Density and relative abundance of large terrestrial mammals of the PANAF site in Boé, Guinee Bissau.

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Preface

This report is the result of a collaboration between the Wageningen University and Research (WUR) and Chimbo Foundation. The student has worked for the Chimbo Foundation for a period of four months as part of the internship program of the MSc study Forest and Nature Conservation. During this internship the student has studied: "The biodiversity of large mammals in the Boé (density and relative abundance), based on camera trap and recce/transect data gathered in Boé based on the PANAF protocol for the PANAF research programme." In addition multiple research and personal goals are set by the student to work on during the internship.

Research goals:

1. Organizing and managing large databases
2. Critical review of previous executed research
3. Improve scientific writing skills
4. Conducting statistical analysis

Acknowledgements

First of all I want to express my gratitude to my supervisor, Annemarie Goedmakers, for guiding me, providing feedback, and monitoring my progression during my internship. Many thanks to Stichting Chimbo who gave me the opportunity for my research on a large database which could be done from home during the COVID – 19 pandemic. I also want to thank Thierry van der Hoeven, Henk Eshuis, Stefanie Heinicke and Anouk Puijk, who gave me more insight of the data that were collected and the characteristics of the PANAF site. Gratitude to Rene Henkens and Piet de Wit, who provided me with feedback on my final report. The same goes for my internal supervisor Pim van Hooft, for supervising me from the Wageningen University.

Abstract

Justification. The forest -savannah mosaic landscape of the Boé, Guine-Bissau, is inhabited by a population of the Western Chimpanzee which is endangered according to the IUCN redlist of species. In addition, this area is also home to many other large mammal species. However the density, richness, and diversity of this mammal community is not yet completely understood. **Aim**. Therefore, the goal of this study is to better understand the density and relative abundance of mammal community in different habitat types of the PANAF site in Boé, Guinee Bissau. **Method**. The Max Planck Institute for Evolutionary Anthropology (MPI) designed the Pan African Programme (PANAF) protocol to record Chimpanzee behaviour in the Boé. Foundation Chimbo applied this protocol to place camera traps at 95 locations between the 1st of august 2013 and the 19th of November 2014, to record chimpanzee behaviour. In addition, 16 recces were walked of 10km each, plus 35 transects walks covering a total distance of 128,4 km. These data were also used to provide insight on large terrestrial mammal density and diversity. **Results.** The number of camera days was positively correlated to mammal density but negatively to mammal diversity. Most camera days were obtained in secondary dry forest, but mammal detection per day was highest in the gallery forest. The most frequent detected species (of 34 that were detected) was; the sooty mangabey (*Cercocebus atys)*, followed by the guinea baboon (*Papio papio),* and the western chimpanzee *(Pan troglodytes verus*). Mammal diversity was highest in fallow and young secondary forest. The overall highest mammal abundance could be found in two different clusters. One large cluster in the south-west, and one in the north – east of the PANAF research site. Chimpanzee recordings per day was highest in gallery forest. In addition, there was a significant difference in chimpanzee detections rate per day between sacred sites with drumming trees compared to non- sacred sites without drumming trees. Chimpanzee nests were the most abundant sign of chimpanzee activity in the area. Between 5 (recces) and 7 (transects) nests were found per kilometre. Transect lines with high nest counts overlap with locations where most chimpanzees were detected per day on the camera trap. **Conclusion.** The two clusters in the south-west and north-east, detected the most mammals and chimpanzee nests. These clusters are comprised out of gallery forest and young secondary forest. Recommended is to place more camera traps, evenly distributed over the habitats, in order to get a better understanding of the mammal community per habitat.

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1: Introduction

1.1: Background and research programs.

Fast expansion of the human population and conversion of vegetation have led to forest fragmentation, isolation and habitat loss worldwide (Morris, 2010) (IUCN, 2017). Species that inhabit these forests are more vulnerable to extinction as the opportunities to disperse to neighbouring habitats decreases, which makes that these populations become more isolated. In addition, smaller forest patches are more vulnerable to various alterations, which results in a faster degradation process, which leads to a less resourceful habitat (Stevens & Husband, 1998). Large mammals that inhabit forests are especially affected by this as they need a large area in order to have a stable population size. The chimpanzee (*Pan troglodytes*), is also effect by this, as this species inhabits a forest – savannah mosaic, which is disappearing at an alarming rate (Humle et al., 2018). The IUCN indicates that main threats to this species are related to agricultural expansion, deforestation, and livestock farming (Estrada et al., 2017). Therefore, extensive data and research is required in order to protect this species as well as possible to prevent further population decline.

Chimbo Foundation is a Dutch NGO that works in Boé, Guinea Bissau to contribute to the survival of the western Chimpanzee (*Pan troglodytes versus*) (Figure 1). Chimbo is collaborating with the Max Planck Institute for Evolutionary Anthropology (MPI) in Leipzig, Germany that set up the Pan African Programme (PANAF) research programme in Boé, Guinee Bissau. The PANAF research programme established long-term research sites (LRS) and temporary research sites (TRS) to collect data on *"ecological, social, demographic and behavioural data on 35 to 40 chimpanzee populations spread out over their whole natural range*" (Max Planck Institute for Evolutionary Anthropology, 2012). The Boé area is, besides a habitat for chimpanzees, also home to a large variety of other mammals, like the African golden cat (*Caracal aurata*), which is classified as "Vulnerable" according to the IUCN redlist (CATnews, 2016).

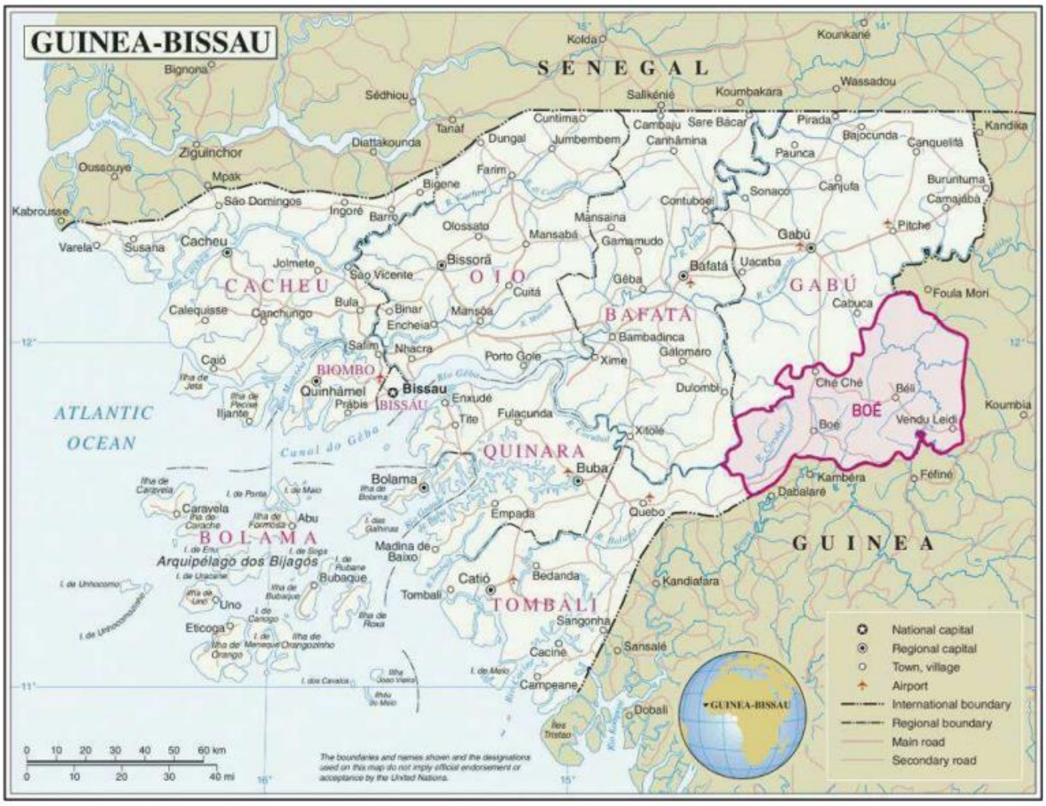

Figure 1: Guinee Bissau, with Boé in red	(Foundation Chimbo, 2020)

1.2: Objective of current research.

The Pan African chimpanzee survey (PANAF), is a data collection protocol designed by the MPI. This protocol was developed to monitor the several chimpanzee populations and their behaviour. In Boé data were collected by placing 25 camera traps in a grid of 7x8 km (56km2). In addition recces and transect walks were done covering a total distance of 128 kilometre. These camera traps and transect recorded data over a period of 12 months, resulting in more than 20,000 images available for analysis. Until now these recordings were primarily used to analyse chimpanzee numbers and behaviour.

Boé is, besides by chimpanzees, inhabited by many other large mammal species. Some areas in the Boé are quite untouched due to the poor accessibility of the area. This makes it more difficult to access the area for destructive activities like logging and mining. However, this poor accessibility also makes it more difficult to get a good understanding of the fauna that is present in the area. Therefore, limited visits to the area combined with camera traps seem to be the most efficient way to get a detailed idea of what species occur in the Boé. The over 20,000 images that were recorded with the camera traps according to the MPI protocol contain a lot of data that give information on the abundance, density and whereabouts of other large terrestrial mammals.

The aim of this research was to identify what species of large terrestrial mammals occur in Boé. Furthermore, it is relevant to know how abundant they are in where they occur. The following research question is formulated in order to reach this goal:

Main research question.
"What is the density and relative abundance in different habitat types of the large mammals of the PANAF site in Boé, Guinee Bissau.

Sub-questions.
The sub-questions are used to get a more detailed overview of each individual species that occurs on the camera traps.

- What large mammal species are present in Boé?
- What are the relative abundance of species found on the camera traps/during recces or transects?
- What are the differences in mammal species detection, richness and diversity between habitat types of each camera trap?
- Is the number of chimpanzees that are recorded by the camera traps correlated with number of nest sightings during the recces and transects?

1.3: Hypothesis

I have to fallowing corresponding hypothesis:

h1. The western chimpanzee is one of the most detected species, as the camera traps locations were deployed near drumming trees to recored chimpanzee behaviour.

h2. Mammal richness and diversity per are highest in the gallery forest as this habitat has the most natural resources and more suitable climatic conditions (Hema et al., 2017).

h3. Nest density will overlap with the areas where most chimpanzee are detected, as chimpanzee are one of the most territorial mammals, where individuals roam within their own territory. Meaning that that nest construction will also happen in this area (Lemoine et al., 2020).

2: Method and Statistical analysis.

It was very important to structure and organize the current database first before any analysis took place. Some preliminary work was already done, but it was not completely clear to what extent that database was out in order. The data still needed to be checked on duplicates, spelling errors, and other small details. Furthermore, the data had to be reshaped in a such way that it could be analysed using Rstudio and/or SPSS statistics.

All data that have been collected by the camera traps, line transects and recces were processed in the Pan_African_data_entry_sheets_BOE_20180827 data base. This dataset included all data that were collected between August 2013 and November 2014. Some adjustments were required, before a statistical analysis could be executed, this will be explained in the sections below.

Pre-processing.

Eight habitat types were defined in 2013/2014, but a more recent study, done by Thierry van der Hoeven (*Van der Hoeven 2020*) used satellite images,-and field data to create an new image of the land use in the Boé.

Table 1: New land use types comprised out of the old ones that were established in 2013/2014

Old Habitat types	**New habitat types**
Forest - old secondary + Forest fragment + Forest on rock/ Forest old secondary	Secondary Dry Forest
Forest - Young secondary forest + Fallow	Fallow and Young secondary forest
Gallery Forest + Forest on Rock	Gallery Forest
Savannah - Wooded	Wooded savannah

Another important aspect of the camera trap locations are the cameras placed at drumming trees. Chimpanzees use these trees to generate low non-vocal autistics, by hitting buttresses with their limbs or stones that they found around the tree. These sounds are audible to humans from at least 1km away(Chimbo, 2010; Kühl et al., 2016). The exact reason for why chimpanzees do this is not yet completely understood. To get more data on this behaviour, the PANAF research deployed camera traps near 14 sites with drumming trees, which recorded 1,405 camera days. However, this non-random placement of the camera traps might create a positive bias in chimpanzees numbers, as these location are already known to be regularly visited by chimpanzees. In addition, a potential influence on the occurrence/diversity of terrestrial mammals are the sacred sites of the PANAF. These specific locations are less frequently visited by humans, as they are sacred to the local communities. This means that alteration of the vegetation is less likely to happen, making it a more stable environment. Some species might prefer these less disturbed sites over areas that are more frequently modified. In total 2,737 camera days were recorded divided over 28 locations in sacred sites. What kind of impact the drumming trees and sacred sites have on the mammals population will be explained in another chapter of this report.

Camera trap footage and database changes.
In total 24,786 videos were recorded between 2013 and 2014. The database Pan_African_data_entry_sheets_BOE_20180827 needed four adjustments in order to do a more accurate analysis on mammal populations in particular

1. Non-mammalian species were excluded from the database as they are not the focus of this research.
2. All videos that had NA or Unidentified were checked, to see if species could be recognized. Footage, with species that could not be identified were removed. In addition, all footage that recorded humans were also removed.
3. Spellings errors were corrected and species that were placed in the wrong genus were repositioned.
4. It was checked whether or not species were correctly identified. This resulted in a database that contained 9,594 videos, with footage of terrestrial mammals recorded in 7,583 camera trap days.

Camera traps, Recces and Transects.
The Pan_African_data_entry_sheets_BOE_20180827 database was divided in three separate excel files after the pre-processing. The file named **Graphs** contained all data related to the camera traps, and was used the calculated the following parameters:

The file was first used to determine if mammal abundance per site was correlated with the amount of camera days per location and corrected for it.

- Species abundance: (Total number of individuals per species recorded by the camera trap per site)
- Species richness: (Total number of different large terrestrial mammals species present on camera trap per site)
- Species diversity: (Both species richness, and species abundance)
- Sacred sites (If there is a significant difference in mammal abundance between sacred and non- sacred sites)
- Drumming trees (If Chimpanzee numbers were greater at sites with drumming trees)

The file named **Reccess** contained all data that was related to the recces and therefore used to determine chimpanzee activity. In total 16 reccess walks were done, which were all 10km long, 500m equidistant. The recce data did not include any coordinates, which made it difficult to relate it to the data of the camera traps and transects. The file named **Transects** contained all data related to the transects lines, and was used to explore where most chimpanzee activity was recorded. Walking a transect in one day was sometimes difficult due to the inhospitable terrain. Therefore. the transects with a length of 3,25km were separated in two parts (north and south), with 500m between them. Now difficult areas could be walked in two days, where easier transects could be covered in one day (Schijndel, 2014). In total 128,4 kilometre was covered divided over 35 walks. These 35 walks can be divided over 14 different transects. Database included the coordinates of the transects, which made it easier to compare the data with the camera trap data.

Statistical analysis.
A **pearsons correlation** test was used in order to see if mammal abundance correlated positively number of camera days per location. In addition a correlation analysis was done to see if biodiversity increases or decreases, when more camera days are recorded per location. Abundance data and camera day data were checked for normality, by performing a **shapiro wilk test** for normality. Biodiversity in the PANAF site was determined by using the **Shannon diversity Index** (SDI). The shannon diversity index was calculated by using the following formula: ($H = -\sum pi \ln pi$). H is the shannon diversity index. Pi is the total amount of 1 species divided by $\sum$, which is a sum of all species per location per day. Then all the locations are summed and divided by the total number of

traps per habitat. Mammal and chimpanzee density difference per or grid cell was tested by doing non parametric t- test (**Mann Whiney- U**). First, each camera trap location was given their own id, to make it function as an independent sample. Second, for each independent sample a detection number per day was calculated. This was done by calculating the number of detections per location divided by the number of camera days per location. The independent samples were later categorized per grid cells (which are squared blocks of 1x1 kilometre) and habitat type. Resulting in that a specific grid cell could have multiple independent samples.

Camera trap locations.

The PANAF research site is a vast area consisting out of multiple habitat types. In total 95 location were recorded divided over 32 different grid cells and 8 habitat types (*see figure 1*). The first camera was installed in grid cell b2 on the 1st of august 2013. The last deployment of a camera traps was in cell f6 on the 5th of April 2014. The first grid cell that had no camera traps left was cell a3, where the last camera was uninstalled on the 22nd of April 2014. The last camera trap that was removed was deployed in grid cell g2 and was uninstalled on the 19th of November 2014. Grid cell b6 recorded for the longest time (468 days) and grid cell a3 the shortest amount of time (63). Of the 84 trap locations, 5 traps returned without footage of terrestrial mammals, this was because they were only deployed for one day and after that relocated.

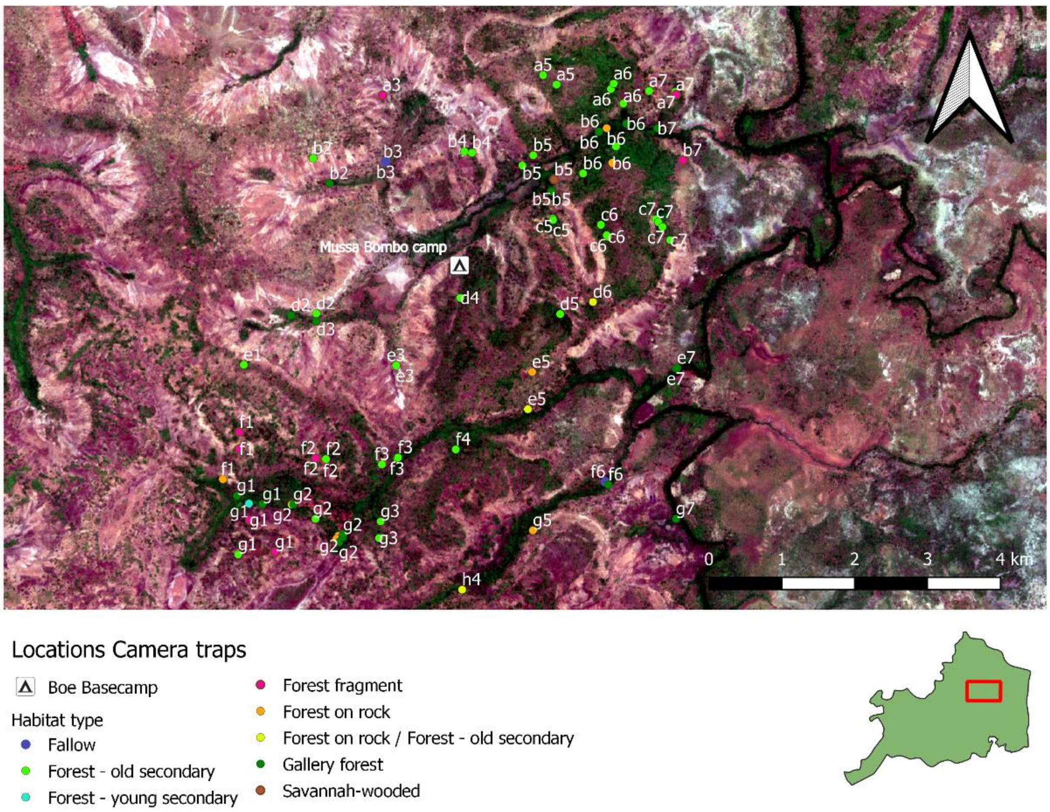

Figure 2: Locations of the camera traps dived over 32 different grid cells, displaying original database The highest sum of camera traps (42) were deployed in old secondary forest. After old secondary forest the following habitat types were surveyed from most 2nd highest number of traps to the least number of traps; Gallery forest (24), Forest fragment (11), Forest on rock (9), Forest on rock/ Forest old secondary (4), Fallow (3), Young secondary forest (1), and Savannah wooded (1)

3: Results

This chapter is divided in four parts: The first part provides the descriptive statistics, with a general overview of species occurrence and camera days. The second part will be about mammal density found by the camera traps. The third part is about species richness and diversity. The fourth will be about the transects and the recces.

3.1:Camera days and recorded mammal species.

The number of camera days recordings each site and habitat type differ a lot.

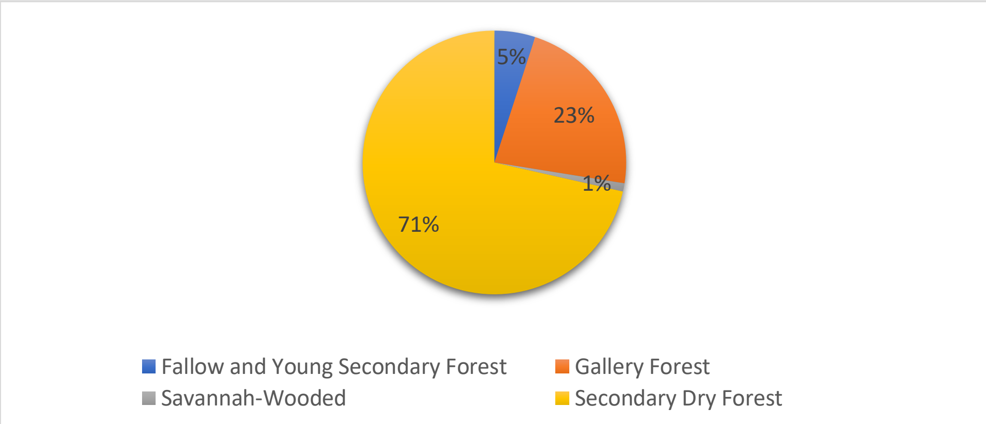

Figure 3: Circle diagram showing the % of camera days for each habitat

Secondary dry forest has the most recorded camera days, that contain 71% of all recordings (*figure 2*). The Savannah – Wooded habitat type only contained 1% of all recordings, and therefore this footage might not provide enough data to represent the mammal community. A higher number of camera days might result in a larger detection rate per habitat, and therefore providing an incorrect depiction of the mammal community.

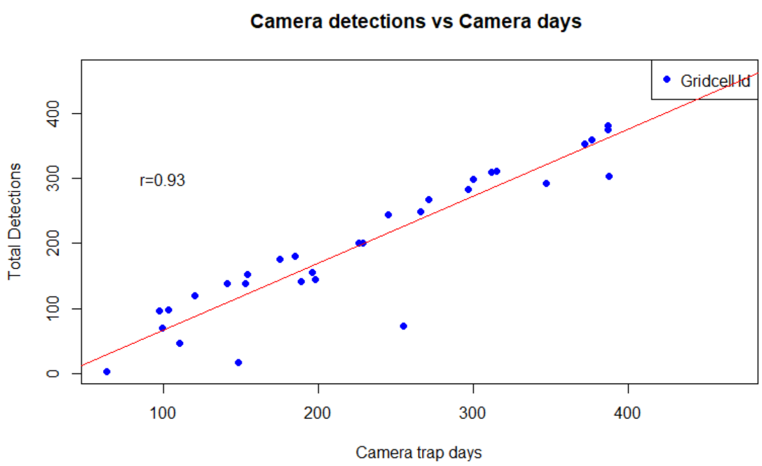

Figure 4:Scatterplot between Total mammal detections per cell (y) and camera trap days (x), showing a significant (p=-2.473e-15), strong positive correlation. Total detection is the number of recordings that were made of individual mammals and groups of mammals.

The Pearson's correlations test shows that there is a strong correlation (r=0.93) between the number of camera traps days and the total mammal detections (*figure 3).* This strong correlation verifies that there is a higher detection rate when the number of camera days increases. It's important to take the number of camera days into account when doing further analysis on diversity and richness per habitat and site.

In total 34 different terrestrial mammal species (18 diurnal and 16 nocturnal) from 15 different families were recorded in the PANAF site of Boé (*see table 1*). Their conservation status ranges from least concern (26), to near threatened (3), followed by vulnerable (4), to endangered (1) and finally critically endangered (1). In addition four different types of feeding behaviour were found among the different species that were recorded; with most the common one being omnivorous (5), followed by herbivorous (20), carnivorous (6) and the least were common insectivorous (3).

Table 2: All species that were recorded by the camera traps. N is the number of detection per day per species, actual individuals were not counted. Species name, diet, behaviour, and population status according to (IUCN, 2020)

Species	**Family**	**Scientific name**	**Diet**	**Behaviour**	**IUCN**	**N**
Aardvark	Orycteropodidae	*Orycteropus afer*	Insectivores	Nocturnal	LC	0.001
African brush-tailed porcupine	Hystricidae	*Atherurus africanus*	Herbivorous	Nocturnal	LC	0.003
African Buffalo	Bovidae	*Syncerus caffer*	Herbivorous	Diurnal	NT	0.006
African civet	Viverridae	*Civettictis civetta*	Omnivorous	Nocturnal	LC	0.016
African golden cat	Felidae	*Caracal aurata*	Carnivorous	Nocturnal	VU	0.000
African palm civet	Nandiniidae	*Nandinia binotata*	Omnivorous	Nocturnal	LC	0.001
Banded mongoose	Herpestidae	*Mungos mungo*	Insectivores	Diurnal	LC	0.005
Bushbuck	Bovidae	*Tragelaphus scriptus*	Herbivorous	Diurnal	LC	0.055
Campbell's mona monkey	Cercopithecidae	*Cercopithecus campbelli*	Omnivorous	Diurnal	VU	0.000
Common duiker	Bovidae	*Sylvicapra grimmia*	Herbivorous	Diurnal	LC	0.000
Common genet	Viverridae	*Genetta genetta*	Omnivorous	Nocturnal	LC	0.001
Common warthog	Suidae	*Pharcochoerus africanus*	Herbivorous	Diurnal	LC	0.019
Crested porcupine	Hystricidae	*Hystrix cristata*	Herbivorous	Nocturnal	LC	0.022
Gambian pouched rat	Nesomyidae	*Cricetomys gambianus*	Herbivorous	Nocturnal	LC	0.010
Greater cane rat	Thryonomyidae	*Thryonomys swinderianus*	Herbivorous	Nocturnal	LC	0.000
Green monkey	Cercopithecidae	*Chlorocebus sabaeus*	Herbivorous	Diurnal	LC	0.027
Guinea baboon	Cercopithecidae	*Papio papio*	Herbivorous	Diurnal	NT	0.311
Honey badger	Mustelidae	*Mellivora capensis*	Omnivorous	Nocturnal	LC	0.003
Leopard	Felidae	*Panthera pardus*	Carnivorous	Nocturnal	VU	0.004
Marsh mongoose	Herpestidae	*Atilax paludinosus*	Carnivorous	Nocturnal	LC	0.006
Maxwell's duiker	Bovidae	*Philantomba maxwellii*	Herbivorous	Diurnal	LC	0.105
Patas monkey	Cercopithecidae	*Erythrocebus patas*	Herbivorous	Diurnal	NT	0.008
Red river hog	Suidae	*Potamochoerus porcus*	Herbivorous	Diurnal	LC	0.036
Red-flanked duiker	Bovidae	*Cephalophus rufilatus*	Herbivorous	Diurnal	LC	0.019
Serval	Felidae	*Leptailurus serval*	Carnivorous	Nocturnal	LC	0.000
Side-striped jackal	Canidea	*Canis adustus*	Carnivorous	Nocturnal	LC	0.003
Slender mongoose	Herpestidae	*Herpestes sanguineus*	Carnivorous	Nocturnal	LC	0.003
Sooty mangabey	Cercopithecidae	*Cercocebus atys*	Herbivorous	Diurnal	VU	0.371
Striped ground squirrel	Sciuridae	*Ictidomys tridecemlineatus*	Herbivorous	Diurnal	LC	0.003
Waterbuck	Bovidae	*Kobus ellipsiprymnus*	Herbivorous	Diurnal	LC	0.007
Western chimpanzee	Hominidae	*Pan troglodytes verus*	Herbivorous	Diurnal	CR	0.183
Western red colobus	Cercopithecidae	*Piliocolobus badius*	Herbivorous	Diurnal	EN	0.000
White-tailed mongoose	Herpestidae	*Ichneumia albicauda*	Insectivores	Nocturnal	LC	0.017
Yellow-backed duiker	Bovidae	*Cephalophus silvicultor*	Herbivorous	Diurnal	LC	0.028

Table 2 shows the species recorded by the camera traps and in what quantity that they were recorded. The three most common families are the Bovidae family (8 species), followed by the Cercopithecidae (6 species) and the Herpestidea (4 species). The three most frequently recorded species in the PANAF site are the Sooty mangabey (*Cercocebus atys)*, followed by the Guinea baboon (*Papio papio),* and the Western chimpanzee *(Pan troglodytes verus*). Species weight ranged from 8kg (Maxwell's duiker) to 550kg (African Buffalo). In addition, several smaller mammals were also included in the database to give a more complete picture of the species diversity.

3.2: Mammal detection.

Mammal detection per habitat type.

Habitat types (*See table 1*) can differ in mammal density, as each of these habitat types might offer a variety of resources that are important to different species.

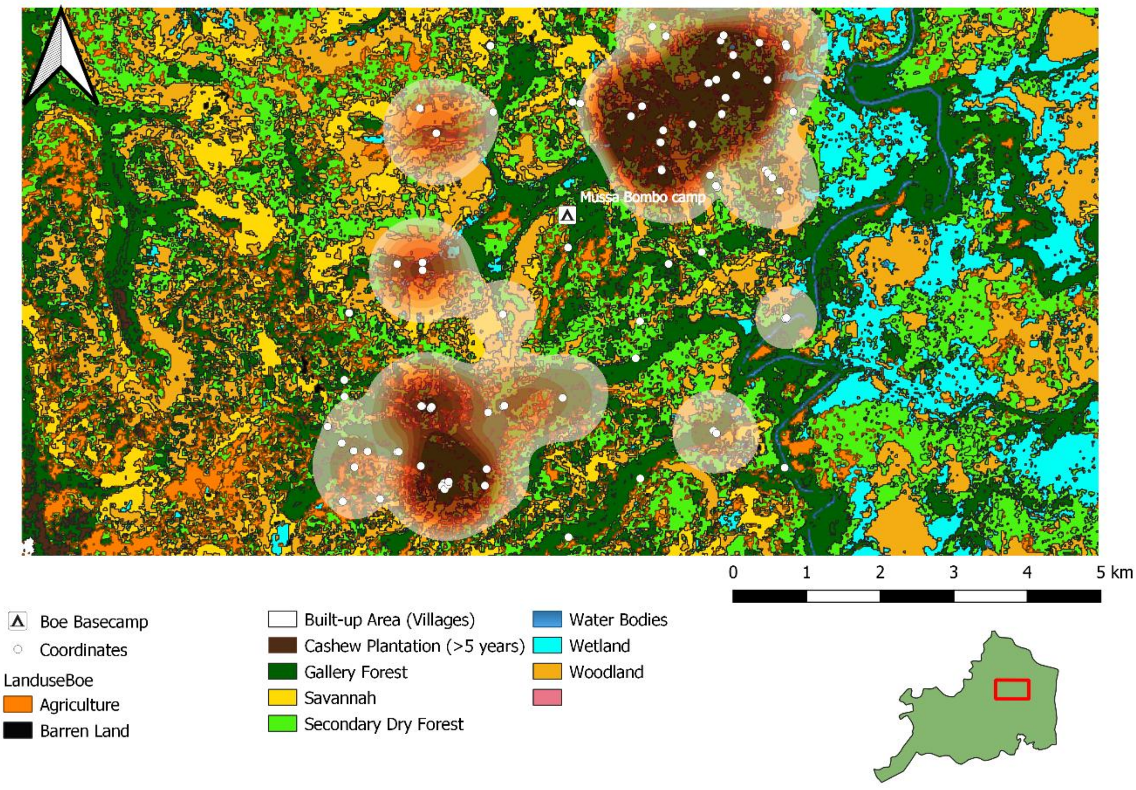

Figure 5: Heat map showing total mammal detection per day recorded by the camera trap. Each white dot represents a camera trap location. Mammal density is displayed by the reddish circles, the darker red indicating a higher density. The new land use according to Van der Hoeven 2020.

Mammal occurrence per day seems to be highest in the gallery forest (*table 3*). The other habitat types seem to have relatively similar mammal densities. In addition, the upper right corner, and bottom left corner seem to be most preferred by mammals. The centre between these two areas (which is mostly comprised out of gallery forest and secondary dry forest) seem to lack mammal recording. In wetlands no camera traps were placed. However, 3 camera locations near wet lands do show a relative moderate abundance of mammals (*see figure 4*). However the sparse placement of camera traps near wetlands might provide biased results.

Table 3: Mammal detection per habitat. Detection per day is calculated by dividing the total number of detections per habitat divided by the total number of camera days per habitat

Habitat	Total detections	Detections per camera day
Fallow and Young Secondary Forest	449	1.18
Gallery Forest	4217	2.47
Savannah-Wooded	14	0.18
Secondary Dry Forest	4914	0.91

As the heat map shows, mammal density per day is highest in the gallery forest, followed by fallow and young secondary forest habitat (*Table 3*). Secondary dry forest recorded close to one mammal per day, where savannah – wooded would need between 5 and 6 days for 1 mammal to pass by.

Mammal species prefer one habitat over another, as each vegetation type has its own characteristics. The two habitats that can be compared are secondary dry forest (N 53) and gallery forest (N 27), as only these two habitat types have enough samples for a comparison. The non- parametric t- test for independent samples (Mann-Whiney U test) shows that there is a significant difference in mammal detections per day between secondary dry forest and gallery forest (p-value = .047).

Mammal Density per grid cell.
Mammal detection per grid cell (1x1 kilometre) could also differ as the location on the PANAF site might play an important role. In addition, some grid cells are comprised out of different habitats, and therefore offer a more resourceful sanctuary for mammals.

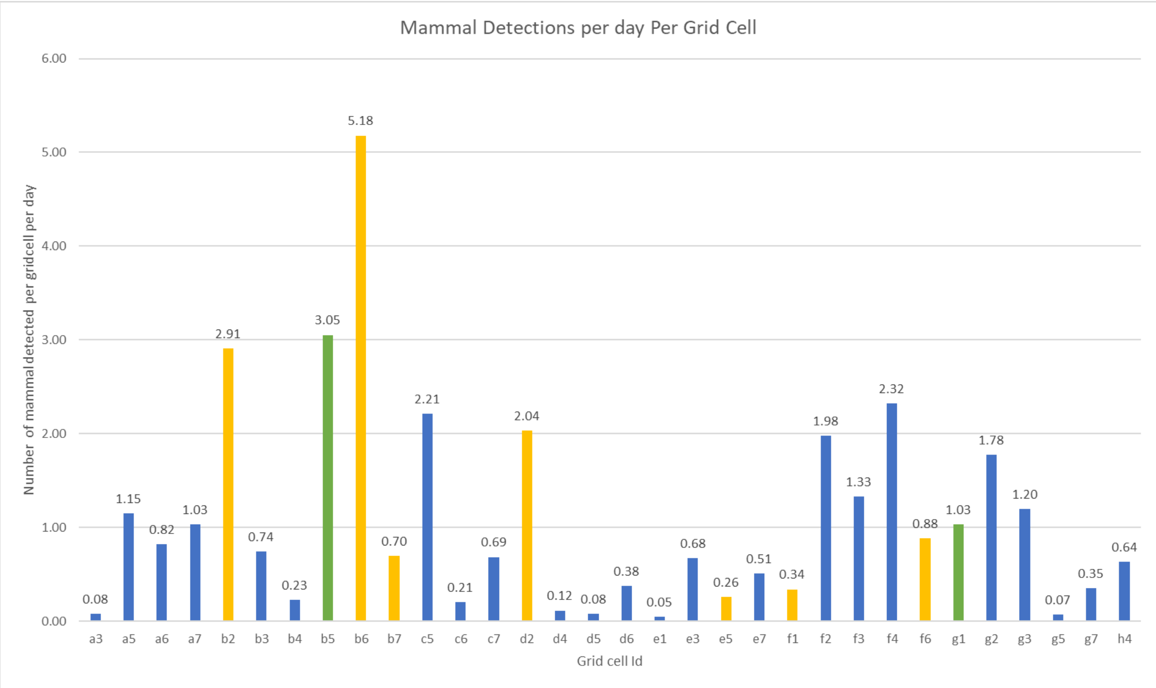

Figure 6: Mammal detection per grid cell, in the PANAF site of Boé. Were the total number of mammal detection per grid cell is divided the amount of camera trap days in the grid cell. In addition 22 grids cells consisted out of 1 habitat type (blue), were 8 grid cells (yellow) comprised two habitat types, and 2 out of 3 habitat types (green).

The grid cell with the highest mammal detection per day (5,18) is cell b6 that is comprised of dry secondary forest and gallery forest (*figure 5*). This grid cell can be found in the top right cluster, where mammal density is relatively high (*figure 4*). Grid cell b5 that had second highest detection rate (3,05) per day can also be found here. The other cluster with a high density per day are mostly cells with the letters f and g. The average mammal detection per day is 1.09, meaning that each location detects around one mammal per day. Most grid cells with the letter e and d have a relatively low detection rate per cell, as they did detect less than 1 mammal per day. The ten cells comprised out of multiple habitats had a higher than average detection rate (1,63 mammals per day).

Chimpanzee density.

The aim of this study is to get a better understanding of the mammal community at the PANAF site of the Boé. In addition, special attention is given to the western chimpanzees as it is one of the species that is critically endangered according to the IUCN Red List.

Table 4: Chimpanzee recording per habitat per day. The total number of detections was divided by the total number of days recorded per habitat

Habitat	Amount of detections	Detections per day
Fallow and Young Secondary Forest	102	0.27
Gallery Forest	755	0.44
Savannah-Wooded	9	0.12
Secondary Dry Forest	510	0.09

Chimpanzee are present in each habitat type, but seem to have to highest the detection rate in the gallery forest (*Table 4)*. On average 0.23 chimpanzees were detected per day, meaning around 4-5 days of recording are need to detect one chimpanzee. Chimpanzee detection rates per day were not significantly different between secondary dry forest and gallery forest ($p = .13$). However, two other factors might play a role in determining chimpanzee detection rate.

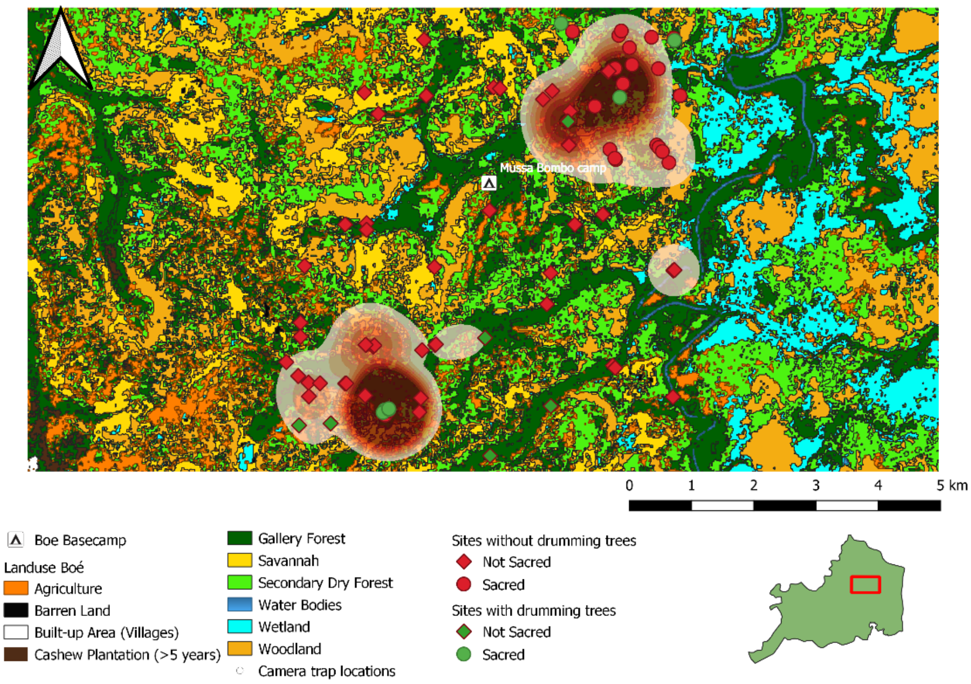

Figure 7: Heat map showing chimpanzee recordings per day. Sites without drumming trees are collard red. Camera sites with drumming trees are indicated with a green circle or diamond. Sacred sites are indicated with a circle and non-sacred are indicated with diamond sign. The land use types (Van der Hoeven 2020).

The chimpanzee density clusters seem to be comparable to the total mammal density, as there are two large clusters one in the north-east and one in south - west (*figure 7*). Chimpanzee detections centre around sites with drumming trees and sacred sites . This is confirmed by the non-parametric t-test which shows a significant difference between sites with drumming trees and sites without drumming trees ($p = .0002221$). In addition, chimpanzee density in sacred and non-sacred sites are also significantly different ($p = .033$). However it should be taken into account that out of the 14 sites with drumming trees, 7 are located within sacred sites. For other mammals detection per day was not significantly different between sacred and non-sacred sites ($p =.139$)

3.3: Mammal richness and diversity.

Mammal Richness
In total 34 different species of terrestrial mammals were detected by the camera traps, found over 4 habitat types. Most species were found in the secondary dry forest (32), and the lowest number of species (2) were detected in the savannah-wooded habitat (*table 5*).

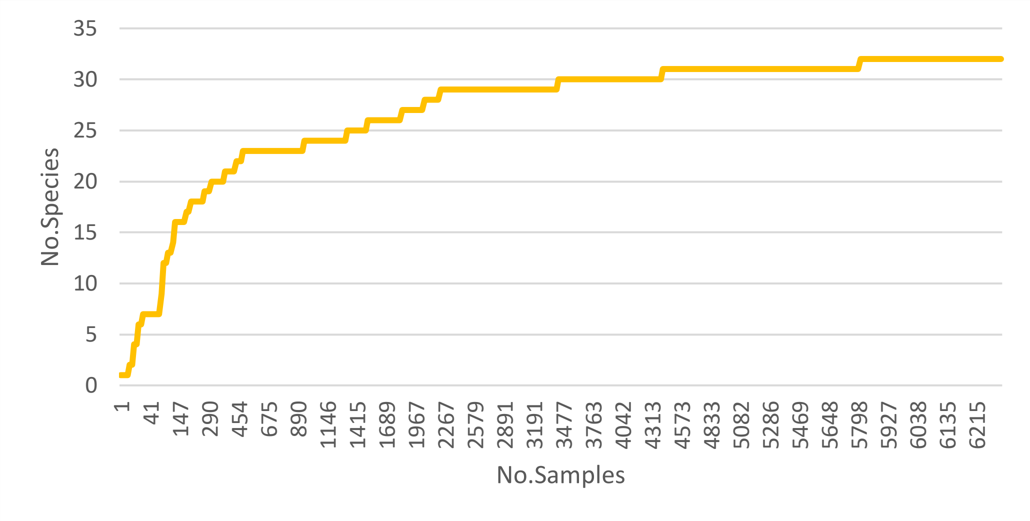

Figure 8: Species accumulation curve of secondary dry forest, were the number is samples (x- axis) is the number of camera days.

The number of species increases relatively fast in the beginning, where most species are detected within 500 days. This steep increase if continued with a somewhat small increases that starts to flatten after 2000 camera days. Species number continues to increases slowly over a very long period of time. This means that new species showing up is quite rare.

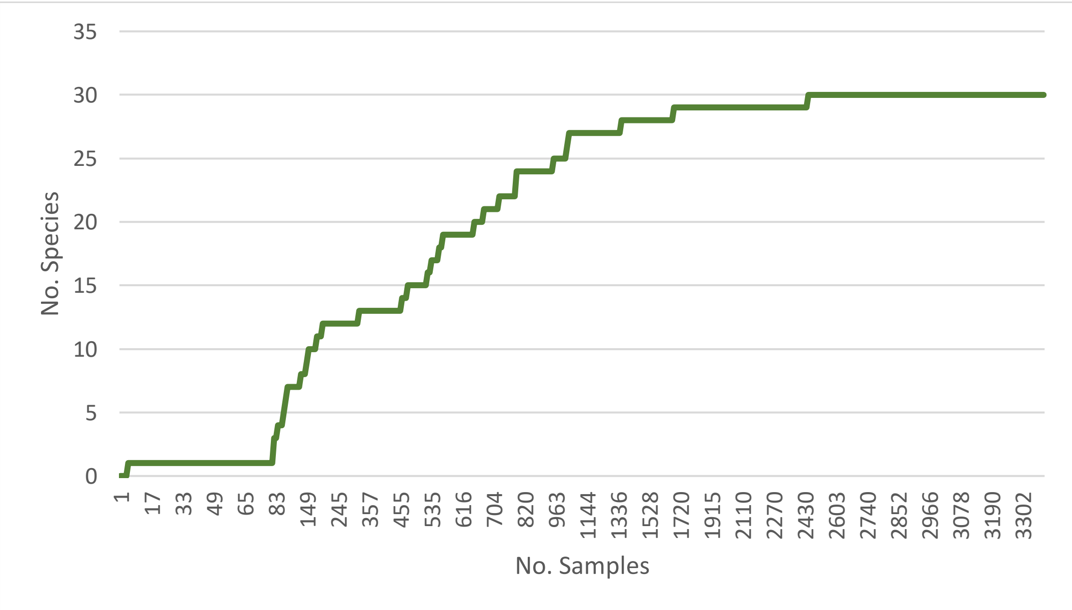

Figure 9: Species accumulation curve of Gallery Forest, were the number is samples (x- axis) is the number of camera days.

Figure 9 shows the species accumulation curve of the gallery forest. The number of species increases not at the start, but after around 80 days. New species are recorded over a period of 1000 camera days. After around 1500 days the in the growth begins to flatten. Around 5 more species are detected after the curve begins to flatten. Most of the species in this habitat are recorded after 2500 camera days.

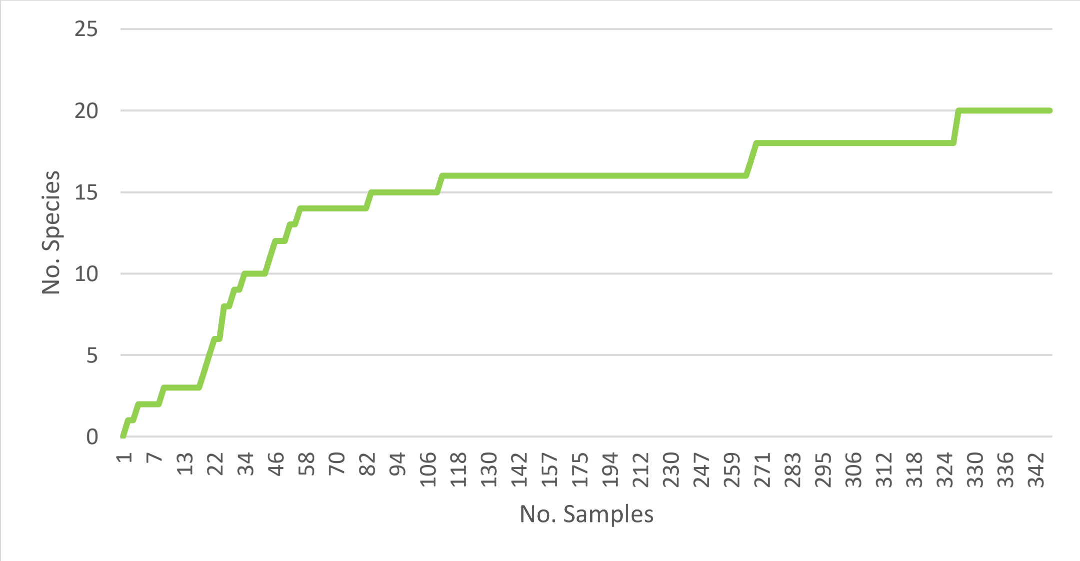

Figure 10: Species accumulation curve of fallow- young secondary, were the number is samples (x- axis) is the number of camera days.

The species accumulation increases rapidly in the fallow and young secondary forest, which is faster compared to secondary dry forest and the gallery forest. After 50 days the curves growth begins to flatten. This flattening trend continues for a while, but there is again a small increase in the number of species after 260 camera days.

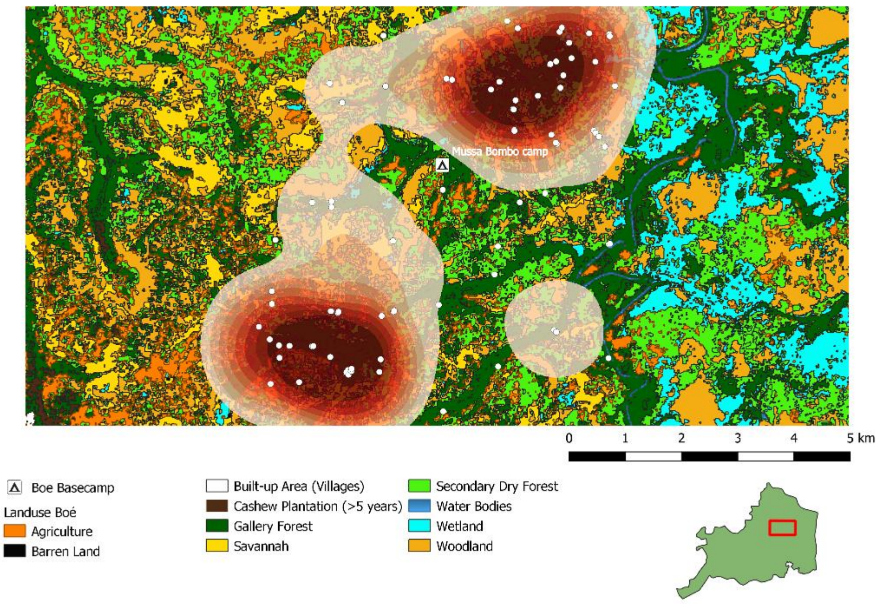

Figure 11: Heat map showing mammal richness per day, were the total number of species found at each location is divided by the number of days recorded. The land use types were created by Thierry van der Hoeven (Van der Hoeven 2020).

Species richness follows the same trend as the species density, as the there are two large clusters, on the north -east and one south- west. The hot spots, are mainly centred around the gallery forest. In addition, a relatively high species richness is found in the wooded-savannah habitat as the results of the fact that most common species appear already after a few camera days. Secondary forest and camera traps near water bodies have a relative low diversity.

The three most frequently recorded species in the PANAF site are the sooty mangabey (*Cercocebus atys)*, followed by the guinea baboon (*Papio papio),* and the western chimpanzee *(Pan troglodytes verus*).

Table 5: Three most common detected species per habitat

	Fallow and Young Secondary Forest	**Gallery Forest**	**Savannah-Wooded**	**Secondary Dry Forest**
Most abundant				
1	Sooty mangabey	Guinea baboon	Western chimpanzee	Sooty mangabey
2	Western chimpanzee	Sooty mangabey	Waterbuck	Guinea baboon
3	Maxwell's duiker	Western chimpanzee	-	Western chimpanzee

Of the four most common species only the western chimpanzee was observed in all habitats. The three most common species were all primate species, These primates species live in family groups, making it more likely to be recorded by the camera traps.

Some species were only detected once or twice, and are therefore quite a rare sighting. Therefore it is difficult to make predictions about the whereabouts of these species.

Table 6: Table containing the least common species.

Detection rata	**Fallow and Young Secondary Forest**	**Gallery Forest**	**Savannah-Wooded**	**Secondary Dry Forest**
Least abundant				
< 2	-	Western red colobus	-	African golden cat,
	-	-	-	Common duiker
< 3	-	Campbell's mona monkey	-	Greater cane rat
	Serval	-	-	Serval
>3 and < 10	Aardvark	-	-	Aardvark
	-	African palm civet	-	African palm civet
	-	Common genet	-	Common genet

In total 9 species were detected less than 10 times (*table 7*). The secondary dry forest detected the most species that were least common (7), followed by the gallery forest (5). Fallow and young secondary forest were visited by species that were only detected once. In addition, cameras in savannah – wooded did not detect any species that were among the least common ones. Most of the 9 species were nocturnal (6), and the rest diurnal (3). The type of diet among the least common species was very diverse, but most species were herbivorous (3) or omnivorous (3). In addition, most species that were least common are also solitary species, making it harder to be detected by a camera trap compared to those living in a herd or family.

Mammal diversity.
Mammal diversity is the combination of the mammal abundance and richness.

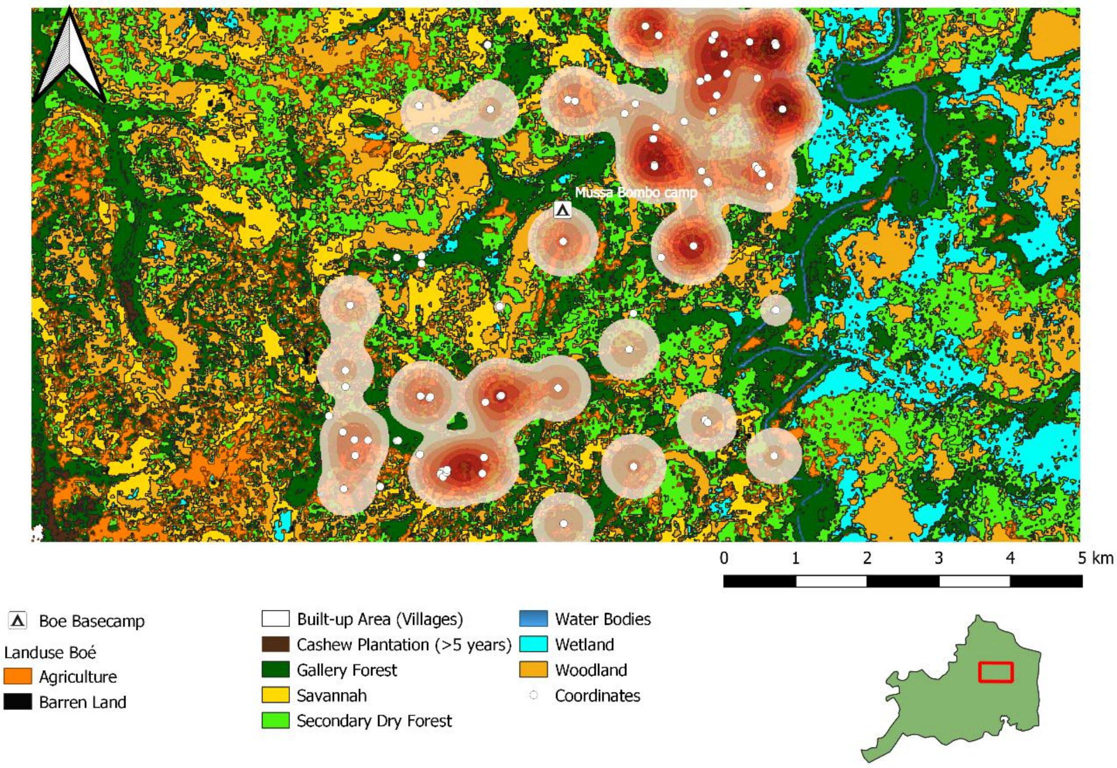

Figure 12: Heat map showing the Shannon Diversity Index per day per location. Shannon Diversity Index per location in each habitat type calculated with the formula (H = -∑pi lnpi). H is the shannon diversity index. Pi is the total amount of 1 species divided by ∑ , which is a sum of all species per location. The land use types (Van der Hoeven 2020).

Shannon diversity is more evenly distributed then mammal density in the PANAF site, as more smaller cluster are shown on the map. But still the right-top and left bottom are the most diverse (*figure 7*). Gallery forest seems to contain the highest SDI, where savannah-wooded has the lowest. Secondary dry forest seems to have a similar diversity compared to gallery forest.

Table 7: Shannon Diversity Index (SDI) per location in each habitat type calculated with the formula (H = -∑pi lnpi). H is the shannon diversity index. Pi is the total amount of 1 species divided by ∑ , which is a sum of all species per location in each habitat. Average SDI is calculated taken the average of all different locations per habitat, per day.

Habitat type	Number of locations	Average SDI per habitat
Fallow and Young Secondary Forest	3	0.023
Gallery Forest	27	0.016
Savannah-Wooded	1	0.009
Secondary Dry Forest	53	0.018

The Shannon diversity index (SDI) of the PANAF site differs per habitat type (*see table 8*). Fallow and young secondary forest, (which are habitat types not indicated as land use in (*figure 12*)), seem to have the highest SDI per habitat type. The second and third most diverse habitats types are secondary dry forest and gallery forest, which are relatively similar in diversity. However, secondary dry forest does have far more locations compared to the gallery forest, increasing the chance of detecting more different species.

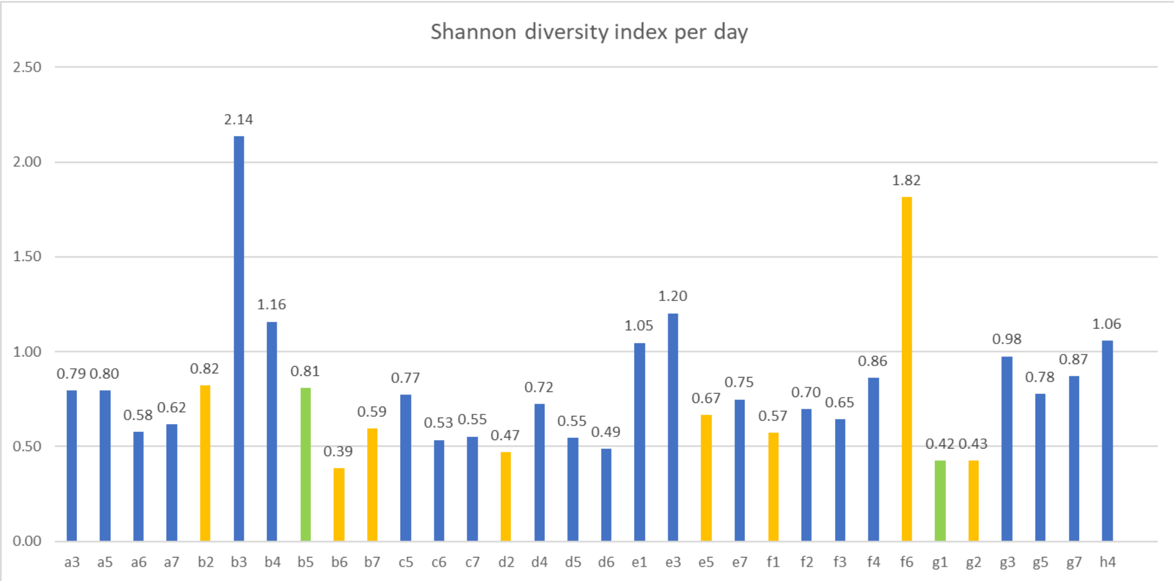

Figure 13: Shannon Diversity Index SDI per grid cel/ per dayl calculated with the formula (H = -∑pi lnpi). H is the SDI. Pi is the total amount of 1 species divided by ∑ , which is a sum of all species in that cell. Ln is the natural logarithm of earlier established Pi. The calculation is based on all species that were detected per grid cell. In addition 22 grids cells consisted out of 1 habitat type (blue), were 8 grid cells (yellow) comprised two habitat types, and 2 out of 3 habitat types (green).

The highest SDI was found in grid cell b3 (2,14), which is located in fallow and young secondary forest. The second and third highest SDI can be found in grid cell f6 (1,82) and grid cell e3 (1,20) which are located in fallow and young secondary, gallery forest and secondary dry forest. The two lowest SDI were found in grid cell b6(.39) and g1 (.42) which are in secondary dry forest and gallery forest. This means that the habitat of secondary dry forest and gallery forest contained both grid cells that have a high and low mammal diversity.

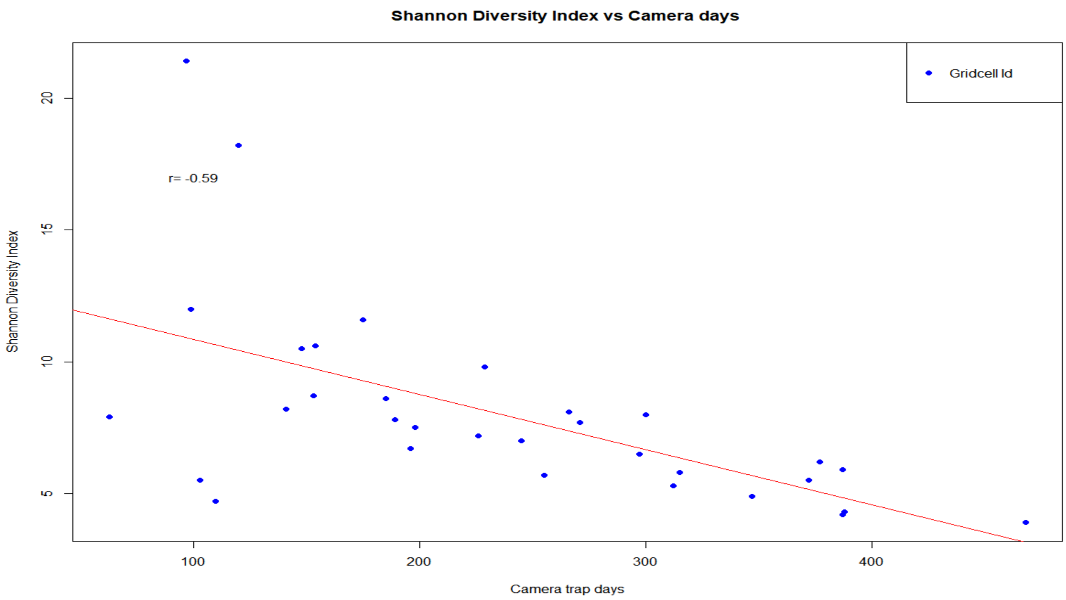

Figure 14: Scatterplot between the Shannon Diversity Index (y) and Camera trap days (x), showing a significant (p= 2.914e-05), strong negative correlation (r=-0.59)

SDI number declines when the amount of camera days increases (*Figure 14*). This is related to the fact that common species are seen after less camera days then rare ones. Fallow and young secondary forest has the highest diversity, but is in camera days far below gallery forest and secondary dry forest (only 5% of the total amount). Therefore, the new species density per day in this habitat is relatively high in fallow young secondary forest. Secondary dry forest has the most camera days, and is the second most divers habitat. Gallery forest has 25% of all camera days and is the third most divers habitat.

3.4: Chimpanzee activity recorded by Recces and transects lines

Recces

More methods (besides camera traps) were used to determine chimpanzee density in the PANAF sites. Walking test transects (recces) to explore the areas was also done in 2013 and 2014. In total 16 recces lines were walked, with a length of 10km each. Meaning that around 160km of recces were walked. The main goal of these recces was to explore the area, to detect chimpanzee activity in the PANAF site and to select were to place he grid for the transect and cameras.

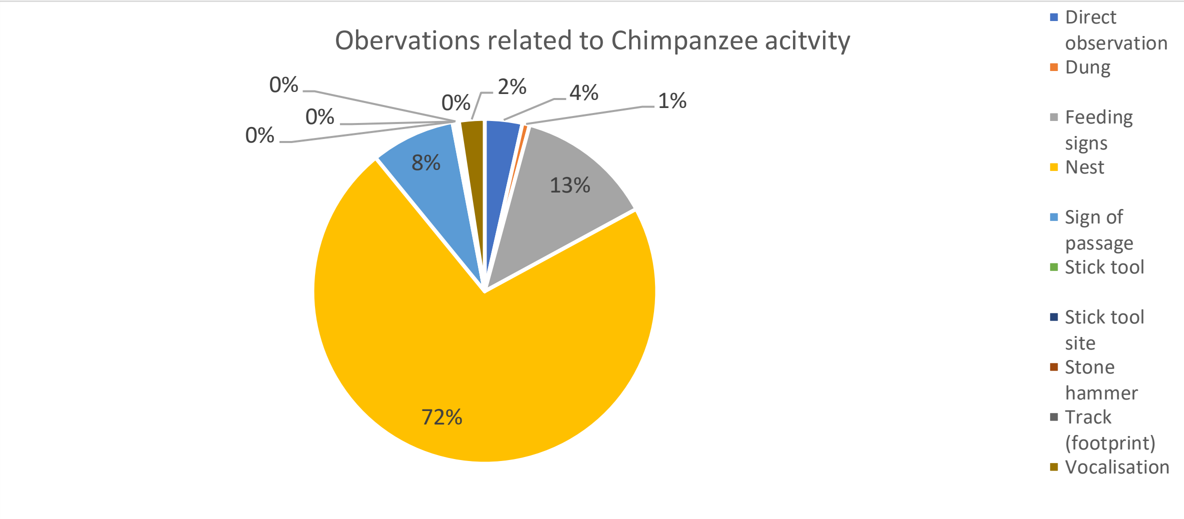

Figure 15: Circle diagram giving a percentage to each observation related to chimpanzees activity. Some of the observation that were related to chimpanzee activity were only recorded once, which therefore is given a 0% .

Individual nest observation was the most common sign of detecting chimpanzee activity (see figure 11). In total 839 nests were found during the walking of the recces, meaning that around 5 nests were counted per kilometre. This activity sign was followed by feeding signs (13%) and signs of passage (8%). Tools were found only once during the recces, and this is therefore the least common activity sign. Direct observations were quite rare (4%), with in total are 41 direct sightings.

Table 8: This table gives a percentage of how often each habitat was recorded during the recces walks.

Habitat	Total Observations	%
Fallow and Young Secondary Forest	69	6.0
Gallery forest	254	21.9
Savannah – Wooded	122	10.5
Secondary Dry Forest	713	61.6

The habitat type that was most recorded showing a sign of chimpanzee activity during the recces is secondary dry forest (*table 9*). The other three habitats combined (38,4) are just above the half of secondary dry forest, which means that there is a very unequal observation distribution among habitat types. However, the covered distance per habitat was not recorded in the database, which makes it difficult to make estimates about the presence of chimpanzee.

Transects lines

Walking transects in order to count nests was another method to detected chimpanzee density. In total 128.4 km of distance was covered divided over 35 walks. These 35 walks can be divided over 14 different transects. Each individual transect was around 3700 meters in length and was recorded at least two times.

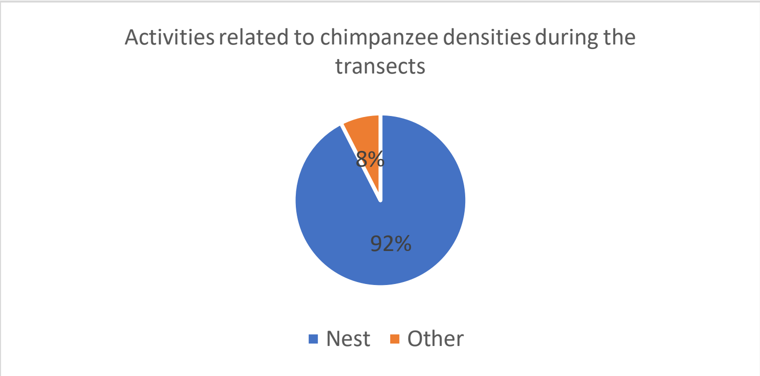

Figure 16: Circle diagram showing the ration of chimpanzee activities signs that were during walking the transect routes. Chimpanzee nests were recorded most frequently as sign of chimpanzee activity. Other signs included; direct observation, dung, feeding signs, sign of passage, stone throwing-site, stone throwing-stone and vocalisation.

Most observation made during the transect walk that were related to chimpanzee activities were nest counts (*Figure 16*). In total 908 nests were detected over 128 kilometres, meaning that around 7 nests are detected per km. This is 2 nests per kilometre more the number that was found during the recces walks.

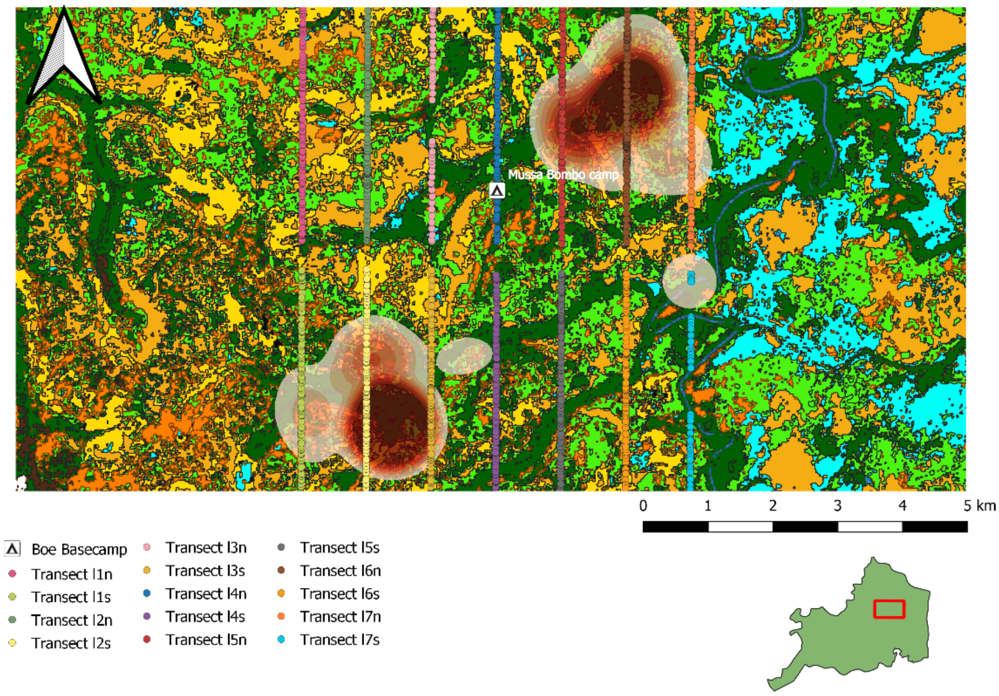

Figure 17: Heat map including of chimpanzee density including the difference transects routes. A darker red colour means that more chimpanzee were recorded near that location. The land use types according to (Van der Hoeven, 2020)

Transect line 2s,3s,5n,6n and 7n are close to the areas were the chimpanzee detection was the highest (*figure 17*). Therefore, nest counts were expected to be higher in these areas as more chimpanzees were detected around that area.

Table 9: Number of nests detected per transect per kilometre per transect route, with an average nest count of 7 per kilometre per km of all transects. Transect Id identifies which transect was done and nest per km gives the average number of nests that were found per kilometre on that transect. The "l" in the transect name stand for line, were the "n" stands for north and the "s" for south.

Transect Id	Nest per Km	Transect Id	Nest per Km
l1n	1.0	l5n	4.0
l1s	12.1	l5s	6.1
l2n	3.4	l6n	23.4
l2s	4.1	l6s	3.6
l3n	2.7	l7n	6.0
l3s	11.3	l7s	0.9
l4n	6.4		
l4s	13.1		

Transect l6n has the highest nest density per km (*table 10*). The second highest nest count per km is in transect l4s, which is on the eastern border of a cluster with high chimpanzee counts. The third transect with the highest nest count is transect l2s, which is on the left border of same cluster as transect l4s. The transect that runs through the middle of this cluster is transect l4s, which has a relatively low nest count per kilometre. Transects l5n and l7n also have a relative low nest count, while they are at the border of a cluster with a high chimpanzee count. Transect l4s, has almost average nest count per km, however the map does not show any chimpanzee detection near that area. But in general, chimpanzee nest density seems to increase when the transect line is closer to clusters in the north or south.

Table 10: Showing the percentage of how often each habitats is observed during the transect walks.

Habitat type	Total observations	%
Fallow and Young Secondary	33	3.4
Gallery Forest	188	19.1
NA	120	12.2
Savannah - wooded	64	6.5
Secondary Dry Forest	577	58.8

Secondary dry forest was the habitat in which sign of chimpanzee activity were most observed during the transects, followed by gallery forest (*see table 11*). Another habitat type that frequently occurred was NA, which stands for "Not applicable". Here a specific habitat was not assigned in the excel file. Unfortunately, not much can be said about nest density per habitat, as the of distance covered in each habitat is not available.

4: Discussion and recommendations

The aim of this study was to find out to identify what species of large terrestrial mammals occur in Boé. Furthermore, it is relevant to know how abundant they are in where they occur. The results indicated that the number of camera days was positively correlated to mammal density but negatively to mammal diversity. Most camera days were recorded in secondary dry forest, but mammal detection per day was highest in the gallery forest. The most frequent detected species (of 34 that were detected) were; the sooty mangabey (*Cercocebus atys)*, followed by the guinea baboon (*Papio papio),* and the western chimpanzee *(Pan troglodytes verus*). Mammal diversity was highest in fallow and young secondary forest. The overall highest mammal abundance could be found in 2 different clusters. One large cluster in the south-west, and one in the north – east of the PANAF research site. These two clusters are mostly comprised out of gallery forest and secondary dry forest. Chimpanzee recordings per day was highest in gallery forest. In addition, there was a significant difference in chimpanzee detections rates per day between sacred sites with drumming trees compared to non-sacred sites without drumming trees. Chimpanzee were predominantly detected in the same area where mammal detections were the highest. Chimpanzee activity was also recorded by walking recces and transects. Chimpanzee nests was the most abundant sign of chimpanzee activity in the area where between 5 (recces) and 7 (transects) nests were found per kilometre. Transect lines with the highest nest count per kilometre generally overlaps with area where most chimpanzees were detected per day on the camera trap.

Strengths and limitations

The strength of this report is the quantity of data that was available for the analysis. In addition, the detailed description of how most data were collected was valuable addition as it provided the opportunity for a more critical analysis. Furthermore, the method of how the data were collected was based on the protocol of The Pan African chimpanzee survey (PANAF), which was designed by the Max Planck Institute for Evolutionary Anthropology**.** This gave the unique opportunity to work on a database that was designed by a very well know research institute. However, this opportunity also comes with a limitation. Camera traps placement was now mainly focussed on recording chimpanzee behaviour, which is the main goal of MPI. This resulted in a positive biased detection rate of chimpanzee on the videos. In addition, the non-random placement of the camera traps made it difficult to see the impact of the habitat type and other environmental or anthropogenic factors.

Mammal density

Most mammals per day were detect in gallery forest, which recorded mostly primate species. Other studies of Gippoloty and Dellómo also found that primates are the most represented group in the large mammal community in Guinea Bissau (Gippoliti & Dell'Omo, 2003). Where the green monkey (*Chlorocebus sabaeus*) seems to be the most abundant species. Primates occurred in all habitats, but only the western chimpanzee was observed in savannah-wooded habitat but in lower numbers. This was most likely caused by limited number of camera days and the fact that most primates prefer a forest habitat over wooded-savannah (Bryson-Morrison et al., 2017; Maria J. Ferreira da Silva, Catarina Casanova, 2012). The Maxwells duiker (*Philantomba maxwellii)*, was mostly found in secondary dry forest. Maxwell's duikers prefers a variety of habitats but is mostly found in woody and swampy habitats (McCollum et al., 2018). Which might explain why its predominantly detected in forest habitat. In contrast to the waterbuck (*Kobus ellipsiprymnus)*, that was only found in the wooded – savannah. This species is a grazer and more depended on grasslands, and therefore it is expected that this species is more abundant in the savannah-wooded habitat type (Okello et al., 2015). Gallery forest counted significantly more mammals per day compared to secondary dry forest. This could be caused by the fact the most detected mammals prefer a habitat that is less disturbed (Bryson-Morrison et al., 2017)and,- or that gallery forest hold more resources compared to secondary dry forest (Derroire et al., 2016). The fallow- young secondary forest accumulation curve showed the steepest increase in the number of species per sample period. In addition, the habitat type had the highest average SDI per habitat per. Suggest that this habitat is most divers compared, to the other habitat types. However, the difference between these habitat types of the Boé should be further examined in order to give accurate results about the mammal density and diversity.

Recces and Transects
Chimpanzee nests were the most abundant sign of chimpanzee activity in the Boé. The recces detected around 5 nests per km and transects 7. The data collection report described the process of the data collection stated the following issues during recording the recces;

> *"The eastern most recce was located on the other side of Fefine river, 1km from the rest due to the river running N-S approximately 500m from the previous recce. Many nests were seen on top of Gobige hill, in the northern section, on this transect, but no other chimpanzee signs; assumed to be neighbouring community, also due to total inaccessibility during the rainy season. Very few signs were seen on the western most recce lines, so the decision was made to establish the grid using data from 16 recce lines."*(Schijndel, 2014)

The difference density of nests between the method might be explained by the difficult accessibility of the terrain in addition with the change in seasonality. Transects that counted with the highest number of nests were located in the area were most chimpanzees were detected on the camera trap (north-east and south west. A study which used the same data plus other environmental variables mentioned that these clusters surround the highly suitable areas for chimpanzees. In addition, the Boé district contains a substantial bauxite deposition region called ronde hill. They found out that chimpanzee nests density was highest in areas in area which were in same location as the planned expansion of the this bauxite mine (Filipe S. Dias, José F. C. Wenceslau, Tiago A. Marques, 2019). The impact of this expansion should be carefully observed, as it could have a large negatief effect on the chimpanzees in this area

Recommendations
Camera traps placement was now mainly focussed to record chimpanzee behaviour, which resulted in a positive biased detection rate of chimpanzee on the videos. It is therefore recommended to place camera traps more randomly to prevent such biases. For analysing mammal richness, abundance and diversity. In addition, traps should be more evenly distributed over the different habitats to get an better idea of each mammal community per habitat type. This placement can be combined with a forest inventory, which can give more detailed information about the habitats.

The way in which data is processed in excel could use some improvements. Camera traps locations should get their own ID column as well, instead of only the column of in which cell they are located. This makes it more easier compare all different locations which each other. Furthermore, dates should be entered in one cell (as for example 01-1-2020), and not an individual cell per day, month and year. Another good addition would be the inclusion of the English name column in the data set. This makes it easier to get a quick general idea of what mammals occur in the area.

The transect and recce data were not used to a large extent in this research. Therefore, it's difficult to formulate recommendations on this. Nests were only recorded from a certain range, however not the specific distance to the nest was recorded. This additional information might give a more precise density estimation of the nests in the area.

5: Conclusions

Mammal detection per location was positively correlated with the number of camera days per location. Gallery forest detected most mammals per day and was significantly different in that regard to secondary dry forest. The four most detected species were primates, including the Western Chimpanzee. However, this could possibly be caused by the non-random placement of the camera traps. A more random placement per habitat of and evenly distributed placement across habitats could provide better insight on how mammals are distributed. Fallow and young secondary forest had both steepest increase in the number of species per sample effort and the highest SDI. Suggest that overall richness and diversity was highest in this habitat type. The overall highest mammal abundance could be found in 2 different clusters. One large cluster in the south-west, and one in the north – east of the PANAF research site. These areas also inhabited the most chimpanzees detected by the camera traps. Furthermore, most chimpanzee nests were count in recces and transects that covered these two clusters. Around 5 nest per kilometre were when doing a recce walk were transects had on average 10 nests per kilometre. Seasonality difference and the more difficult terrain to cover during the recces could explain this difference. The two clusters in the north-east and south-west should be monitored carefully as they contained the highest mammal detection rate and highest number of nest count of chimpanzees. Large disturbance like the expansion of the bauxite mine might endanger these biodiverse areas.

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