Introduction

Nest building behaviors of wild chimpanzees have been reported by primatologists at various sites (e.g., Fruth and Hohmann, 1996; Hernandez-Aguilar et al., 2013; McGrew, 2021). The nests consist of vegetative structures that can remain visible for weeks or months according to the nest decay rate which depends on the site type, season, tree species bearing nest and sun exposure (i.e., degree of openness) in general (Kühl et al., 2008; Kouakou et al., 2009; Ndiaye et al., 2018a). Thus, due to the difficulty of making direct contacts with unhabituated great apes, many research projects and protected area monitoring programs have been carried out using nest counts to collect data for

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ecological and behavioral purposes (Furuichi and Hashimoto, 2004; Ogawa et al., 2007; Kühl et al., 2008; van Casteran et al., 2012; Dutton et al., 2017).

Chimpanzees learn to build day nests during their first three years of life (Fruth and Hohmann, 1996). Weaned individuals build nests in which they sleep at night or sometimes rest during the day (Goodall, 1968). Many studies are focused on nests for a better understanding of the ecology and behavior of chimpanzees (Basabose and Yamagiwa, 2002; Pruetz et al., 2002; Ogawa et al., 2007; Koops et al., 2012; Dutton et al., 2017). These authors agree that nest site selection is related to environmental factors, such as predator avoidance, human hunting pressure, climatic conditions, habitat types, tree species and the availability of ripe fruits among others. For example, chimpanzees rarely build night nests in trees offering ripe fruits, but instead stay close enough to reoccupy the tree early in the morning (Fruth and Hohmann, 1994; Basabose and Yamagiwa, 2002; Hernandez-Aguilar, 2009; Hernandez-Aguilar et al., 2013). Selection of nesting sites and tree species bearing nests by chimpanzees has been described by several authors. For example, Stanford and O'Malley (2008) found that chimpanzees used only 38 of at least 163 available tree species for nesting in Bwindi (Uganda) and, of these, they only used four tree species heavily. In Toro-Semliki in Uganda, chimpanzees prefered *Cynometra alexandri* for the majority of their sleeping nests (Samson and Hunt, 2014). Some studies have focused on the nest building ecology and behavior of chimpanzees in Senegal but most stem from outside of protected areas (Pruetz et al., 2002, 2008; Ndiaye et al., 2013a, 2018a, b; Stewart and Pruetz, 2013; Badji et al., 2018). There exists only relatively old data of nesting behavior of chimpanzees in Niokolo Koba National Park (NKNP), focusing on Mt Assirik in the late 1970s and 2000 (Baldwin et al., 1981; Pruetz et al., 2008). Baldwin et al. (1981), described that environmental factors, namely season, habitat type, tree height, tree species and predation also risk influence nesting behavior, comparing Equatorial Guinea and Senegal. Baldwin et al. (1981) examined many other variables, such as nest height, nest-group size, nests per tree, minimum distance between nests, whether or not the nest was open and girth of the tree bearing the nests. Primatologists have recognized recently the importance of documenting the potential effects of climate change on primates (Sesink et al., 2015; Korstjens and Hillyer, 2016; Sales et al., 2020). Range of mean annual rainfall in Assirik in 1976-79 was between 824 and 1224 mm and the mean annual rainfall was 954 mm (McGrew et al., 1981). Now, in the face of global habitat loss of mammals due to land-use and climate change (Baisero et al., 2020), we think that data on the ecology of chimpanzee in the hot and dry environment of Assirik (NKNP) is needed.

Danger from terrestrial predators is often hypothesized to influence chimpanzee nesting behavior (Baldwin, 1979; Tutin et al., 1981; Pruetz et al., 2008; Stewart and Pruetz, 2013). Stewart and Pruetz (2013) investigated nesting behavior at Issa (Tanzania) where chimpanzees lived in a predator-rich habitat and compared it to a habitat relatively devoid of predators at Fongoli (Senegal) outside of NKNP. These authors found that in Issa, chimpanzees nested more frequently within the same tree as other community members and they built their nests proportionately higher and more peripherally within trees than in Fongoli (Stewart and Pruetz, 2013). A somewhat similar pattern was found by Pruetz et al. (2008) in their comparison of nesting behavior at Fongoli and Assirik. These authors found that Assirik chimpanzees constructed nests higher in the tree canopy and individuals nested in closer proximity to each other, as expected in the environment with higher predator species richness.

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In a larger survey of chimpanzees in Senegal, Ndiaye et al. (2013a, b) found that chimpanzees made their nests mostly in gallery forests during the dry season and showed a preference for particular trees, with *Pterocarpus erinaceus* being the most preferred tree species.

However, in Bagnomba, a site close to the NKNP, the most preferred tree species is *Diospyros mespiliformis* (Badji et al., 2018), which shows that nesting tree preference varies among sites in Senegal. Multiple studies outside of the NKNP in Senegal have described the influence of habitat, season, and tree species on the western chimpanzee nesting behavior (Stewart and Pruetz, 2013; Badji et al., 2018; Ndiaye et al., 2018a, b).

Since the early 1980s, there has been relatively little research in the NKNP, the only national park in Senegal with this "Critically Endangered" species. According to Hunt and McGrew (2002), the study of chimpanzees at the edges of the species' range may also have conservation implications. Documenting behaviors associated with dry-habitats should extend our knowledge of the capacities of chimpanzees to adapt to their environment. Therefore, we stress the importance of investigating chimpanzees in the NKNP, and their ecology and behavior in accordance with the consideration that the NKNP is an area of high conservation value for the western chimpanzee (Heinicke et al., 2019).

The western chimpanzee is one of the more threatened species in the world (Schwitzer et al., 2019), and Niokolo Koba National Park is at the northwestern limit of its geographic distribution. The NKNP is one of the largest natural parks in West Africa, with an area of 913 000 ha. It was added to the list of UNESCO World Heritage Sites in 1981 and classified as "In Danger" in 2007 (UNESCO, 2019). The park contains a significant diversity of mammals, including the western chimpanzee, West African red colobus (*Procolobus badius temminckii*), Lion (*Panthera leo*), African wild dog (*Lycaon pictus*), Leopard (*Panthera pardus*), Spotted hyena (*Crocuta crocuta*), African elephant (*Loxodonta africana*), Hippopotamus (*Hippopotamus amphibious*), Western giant eland (*Taurotragus derbianus*), Roan antelope (*Hippotragus equinus*), and African buffalo (*Syncerus caffer*) (Papaco – International Union for Conservation of Nature, 2009; UNESCO, 2011). However, the park is under heavy pressure related to an international highway running through it and the rapid growth of extractive mining in Kedougou, which is southeast of NKNP (Ndiaye et al., 2018b; Lindshield et al., 2019). Chimpanzees are one of the flagship species of the park. Due to the decline of the western chimpanzee populations (Kühl et al., 2017), the species is listed in Annex I and II of the Convention on the Conservation of the Migratory Species of Wild Animals (CMS) in 2017 (UNEP/CMS/COP 12, 2017), Appendix 1 of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES, 2018) and was reclassified as "Critically Endangered" in the red list of the International Union for Conservation of Nature in 2016 (IUCN, 2018).

Studies that have been done to date of the western chimpanzee in NKNP have focused on the Mont Assirik site (Baldwin, 1979; Baldwin et al., 1981; McGrew et al., 1981, 2014; Tutin et al., 1981, 1983; Pruetz et al., 2008, 2012; Ndiaye et al., 2018b; Lindshield et al., 2019). Chimpanzee nests have also been reported in the southeastern part of NKNP, in the Antenna zone, near the international highway (Pruetz et al., 2012). However, there is a lack of information about chimpanzees at this site.

Additionally, little is known about the relationships between chimpanzees and sympatric mammals, particularly other primate species, in this area of the NKNP. Chimpanzees share habitats with many other large mammals such as leopard, buffalo,

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elephant, lion, other primates species that may potentially influence nesting behavior here. In general, the influence of large sympatric mammals on nesting behavior of chimpanzees is poorly known (Basabose and Yamagiwa, 2002; McGrew et al., 2014; Piel et al., 2019). Information about nesting behavior in a protected area of Senegal is needed for a better understanding of relationships between the chimpanzees and their environment in this extremely hot and dry savannah region, and in comparison with chimpanzees living in other countries and habitat types (Anderson et al., 1983; Brownlow et al., 2001; Hernandez-Aguilar, 2009; Koops et al., 2012; Hernandez-Aguilar et al., 2013; Carvalho et al., 2015; Hakizimana et al., 2015; Dutton et al., 2017). We aim to provide information on a putative new chimpanzee community in the Antenna zone of southeastern NKNP and compare their nesting ecology with that of chimpanzees at other sites. Given the known big ranges of savanna chimpanzees, this is possible and deserves testing that Antenna chimpanzees community could be the same community that is at Assirik, which is only 17.5 km (as a crow flies) from Antenna zone, and which is accessible to it via tributaries of the Niokolo Koba River. Thus, we provide new data on chimpanzees nesting behavior in NKNP in Senegal and how these data can help the conservation of western chimpanzees and their habitats in Senegal. We also present a preliminary assessment of the presence of other medium and large mammals in the Antenna zone, using three months of data from one camera trap as well as data from previous occasional surveys.

Materials and methods

Study site

We conducted our study in the "Antenna zone" (UTM Zone 28N; 752139E, 1442478N) of NKNP, near the Dakar-Kedougou-Bamako transportation corridor (N7 highway) (*Fig. 1*). We collected field data during July 2017, January-March 2018, and September-November 2018.

NKNP is in southeastern Senegal (West Africa) and the region is characterized by a hot and dry climate with mixed tree and grass vegetation (McGrew et al., 1981; Pruetz et al., 2002; Ndiaye et al., 2018a). The vegetation classification falls within a transitional Sudano-Guinean savanna system that is dominated by woodlands and grasslands (Ba et al., 1997). The majority of this savanna landscape consists of open-canopy vegetation (e.g., gallery forest, ecotone forest). The most common tree species include *Adansonia digitata, Afzelia africana, Anogeissus leiocarpus, Bombax costatum, Combretum glutinosum, Combretum nigricans, Daniellia oliveri, Hexalobus monopetalus, Parkia biglobosa, Piliostigma thoningii, Khaya senegalensis, Sterculia setigera, Pterocarpus erinaceus, Tamarindus indica, Terminalia macroptera* and *Vitellaria parkii* (Ba et al., 1997; Pruetz et al., 2002; Ndiaye et al., 2018b). The Kedougou region is one of the rainiest parts of Senegal and the gallery forests here are seasonally flooded. Annual rainfall ranged 900-1800 mm in 1995-2015, with a long-term mean of approximately 1200 mm. During the same period, the mean annual temperature was 28.6 °C (Agence Nationale de l'Aviation Civile et de la Météorologie 2015; Faye et al., 2019). The dry season occurs from November to April and the rainy season occurs from June to October (Ndiaye et al., 2018a), with May as a transitional month. According to Korstjens and Hillyer (2016), rainfall has decreased generally in sub-Saharan Africa since 1901. In recent years, temperature variations have increased in general in Senegal in relation to regional climate change (Funk et al., 2012; Sarr et al., 2013, 2015).

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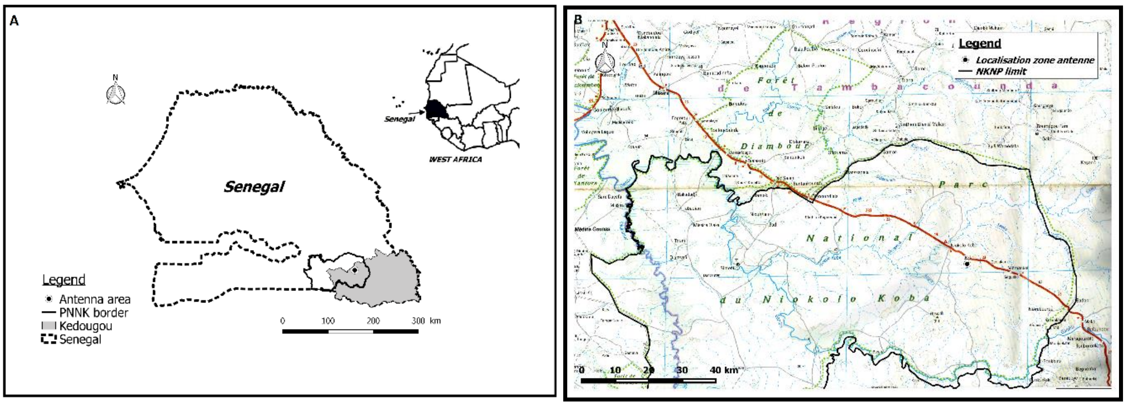

Figure 1. *Locations of Niokolo Koba National Park in Senegal, West Africa (A), and the Antenna zone in the park in relation to the N7 highway and to the Assirik chimpanzee site (labeled "Hassirik") (B). (Projection: UTM Zone 28 datum WGS 84; Data source: Database of Global Administrative Areas, created by PI Ndiaye)*

Data collection and analysis

Recce-transect survey

Primatologists concur that counting chimpanzee nests along line transects is one of the best methods for identifying the presence or absence of wild, unhabituated chimpanzees (Kühl et al., 2008; Junker et al., 2009; Arandjelovic et al., 2014) but applying this method to the savanna environments in Senegal involves intensive sampling of vegetation types that can be poorly suited for nesting, such as plateau grasslands with scattered trees and shrubs (Pruetz et al., 2002). For this reason, we used a recce-transects approach (Maisels et al., 2008) to search opportunistically for nests on the edges of gallery forest in the Antenna zone following Ndiaye et al. (2013a, b; 2018b) in order to maximize the number of nests encountered during the study. The recce-walk method is a survey on foot in a predetermined direction along a path of least resistance, which can deviate by any degree, through the survey area (Kühl et al., 2008; Maisels et al., 2008; Ndiaye et al., 2018b). Recce-transects were conducted in July 2017 and January-March 2018 to record fresh and recent nests, and follow-up surveys were conducted from September 5-November 12, 2018 to additionally sample old and rotting nests (*Fig. 2*). During the last survey period in 2018, we sampled in both the dry and wet seasons. Data collected during the all survey periods were used to visualize the distribution of nests within the study area, while only data collected from September to November 2018 were used for statistical analyses with Excel software (see below) to avoid duplicating data on fresh or recent nests surveyed in January-March 2018.

For each nest we encountered during surveys, including single or multiple nests in close proximity, we recorded the date and time, and the geographic coordinates using a GPS Garmin etrex 10. The accuracy Garmin etrex 10 is about 3 meters 95% of the time. We used the tracking option of the GPS to ensure we measured each nest only once, in case recce-transects overlapped. In addition, we recorded the vegetation type (gallery forest, plateau, woodland, grassland and bamboo) following McGrew et al. (1981), and tree species bearing each nest, using our personal experience and identification keys (Arbonnier, 2009). We measured the height of the nest above the ground using a Tracker 670 laser rangefinder and determined the nest age class according to Tutin and

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Fernandez (1984). We identified fresh nests as being used the night before, with the presence of copious green and moist leaves. In addition, we often found fresh feces or urine on the ground beneath new nests. Recent nests had green leaves that were wilted and drying. Old nests had a mixture of green and brown dried leaves or consisted entirely of brown leaves. Rotted nests ranged from disintegrating brown leaves to leafless structures consisting only of the branchy frame.

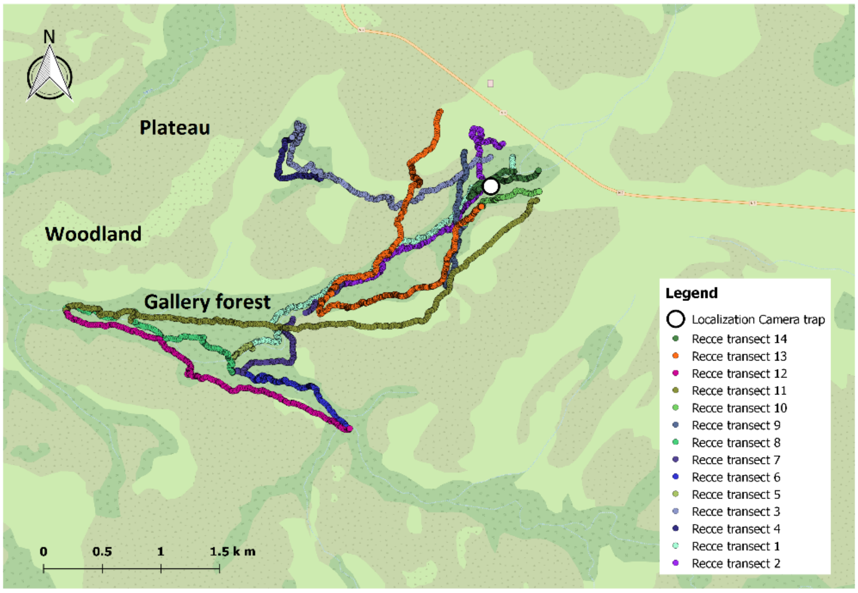

Figure 2. *Locations of recce-transects in the Antenna zone of Niokolo Koba National Park, Senegal, from September 5 to November 12, 2018. (Projection: UTM Zone 28 datum WGS 84; Data source: OpenStreetMap standard, created by PI Ndiaye)*

We used the nests we recorded to determine the chimpanzees' nest encounter rate (Kiszka et al., 2007; Gurarie and Ovaskainen, 2013) as *Equation 1:*

$$N/L \tag{Eq.1}$$

where "N" is the number of censused nests and "L" is the total distance surveyed (km).

Vegetation survey

To assess nesting tree species preference, we conducted vegetation surveys at nesting sites and along the recce-walks in a total of 26 quadrats, each measuring 20 × 20 m (400 m^2) with a total quadrat zone of 10,400 m^2. We measured all trees with a diameter at breast height ≥ 10 cm in each quadrat. The relative abundance of each species was calculated to identify common and rare tree species at nesting sites, identifying species based on personal experience and identification keys (McGrew et al., 1981; Arbonnier, 2009). We determined whether a tree species was preferred for nesting by plotting a histogram comparing the proportion of nests in each tree species with the relative abundance of each tree species. We used a simple linear regression test to evaluate relationships between nesting tree species and the tree species abundances and to determine if chimpanzees prefer certain tree species for nest building in the Antenna zone**.** All the maps are done with Qgis 2.18.28 software.

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Camera trap

Medium and large mammal presence was determined using one camera trap (Bushnell Trophy Cam HD Essential) in order to survey for sympatric mammals. The camera was positioned at a nesting site in a large gallery forest from September, 05 to November, 12, 2018 (N = 68 camera trap days) (*Fig. 2*). We calculated the relative abundance of each species using the equation: (l/L) x 100 according to Hedwig et al. (2018) where "l" is the number of all the individuals of one species captured with the camera trap and "L" is the number of all individuals of all species captured during the survey.

Results

During the preliminary surveys, we recorded 14 fresh and 76 recent nests in July 2017 and 41 fresh and 112 recent nests from January to March 2018 (*Fig. 3A*). During the last data collection period (from September 5 to November 12, 2018), we conducted 14 recce-transects (*Fig. 2*), totaling 34 km in length in a 12 km^2 area and recorded 262 chimpanzee nests including 16 fresh (6%), 23 recent (8.8%), 18 old (6.9%) and 205 (78.3%) rotten nests (*Fig. 3B*). The encounter rate is 7.70 nests/km. Most nests (n = 254; 97%) were in the gallery forests that connect to the Gambia River via "Bo ko", a tributary of the Niokolo Koba River. Only 8 nests (3%) are encountered in woodland. We have not encountered chimpanzee's nest in plateau, grassland and bamboo.

Nest location and nesting tree species preference

The locations of nests in *Figure 3A* and *B* indicate that chimpanzees built their sleeping nests in the same area in the Antenna zone between July 2017 and November 2018.

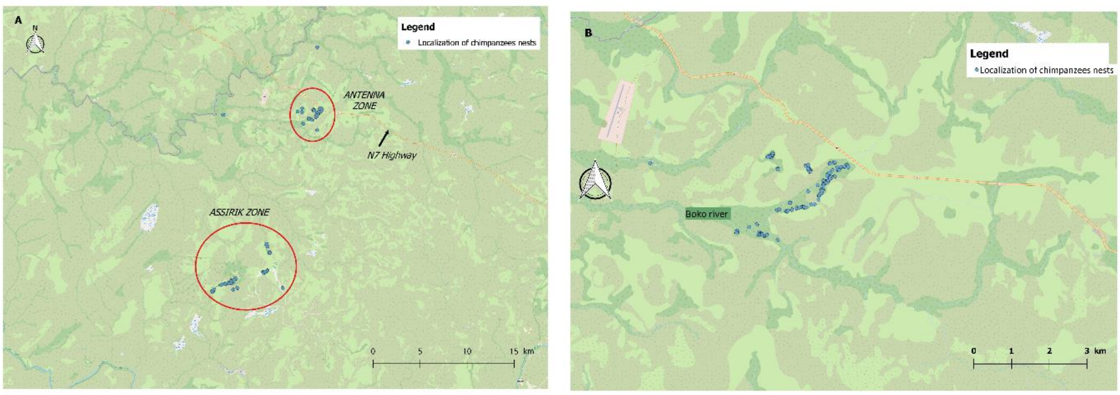

Figure 3. *Location of chimpanzee nests in the Antenna zone, Niokolo Koba National Park, Senegal (A) in 2017 and 2018, in relation to the Assirik zone (unpublished data); (B) from September to November 2018, showing Antenna zone only. (Projection: UTM Zone 28 datum WGS 84; Data source: OpenStreetMap standard, created by PI Ndiaye)*

Chimpanzees in the Antenna zone have at least 34 tree species to construct sleeping nests. Most of the nests (84%) were associated with four tree species, including

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Hexalobus monopetalus (46%), *Pterocarpus erinaceus* (22%), *Anogeissus leiocarpus* (9%), and *Combretum* sp. (7%). The remaining 16% of nests were associated with 30 other species, such as *Malacanta alnifolia* (4.6%), *Khaya senegalensis* (2.7%), *Diospyros mespiliformis* (1.9%) and *Cola cordifolia* (1.5%) among others (*Fig. 4*). We counted 711 trees in the sample quadrats and identified a total of 34 species (*Fig. 4*). Eight of these 34 tree species comprised 73% of the sample, namely *H. monopetalus* (17.7%), *Combretum* sp. (17.9%), *P. erinaceus* (17%), *Piliostigma thonningii* (7.6%), *Lannea microscarpa* (4.9%), *Vitex guineensis* (4.3%), *M. alnifolia* (4.5%) and *A. leiocarpus* (3.5%). These results suggest that *H. monopetalus, P. erinaceus* and *A. leiocarpus* are respectively the most used tree species by chimpanzee to bear their nests in this site. But the most abundant tree species in the study site are respectively *H. monopetalus, Combretum* sp., *P. erinaceus* and *P. thonningii.*

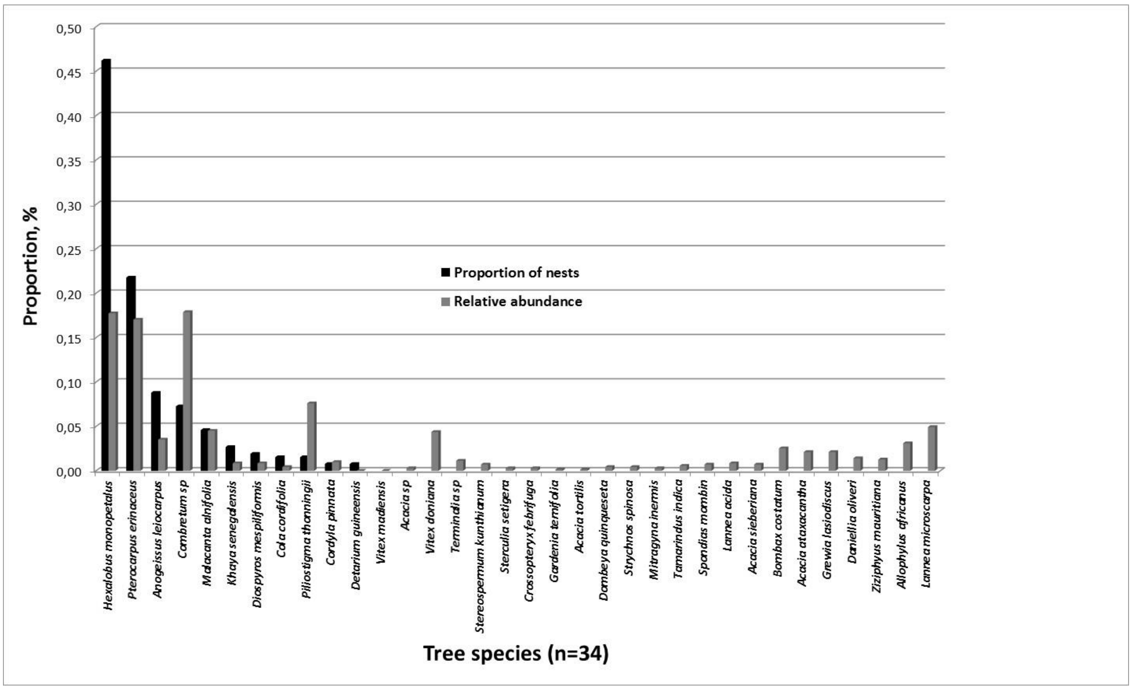

Figure 4. *Tree abundance (%) of 34 tree species (n = 711 trees) and abundance (%) of nests (n = 505) in the Antenna zone (NKNP, Senegal)*

Simple linear regression permitted us to have the values indicated in *Table 1* and *Figure 5*.

Table 1. *Statistical data of linear regression between relative abundance of nests (n = 505 nests) to abundance of trees (n = 711 trees) in Antenna zone, NKNP (Senegal)*

R square	Adjusted R	Standard error	P-value	Ecart-type	Confidence intervals
0.6061	0.5937	22.2803	5.9364	0.1707	95%

Nest height

We did not encounter ground nests during this study. The majority of nests (246 nests; 94%) were between 3 to 14 m above the ground and 36% (94 nests) of these nests

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were between 6 to 9 m (*Fig. 6*). Mean nest height was 8.7 ± SD 3.34 m with a range of 1-30 m and median range of 8 m. More than half of the nests (n = 163 nests; 62%) were at 5-10 m.

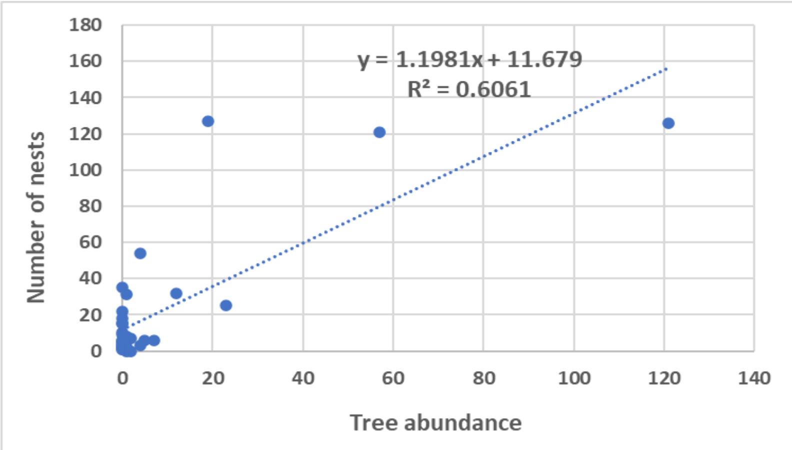

Figure 5. *Overall relationship between relative abundance of nests (n = 505 nests) to abundance of trees (n = 711 trees) in Antenna zone, NKNP (Senegal)*

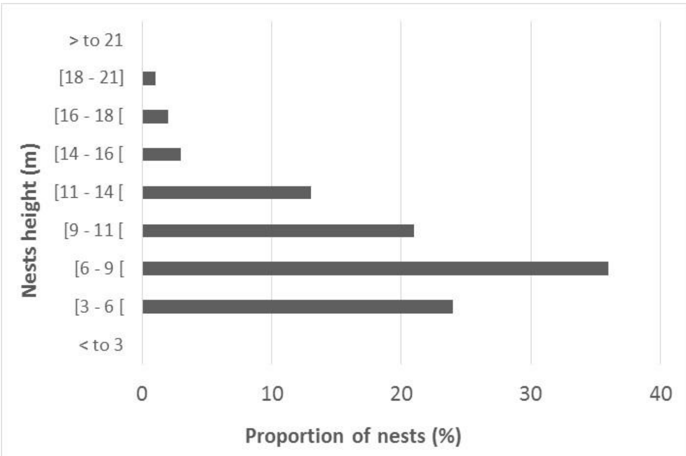

Figure 6. *Proportion (%) and number (n = 262) of chimpanzees nests over four height classes in Antenna zone, NKNP*

Sympatric mammals

We identified nine mammal species in the Antenna zone in addition to the West African chimpanzee (*Pan troglodytes verus*), including, three large carnivore species: the spotted hyena (*Crocuta crocuta*), the lion (*Panthera leo*), the leopard (*Panthera pardus*); four large herbivores: the roan antelope (*Hippotragus equinus*), the warthog (*Phacochoerus africanus*), the African buffalo (*Syncerus caffer*), the bushbuck (*Tragelaphus scriptus*); one small ungulate: the red-flanked duiker (*Cephalophus rufilatus*) and one monkey species: the Guinea baboon (*Papio papio*) (*Table 2*). Guinea baboons (*Papio papio*) and western chimpanzees account for 27.6% and 10.3% of camera trap images, respectively, at our study site (*Fig. 7*). The presence of leopard (*Panthera pardus*) was verified with a camera trap during the preliminary survey.

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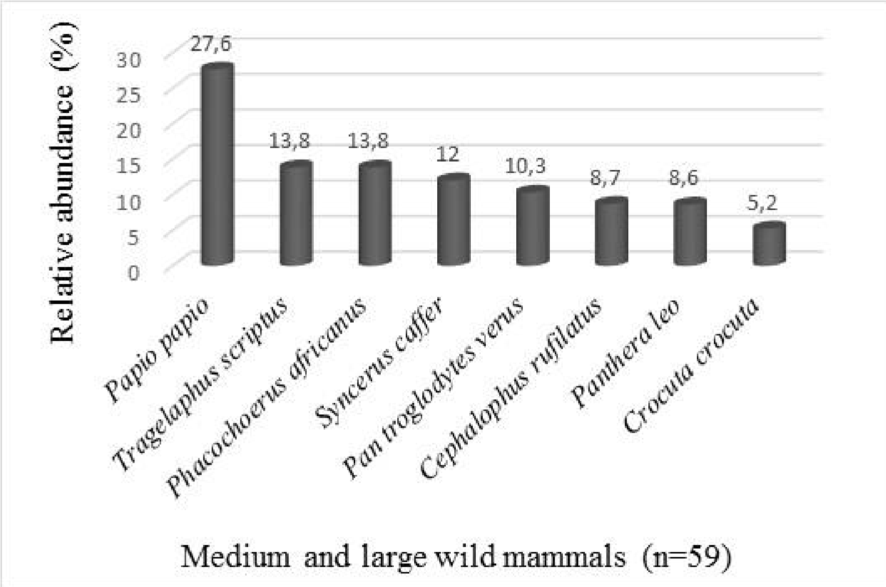

Figure 7. *Relative abundance (%) of medium to large mammalian species recorded on a camera trap in Antenna zone, NKNP*

Table 2. *List of sympatric mammals detected using a camera trap in the Antenna zone, Nokolo Koba National Park between September 5 to November 12, 1998*

Order	Family	Species	English name	French name	IUCN Status	Absolute abundances of species in CT images (n = 59)
Cetartiodactyla	Suidae	*Phacochoerus africanus*	Warthog	Phacochère	LC decreasing	8
	Bovidae	*Tragelaphus scriptus*	Bushbuck	Guib harnaché	LC	8
		Syncerus caffer	African buffalo	Buffle de savane	LC decreasing	7
		Cephalophus rufilatus	Red-flanked duiker	Cephalophe à flanc roux	LC decreasing	5
		Hippotragus equinus	Roan antelope	Hippotrague	LC decreasing	**
Carnivora	Felidae	*Panthera leo*	Lion	Lion	VU decreasing	5
		Panthera pardus	Leopard	Léopard	VU decreasing	*
	Hyenidae	*Crocuta crocuta*	Spotted hyena	Hyène tachetée	LC decreasing	3
Primates	Cercopithecidae	*Papio papio*	Guinea baboon	Babouin de Guinée	NT	16
	Hominidae	*Pan troglodytes verus*	Chimpanzee	Chimpanzé de l'Ouest	CR	6

CR = Critically Endangered; NT = Near threatened; LC = Least Concern; VU = Vulnerable
*Leopard was not included in the calculation of "frequencies of species in CT images" because the picture was recently taken from another camera trap dataset from Antenne and at the time of writing the species identifications from this dataset were incomplete
**We have only one direct observation of roan antelope during the prospections

Discussion

The simultaneous presence of fresh and recent nests indicates the presence of chimpanzees in the Antenna zone in NKNP over the period of our study. The high percentage of rotten nests may be because we carried out the study towards the end of the rainy season. Chimpanzee nests generally decay relatively fast during the rainy season and in gallery forests in the nearby non-protected area of Kedougou (Diaguiri: Ndiaye et al., 2018a; PI Ndiaye, unpublished data).

In this study, within the Antenna zone chimpanzees nest in the most abundant tree species found in this area of NKNP, namely *Hexalobus monopetalus, Pterocarpus erinaceus* and *Combretum* sp., together comprising 84% of the total nests. These patterns are similar to those at other sites in Senegal (Ndiaye et al., 2013b, 2018a; Badji et al., 2018), but differ mostly in the percentage of nests in other species, such as *K. senegalensis, A. digitata, Diospyros mespiliformis* and *H. monopetalus,* at Bagnomba and Diaguiri (Ndiaye et al., 2018a, b). Sousa et al. (2014) also highlighted that chimpanzees in Guinea-Bissau made the majority of their nests in sub-humid forests with sparse canopy and in forest with dense canopy. Dutton et al. (2017) are also described that environmental factors affected nest site and species bearing choices by chimpanzees in Nigeria. According to these authors, *P. t. ellioti* made 52.9% of their nests in only five tree species of the 123 tree species recorded. Many authors, including Ndiaye et al. (2013a, 2018a), Hakizimana et al. (2015) and Badji et al. (2018), have described that chimpanzees prefer certain tree species for sleeping nests in Senegal, Burundi and Cameroon. Physical characteristics of the wood, particularly the hardness and flexibility are one of the most determining properties in this choice. We also recorded several tree species that had nests in them more than we expected based on their abundance at Antenna, including *K. senegalensis*, *D. mespiliformis* and *C. cordifolia*. These data indicate that chimpanzees prefer to nest in these tree species at the Antenna site. These species usually grow up to 7-8 m in height (Arbonnier, 2009), which is lower than the average of the nesting tree height at two sites in unprotected areas of Senegal, including Diaguiri (Ndiaye et al., 2018a) and Bagnomba (Badji et al., 2018). Simple lineaire regression showed a positive value of the correlation coeficience ($R^2 = 0.6061$; $0 < r < 1$). Thus, we can deduce a low relationship between trees species bearing nests and their abundance in the case of Antenna zone. In this case, the number of nests on *H. monopetalus, P. erinaceus* and *Combretum* sp. seem to increase with this tree species abundance. But we trust strongly that chimpanzees have preference for tree and sites bearing nests similar to the others sites in Senegal (Baldwin, 1979; Ndiaye et al., 2013a, 2018a; Badji et al., 2018). Baldwin (1979) found huge differences in nest frequency across vegetation types, at the nearest site to Antenna zone. In the case of our study, we have not focused on the division of nests between vegetation types, although we have not recorded this information. *A. leiocarpus* and *P. thonningii* are generally one of the most tree bearing chimpanzees' nest in Senegal. But we note that *A. leiocarpus* is the third most common tree species bearing chimpanzees' nest in this site and is not among the four most abundant species. *P. thonningii* is the fourth abundant tree species in this site but bear only few nests. It is not listed among the four most common species bearing the nest. Thus, we can hypothesize that the choice of tree species bearing nests by chimpanzee does not depend only on the tree abundance in the sleeping site. Others factors such as the habitat type, presence or absence of predator, social organization and food availability can influence the selection of tree species bearing chimpanzee's nests (Baldwin et al., 1981; Carvalho et al., 2015; Badji et al., 2018). Concentration of nests

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near a major highway also could indicate avoidance of predators, if the letter are discouraged by human activity, such as traffic. Fatal costs to chimpanzees of living near highways has been shown by Cibot et al. (2015) and Krief et al. (2020) at Kibale, Uganda.

While *Hexalobus monopetalus* is among the top species used at other sites, such as Bagnomba and Diaguiri (Ndiaye et al., 2018a, b), it is not the preferred species elsewhere outside the NKNP. *Pterocarpus erinaceus* is the most used species in the Kedougou region (Baldwin, 1979; Ndiaye et al., 2013a, 2018a, b), probably due to the quality of its wood, and particularly its hardness (which explains why this species is often used by woodworkers) (Ndiaye et al., 2013a). In Assirik (NKNP), Baldwin (1979) have described *Pseudospondias microcarpa* and *Erythrophloem suaveoleus* were the most used species to bear nests in forest habitats. But in grassland and woodland, *Pterocarpus erinaceus* was used the most used species. However, *H. monopetalus* is the most abundant species at the Antenna zone, fruits at the beginning of the rainy season, and also has a high-quality wood (Arbonnier, 2009), which may explain why the chimpanzees preferred it in our study. Fruit abundance and vegetation type had much stronger influences on site selection than did other factors for chimpanzees at Kalinzu (Uganda) (Furuichi and Hashimoto, 2004) and we hypothesize that similar factors could promote the high use of *H. monopetalus* by Antenna chimpanzees. Additional long-term research on chimpanzee nesting behavior in Antenna zone might confirm or reveal differences about nesting trees species preferences.

Although chimpanzees select particular trees species for nesting, the principles that guide species preferences are poorly understood. For example, in Semliki (Uganda), another savanna chimpanzee site, *Cynometra alexandri* (Fabaceae, which is the same family as *P. erinaceus*) constitutes only 9.6% of trees in the gallery forest in which their study population range but represented 73.6% of the chimpanzee nests (Samson and Hunt, 2014). However, most authors agree that structural properties of the tree species, their height and feeding are also key choice features in chimpanzees nesting behavior (Hunt and McGrew, 2002; Ogawa et al., 2007; Ndiaye et al., 2013a; Stewart and Pruetz, 2013; Badji et al., 2018). Chimpanzees at the Antenna site may make similar choices in choosing nesting species (Samson, 2012; Ndiaye et al., 2013a; Samson and Hunt, 2014).

The chimpanzees of the Antenna zone continued to build their nests on the edges of gallery forest during and immediately following the rainy season. This contrasts with previous studies showing that chimpanzees nest in higher elevations during the rainy season in most unprotected areas across Kedougou (Ndiaye et al., 2013b) and elsewhere in Africa (e.g., Koops et al., 2012). We hypothesize that the topographic relief in the Antenna zone explains this difference, as the area includes numerous elevated areas at the edges of the gallery forests (Gessain, 1963). However, using only nests may fail to consider the seasonality of chimpanzees ranging and should not imply that only areas where nests are observed are valuable for conservation. Data on human pressures and the availability of fruiting trees are required for a better understanding of chimpanzee distribution.

Chimpanzees in the Antenna zone built the majority of their nests (62%) at 5-10 m in height. This is similar to findings for chimpanzees in the non-protected area of Bagnomba, to the south-east of NKNP (Badji et al., 2018). Despite the presence of potential predators (lion, spotted hyena and leopard), nest heights in the Antenna zone in this study seem to be lower than those described for Assirik, situated only about

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16 km to the west (Baldwin, 1979). But, we want to repeat this study in the same periods and at the same time in these different sites before making a strong hypothesis. The range of heights of nests at Assirik is greater than those recorded in Guinea and Equatorial Guinea (Baldwin, 1979; Baldwin et al., 1981). However, further research is needed to verify if this is still true. In Senegal, the chimpanzees mean nest height is lower than the mean tree height at Fongoli, Assirik and Diaguiri (Baldwin, 1979; Pruetz et al., 2008; Ndiaye et al., 2013a; Badji et al., 2018; Ndiaye et al., 2018).

At Assirik, chimpanzees face four species of large carnivore (Pruetz et al., 2008; McGrew et al., 2014), while at Fongoli, humans have exterminated almost all natural predators, although leopard and hyena persist at low densities (Pruetz, unpublished data). Chimpanzees at Fongoli nested at lower heights and farther apart than did chimpanzees at Assirik and sometimes made nests on the ground (Pruetz et al., 2008). Many researchers have also investigated the relation between chimpanzee nest height and the presence of terrestrial predators elsewhere in Africa (Koops et al., 2012). For example, Gombe (Tanzania) chimpanzee nests may be constructed at any height above 4 m from the ground up to 25 m (Baldwin et al., 1981; Hernandez-Aguilar, 2006). The chimpanzees of Issa (Tanzania) prefer tall trees with high first branches for nesting, thus supporting the hypothesis that elevated height of a sleeping place is a predator defense strategy (Hernandez-Aguilar et al., 2013; Hernandez-Aguilar and Reitan, 2020). Chimpanzees in Issa, where several potential predators exist, did not nest more frequently in forest vegetation than chimpanzees in Fongoli, although forest vegetation is expected to provide greater opportunity for escape from terrestrial predators (Stewart and Pruetz, 2013). According to Baldwin (1979) and Stewart and Pruetz (2013), nest height correlated weakly with tree height, suggesting that height from the ground to the first branch may be a more important factor than tree height alone in selecting a tree in which to nest. Many factors influence nest site selection in chimpanzees, of which danger from terrestrial predators is likely to be one (Tutin et al., 1981). Further study of nesting tree characteristics and preferences is necessary to improve our understanding of the ecology and behavior of chimpanzees in the hot and dry habitat of Antenna zone. The distance between Assirik and Antenna zone is about 16 km. Mt Assirik's environment fulfills all three criteria for savanna with mean annual rainfall range about 824 to 1224 during the long-term study project SAPP 1976-1979 (McGrew et al., 1981; Russak and McGrew, 2008; McGrew et al., 2014). Nest heights in the Antenna zone seem to be lower than Assirik and the presence of predators (lion and leopard) has also been described in this site since many years (Baldwin, 1979; McGrew et al., 2014; Lindshield et al., 2019). Thus, we can hypothesize that nest height does not only depend on rainfall and the presence or absence of predators.

The influence of competitors on chimpanzee behavior in Senegal is relatively unstudied. Therefore, competition may be high between the two non-human primates most frequently captured by cameras in the Antenna zone, chimpanzees and Guinea baboons, for resources related to sleeping mostly. Repeated visits by lions and spotted hyenas to this area may be related to the abundance of their potential prey, especially baboons. The high frequency of baboons at the site may also imply competition for food with the chimpanzees (Matsumoto-Oda and Kasagula, 2000). Thus, there are many reasons (e.g., predation, competition) to examine the diversity of sympatric mammalian fauna that live sympatrically with wild chimpanzees (Russak and McGrew, 2008; Piel et al., 2019).

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Conclusion, recommendations and future studies

Our study provides new data about the nesting behavior of chimpanzees in NKNP. The location of nests near the N7 highway highlights the possible acclimation of chimpanzees to anthropogenic pressures because we encountered the nesting sites not far from the N7 highway (within 500 m to 3 km from the road). We found that *Hexalobus monopetalus* was used most frequently for chimpanzee nests, unlike in other studies in Senegal.

These results will contribute to the ongoing management of NKNP and to the construction of a national action plan for chimpanzees in Senegal.

Further we think that long-term studies are needed for a better understanding of chimpanzee nesting behavior in Antenna zone and of broader, community-ecological relationships to better understand how chimpanzees and other species share landscapes and mutually exploit resources.

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Compliance with ethical standards. This study was carried out following the code of best practices for field primatology of the International Primatological Society (Riley et al., 2014) and recommendations for minimizing risk of disease transmission between humans and great apes by the International Union for Conservation of Nature (Gilardi et al., 2015).

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