Report:

Bauxite Mining and Chimpanzees Population Distribution, a case study in the Boé sector, Guinea-Bissau.

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INDEX

ABSTRACT

Guinea-Bissau is one of the ten poorest countries in the world. The Boé sector, in the southeast, is by its turn the poorest region of the country, with low availability of fertile soils but with high potential for bauxite mining. The sector is also home of western chimpanzee (*Pan troglodytes verus*) populations, which have been tolerating quite well the human presence in low densities. However, the arrival of mining enterprises may cause local extinction of some of these populations.

The objective of this study was to discover the density and distribution of a western chimpanzee population living next to a bauxite deposit in the southeast of Boé, on the border with Guinea. With this information, a better picture of the possible impacts of mining over this chimpanzee population could be drawn.

Two approaches were applied, *Line Transect Sampling* (LTS) method was used as a tool to estimate the density and environmental distribution as a function of their nests and *Camera Trapping* (CT) to identify behavior, associated fauna and to confirm the results from LTS. Additionally, satellite image classification was made to identify all the suitable habitats and effectively occupied area.

From the LTS survey it was estimated a density of 1,80 weaned chimpanzees per km^2 and from the satellite image analyses, $22km^2$ of suitable habitats were identified, leading to a final estimation of approximately 39 weaned chimpanzees living around to the bauxite deposit. An estimation consistent to the minimum of 18 individuals identified by the CT. *Drumming*, a new behavior, unique to the chimpanzees of this region, could also be documented by the CT and is described here as well.

It is concluded that mining indirect impacts are more prone to influence chimpanzees survivorship than direct ones, as to say, water pollution and noise disturbance will be the main factors to disturb their environment than habitat destruction by its own, since little overlapping was found between their home range and the mining site itself. With these discoveries, suggestions can be made to mitigate mining potential impacts and go even further on proposing alternatives to couple environmental conservation with socio-economic development for the whole Boé sector.

INTRODUCTION

An overview of Guinea-Bissau

Guinea-Bissau is bordered by Senegal to the north, by Guinea in the south and east and bathed by the Atlantic Ocean to the west. Its total area is 36.120km² and the topography is low-lying with the highest point not surpassing 300m (Gippoliti *et al.* 2003). The climate is characterized by an average rainfall of 1600 – 2100 mm/yr, with a rainy season between June and November and an average temperature of 28^{0}C, April being the warmest month (reaching 39^{0}C) and January the coldest (reaching 12^{0}C) (Wit, 1989). Forests cover 60% of its territory, being more abundant to the west (Gippoliti *et al.* 2003) and giving space to Savannah eastwards. Population density is higher in the north-west (42 people/km²) and lower in the southern and eastern regions (15 people/km²) (Gippoliti *et al.* 2003).

After its independence from Portugal in 1974, Guinea-Bissau had its first multiparty legislative and executive election only in 1994, but democracy couldn't remain for long periods since then (Gippoliti *et al.* 2003), civil wars and State coups marked the last 20 years of the country's history. Since April 2012 Guinea-Bissau is under a military government, unrecognized by the United Nations. Due to this civil unrest, scientific and conservation studies are hard to be implemented, leaving a gap of information about the country's natural richness.

Chimpanzees Ecology

Chimpanzees (*Pan troglodytes*) habitats ranges from savanna woodlands to tropical moist forests, from sea level up to 2.800m altitude and despite being the most widespread and abundant species of great ape, occurring in 22 countries of Africa, from 13° North to 7° South (Butynski, 2003), *P. troglodytes* is however considered an endangered species by the *2013 IUCN Red List of Threatened Species* (IUCN, 2013). It is also considered endangered by the United States Endangered Species Act and the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), both from 1973. This species probably once dwelled in most part of Equatorial Africa, having a population of about 2.000.000 individuals in the early 20th century, but reduced to some 200.000 after a century (Butynski, 2003). The major threats for chimpanzees are, logging and oil and gas mining, which cause habitat fragmentation and degradation; slash and burn agriculture, that besides habitat fragmentation, also increases human-chimpanzees conflicts, such as intentional kills or accidental deaths in traps to protect plantations, conflicts that only trend to be intensified by the rapid human population growth in Africa; poaching, for meat or pet trade and medical research, since chimpanzees capture is still allowed for scientifically purposes in countries like Guinea, for example; diseases, such as Ebola, facilitated by their increasing proximity and biological similarities to humans (Oates *et al.* 2008). In the specific case of Guinea-Bissau, chimpanzees suffer with habitat loss, mainly for cashew and banana plantations (Gippoliti *et al.* 2003).

Taxonomically, chimpanzees can be divided in four subspecies, *P. t. verus,* the western chimpanzee, *P. t. ellioti,* the Nigeria-Cameroon subspecies, *P. t. troglodytes,* the central chimpanzee, and *P. t. schweinfurthii*, the eastern subspecies (Butynski, 2003). Nevertheless, recent genomic studies have been suggesting that *P. t. troglodytes* and *P. t. schweinfurthii* form a unique grouping, since gene flow may be still occurring among those two populations (Vigilante, 2003). Since this question is still unsolved and in order to keep the taxonomic tradition, this study will consider the four subspecies division. From those, the two of biggest concern are *P. t. verus*, in the IUCN Red List since 1988 and counting today with 21,300 – 55,600 individuals (Oates *et al.* 2008), and *P. t. ellioti*, the most recently named subspecies and counting with only 6.000 individuals restricted to Nigeria and Cameroon. *P. t. verus* can be presently found in ten countries, from southeast Senegal to southwest Ghana. It is mostly abundant in Côte d'Ivoire, Mali, Guinea, Liberia and Sierra Leone (Butynski, 2003); the last three falling entirely within its natural range, thanks to the great diversity of suitable habitats in these countries (Kormos & Bakarr, 2003). By the other hand, western chimpanzees are considered highly endangered in Senegal and Ghana, where the estimations don't surpass some hundreds, and already extinct in the wild in Benin, Togo and probably Burkina Fasso (Butynski, 2003; Oates *et al.* 2008). In Guinea-Bissau no countrywide estimation were ever made, but pioneer studies in the country suggest the population lies between 600 and 1000 individuals (Gippoliti *et al.* 2003), although Serra *et al.* (2007), based on interviews with poachers and other experienced villagers, reached an estimation of 710 individuals for the Boé sector alone. The Upper Guinea Forest ecosystem, which extends itself from Guinea to Togo, holds the biggest western chimpanzees population densities even though approximately only 25% of its original vegetation cover still remains. In 2003, there were 26 protected areas in the countries where *P. t. verus* is found, corresponding to 6,6% of its natural range, but housing an estimation of 10.400 – 11.600 individuals, what represent between 19% and 54% of their whole population (Kormos & Bakarr, 2003).

In the year of 1988, chimpanzees were declared extinct from Guinea-Bissau but following surveys were able to identify populations in the south of the country, from Parque Natural das Lagoas de Cufada in the south-west to the regions of Quinara and Tombali and, in the southeast, in the Boé sector (Gippoliti *et al.* 2003).

P. troglodytes are omnivorous but highly dependent on fruits, the amount of meet consumed and other elements of their diet will vary depending on the environment they inhabit. Oil palm tree (*Elaeis guineensis*) is one of the most significant plant in their diet, from which they can consume the fruit, nut kernel, petiole of young leaves, flower buds, pith and palm heart all year round. The availability of food resources, more than shaping the community's range and size, also determines their tool use frequency, since otherwise expendable and hard-to-get food resources become more valuable in scarcity seasons and environments. Every known chimpanzee community use tools, each one having its own range of objects. Nut cracking, using a stone hammer and an anvil (normally an exposed root or another stone), maybe the most sophisticated behavior, was only observed in *P. t. verus* subspecies communities restricted to the evergreen forests (Humle, 2003).

Food shortage is also dealt with group fission, enabling the individuals to explore their home range reducing intra-specific competition. This kind of community organization is called fission-fusion social structure and is also influenced by the group's composition (such as number of sexually mature females present), the presence of predators, home range size and availability of nesting sites (Humle, 2003). Fusion of sub-groups can also occur between members of neighboring communities, what makes tricky to determine their real size. Ogawa *et al.* (2006) affirms that this fission-fusion strategy has evolved as an adaptation to equilibrate the amount of energy necessary for their large body size and their patchy distributed resources.

Chimpanzees that have been foraging can meet their whole group again at the sleeping sites, a good alternative for communities with a big home range, since sleeping sites are more clustered than their resource founds (Ogawa *et al.* 2006). Preferable habitat and trees for nesting vary according to resources availability, proximity to human activities, presence of predators and to the community's structure. Chimpanzees prefer to nest on the canopy of trees, where they can prepare it by braiding close branches to each other, braking or banding them to form a round and solid structure where they normally spend a night or a small resting period during the day. Nests on the ground can also be found but are less common, since they leave chimpanzees more exposed to predators, like leopard (*Panthera pardus*). (Humle, 2003).

<u>Bauxite Mining in the Guineas</u>

In most countries of West Africa, intensive mining have started during the 1960's. Besides phosphate and diamond, bauxite has also been highly exploited. In Guinea, a partnership between the government and the private consortium Halco Mining Inc. was created in 1963 under the name of *Compagnie des Bauxites de Guinée* (CBG), being responsible, today, for the exploitation of four deposits of this mineral in the city of Sangarédi and its surroundings (Sangarédi, Bidikoul, Silidara, N'Dangara), in the region of Boké. CBG has exclusive rights guaranteed until 2038 and besides Sangarédi, also has easy access to the port city of Kamsar to where all the bauxite production is transported by railway (Diallo, 2010). Rio Alcan and Alcoa, the main shareholders of the Halco Mining consortium, are currently proceeding with the viability studies for the construction of an aluminum refinery in this city (Diallo *et al.*, 2010).

In a much earlier stage of its mining history is the neighbor country of Guinea-Bissau. Prospections have been made since the 1970's mainly by enterprises from Portugal and former USSR. In spite of that, Guinea-Bissau currently exploits its mineral resources only for acquiring raw materials for construction. The first mining licenses have been recently conceded to GB Phosphates LTD to exploit phosphate in the region of Farim, in the center north of the country, and to Bauxite Angola S.A. to exploit bauxite in the sector of Boé. In Boé, nine deposits where identified, from which six present economic significance (Adam, Eva, Caim, Rachel Rebeca, Vendou Leidi and Fello Canhage. See Figure 1 for more details), totalizing 113Mt of available mineral. Besides the required structure in the Boé, there is also a plan for constructing a railway and a port in the city of Buba to export the bauxite (Diallo, 2010).

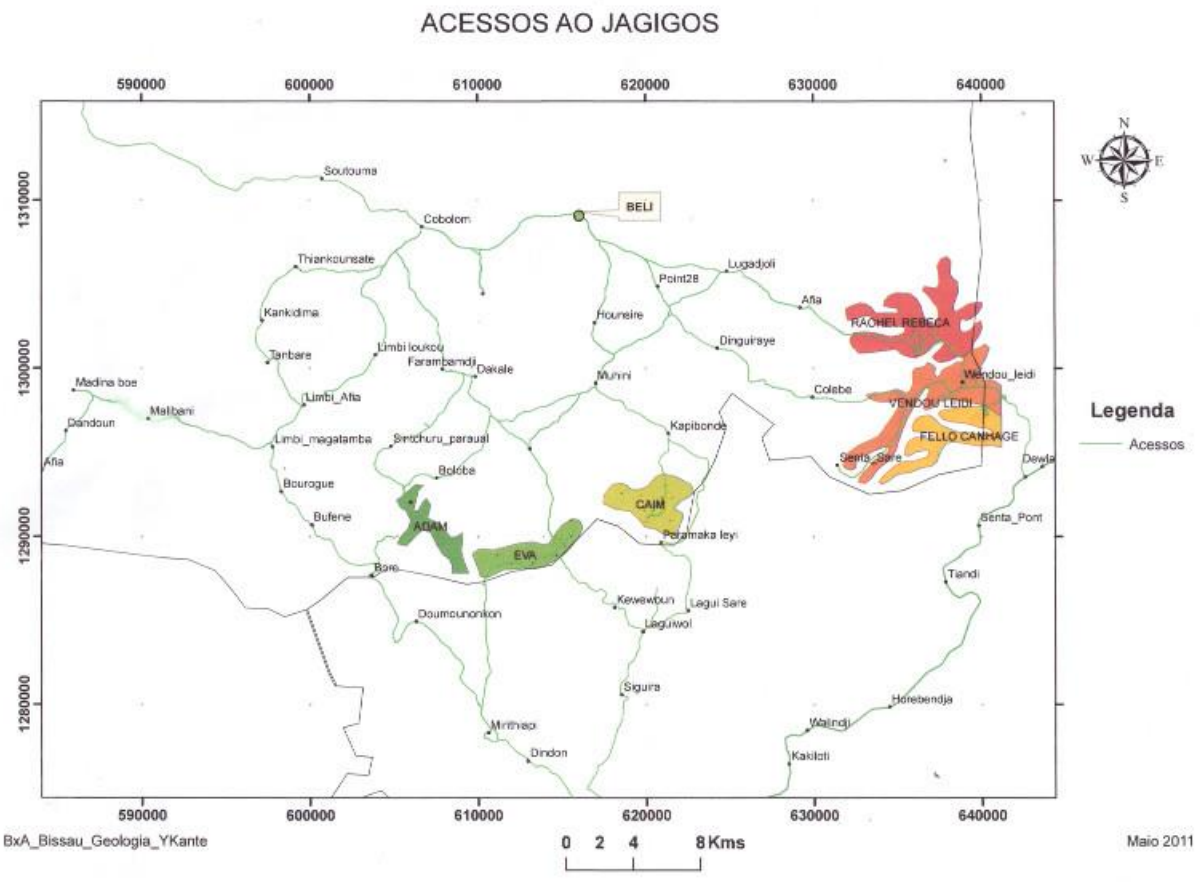

Figure 1: The six bauxite deposits in the Boé sector (Map cordially ceded by Bauxite Angola S.A.)

The cases of Guinea and Guinea-Bissau are cited here not only because they are close to each other (Sangarédi is only 100km away from Béli, the base village for the enterprise in Boé), but also because their similarities. Kamsar is located in the Upper Guinean Forests ecosystem, one of the 34 world's biodiversity hotspots (Myers *et al.*, 2000), and besides having its mangroves relatively well preserved despite human presence, also neighbors three protected areas, the Kapatchez delta and the Tristan and Alkatraz islands, created as part of Guinean efforts as member of Ramsar Convention, but presently unprotected, thanks to the lack of State's attention and the proximity to the mining industrial installations (Diallo *et al.*, 2010). The future bauxite harbor near Buba, in Guinea-Bissau, is located in a protected area as well, the Parque Natural das Lagoas de Cufada, declared in 2000 (Gippoliti *et al.* 2003). It shelters the biggest fresh water superficial reserves of west Africa (Cufada, Badasse and Biorna), also being part of the list of Ramsar wetlands of international importance and making it a well-known site for its ornithological interest, attracting a great diversity of migrant birds (Gippoliti *et al.* 2003; Diallo, 2010). The Grande de Buba river is site of barracuda (*Saphyraena* spp.) creation, where it is communally and responsibly managed by the local fishermans since 1990. The construction of a future port in Buba is another factor that will resemble Kamsar. The buildings area will occupy 7.000 from the 89.000ha (7,9%) of the park area. Considering it will be completely built in a sub-humid forest area, the work will tear down 52,7% from the 13.546ha of this kind of vegetation present in the park. The sub-humid forest is the formation that shelters most part of the fauna and touristic and scientific interests of the park (Diallo, 2010).

In the juridical scope, however, the reality of those two countries is not that similar. While Guinea has a more complete legislation, Guinea-Bissau, due to its political instability, is still struggling to approve an environmental code and regulate the management and control of chemically hazardous substances, for example. Even not having such laws, the country has already legislation on wild life, water, forests, mining and on the content and methodology of environmental impact studies (Diallo, 2010). Moreover, hunting is prohibited in the Hunting Reserves, such as the Canthanez Forest and the whole sector of Boé (Gippoliti *et al.* 2003).

Even with a more advanced environmental legislation, Guinea still suffers from the consequences of mining activities. Diallo (2010) names the main impacts over the environment found by a study held by the NGO Guinée Ecologie: air pollution thanks to the dust resultant from bauxite milling (thrown in the atmosphere uninterruptedly for the last 45 years); water pollution and damage to great part of mangroves (with consequences for fishing and other ecosystem's resources); many species of fauna and flora have disappeared or became rare since the beginning of the mining exploitation (being the shortage of firewood, fruiting trees and medicinal plants of particular impact to the local community); rise of hunting pressure over wild life thanks to the arrival of immigrants workers and noise pollution, driving away wild life. Considering those facts, a study like this is important to reveal the potential impact bauxite mining can have over wild life, especially in Guinea-Bissau, where the smaller presence of State leads to a bigger susceptibility of the environment.

The case of Boé sector

The Boé sector is located in the south-east of Guinea-Bissau, limited at north and west by the Corubal river and at south and east, by the Guinean border. Its soils are shallow and derived from lateritic crusts, in consequence, a savannah type vegetation is predominant and forest only develop where the soil is deep enough and not flooded for long periods (Wit, 1989). Its topography is more mountainous than the rest of the country, with culminating point at 292m, close to the village of Vendu Leidi, in the western fringe of the Fouta Djallon massif, and proved to contain large bauxite deposits, as other hills in the sector.

The lateritic plateaus, mostly present in the southeast of the sector contain bauxite in concentrations high enough for attracting mining enterprises. In Ronde Hill, for example, prospections were made during the late seventies and early eighties by Russian efforts and more recently by Bauxite Angola S.A., revealing a rentable deposit of this mineral. A new road was built by this company in partnership with C*ompagnie Bauxite de Guinée* (CBG) to link the village of Munhini (Northwest of Ronde Hill) to Guinea-Conakry and facilitate the transit of big machinery for bauxite exploitation (Wit, 2011). The evaluation of the effects of this road (and the future mining activities that will follow) is of extreme importance since this road cross the crest of the Hill, an area of enormous biodiversity interest and, as being a culminating point, also important for the local hydrology, having a role in the regulation of the water quality and availability at the valleys below (Wit, 2011).

Those valleys, drained by the Jabere and Paramaka rivers, are also home of some chimpanzee (*Pan trogloditis verus*) populations, extremely susceptible to the environmental stress brought by the arriving of the mining and its workers (Wit, 2011). The present agricultural pressure realized by the four villages around the area (Munhini and Capebonde on the Guinea-Bissau side and Paramakadow and Paramakaley on the Guinea-Conakry territory), which apparently haven't influenced drastically those populations for the previous years, could also become a matter of worry if the mining activities damage buffer zones, since it would force crop feeding behaviour, leading to a human – chimpanzee conflict with the local villagers (Hockings & Humle, 2009). Moreover, the presence of roads, such as the ones already constructed by Bauxite Angola S.A. may attract more intensive chopping of wood, agricultural activities (in those areas, particularly of cashew plantations) and poaching. This, summed to the absence of a permanent State's control, as attested by Wit (2011), can also contribute to accelerate the environmental changes in the areas around it. Considering this situation, a more precise evaluation of chimpanzees distribution around this area is needed to understand the potential impact of the mining on that population and to propose ways to mitigate potential negative impact.

OBJECTIVE

The aim of this project is to evaluate demographic structure and habitat use of the chimpanzees populations in Ronde Hill and the valleys besides it, defined by Jabere and Paramaka rivers, and confront this information with the mining plans provided by Bauxite Angola S.A. More specifically, this study has as objective to:

(1) Lead to a reliable estimation of the chimpanzee population density and abundance for the areas around Ronde Hill;
(2) Map the population distribution and identify the areas of overlapping and proximity with the mining area, roads and other mining related settlements;
(3) Suggest, based on the results of this research and on literature review, measures for reducing potential impact on the chimpanzee population.

METHODOLOGY

Study Site

This survey was held on Ronde Hill, where the Caim bauxite deposit is located, and its surrounding valleys, determined by Paramaka and Jabere rivers and their affluents (comprising Jabeje, Barquere, Gra, Mussa and Tuncotanca rivers) (See Figure 2), roughly around 11° 41' N, 13° 54' W. It is located next to the southeastern border with Guinea and the closest human densification are Capebonde Village in Guinea-Bissau and Paramakadow and Paramakaley villages on the Guinean side.

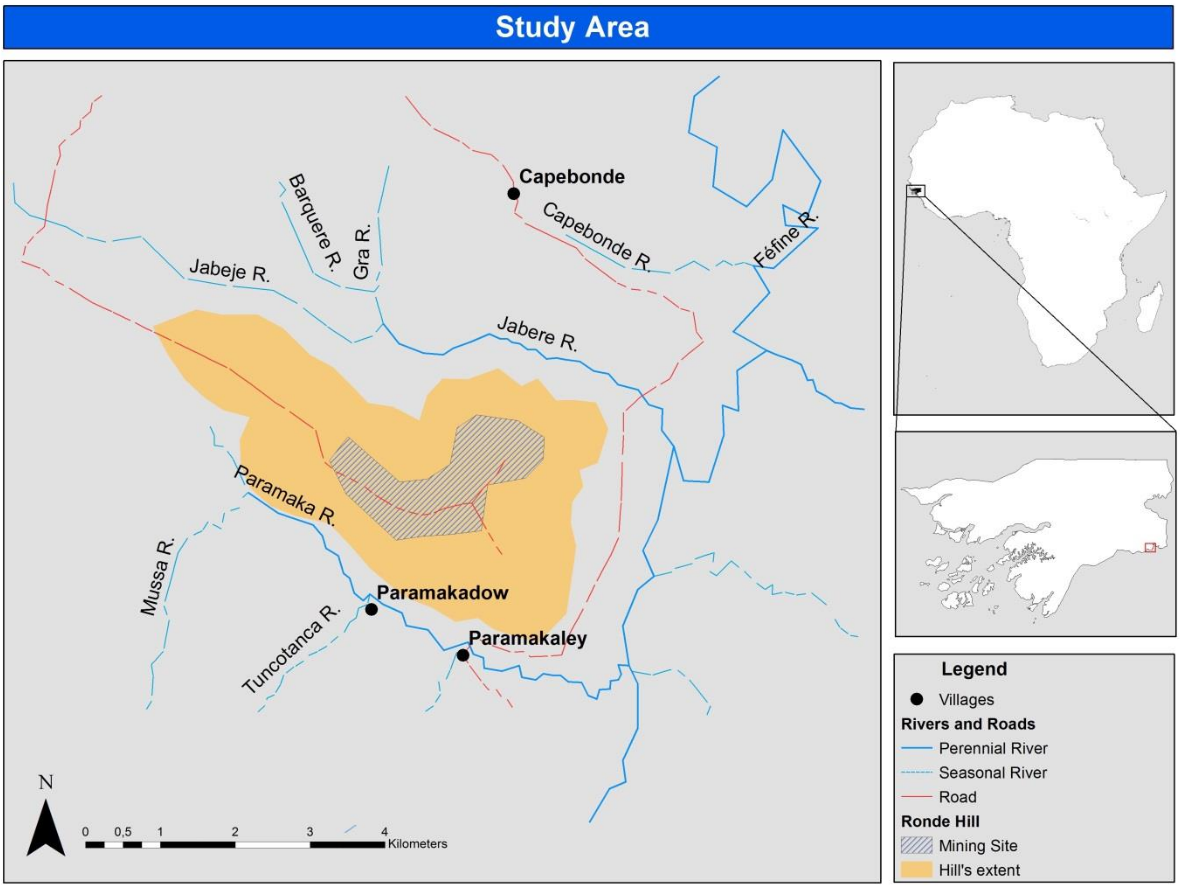

Figure 2: Map highlighting the main elements of the study area.

Vegetation satellite sensing

Free satellite images of the study area were obtained from the website https://maps.google.com/ and joined together with the free source software GIMP 2.0 to obtain a single image with the full extent of the study site. Posteriorly, it was analyzed in software ArcGIS 10.1 in order to distinguish its main vegetation covers and calculate their respective areas.

Field methodology

Considering the reduced time and resources available, to obtain a more efficient and unbiased data collection, this study was divided in two main phases. The first of them consisted of a *Reconnaissance* (Recce) *walk* along Ronde Hill and Jabere and Paramaka rivers in order to identify the different environments along their valleys. With the Recce walk a clearer picture of the most suitable habitats for chimpanzees could be drawn, providing enough information to go on to the next phase in the research, the *Line Transect Sampling* (LTS). The LTS provided a more systematic estimation of the chimpanzee population characteristics by recording nests and eventually other signs of chimpanzee activities, such as dung or feeding marks. Summed to those approaches, *Camera Trapping* (CT) was placed in locations where high chimpanzee activity were identified and eventual dung and herbal samples were collected to rise information about feeding habits.

Reconnaissance walk

Between the spring of Jabeje river and the mouth of Jabere river there is a length of around 11km that defines the north valley of Ronde Hill. Paramaka river, a little bit smaller (8 km), defines its south and southwest valleys. The Recce walk performed across the east flank of the Hill and the whole extension of those river valleys, trying to keep as close as possible to their margins. During the walk, it were recorded the fula and creole names of all the recognized nesting trees within the observers sight, accessing their scientific name with Catarino's *et al.* (2006) guide for Guinea-Bissau plants, number of nests present and their decay stage was also recorded, fallowing Plumptre & Reynolds (1997) suggestion:

1 – if the nest is still fresh and solid, with green leaves and faeces or feeding signs underneath;
2 – if it is still solid but the leaves have signs of drying;
3 – if the nest presents only dried leaves and/or is starting to lose its structure;
4 – if it have lost all leaves but is still recognizable as a nest due to the presence of broken branches and twigs.

UTM coordinates of every nesting tree was taken with the help of a GPS device (GARMIN eTrex 10) and the environment around it was also recorded, as well as when any considerable change during the walk was attested. Environmental classification followed the categories: Primary Forests for clearly undisturbed forested habitats; Forest Fragment for isolated forest areas surrounded by agricultural fields or Savannah; Colonizing Forest for the border of forested areas with Savannah or abandoned agricultural lands; Young Secondary Forest for agricultural fields abandoned for more than 5 years that started to recompose their forest structure; Old Secondary Forests for forested areas with physiognomy almost similar to primary forests but showing signs of previous disturbance, such as old trunks very ramified or with sings of cutting; Fallow for abandoned agricultural fields, subdividing them according to the age of abandonment. Grassy Savannah for open grasslands; Shrubby Savannah for grasslands rich in shrubs; Wooded Savannah for grasslands with trees; Slash-and-Burn field for active agricultural areas; Plantation for permanently cultivated areas, such as Cashew cultivations; and Village for any human settlement.

Other eventual clues of chimpanzee activity, such as dung and feeding signs were also recorded and UTM coordinates taken. The Recce walks were done in the first week of April, from 8:00h to 16:00h, since the light availability between those hours would provide the most efficient observations.

Line Transect Sampling

After a pre-analysis of the data collected at the Recce walk stage, a broad view of the possible chimpanzee distribution around the Ronde Hill could be established, making possible a more concrete planning of the LTS. The LTS followed a South-North sense, comprising five lines of 5km each and 1km away from each other, crossing Ronde Hill and the gallery forests of Paramaka and Jabere rivers. Each line was walked four times with an interval of 14 days between each repetition, totalizing 100km of walk. During the LTS three people walked straight lines with the help of a compass and a GPS device, taking the UTM positioning of the starting and ending points as well of all the observations of chimpanzees nests. Besides registering the location of the observations, the perpendicular distance from the central line and the Circumference at Breast Height (CBH) of all nesting trees was also measured, both with the help of a measuring tape. On the following repetitions measures were only taken from newly spotted nests. Nests spotted on the previous repetitions were prevented from being recounted by comparing new nest's GPS location with previous points and checking for tree species and CBH in case the doubt still persisted. This approach was preferred in spite of marking them with stakes under the tree, as done by Plumptre & Reynolds (1997), because of the practicality of avoiding carrying and manufacturing stakes and because the author believes checking the previous data in the field is safer than relying the identification of old nests by stakes, since they are passive of being damaged or removed by wind, animals or fire.

Camera Trapping

Six Bushnell Trophy cameras, model 119476, were available to be placed at promising/interesting locations for chimpanzees activity (such as feeding spots, travel paths, tool use sites, water holes in dry regions, bridges for water crossing, etc.). This provided additional information for understanding habitat use, cultural singularities and, to a less degree, social structure.

Chimpanzees tend to make their own path by repeatedly following the same ones, they also have preferred bridges (fallen trees, branches or rocks) over water sources in the forest such as swamps and rivers. Bridges can be located over temporary or permanent water sources that will not dry up throughout the dry season. Waterholes are also important camera trap locations, especially if they are in low density. Fruiting trees, like *Dialium guineense*, *Parkia biglobosa*, *Sorindeia juglandifolia* and *Ficus sur* tend to be hotspots for chimpanzee activity and larger individuals which are rarer in abundance may increase the chance of filming. Chimpanzees have preferred drumming sites where trees with characteristic scars and drumming rocks are present on the spot. All those considerations were taking into account when selecting good places for CT.

Data Analysis

For LTS, if it is supposed that all nests within a distance w from the line transect are detected, then the estimated density of nests can be written as:

$$\hat{D}_{nests} = \frac{n}{2\mathrm{L}w} \qquad (1)$$

Where n is the total number of observations, L the total length of the transect and the term 2Lw the area of the rectangle that includes all observations from the transect. However, not all nests within distance w can be surely spotted from the central line. Thus, it is necessary to include a function of detection probability on equation 1 to make it more reliable:

$$\hat{D}_{nests} = \frac{n}{2\mathrm{L}\int_0^w \hat{g}(x)dx} \qquad (2)$$

The detection probability function $\int_0^w \hat{g}(x)dx$ varies from 1 at $x = 0$ (detection is certain when the nest is at the central line) to 0 at $x = w$ (where the nest is located at the threshold beyond which no nests can be detected anymore). This function is composed by a key function and a series expansion (see Appendix 1) with parameters estimated according to the perpendicular distances from the transect of the nests observed in the field. The best functions to describe the present data were chosen based on the lowest Akaike's Infromation Criterion (AIC) with help of the software DISTANCE 6.0. For more details on the statistical foundations of density estimation, see Buckland *et al.* (1993).

Weaned chimpanzees density and abundance were estimated from the nests density in four different ways with the help of software DISTANCE 6.0: Standing Crop Nest Counts (SCNC) and Marked Nests Counts (MNC), both considering individual and clustered nests for analysis. For the SCNC it was considered only the nests surveyed in the first walk of the LTS and the chimpanzees density was taken as a function of the estimated nests density divided by the nest production rate and nest disappearance time (Plumptre, 2003), according to the formula modified from Kühl *et al.*, 2008:

$$\widehat{D}_{weaned\ chimpanzees} = \frac{\widehat{D}_{all\ nests}}{\hat{r}+\hat{t}} \qquad (3)$$

Where r is the rate of nest production per individual per day and t is the mean life period of the nests. Both $\hat{r}$ and $\hat{t}$ can only be estimated by field studies and may vary between populations and geographic areas. Thus, the ideal procedure would be estimating those values in previous studies in the research area. However, they are time consuming and sometimes unpractical in certain occasions. For example, for estimating the rate of nest production ($\hat{r}$), it is necessary to follow an habituated chimpanzee population from dawn to dusk and ensure that all the nests produced by the individuals during the study period were recorded (Plumptre & Reynolds, 1997). For the estimation of nests mean life ($\hat{t}$), a sufficient number of nests must be spotted at the same day they were produced and revisited frequently until they have decayed to the point they could not be identified as nests anymore. $\hat{t}$ may vary, for example, from approximately 46 days in Budongo Forest Reserve, Uganda (Plumptre & Reynolds, 1997) to approximately 294 days in Lagoas–de–Cufada Natural Park, southwestern Guinea-Bissau (Carvalho *et al.*, 2013), thus demanding a long time available for conducting the study.

Since in the present case chimpanzees are not habituated and there were time limitations, neither the rate of nest production and nests mean life span could be estimated for the study site, alternatively, it was used estimations obtained from other studies. $\hat{r}$ was assumed to be 1,09 nests/day per individual, after Plumptre and Reynolds (1997) study in Budongo Forest Reserve, Uganda. For $\hat{t}$, there are some tens of different estimations, the one chosen as the most adequate for this study was 194 days, obtained by Fleury-Brugiere & Brugiere (2010) in the Haut Niger National Park, Republic of Guinea. This was considered the most adequate due to the proximity of the sites and to the similarities in both vegetation and climates.

Borrowing estimations from other study areas may lead to errors. The MNC method reduces this risk by not relying on the nests means life span for the calculations. For the MNC analysis, all the nests counted in the first LTS repetition were excluded and only the new nests spotted on the subsequent walks were taken into account. Like this it is possible to assume all nests included in the analysis were built during the study period and then their decay time becomes irrelevant (Plumptre, 2003). Thus, the density of chimpanzees can be calculated as formula 4, below (modified after Kühl *et al.*, 2008):

$$\widehat{D}_{weaned\ chimpanzees} = \frac{\widehat{D}_{new\ nests}}{\hat{r}+T} \qquad (4)$$

Where $\hat{r}$ is the same estimation from formula 3 an T, the elapsed time, in days, between the first and last walks of the LTS.

Chimpanzees tend to build nests in groups (Ogawa *et al.*, 2007), thus it is much more frequent to find them in clusters than individually. Buckland *et al*. (1993) says it affects the detection function and consequently the final estimation of density, since a bigger cluster would be easier to be spotted from a farther distance, generating a cluster size bias in the data collection. One strategy to avoid this error is to consider the observation of clusters instead of single nests in software DISTANCE 6.0. For that, a post-field clustering was made with help of ArcGIS, by entering all the individual nests data collected in the field into the program and joining those of the same age class and within a radius of 20m from each other into a single cluster. Despite the threshold distance of 50m being sometimes used to define a nest cluster (Morgan *et al.*, 2006; Sousa *et al.*, 2011), the present study preferred to use 20m, like in Marchesi *et al.* (1995), Ogawa *et al.* (2007) and Kouakou *et al.* (2009) since it was observed in the field this distance would describe better the limit distance between each nest within the cluster and prevent the risk of grouping two clusters together. After clustering in ArcGIS, resulting data was a list of the number of nests in each cluster and their average distance from the line transect. Calculations with ungrouped nests were also made just for the matter of comparison. Besides, the threshold distance (w) was defined respectively to each analyses aiming to exclude the outliers observations caused by group size bias (i.e. removing from the data those nests far in the distance that wouldn't have been observed if weren't grouped). w was defined as to exclude around 10% of the farthest observations and to maintain the shape criterion, as suggested by Buckland *et al.* (1993).

RESULTS

Nesting Behaviour

In total, 1137 nests were identified during the four transect repetitions, from which 608 only in the first one. Table 1 presents the ten most preferred tree species for nesting. Together, these species are responsible for hosting 90% of the nests found in this study. Ground nests were also included in this analysis, but didn't have significant contribution since only seven were found, totalizing 0,62% of the whole sample. *Parkia biglobosa* was by far the most used species for nesting, corresponding to almost half of the tree choices (Tab. 1). Unfortunately, it was impossible to identify all the species. A recurrent species named by the guides as Bandjala could only be identified until the family level, appearing in the following tables as "Unidentified Leguminosae". Other tree, recognized as Sataga, could not be surely scientifically identified, thus, the two possible correspondent species name are shown.

Table 1: Tree species most used for nest production, according to the data obtained in the transects.

Tree Species	No. of Nests	% of Sample
Parkia biglobosa	507	44,59
Khaya senegalensis	150	13,19
Pterocarpus erinaceus	91	8,00
Erythrophleum suaveolens	61	5,36
Unindentified Leguminosae	54	4,75
Parinari excelsa	42	3,69
Cola cordifolia	34	2,99
Dialium guineense	28	2,46
Mitragyna inermis	20	1,76
Lecaniodiscus cupanioides or *Trichilia prieuriana prieuriana*	19	1,67

Parkia biglobosa and *Khaya senegalensis* together were responsible for housing almost 60% of all the nests recorded. This was expected since the field stage, since these species were recognized in the field to host elevated number of nests at once. During the research, an individual *Parkia biglobosa* was observed with 25 nests (22 recent and other 3 old) and another one with 24 (5 fresh and other 19 recent). *Khaya senegalensis* in its turn, had an individual with 16 nests (2 old and 14 very old). The full list with all the species used for nesting, together with their correspondent families, fula and creole names, can be found in Appendix 2.

Habitat Use

The following figure (Fig. 3) shows a vegetation classification of the study area, based on satellite imagery. Land cover was divided in four categories, allowed by the image resolution: Late Stage Forest comprises primary and secondary forests on a late stage of succession; Early Stage Forest corresponds to colonizing and young secondary forests; Savanna comprises bare grasslands or with shrubs; Agricultural Fields represents active agricultural lands as well as those abandoned from less than three years. This gross division of the vegetation cover was also used for estimating the nests density over the habitats, since they group together the physiognomies with approximately the same level of visibility.

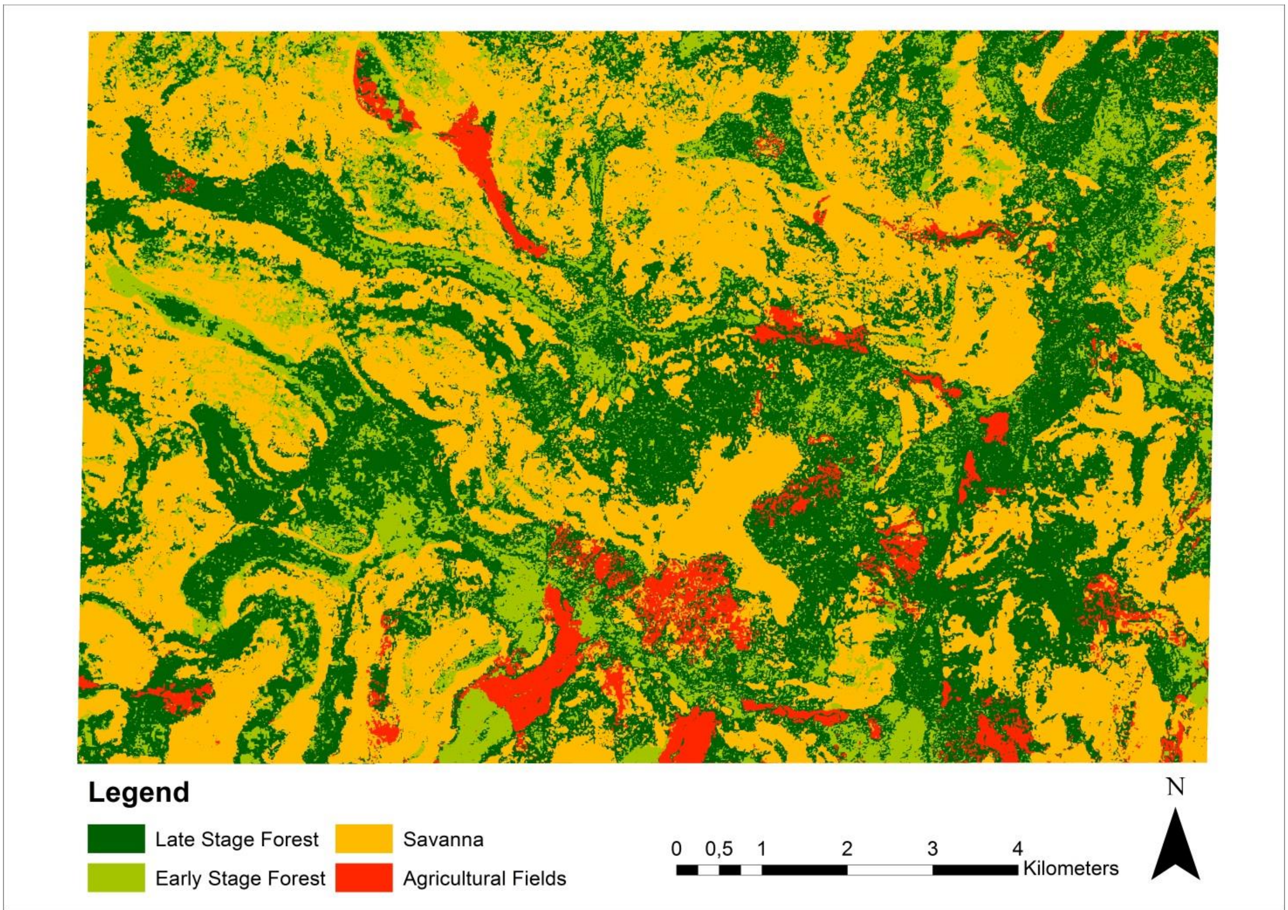

Figure 3: Main vegetation cover of the study area, according to satellite image classification. For more details, see text. Classification obtained with the help of software ArcGIS 10.1.

Frequency of nest spotting varied among vegetation types. Table 2 shows the main habitats where nests were seen. Three nests were observed in a recently burned agricultural field but were included in the old secondary forest habitat, since they were probably made when the original vegetation was still present. Areas presented in Tab. 2 don't correspond to the total area of Fig. 3, but only to the perimeter effectively occupied by the chimpanzees, corresponding to Ronde Hill and Paramaka, Jabere and Jabeje valleys. It is important to highlight that this distribution doesn't represent the preferred habitat for nesting nor the proportional occupation of the territory by chimpanzees, since the area of each habitat in the study site is different, as well as the visibility among the vegetation types. Fallow areas become harder to have their real age identified as older they get, so, it may be possible that fallow areas older than 1 year are not correctly identified.

Table 2: Distribution of nests according to habitat type

Satelite Classification	Area (Km^2)	% Area	Field Classification	Observed Nests	% Observations
Late Stage Forest	15,15	42,73	Forest – primary	39	3,4
			Forest – old secondary	451	39,7
			Gallery Forest – primary	35	3,1
			Total	525	46,2
Early Stage Forest	6,81	19,21	Forest – young secondary	276	24,3
			Forest – colonizing or fragment	86	7,6
			Gallery Forest – young secondary	17	1,5
			Fallow – 3 years	97	8,5
			Fallow – +3 years	85	7,5
			Total	561	49,3
Agricultural Fields	1,11	3,12	Fallow – 1 year	31	2,7
			Fallow – 2 years	17	1,5
			Total	48	4,2
Savanna	12,39	34,95	Savannah – wooded	3	0,3
			Savannah – shrubs or herbs	0	0,0
			Total	3	0,3
Total	35,45	100,00		1137	100

LTS survey

Table 3 summarizes the results for the weaned chimpanzees density and abundance by the four approaches applied in DISTANCE 6.0. It presents the detection function that best fitted the data according to the lowest AIC, the number of objects effectively used for the calculations (after applying the strip width *w*), the density results, the coefficient of variance and the 95% confidence interval. The abundance of weaned chimpanzees was calculated by multiplying the density by the sum of the areas of late and early stage forests presented in tab. 2, since those were the most suitable habitats for chimpanzees and since the satellite image classification could not differentiate active agricultural fields from those abandoned from less than 2 years.

Table 3: Density estimations obtained by the four different approaches applied in DISTANCE 6.0 (DF: Detection Function; AIC: Akaike's Information Criterion; CV: Coefficient of Variance; CI: Confidence Interval; SCNCi: Standing Crop Individual Nests Counts; SCNCc: Standing Crop Clustered Nests Count; MNCi: Marked Individual Nests Count; MNCc: Marked Clustered Nests Count).

Method	Best DF	AIC	N° of obser-vations	Density [95% CI] (ind./km^2)	% CV	Abundance [95% CI]
SCNCi	Uniform+cosine	2110,38	537	1,53 [0,98-2,40]	17,66	34 [22-53]
SCNCc	Hazard-rate+cos	505,34	134	1,52 [0,98-2,35]	21,44	33 [22-52]
MNCi	Uniform+cosine	540,75	168	2,02 [0,75-5,45]	37,89	44 [16-120]
MNCc	Half-normal+cosine	120,72	45	1,80 [0,96-3,36]	29,82	39 [21-74]

CT analysis

In the analysis of the trap cameras images, 20 mammal species could be identified (Tab. 4). Besides, some birds, rodentia and chiroptera could be recognized but not identified till the species level.

Table 4: Mammals observed with the trap cameras with their respective family and place of spotting.

Species	Family	Environment
Cercopithecus aethiops sabaeus	Hominidae	Border with savannah Forest on the hills Gallery Forest
Cercopithecus mona campbelli	Hominidae	Border with savannah Forest on the hills Gallery Forest
Pan troglodytes verus	Hominidae	Border with savannah Forest on the hills Gallery Forest
Cercocebus atys	Hominidae	Border with savannah Forest on the hills Gallery Forest
Funisciurus pyrropus	Sciuridae	Gallery Forest Forest on the hills
Atherurus africanus	Hystricidae	Border with savannah Gallery Forest
Hystrix cristata	Hystricidae	Border with savannah Gallery Forest
Atilax paludinosus	Herpestidae	Border with savannah (maybe) Gallery Forest
Ichneumia albicauda	Herpestidae	Border with savannah

Cricetomys gambianus	Nesomyidae	Border with savannah Gallery Forest
Civettictis civetta	Viverridae	Border with savannah Gallery Forest
Genetta genetta	Viverridae	Border with savannah Gallery Forest Fallow
Felis serval	Felidae	Border with savannah
Felis caracal (maybe)	Felidae	Border with savannah
Phacohoerus africanus	Suidae	Border with savannah
Potamochoerus porcus	Suidae	Border with savannah Forest on the hills Gallery Forest
Tragelaphus scriptus	Bovidae	Border with savannah Forest on the hills Gallery Forest
Cephalophus maxwelli	Bovidae	Gallery Forest
Cephalophus dorsalis dorsalis	Bovidae	Forest on the hills
Cephalophus niger	Bovidae	Forest on the hills

No animal observed is known to be a natural predator of chimpanzees, however, *Cercocebus atys* was sometimes observed being hunted by them. With respect to the chimpanzees caught in the footages, it can be said the population along the Jabere river is composed of at least 22 individuals, twelve adults, being 4 males and 7 females (one not identified), six juveniles and four infants. The images could also testify an undocumented behavior, unique to the chimpanzees of Guineas region. This behavior will be named here as *Drumming* and was caught four times by the footages. It was always performed by males and in three of the occurrences it consisted of taking a rock, slightly bigger than their fists, start a growing vocalization that culminate in throwing the rock to the base of a tree trunk. It was followed by a detachment of the drumming site, being accompanied by high exaltation with vocalization or not. In the fourth case, the same behavior was observed but the male hit the tree with his feet instead of a rock, also leaving the site with vocalization. Chimpanzees that realized this behavior were alone (in the range of the camera) or in the presence of another male. Besides that, juvenile chimpanzees were observed practicing it in two occasions, in this case they only proceeded in hitting the drumming tree with a rock or with their bare hands, without any vocalization. From the six drumming trees identified in this study, five were from *Ceiba pentandra* and one from *Cola cordifolia* species. By observing the secondary growth within the scars on the trunks of these trees (Figs. 4), it can be said they are resultant from impacts from many years ago, suggesting the drumming have been occurring in the same sites for generations.

Figure 4: A drumming tree (*Ceiba pentandra*) with scars and drumming rocks on the base. Recent scars are indicated with arrows and old ones with a circle.

Figure 5: Buttress roots of a *Ceiba pentandra* covered with drumming scars. Each hole in the bark corresponds to a drumming occasion. A probable drumming rock can also be seen in the ground.

Bauxite Mining

In a meeting in the month of April, Bauxite Angola kindly offered necessary information on their mining plans in the region. Maps were also provided, which could be merged with the results from this research. Chimpanzees' home range was inferred by taking into account suitable habitats and nests observed during the Recce Walks and LTS stages. The territory occupied during the dry season was inferred by all fresh and recent nests observed as well as dung found and vocalizations heard during the month of April and early March. The resultant map is shown on Figure 6. A small overlapping with the chimpanzees' territory and the northeastern edge of the mining area can be observed, moreover, it is located right in the middle of the chimpanzees home range and right next to one of their refuge during the dry season. The southern dry season refuge may extend itself more to the south but its real extension couldn't be further investigated during this research. The camping area for the mining workers is also highlighted, its location was explained in the meeting with Bauxite Angola, but its size is uncertain, since during the study period its constructions hadn't started yet, so a wide estimation is presented in the map.

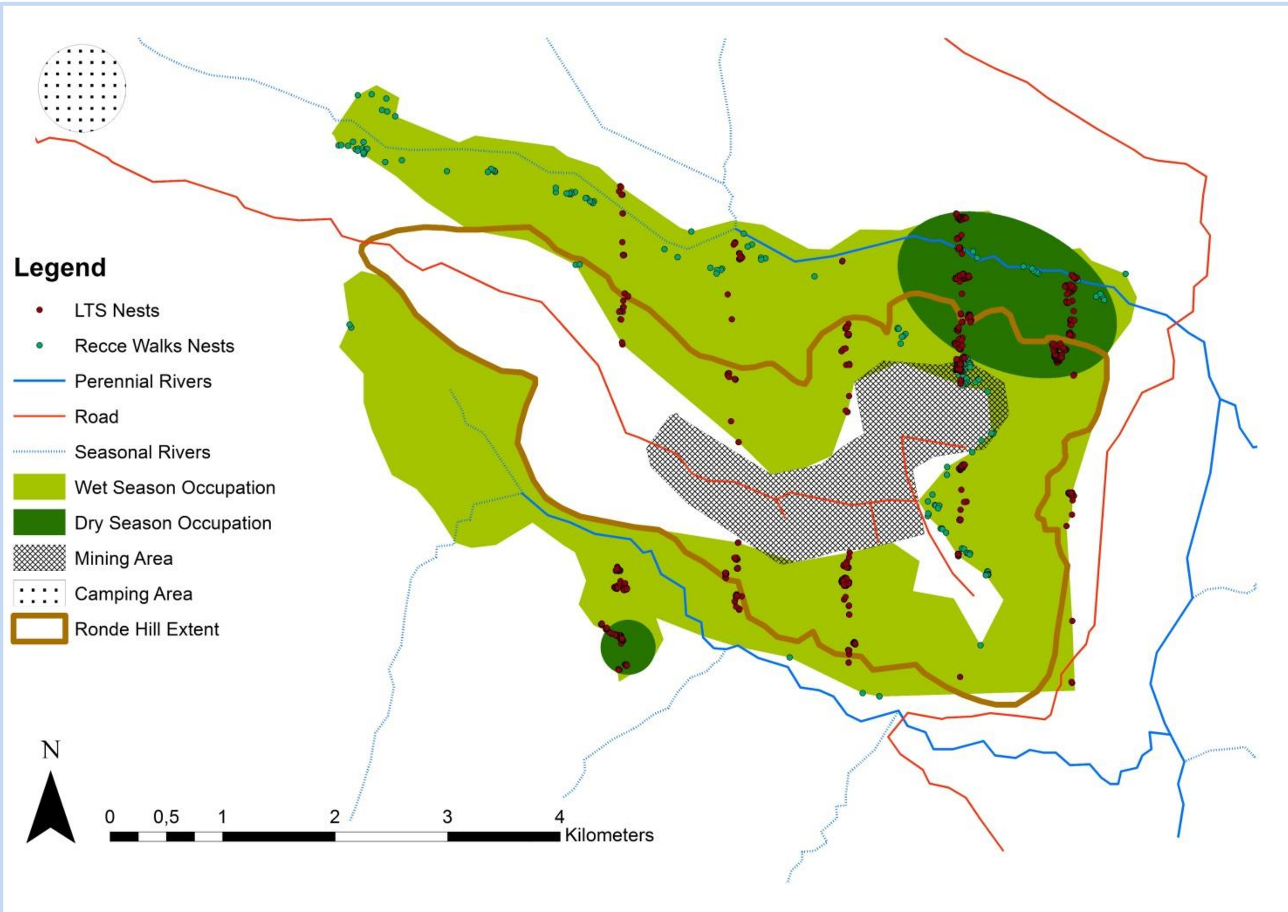

Figure 6: Overlapping of the mining site and chimpanzees` territory. Green dots represent the location of nests observed during the Recce Walk and red ones during the LTS survey.

DISCUSSION

Chimpanzees nesting and distribution

Figure 7: *Parkia biglobosa*

Compared with other studies (Humle, 2003; Sousa *et al.*, 2011), the high preference for *K. senegalensis* and especially *P. biglobosa* for nesting is unique. Humle (2003) cites a study that listed these two species among the most preferred trees for the Guinea's chimpanzees, but their proportion of use is much lower (17,8%) than the one found here (57,8%, Tab. 1). *P. biglobosa* itself hosted 44,6% of the nests in this study. Those two species are not significantly more abundant in relation to other nesting trees, so other reasons may explain this result. First, *P. biglobosa* fruits are appreciated by chimpanzees (all dung samples collected during the study had a considerable amount of its seeds), and since the study period coincided with *P. biglobosa* fruiting (from April to July), visiting these trees for feeding may have influenced nesting choice by the group. Second, the size and branched structure of the tree (Fig. 7) supports the production of over 20 nests in a single plant, as witnessed in this study. This same argument can be used to explain the high preference for *K. senegalensis* as well (Fig. 8).

In Sousa *et al.* (2011) survey on Cantanhez National Park, southwestern Guinea-Bissau, where *P. biglobosa* and *K. senegalensis* are also present, 92%

Figure 8: *Khaya senegalensis (source: http://it.wikipedia.org/wiki/File:Khaya_senegalensis_MS_2037.JPG)*

of the nests were made in oil palms (*Elaies guineense*). Despite this species being present in the Boé sector, no palm was reported to contain chimpanzee nests in the present study, what shows a contrasting nesting behavior among these two areas. This difference can be explained by the more restricted distribution of oil palms in the Boé sector, where the soil conditions allow good growth of *E. guineense* only in gallery forests or other humid areas. Gallery forests grow over the most fertile soils of the sector, consequently, it is the most disturbed vegetation for agricultural activities, besides, *E. guineense* is extremely exploited for the production of palm oil, thus, the anthropic pressure in the oil palm environments may have chased Boé chimpanzees from those trees, situation that may not have occurred in the legally protected Cantanhez National Park. Given its characteristic shape, nesting in oil palms requires different abilities from those of other tree species (Sousa *et al.,* 2011), consequently, prevention of nesting in palm trees for a couple of decades could be enough to exclude this habit (and the skills for it) from a generation to another.

Considering the environment use, it can be seen by Table 2 (in Results) that primary forests (including gallery forests) are underrepresented in the nests survey. This doesn't mean this is an unfavorable environment for nesting, but a consequence of its reduced cover along the study site, as a result of the slash-and-burn pressure by surrounding villages. The demand for fertile soils is so strong that approximately 52% of the original vegetation cover of those areas have already been pulled down, giving space nowadays to agricultural plots, fallow areas or secondary forests (tab. 2). This is a reality that extends through the entire Boé sector, where the present 12.000 inhabitants have reached the support capacity of the region, according to Wit (1989). In spite of that, chimpanzees can tolerate quite well some anthropic impacts in their environment. It was testified they can make nests in every environment where sufficiently large trees are available, being excluded savanna and areas with constant human occupation, such as villages or active agricultural

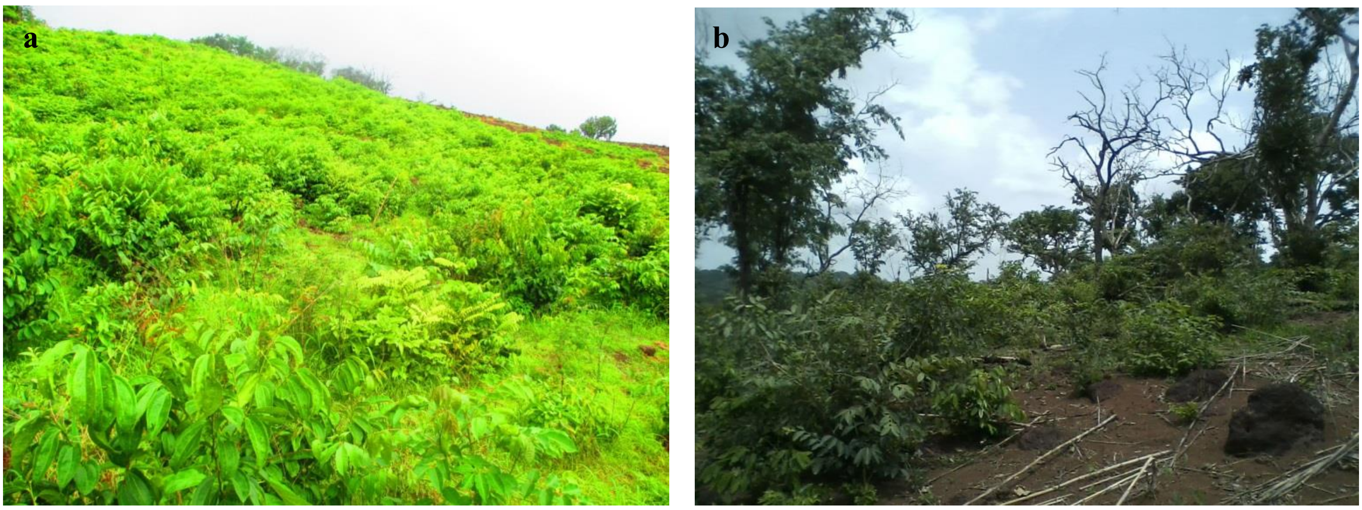

Figure 9: Abandoned agricultural fields after six months of harvest, close to (a) Paramakadow village, Guinea, and (b) Ronde Hill. The one on the left had its vegetation completely removed for establishing the plantation. The one on the right, on the other hand, had some trees preserved, which can host chimpanzee nests.

fields. It was also observed they dwell fine even fallow areas with just one year of abandonment, ensuring some trees big enough for constructing nests are maintained (Fig. 9b). It was observed that after the starting of the rainy season, their distribution was slightly altered, spending less time in the Gallery Forests and more in the Forests at the hills. This can be explained by the increase of water availability, away from the river course after mid-May. However, since this study couldn´t be held year-round, their complete seasonal distribution cannot be surely inferred.

Worse than agricultural expansion, seasonal burnings are another threat for chimpanzee habitat. It is mainly produced by the *Boenques*, nomad cattle herders in great part coming from Guinea. During the late dry season, they put fire on the more dense vegetation to protect their cattle from the dangers within and to stimulate budding, very appreciated and nutritious for the bovines. The extremely dried vegetation favors the fast spreading of fire, which generally become uncontrollable and burn a much bigger area than effectively used by the Boenques. This study itself suffered with it, when in early May the whole north flank of Ronde Hill was burned by a Boenque family installed next to it, destroying an area of at least 300he and affecting three transects. No new nests were spotted in the following repetitions on the affected areas. Burning for opening an agricultural area is not as harmful, since it is restricted to the plantation field (around one hectare per family) and prevented for spreading by the creation of buffer zones (cutting all the vegetation in a stripe two meter large around the field) and with the vigilance of the own farmer. Although burning by hunters is another threat often reported in the Boé sector, it wasn't proven to be occured in the study area and period.

Density and abundance estimations

From the summary in tab. 3, it can be noticed a distinction between the results of the SCNC and MNC results. Since MNC is more reliable then SCNC (Plumptre, 2003), the reduced density obtained by SCNC may be a consequence of the choice of nest's mean life span. The decay time of 194 days borrowed from Fleury-Brugiere & Brugiere (2010) can be an overestimation for the present study area and then the true density would be bigger than the 1,53 ind./km^2 obtained by this method. Still with respect to SCNC, there was almost no difference between individual and clustered nest counts. A total of 608 nests were available for the SCNC analysis, this elevated number makes difficult the distinction of adjacent nest groups, thus, affording the assumption that nests are distributed randomly along the study site (as also done by Pruetz *et al.*, 2002 and Fleury-Brugiere & Brugiere; 2010), thus don't making much difference for the calculations if they are treated individually or in groups.

In the case of the MNC approach, there is a significant difference between the individual and clustered nests analysis (Tab. 3 in Results). Since in the MNCi analysis only 168 nests were recorded, clustering those observations resulted in a very small data set, then becoming more unlikely to approach their distribution to a random one. Thus, MNCc is elected as the most reliable estimation thanks to its more trustworthy assumptions and lowest AIC among all the methods tried (Buckland *et al.,* 1993).

Comparing these results with those from the trap cameras, it can be seen they are close to each other. 18 weaned individuals were spotted in the trap cameras, a number very close to the 21 estimated by the lowest 95% CI from the MNCc. Actually, 18 is the minimum, and not the absolute, number of weaned individuals proven to dwell the area. Indeed there are reasons to expect this number to be higher, since all the six cameras available were placed along or close to the Jabere river valley, for logistical practicalities, but chimpanzees vocalizations were also heard and new nests spotted close to the spring of Paramaka river, on the Guinean side of the border. Since this area was more than 5km apart from where the cameras were placed, with a considerable savanna strip between them, it is possible this area houses a different group of chimpanzees, semi-isolated from the ones monitored around the Jabere valley and not spotted by the cameras footages.

Going further and assuming the proportion of weaned chimpanzees for the total population observed in the footages is approximately the same as the true proportion of the study site, it is possible to multiply the abundance obtained by the factor 22/18 = 1,22 (total n^o of chimpanzees/n^o of weaned chimpanzees), and then estimate the density and total number of chimpanzees in the area including the infants. For the MNCc, this gives a density estimation of 2,20 ind./km^2 ([1,17-4,11] 95% CI) and total estimation of 48 individuals ([26-90] 95% CI) in the study area.

Table 5 compares some density estimations of other studies in savanna woodlands. The present study resulted in an estimation far higher than the others using the Nest Counts methodology. This is a consequence of the reduced survey area, which was known to host a spatially concentrated population. For a matter of comparison, the effective area used in this research, of approximately 35,5km^2, is much smaller than the 554 km^2 of the Mafou core area of Haut Niger National Park (Fleury-Brugiere & Brugiere, 2010) or the 3352 km^2 of Ugalla (Ogawa *et al.*, 2007). A large scale study along the whole Boé was made by Serra *et al.* (2007), in which the chimpanzees abundance was estimated by extrapolating the average number of individuals per village area, obtained by interviews with some experienced villagers, to the whole extent of the sector. This resulted in an estimation of 2,4 ind./km^2, very large if compared with the results from this and the other studies shown in table 5. Large scale studies along the whole Boé Sector applying the Nest Counts methodology would probably reveal lower estimations. In savanna mosaic environments, chimpanzees populations tend to be patchily distributed (Ogawa *et al.*, 2007), restricting themselves to the most suitable habitats, rich in gallery and semi-deciduous forests, as was the case of the present study area, thus, more systematic approaches are necessary to reach more precise estimations then the ones obtained by Serra *et al.* (2007).

Table 5: Comparison of chimpanzees density estimations in savanna woodlands habitats along Africa.

Study Site	**Methodology**	**Density (ind/km^2)**	**Reference**
Parc National du Niokolo Koba, Senegal	SCNCi	0,13	Pruetz *et al.* (2002)
Masito, Tanzania	Kano (1972)	0,16 - 0,71	Moyer *et al.* (2006)
Ugalla, Tanzania	Various	0,08	Ogawa *et al.* (2007)
Boé Sector, Guinea-Bissau	Interviews	2,40	Serra *et al.* (2007)
Haut Niger National Park, Republic of Guinea	SCNCi	0,87	Fleury-Brugiere & Brugiere (2010)
Ronde Hill, Guinea-Bissau	MNCc	1,80	This Study

Drumming

Humle (2003) says male hierarchy is generally heavily formalized in chimpanzees, in opposition to female hierarchy, in consequence, males frequently communicate their status to one another while it rarely happens among females. The drumming behavior described in the present research could be a representative of a male status communication. Two factors lead to this conclusion, first, it is only made by males, alone or in the presence of another male; second, the buttress roots of *Ce. pentandra* and the large trunk of *Co. cordifolia* produce an echoing sound when impacted that can be heard from quite a long distance. It is known locally that it is practiced by chimpanzees from the whole Boé sector and also from Guinea. Similar behaviors of other chimpanzee population is not documented, thus, this represents a unique culture of Guinean populations, offering an extra reason for their preservation.

Mining possible impacts

As it can be seen by Figure 6, the mining site has a small overlap with the chimpanzees territory in its northeastern edge, the rest of its extension will be established on the top of Ronde Hill, an area covered with grassy savannah and not dwelled by chimpanzees. Nevertheless, it will be still at the exact middle of their distribution and right next to one of their refuge during the dry season thus, indirect influence is certain. The access road also doesn't cross their home habitat, but the noise produced by the constant traffic surely will be a source of stress, not only for chimpanzees, but for the whole local fauna. As revealed in the Bauxite Angola meeting, the workers camp is planned to be constructed close to the spring of Jabeje river, the main tributary of Jabere, to avail its permanent font of water. This area contains one of the last untouched gallery forests of the region and the pressure caused by the immigrant workers would lead to its degradation, affecting the water quality of the whole Jabere micro basin and the resources availability for the local communities (for example, Munhini villagers use to visit this area for palm oil extraction and hunting). Thus, the main threats for chimpanzees and local fauna brought by the mining and its infra-structure, as identified in this study, can be listed as follows:

(1) The northeastern part of the mining site will neighbor an area occupied by chimpanzees during the dry season, located at the middle course of Jabere river. Despite not overlapping that territory, its extreme proximity will surely affect the population, since during the dry season this is one of the few places with permanent availability of water, thus, concentrating resources and individuals and being a delicate area concerning environmental impacts.

(2) Water pollution in the rivers surrounding the mining site (Paramaka, Jabere, Jabeje and Féfine) in consequence of waste production by the mining operations and by the workers at the mine and irresponsible use of the water resources during the mining process and at the workers camp. Additionally, exploitation of the top of the hill will cause siltation of these rivers, located in the valleys bellow, especially in the areas where the original vegetation is absent and sediments cannot be retained.

(3) Noise pollution, resultant by the explosions while digging the site and by the machinery activity in it and in the access road.

In addition to the environmental impact, social impact will also be considerable with the mining enterprise. Environmental change will lead to social consequences in a long term, like reduction of forest resources and suitable lands for agriculture, as previously said. Mining social impacts are not the focus of this research, but it is clear that even after the ending of the mining activities, the sum of social and environmental rupture is disastrous for a society that already live in the edge of their resources use.

CONCLUSION

Density and abundance estimations

Estimation of density of weaned chimpanzees resulted in a value of 1,80 ind./km^2, resulting in an abundance of approximately 39 individuals dwelling the area. If considering the proportion of weaned to infant chimpanzees observed on the CT survey, the density rises to 2,20 ind./km^2 and the abundance to 48 individuals, including the infants.

Population distribution and proximity to mining area

Considering the nests distribution and other clues collected during this study, it can be concluded the chimpanzees` home range extends mainly along the valleys of Jabere and Paramaka rivers and the flanks of Ronde Hill, but not on its top, where the land is covered with grassy savanna. During the dry season, they tend to concentrate themselves at the areas surrounding the middle course of Jabere river and the hills south to the high course of Paramaka river. Chimpanzees around Ronde Hill dwell fine in every habitat with sufficient vegetal cover (i.e. big trees for nesting) and free of permanent human presence, this is also valid for agricultural areas, which can be inhabited again just some months after abandonment. The main threat caused by the local population is the intentional burning for cattle herding, which can destroy hundreds of hectares of their territory.

Roads and other mining related infrastructure are not located in the chimpanzees' habitat, but their proximity can still cause some damage to the population, in consequence of water and noise pollution, for example. Since the mining site will be located on the top of Ronde Hill, it will cause few direct destruction of chimpanzees' habitat, however, its northeastern edge overlaps an area occupied by chimpanzees during the wet season and neighbors one of their refuge during the dry season, thus especial attention must be paid to this specific area.

Suggestions for reducing potential impacts

The tenuous equilibrium between human and chimpanzee populations can be broken with the arrival of the mining activities. It will impact drastically the environment that already reached its support capacity for the inhabitant population, damage the water quality of the rivers next to it and harm the local fauna. With that perspective, this work aims to propose some suggestions to mitigate these consequences and prevent chimpanzees to be extinct from Ronde surroundings:

(1) Pay especial attention to the northeastern area of the mining site and even consider not exploiting this region or stopping activities during the dry season, in

order to prevent disturbance on the chimpanzees' most important territory.

(2) Water pollution can be reduced by reallocating the workers camp farther from the Jabeje spring, collecting water from a profound well and/or treating the effluents before returning them to the environment.

(3) Noise pollution can be partially eliminated by using less noisy explosives, technology already accessible for Bauxite Angola S.A., according to their own information.

(4) Reforesting the mining area after the activities is a common compensatory measure used worldwide. It is not clear if this is present on the contract of this enterprise with Guinea-Bissau government, but must be required anyway. It should be focused on the areas surrounding the rivers and on the hills around the mining site, paying attention to replant not only profitable species for the local human community, in order to replace their previously taken livelihood, but also to provide for the habitat needs of chimpanzees and restore the quality of nature.

Just stopping mining attempts isn't the best solution. Guinea-Bissau is one of the ten poorest countries in the world, and here, more than elsewhere in West Africa, biological conservation should be joined with attempts to encourage economic growth. Efforts to implement a National Park in the north of Boé are already in course. Considering the resources shortage faced by the region and that chimpanzee population tolerate human presence to a certain extent, the best solution would be transforming the whole Boé sector into a community-based conservation area. It is undeniable that chimpanzees have a popular appeal and could serve as locomotive to environmental conservation. Furthermore, if a tourism structure is well developed, income can be generated to the local community, being an alternative to the present environmental pressure. However, as warned by Gippoliti *et al.* (2003), chimpanzees can be affected by many human diseases, so special care must be taken for avoiding transmission from tourists. Further, for being part of the most western populations, Boé chimpanzees developed a unique tradition which can be exemplified here by the drumming behavior, a male communication system only shared with the neighbor populations from Guinea, representing an extra reason for their conservation.

Questions for following studies

During the course of this study (late dry season and the early rainy season) a change in environmental distribution of the chimpanzees could be observed, but the reduced time available didn’t allow a better evaluation of this variance in habitat use, thus, a year-round survey in the region is essential to clarify their seasonal distribution. Besides, it would also ensure if there is a preference for nesting in *P. biglobosa* trees or if it is only a seasonal tendency. The drumming is also something that shouldn´t be ignored, further research on this behavior could contribute a lot to understand chimpanzee culture, beyond promoting popular interest and contributing to ecotourism. A monitoring of the population during the mining implementation should also be considered, it could serve as a synchronic analysis of the impacts, allowing rapid attitudes in case big damages are observed.

BIBLIOGRAPHY

Buckland, S.T., Anderson, D.R., Burnham, K.P. and Laake, J.L. 1993. *Distance Sampling: Estimating Abundance of Biological Populations.* Chapman and Hall, London, reprinted 1999 by RUWPA, University of St. Andrews, Scotland.

Butynski, T. M. (2003) The Robust Chimpanzee *Pan troglodytes*: Taxonomy, Distribution, Abundance, and Conservation Status. In: Kormos, R., Boesch, C., Bakarr, M.I. and Butynski, T. (eds.). *West African Chimpanzees. Status Survey and Conservation Action Plan.* IUCN/SSC Primate Specialist Group. IUCN, Gland, Switzerland and Cambridge, UK. pp 5-11.

Carvalho, J. S., Marques, T. A, & Vicente, L. (2013). Population status of Pan troglodytes verus in Lagoas de Cufada Natural Park, Guinea-Bissau. *PloS one*, *8*(8), e71527. doi:10.1371/journal.pone.0071527

Catarino, L., Martins, E. S., Pinto-Basto, M. F., Diniz, M. A. *Plantas Vasculares e Briófitos da Guiné-Bissau.* Lisboa: Instituto de Investigação Científica Tropical e Instituto Português de Apoio ao Desenvolvimento, 2006, 298pp.

Diallo, M.S. *Praticas das indústrias extractivas na Africa ocidental, Síntese comparativa de quatro estudos de casos (Guiné-Bissau, Guinée, Senegal, Serra Leoa)*. Gland, Switzerland: IUCN, Dakar, Senegal: ASAN, Bissau, Guinea Bissau: AD, Conakry, Guinea: GUINÉE ECOLOGIE, Freetown, Sierra Leone: EFA, 2010, 34pp.

Diallo, M. S., Sylla, K., Bah, A. L. B. *Pratiques des Industries Extractives : le Cas de Kamsar en Guinée*. Conakry, Guinea: GUINÉE ECOLOGIE, 2010.

Fleury-Brugiere, M.-C., & Brugiere, D. (2010). High Population Density of Pan troglodytes verus in the Haut Niger National Park, Republic of Guinea: Implications for Local and Regional Conservation. *International Journal of Primatology*, *31*(3), 383–392. doi:10.1007/s10764-010-9391-9

Gippoliti, S., Embalo, D. S., Sousa, C. (2003) Guinea-Bissau. In: Kormos, R., Boesch, C., Bakarr, M.I. and Butynski, T. (eds.). *West African Chimpanzees. Status Survey and Conservation Action Plan.* IUCN/SSC Primate Specialist Group. IUCN, Gland, Switzerland and Cambridge, UK. Pp 55-61.

Hockings, K. & Humle, T. (2009). *Best Practice Guidelines for the Prevention and Mitigation of*

Conflict Between Humans and Great Apes. Gland, Switzerland: IUCN/SSC Primate Specialist Group (PSG).

Humle, T. (2003). Behavior and Ecology of Chimpanzees in West Africa. In: Kormos, R., Boesch, C., Bakarr, M.I. and Butynski, T. (eds.). *West African Chimpanzees. Status Survey and Conservation Action Plan.* IUCN/SSC Primate Specialist Group. IUCN, Gland, Switzerland and Cambridge, UK. Pp 13-19.

Humle, T., Boesch, C., Duvall, C., Ellis, C.M., Farmer, K.H., Herbinger, I., Blom, A. & Oates, J.F. (2008). *Pan troglodytes ssp. verus*. In: IUCN 2013. IUCN Red List of Threatened Species. Version 2013.1. <www.iucnredlist.org>. Downloaded on 19 November 2013.

IUCN (2013). IUCN Red List of Threatened Species. Version 2013.1. <www.iucnredlist.org>. Downloaded on 19 November 2013.

Kano, T. (1972). Distribution and adaptation of the chimpanzee on the eastern shore of Lake Tanganyika. *Kyoto Univ. Afr. Stud.* 7: 37-129.

Kouakou, C. Y., Boesch, C., & Kuehl, H. (2009). Estimating chimpanzee population size with nest counts: validating methods in Taï National Park. *American journal of primatology*, *71*(6), 447–57. doi:10.1002/ajp.20673

Kormos, R. & Bakarr, M. I. (2003). Regional Summary. In: Kormos, R., Boesch, C., Bakarr, M.I. and Butynski, T. (eds.). *West African Chimpanzees. Status Survey and Conservation Action Plan.* IUCN/SSC Primate Specialist Group. IUCN, Gland, Switzerland and Cambridge, UK. Pp 27 – 29.

Kühl, H., Maisels, F., Ancrenaz, M. & Williamson, E. A. (2008). *Best Practice Guidelines for Surveys and Monitoring of Great Ape Populations.* Gland, Switzerland, IUCN SSC Primate Specialist Group (PSG).

Marchesi, P., Marchesi, N., Fruth, B., & Boesch, C. (1995). Census and Distribution of Chimpanzees in Côte D'Ivoire, *Primates. 36*(October).

Morgan, D., Sanz, C., Onononga, J. R., & Strindberg, S. (2006). *Ape Abundance and Habitat Use in the Goualougo Triangle, Republic of Congo*. *International Journal of Primatology* (Vol. 27, pp. 147–179). doi:10.1007/s10764-005-9013-0

Moyer, D., Plumptre, A. J., Pintea, L., Moore, J., Stewart, F., Davenport, T. R. B., … Mwangoka, M. (2006). Surveys of chimpanzees and other biodiversity in Western Tanzania.

Myers, N., Mittermeier, R. a, Mittermeier, C. G., Da Fonseca, G. a, & Kent, J. (2000). Biodiversity hotspots for conservation priorities. *Nature*, *403*(6772), 853–8. doi:10.1038/35002501

Oates, J.F., Tutin, C.E.G., Humle, T., Wilson, M.L., Baillie, J.E.M., Balmforth, Z., Blom, A., Boesch, C., Cox, D., Davenport, T., Dunn, A., Dupain, J., Duvall, C., Ellis, C.M., Farmer, K.H., Gatti, S., Greengrass, E., Hart, J., Herbinger, I., Hicks, C., Hunt, K.D., Kamenya, S., Maisels, F., Mitani, J.C., Moore, J., Morgan, B.J., Morgan, D.B., Nakamura, M., Nixon, S., Plumptre, A.J., Reynolds, V., Stokes, E.J. & Walsh, P.D. (2008). *Pan troglodytes*. In: IUCN 2013. IUCN Red List of Threatened Species. Version 2013.1. <www.iucnredlist.org>. Downloaded on 19 November 2013.

Ogawa, H., Idani, G., Moore, J., Pintea, L., & Hernandez-Aguilar, A. (2007). Sleeping Parties and Nest Distribution of Chimpanzees in the Savanna Woodland, Ugalla, Tanzania. *International Journal of Primatology*, *28*(6), 1397–1412. doi:10.1007/s10764-007-9210-0.

Plumpte, A. (2003). "Censuing Chimpanzees". In: *Status of Chimpanzees in Uganda*. Wildlife Conservation Society.

Plumptre, A. J. & Reynolds, V. (1997). "Nesting Behavior of Chimpanzees: Implications for Censuses". *International Journal of Primatology*, 18(4): 475-484.

Pruetz, J. D., Marchant, L. F., Arno, J., & McGrew, W. C. (2002). Survey of savanna chimpanzees (Pan troglodytes verus) in Southeastern Sénégal. *American Journal of Primatology*, *58*(1), 35–43. doi:10.1002/ajp.10035

Sousa, J., Barata, A. V, Sousa, C., Casanova, C. C. N., & Vicente, L. (2011). Chimpanzee oil-palm use in southern Cantanhez National Park, Guinea-Bissau. *American journal of primatology*, *73*(5), 485–97. doi:10.1002/ajp.20926.

Serra, A., Silva, C., Lopes, E. *Étude de faisabilité du projet «Développement touristique de la Boé au profit de la conservation des Chimpanzés et des populations locales»*.WWF; Chimbo Foundation; IUCN & IBAP. Bissau, 2007.

Vigilant, L. (2003). Genetic Perspectives on *Pan troglodytes verus*. In: Kormos, R., Boesch, C., Bakarr, M.I. and Butynski, T. (eds.). *West African Chimpanzees. Status Survey and Conser-*

vation Action Plan. IUCN/SSC Primate Specialist Group. IUCN, Gland, Switzerland and Cambridge, UK. Pp 21-23.

Wit, P. *Démarrage des activités d'exploitation de bauxite dans la Boé par l'entreprise "Bauxite Angola"*. Conseil Directif de Daridibó. July (2011).

Wit, P. & Reintjes, H. C. (1989). An agro-ecological survey of the Boé province, Guinea Bissau. *Agriculture, ecosystems & environment* 27.1: 609-620.

http://www.mobot.org/MOBOT/Research/APweb/welcome.html (Accessed in 27/11/2013)

APPENDICES

Appendix 1: Commonly chosen models for *g(x)*. *w* is the threshold distance beyond which no nests can be observed; *x* is de perpendicular distance from the transect. a_j, σ and *b* are parameters estimated to fit well the data collected. For further information, see Buckland *et al.* (1993).

Key Function	**Series Expansion**
Uniform $1/w$	**Cosine** $\sum_{j=1}^{m} a_j \cos\left(\frac{j\pi x}{w}\right)$
	Simple polynomial $\sum_{j=1}^{m} a_j \left(\frac{y}{w}\right)^{2j}$
Half-normal $e^{-x^2/2\sigma^2}$	**Cosine** $\sum_{j=1}^{m} a_j \cos\left(\frac{j\pi x}{w}\right)$
	Hermite polynomial $\sum_{j=1}^{m} a_j H_{2j}\left(\frac{y}{\sigma}\right)$
Hazard-rate $1 - e^{-(x/\sigma)^{-b}}$	**Cosine** $\sum_{j=1}^{m} a_j \cos\left(\frac{j\pi x}{w}\right)$
	Simple polynomial $\sum_{j=1}^{m} a_j \left(\frac{y}{w}\right)^{2j}$

Appendix 2: Complete list of nesting trees, with their respective family, scientific, fula and creole names as well as total number of correspondent nests and contribution to the total sample.

Scientific Name	Family	Fula name	Creole name	No. of Nests	% of Sample
Parkia biglobosa	Leguminosae/ Mimosaceae	Nete	Faroba	507	44,59
Khaya senegalensis	Meliaceae	Kay	Bisilon	150	13,19
Pterocarpus erinaceus	Leguminosae/	Bane	Pó-de-Sangue	91	8,00

	Papilionaceae				
Erythrophleum suaveolens	Leguminosae/ Caesalpinaceae	Tele	-	61	5,36
UNKNOWN	Leguminosae	Bandjala	-	54	4,75
Parinari excelsa	Chrysobalanaceae	Cura	Manpatás	42	3,69
Cola cordifolia	Sterculiaceae	Gumbambe	-	34	2,99
Dialium guineense	Leguminosae/ Caesalpinaceae	Meco	Veludo	28	2,46
Mitragyna inermis	Rubiaceae	Bore	-	20	1,76
Lecaniodiscus cupanioides; Trichilia prieuriana prieuriana	Sapindaceae; Meliaceae	Sataga	-	19	1,67
Afzelia africana	Leguminosae/ Caesalpinaceae	Lengue	-	12	1,06
Pericopsis laxiflora	Leguminosae/ Papilionacea	Culo-culo	-	11	0,97
UNKNOWN	UNKNOWN	Foefelum	-	11	0,97
Antidesma membranaceum; Trema orientalis	Euphorbiaceae; Ulmaceae	Quere	-	10	0,88
UNKNOWN	UNKNOWN	Mansangara	-	7	0,62
GROUND	-	-	-	7	0,62
Vitex doniana	Verbenaceae	Bume		7	0,62
Piliostigma thonningii	Leguminosae/ Caesalpinacea	Barque	Pó-de-Cancura	6	0,53
UNKNOWN	UNKNOWN	Meco-djon	-	5	0,44
Detarium senegalense	Leguminosae/ Caesalpinacea	Boto	-	4	0,35
Sorindeia juglandifolia	Anacardiaceae	Sangue-bombo	-	4	0,35
Spathodea campanulata	Bignoniaceae	Cafauando	-	4	0,35
Prosopis africana	Leguminosae/ Mimosaceae	Tchelem	Pó-de-Carbom	4	0,35
UNKNOWN	UNKNOWN	Carnafassa	-	3	0,26
UNKNOWN	UNKNOWN	Colitetaga	-	3	0,26
Lannea velutina	Anacardiaceae	Tchuco	-	3	0,26
UNKNOWN	UNKNOWN	Curaongola	-	3	0,26

UNKNOWN	UNKNOWN	Waka-waka	-	3	0,26
UNKNOWN	Leguminosae/ Mimosidaea	Bandjala-danei	-	3	0,26
Anthonotha crassifolia	Leguminosae/ Caesalpinacea	Bube	-	2	0,18
Xeroderris stuhlmannii	Leguminosae/ Papilionaceae	Bandanei	Pó-de-Sangue-Branco	2	0,18
Alchornea cordifolia	Euphorbiacea	Gracassaque	-	2	0,18
Ficus sur	Moraceae	Ibê	Cola-de-matu	2	0,18
Anisophyllea laurina	Rhizophoraceae	Kanse	-	2	0,18
UNKNOWN	UNKNOWN	Liana	-	2	0,18
Daniellia olivieri	Leguminosae/ Caesalpinaceae	Tchê-vê	Pó-de-Incenso	2	0,18
Ceiba pentandra	Bombacaceae	Bantam	Polon	1	0,09
UNKNOWN	UNKNOWN	Buro-buro	-	1	0,09
Pterocarpus santalino-ides	Leguminosae/ Papilionaceae	Djego	-	1	0,09
UNKNOWN	UNKNOWN	Gurundungo	-	1	0,09
UNKNOWN	UNKNOWN	Boilacundje	-	1	0,09
Spondias mombin	Anacardiaceae	Tchale	-	1	0,09
UNKNOWN	UNKNOWN	Garanden	-	1	0,09
TOTAL				**1137**	**100,00**