MEFE

FINAL REPORT ON ELEPHANT AND APE SURVEYS IN THE ODZALA-KOUKOUA NATIONAL PARK, 2005

To
The Government of Congo
The European Union
CAWHFI
RAPAC
WCS

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Wildlife Conservation Society

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INTRODUCTION

The forest estate of the Republic of Congo covers a massive 224,710km^2 of lowland forest, seasonally inundated forest, and permanent swamps. Of this total some 113,870km^2 is attributed to industrial logging companies, and most of the remainder of *terra firma* forest is classified as production forest. The forests of Congo, particularly in the north, are known to contain outstanding populations of large charismatic mammals, including forest elephants (*Loxodonta africana cyclotis*), western lowland gorillas (*gorilla gorilla gorilla*), common chimpanzees (*Pan troglodytes*), forest buffalo (*Syncerus caffer nanus*), bongo (*Tragelaphus eurycerus*), and forest leopard (*Panthera pardus*).

In 2005, the National Park system of Congo covered some 21,211km^2 in three parks, Conkouati-Douli in the south, Odzala-Koukoua in the centre-north, and Nouabalé-Ndoki in the far north (Figure 1). Of these Odzala-Koukoua National Park (PNOK) is by far the largest, covering a surface area of 13,545km^2. Indeed Odzala is the largest forested national park in central Africa, second only to the Salonga NP in DRC. Research and monitoring in the PNOK over the last 2 decades has demonstrated that the park contains an extraordinary abundance of forest elephants and gorillas (Fay and Agnagna 1991, Fay and Agnagna 1992, Maisels 1996, Vanleeuwe et al. 1997, Marechal et al. 1998, Vanleeuwe et al. 1998, Vanleeuwe and Gautier-Hion 1998, Bermejo 1999, Magliocca 1999, Magliocca et al. 1999, Querouil et al. 1999, Gatti et al. 2004). Indeed western lowland gorilla densities in Odzala may be the highest on the continent.

The PNOK has, however been under considerable threat from poaching for many years, particularly of elephants, to supply the ivory trade (Hecketsweiler et al. 1991, Nishihara 1997, 2002). The PNOK region has also seen several outbreaks of the Ebola virus in both humans and gorillas, including a major die-off of gorillas at the Lossi Gorilla Sanctuary some 22km to the southwest of the PNOK (Walsh et al. 2004)

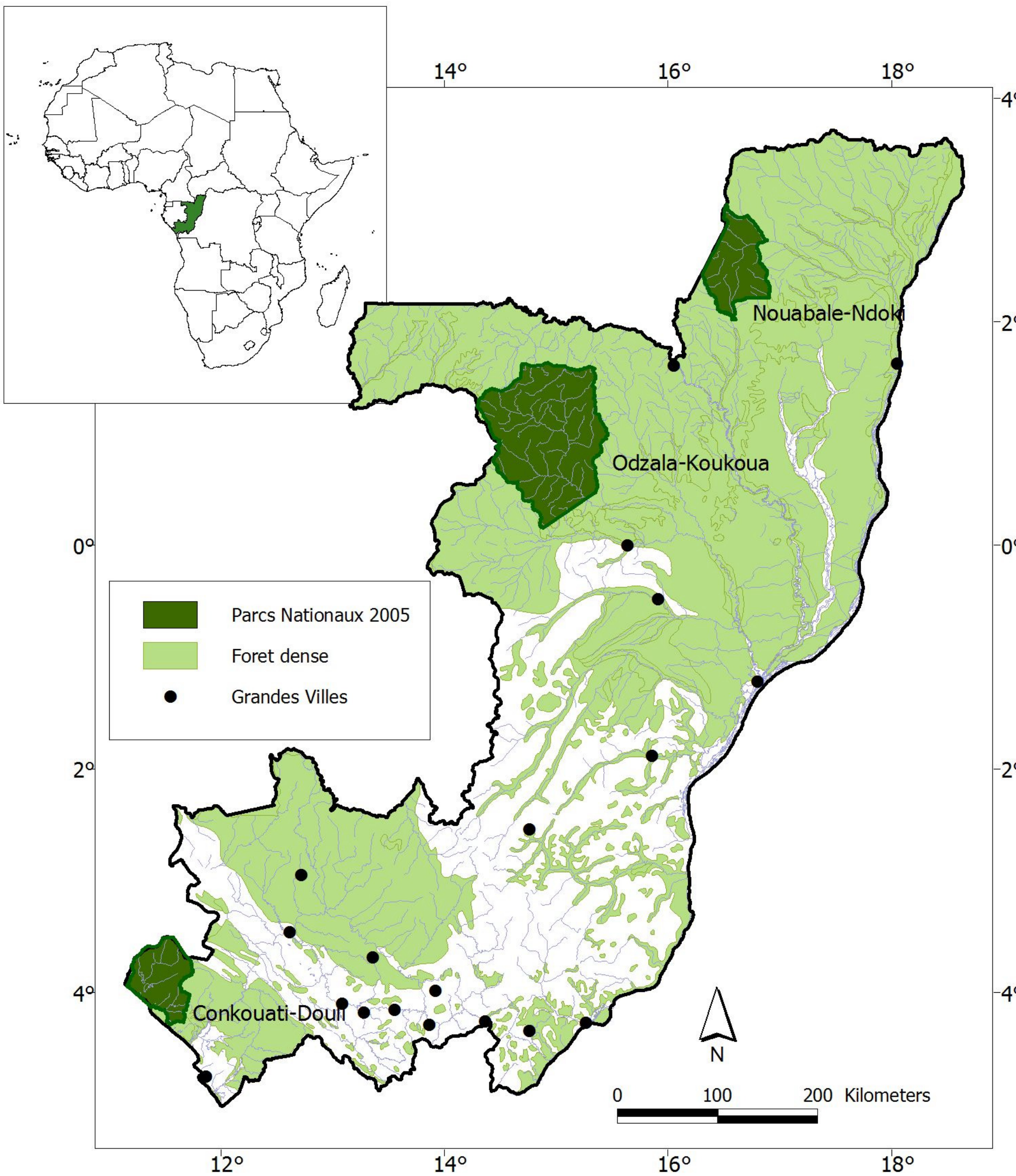
Despite an enormous effort over recent years in patrol-based monitoring using “Cyber-tracker” hardware and software, the PNOK has never been systematically surveyed, and the abundance and distribution of large mammals and human impacts and the possible impact of Ebola are poorly known. It is essential for management of the park to have a good understanding of the relative abundance and distribution of these species, particularly as elephant poaching and illegal hunting are thought to have had a significant impact on the fauna of the park in some areas. Also of particular importance is the potential impact of the Ebola virus on great apes in the region and the risks to humans from this disease. Predictions of rates of spread of Ebola from outbreak areas suggest that the great ape population is under considerable threat from Ebola and has been for some time (Walsh et al. 2005), with serious implications for human well-being.

To address the lack of information and understanding of these issues a systematic survey of PNOK was initiated and completed in late 2005, under the auspices of the *Espèces Phares* Programme of the European Union. Fieldwork was completed and coordinated by PNOK and WCS-Congo research and monitoring staff. The WCS Forest Elephant Program and WCS-Congo provided technical supervision on all aspects of survey design, training, fieldwork, and data analysis.

The goal of the survey was: *To quantify the density and distribution of elephants, apes, and human sign in the PNOK, and to evaluate the potential impact of humans and the Ebola virus on these species.*

This report describes survey design, field methodology, and results of the first un-biased systematic survey of large mammals and human impacts of the PNOK. The implications of the survey results for management of PNOK and its surrounding area are discussed.

Figure 1. The forests and national parks of Congo in 2005



STUDY SITE AND METHODS

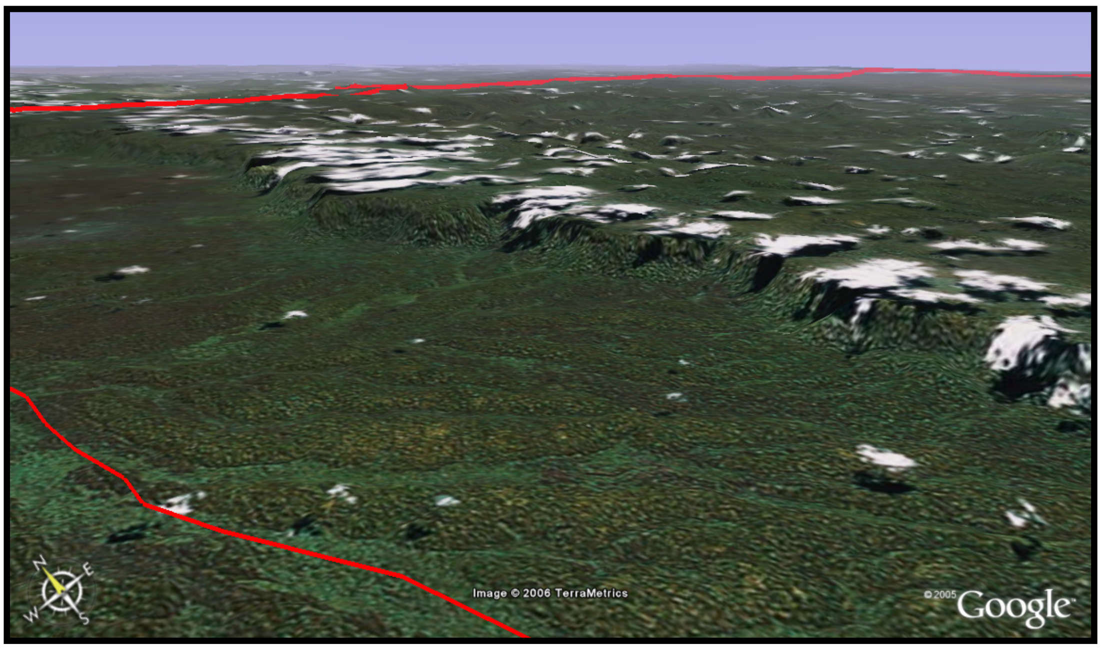
Study site

Details of the study site can be obtained in (Maisels 1996) and (Hecketsweiler et al. 1991), but main features are briefly descried here.

Relief and altitude

The altitude of the PNOK varies between 300-800 m, with a general rise from southeast to northwest. An escarpment runs north south along the western boundary of the PNOK, which drops towards the west from altitudes of 600m to about 250-300 m on the Gabon side. The escarpment is frequently bathed in cloud as shown in Figure 2 below.

Figure 2. 3-D visualization of the escarpment, northwestern PNOK.



The relief of the south and east of the Park is primarily rolling gentle hills, with widely spaced valleys following the river network. The northwest of the Park is hillier with a dense river network, steeper slopes and narrower ridges.

Hydrology

The main rivers of the PNOK are the Mambili and the Lekoli. Their courses are flat alluvial floodplains, up to 3-4 km wide at some points. The PNOK is largely within the catchment area of the Mambili, and forms its northern and eastern boundaries. The Mambili flows southeast into the Likouala-Mossaka, which eventually drains into the Oubangui. The other main rivers draining the PNOK and its surroundings are the Koukoua and the Lokoué, which join the Mambili from the northwest, the Lekoli, which bisects the protected area from west to east and runs into the Mambili to the south of the PNOK.

Soils

The majority of the PNOK, with the exception of river valleys and the southeast sector are red ferralitic soils which have a sandy-clay structure and are base-poor. To the north of the Koukoua these soils overly schists; to the west of the escarpment they are on granito-gneiss while to the southwest they are on quartzite. Soils on doleritic intrusions occur sporadically. These features are deep, sandy and more fertile than the rest of the PNOK soils types. Doleritic intrusions have been cited as important in the creation of forest clearings (or *bais*) (Klaus et al. 1998) which are numerous in the PNOK. To the southeast of the PNOK, overlying the Batéke Plateau sands, the ferralitic soils are sandy, highly leached, poorly humified, and chemically poor. River valleys are generally associated with hyrdomorphous gley soils.

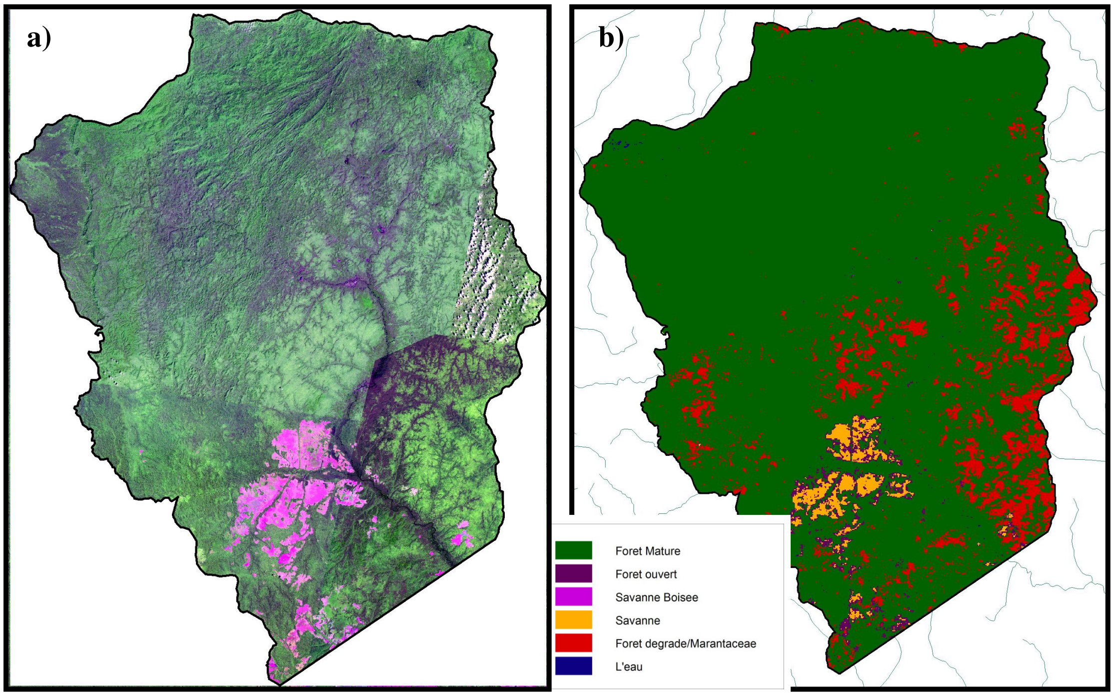
Climate

Mean annual temperatures are between 23-25^{o}C, with low annual variation (<1^{o}C) and a low daily temperature range also (<10^{o}C). Mean annual rainfall is ca. 1500mm with a bimodal distribution, and the two annual peaks falling in October and March-May. The PNOK straddles the equator and therefore is influenced by the rainfall regimens of the northern and southern hemispheres. Thus, the north of the park has a small wet season roughly a month later than the south. Relative humidity is always high (>80%). Savannahs and wooded savannahs are the exception, and often reach considerably higher daily temperatures and lower humidity due to the open habitat.

Vegetation

The semi-deciduous forests of the PNOK are typical of the most widespread of the guineo-congolian forest (mixed moist semi-evergreen guinea-congolian rainforest as classified by (White 1983)), which stretch from southeast Cameroon and eastern Gabon and include the whole of the Congo basin. The PNOK is an interesting mix of several relatively heterogeneous vegetation types. To the north is tropical moist forest, while to the south lies a zone of forest-savanna mosaic; with gallery forests running along watercourses. The savannas are mostly on the Batéke Plateau sands. Along the rivers are inundated forests with extensive swamp forests associated with the Mambili floodplain, which are also found to the northwest where swamps and seasonally flooded forests are the dominant vegetation types. The PNOK contains wide areas of Marantaceae forest which are characterized by sparse tree cover and a dense layer of understorey herbs in the families Marantaceae and Zingiberaceae. Marantaceae forest has the most heterogeneous flora of any of the vegetation types studies in the PNOK (Lejoly 1996).Small pockets of mono-dominant *Gilbertiodendron dewevrei* forest are found along watercourses. The PNOK is also characterized by the presence of over 100 forest clearings ranging in size from less than 0.5ha to some over 10ha. These clearings called bais are dominated by herbs in the families Graminae and Cyperaceae and attract high densities of large mammals, particularly elephants and gorillas.

Figure 2. Vegetation of Odzala-Koukoua National Park from a) Landsat TM imagery (CARPE), and b) derived vegetation classification by Matt Hansen (CARPE/UMD/USD)

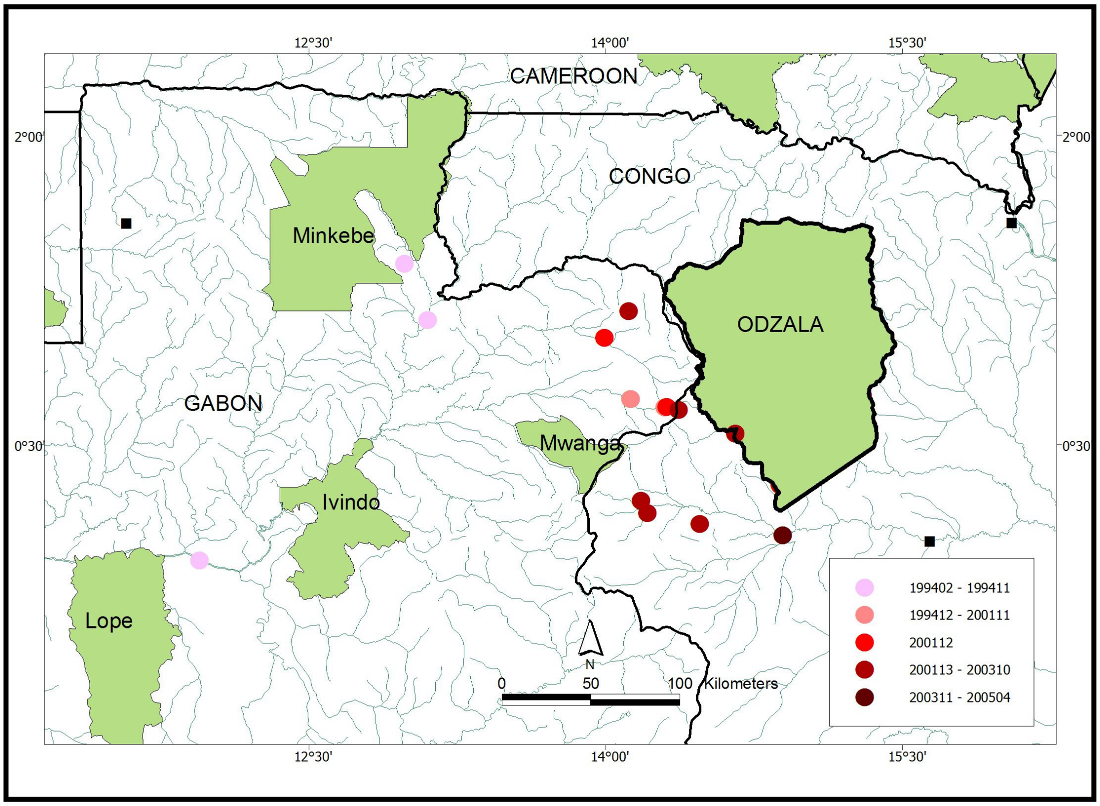


Methods

Survey design

Survey designs changed considerably in the run up to fieldwork. The original goal of the survey was to estimate elephant abundance across the PNOK, therefore a survey was designed to obtain the most precise estimate of elephant abundance and distribution with the funds that were available. However due to funding and management difficulties in PNOK, implementation of this survey was postponed several times. During the delays, outbreaks of Ebola in the human population surrounding PNOK and positive cases of Ebola found in wild gorillas (identified from carcasses) suggested that an Ebola episode was underway in the region, including potentially the PNOK. If this were the case, the most likely source was from the Lossi Gorilla Sanctuary to the southwest of the park. The goal of the survey was modified to that of obtaining the most precise information on the abundance and distribution of great apes while also providing estimates of elephant abundance, albeit less precise than originally planned. It was hypothesised that, if indeed Ebola was present in the PNOK apes, a gradient of increasing ape density would be found from southwest to northeast from a point of origin at Lossi. Data that had been analysed by Peter Walsh (and later published (Walsh et al. 2005)) indicated that a generally west to east progression of Ebola across the region was underway (Figure 3). Data from the PNOK monitoring teams became available during planning of gorilla surveys which supported this hypothesis.

Figure 3. Human outbreaks of the Ebola virus show a west to east progression of Ebola (The legend shows dates of recorded cases in the form year_month)



Survey designs were developed using the software programme Distance 4.1 (Thomas et al. 2004) under the major constraints of 1) a fixed and relatively small total budget), 2) the necessity to maximise the precision of abundance estimates, 3) test the competing hypotheses that Ebola moves as a front across ape landscapes, or that it is manifested as discrete geographically disparate eruptions, 4) that large water bodies (the Mambili in this case) act as barriers to Ebola since they prevent movements of apes. These points may be taken as indicating that the survey team was already under no doubt that an Ebola epidemic was spreading across PNOK. This was not the case, however the survey team were acutely aware of the importance of this survey in providing data on the spatial distribution of gorillas in the PNOK which could be paramount for developing strategies to protect gorillas in PNOK and elsewhere, and thus simply wanted to maximise the quality of the data, and thus proceeded as if Ebola was already present.

The PNOK was stratified according to hypothesised ape abundance as supported by monitoring data, with a low-density stratum in the west and a high-density stratum in the east (Figure 4). The density of transects was doubled in the eastern stratum compared to the western stratum in order to 1) increase the precision of the total density estimate of apes, and 2) to maximise the probability of locating an “Ebola front” if indeed one existed. A front would be characterised by few or no apes to the west and a sudden increase to normal densities to the east.

The hypothesis that the Mambili River was a potential barrier to Ebola was tested by running paired transects on the west and east banks on the southern portion of the river.

The survey was designed to answer the following priority questions:

1. What is the density and distribution of great apes in the PNOK?
2. What is the impact of the Mambili River on ape density?
3. Is there evidence of an Ebola outbreak in the park, and if so what are the impacts on the ape population
4. What is the abundance and distribution of elephants in the PNOK?
5. What is the level and distribution of human activity in the PNOK and what are their impacts on elephants and apes?

Line transects were all 1km long with a total of 73 transects for the systematic park survey, and a further 60 transects along the Mambili River. Classic line-transect methods were used based on the protocols developed by the MIKE programme in central African forests. Reconnaissance walks linked line-transects, along which all signs of elephants, apes, and humans were noted using cybertrackers. Methods are summaries below.

Survey designs were completed using the "systematic segmented trackline sampling" option of Distance 4.1, as systematic designs with a random start are more robust to variations in the distribution of the population being sampled in terms of estimator precision (Strindberg 2001). This is a survey design class that superimposes a systematic set of parallel tracklines onto the survey region with a random start, along which line transect segments are evenly spaced, again with a random start, at intervals and lengths determined by the user. Spacing and length of line transects varied by stratum and site according to the required sampling intensity. To potentially improve precision line transects were oriented at 90^o to major river drainages to run parallel to possible gradients in elephant density.

Summary of field methods

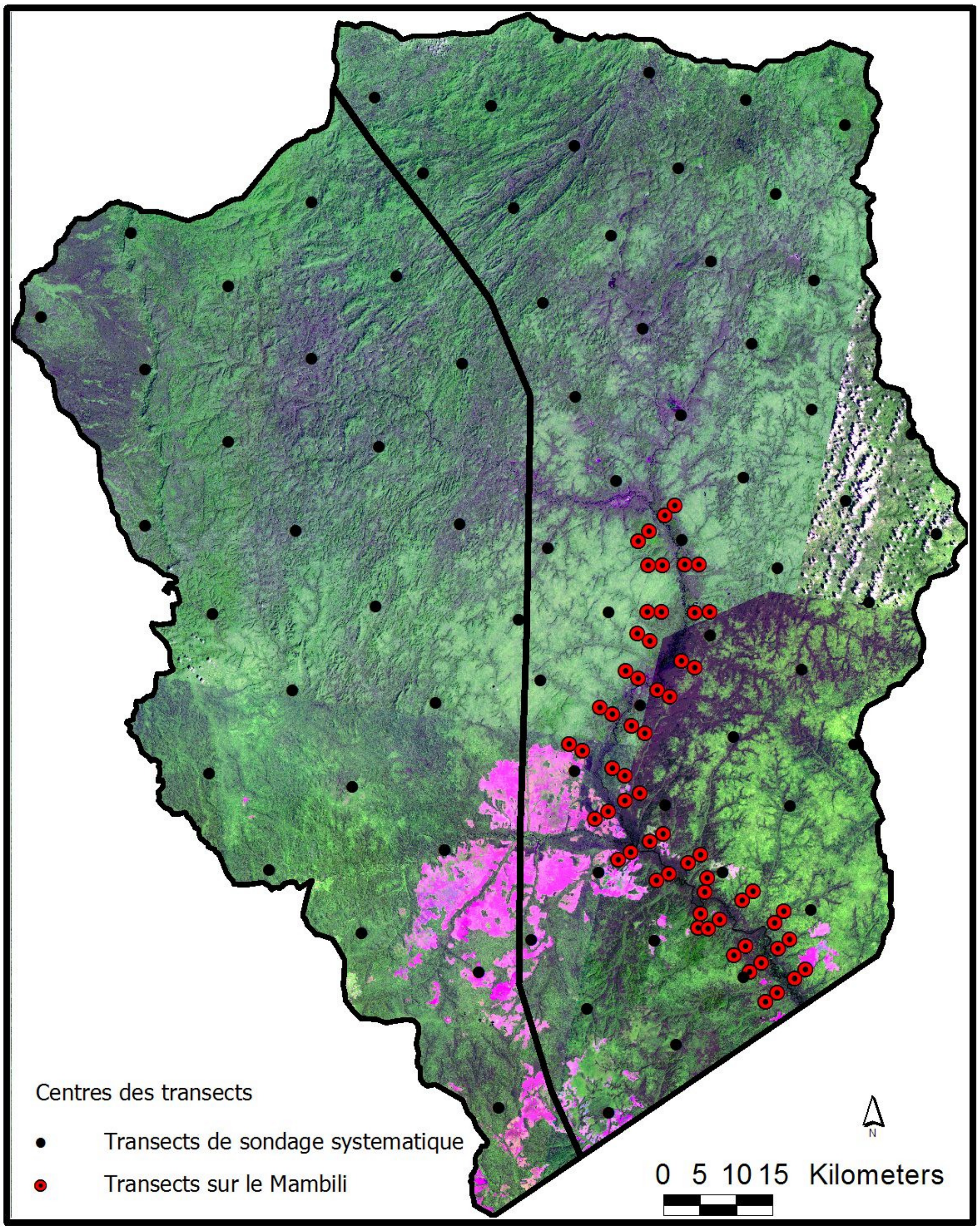
The start and end point of each line transect was uploaded to a GPS to assist field navigation. If in the field a line transect began in a swamp or river, it was displaced to the nearest location that could be found in *terra firma*. Similarly, when line transects traversed inundated areas, that portion of the transect was discarded, and an equivalent length was added to the end of the transect. Line transects were oriented using a sighting compass from the start point, and cut with a minimum of damage to the understorey. Observers walked slowly (ca 0.5-0.75 $kmhr^{-1}$) along the line transect scanning the ground for elephant dung piles. Distance along transects was measured using a Hip-chain and topofil to the nearest metre, and the distance of the centre of each elephant dung pile or ape nest to the centreline were measured to the nearest centimetre using a 10m tape measure. Survey methods are described in detail in (White and Edwards 2000b, Hedges and Lawson 2006).

In the field the end of one line transect and the beginning of another were connected by reconnaissance walks following a "path of least resistance" through the forest (White and Edwards 2000a). On reconnaissance walks a general heading was maintained in the desired direction of travel, but researchers were free to deviate to avoid thickets and steep hills or to follow elephant trails, human trails, and even logging roads. On reconnaissance walks, a continuous GPS tracklog was maintained, with a fix taken every 10-15 seconds.

Gorilla nest groups were identified as any nest group with at least 1 nest at ground level. If no nests were on the ground but there was a secondary means of identification (from dung or prints) the nests group was classified according to the signs, though this could only be used for fresh and recent nests where there was a clear connection between sign and nests. All other nests were classified as “un-identified” ape nests.

Data from line-transects were recorded into notebooks, while Cyber-trackers were used to record data from reconnaissance surveys. Unfortunately almost all the reconnaissance survey data were lost either due to hardware malfunction or to user errors.

Figure 5. Survey design (each dot represents a 1km line-transect)



Analytical methods

Elephant and ape densities were estimated using Distance 4.1 software (Thomas et al. 2004). Interpolated maps of animal densities were carried out using the Spatial Analyst module of ESRI ArcView 3.2. Generalized Linear Models (GLMs) were used to investigate the potential effects of environmental conditions and human influence on the availability of suitable habitat for gorillas (McCullagh and Nedler 1989). The data collected during an Odzala-wide line transect survey were combined with the data from an intensive survey conducted along the Mambili river within the Odzala study area. To fit the spatial model to the nest site count data, first the perpendicular distances of the center of the nest site from the transect line were used to estimate the effective strip half-width (μ) using standard line transect estimation procedures (Buckland et al. 2001). The effective strip half-width was estimated using the Multiple Covariate Distance Sampling engine implemented within the Distance software, which allowed us to investigate the potential effects of covariates such as observer and vegetation type on detectability of the nest sites (Marques and Buckland 2004). Then the survey transects were divided into segments of a set length, and each detected gorilla nest site was assigned to a segment with associated covariate values. The response variable was the number of nest sites found along each segment and the covariate values - associated with the mid-point of each segment - that were thought to potentially impact gorilla distribution and density (and thus nest site distribution and density) were obtained from Geographic Information System (GIS) data. The model fit to these data is the count model described by (Hedley and Buckland 2004) and has the form:

$$n_i = \exp\{\log(2l_i\hat{\mu}) + \beta_0 + \sum_{j=1}^{q} z_{ij}\}\,.$$

Here n_i is the number of nest sites detected in the i^{th} segment, l_i is the length of the i^{th} segment and $\hat{\mu}$ is the overall estimate of the effective strip half-width. The term $2l_i\hat{\mu}$ then gives the area effectively surveyed on transect i. β_0 is the intercept, and z_{ij} is the j^{th} covariate associated with the ith segment. A quasi-Poisson distribution was assumed due to the overdispersion in the data caused by the large number of zero counts. The GLMs were fit in R (Venables et al. 2004). The final step was to use the selected spatial model to generate a density surface for the survey site using a prediction grid comprised of the selected covariates.

RESULTS

Density and distribution of great apes

Gorillas

The mean encounter rate of gorilla nest groups was 0.69 groups km^{-1} (95% CI 0.70-1.20), which with an effective strip width (ESW) of transects led to an estimate of 62.47 nest groups km^{-2}. If the mean nest lifespan of 78 days calculated for the Lopé Reserve, Gabon is used to correct for nest decay, there were an estimated 0.8 gorilla groups km^{-2}. Using fresh and recent nests only, mean nest group size was calculated to be 4.6, this the estimated density of gorillas throughout the park was estimated to be 3.7 weaned gorillas km^{-2}, and total population an enormous 50,120 weaned individuals (3.7 x 13546).

There was a highly significant difference in the gorilla nest density by vegetation type. In mixed closed canopy forest, just 2 nests groups were seen from a total of 22.4km of transect walked in that vegetation type (0.09 nests km^{-1}), while in Marantaceae forest, 49 nest groups were recorded from 38.0km of line-transects (1.29 nests km^{-1}).

There was no difference in the abundance of gorillas by survey stratum, however there was a marked gradient in north-south distribution. Gorillas were almost exclusively found in the southern half of the PNOK, with nests being recorded on just 4 transects in the northern sector. Three of the four transects were in close proximity to the town of Sembe, while one was in the heart of the park (Figure 7).

Gorilla abundance and Ebola

There was no significant correlation between gorilla nest density and distance from the Lossi Gorilla Sanctuary. Indeed there was an almost significant *negative* correlation indicating that density decreased with distance from the Lossi Sanctuary. There was no significant difference in either the encounter rate or the density of gorillas on the west compared to the eastern bank of the Mambili River (Figure 7). There was however a noticeable absence of gorillas on the east bank in proximity to the Lokoué Bai (Figure 7), which had been a site of apparent high gorilla mortality suspected to have been caused by the Ebola virus.

Spatial modelling of ape abundance

Using the combined Odzala-wide and Mambili intensive survey data the effective strip half-width (μ) was estimated as 5.95 m (aside from perpendicular distance to the transect line no additional covariates were selected for inclusion to model the detection function). The 1 km transects were divided into segments of 333.34 m in length. The initial set of GIS covariate data included biological covariates such as distance to river, distance to bai, distance to Marantaceae, vegetation type, covariates indicative of human disturbance such as distance to the park boundary, distance to road, distance to village, survey stratum, covariates indicative of disease such as distance to nearest case of Ebola in (a) animals, (b) humans and (c) specifically in gorilla carcasses, and additionally the X and Y coordinates themselves were included as they could serve as proxies for other covariates that were not available to us.

The spatially referenced covariates survey stratum (Strata), x-coordinate (XCoord), distance to nearest case of Ebola in (a) animals (Dist2Ebola_animal), (b) humans (Dist2Ebola_human) and (c) specifically in gorilla carcasses (Dist2Carcasses) were selected for inclusion in the final model (see Figure 6). The model indicated that gorilla nest sites were more abundant in the western survey stratum and were more frequently found with increasing x-coordinate value. Similarly nest site counts were seemed to increase with increasing distance to nearest case of Ebola in animals and gorilla carcasses, but unexpectedly showed the reverse relationship to distance to nearest case of Ebola in humans. Confidence intervals are unavailable for these analyses at this time, but will be given on completion of this analysis. ***These results should be interpreted with caution given the problems in model fitting due to the large number of zeroes in the data.***

The spatial model resulted in an estimate of 998,682 nest sites within Odzala NP. Assuming 78 days to nest decay and a nest construction rate of 1 this gives an estimate of gorilla group abundance of 12,803. Using the mean nest site size of 4.6 per nest sites (calculated from these data) this gives an estimated gorilla abundance of 58,893 for Odzala NP. These results are higher though comparable to those obtained using standard line transect analyses. The overall density of nest sites is 73.72/km^2, while that for the western and eastern survey stratum is 89.90/km^2 and 60.93/km^2, respectively. Using the same conversion parameters as previously, this gives a global, western and eastern density estimate of gorilla groups of 0.9452/km^2, 1.1525/km^2, and 0.7812/km^2, respectively, and of individual gorillas of 4.02/km^2, 4.90/km^2, and 3.32/km^2, respectively.

Figure 6: Plot of the predicted densities (gorilla nest sites/km2) for Odzala from the fitted model that included an offset term and the covariates: x-coordinate, survey stratum, distance to cases of ebola in (a) animals, (b) humans and (c) specifically in gorilla carcasses [N ~ offset + XCoord + Strata + Dist2Ebola_animal + Dist2Ebola_human+ Dist2Carcasses]

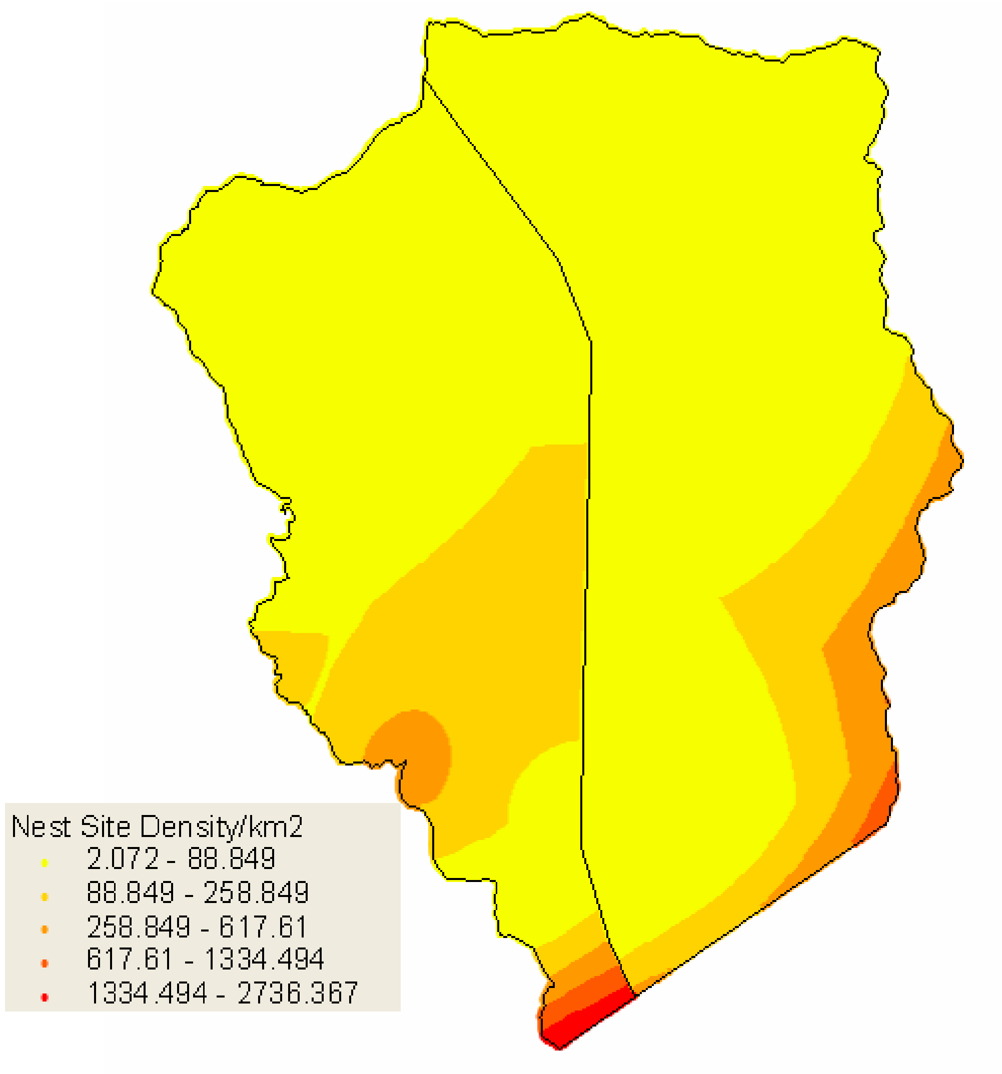


Figure 7. Interpolated gorilla nest group density in the PNOK

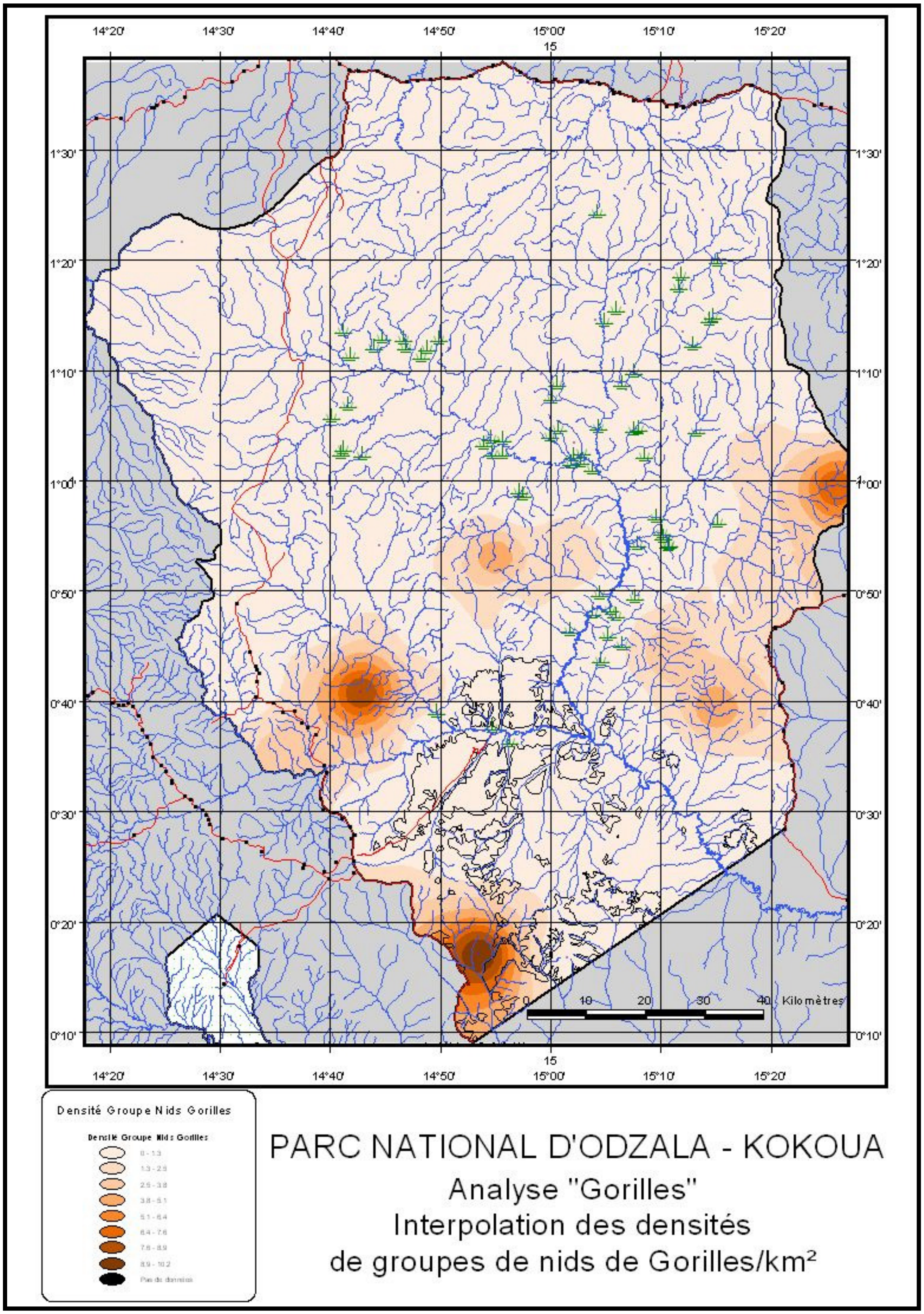
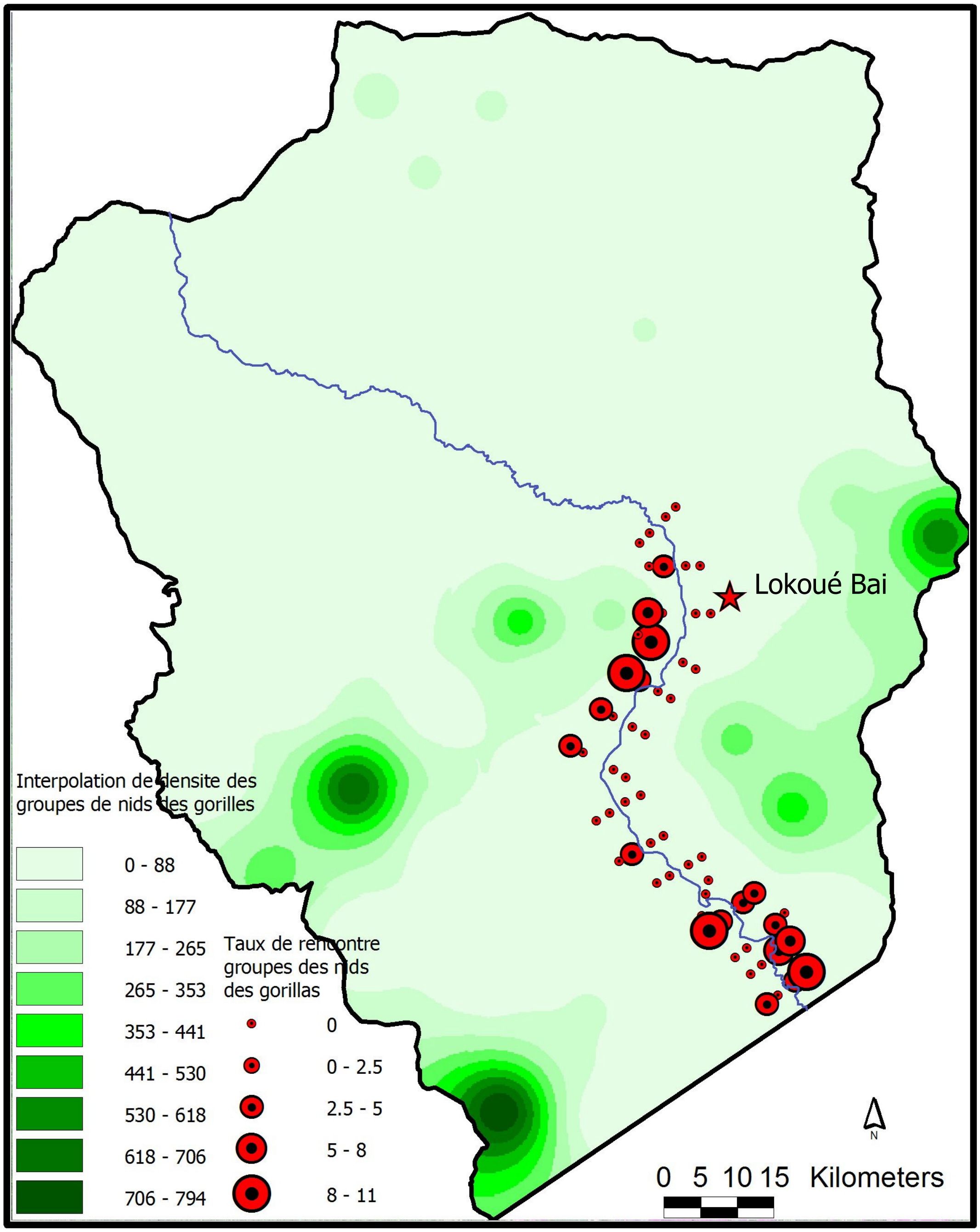


Figure 8. Interpolation of overall density of gorilla nests and nest group encounter rate (km^{-1}) along the Mambili River



Unidentified apes

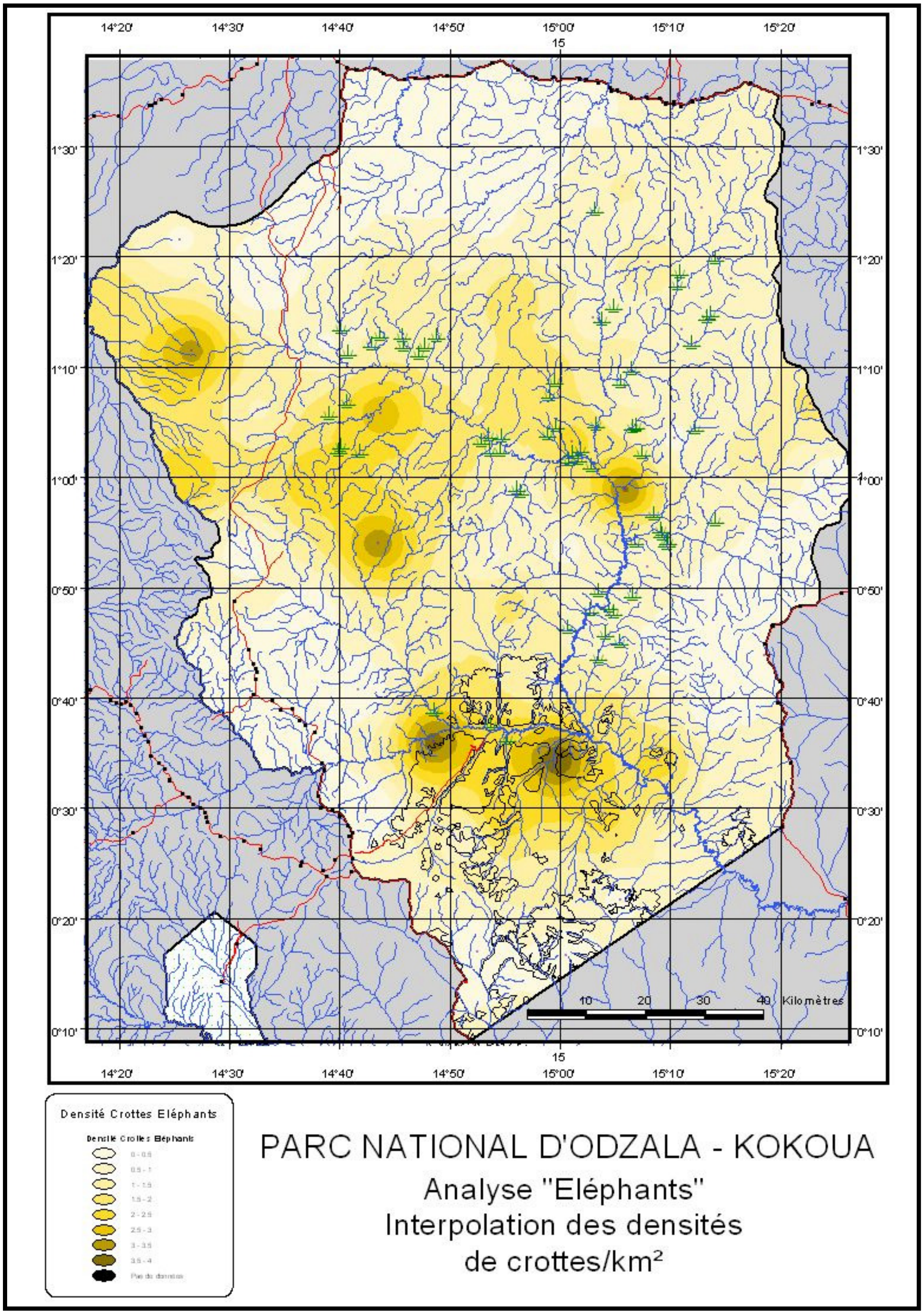
Based on a nest lifespan of 113 days (White and Edwards 2000b) the density of un-identified apes was estimated at very low across the entirety of the PNOK, at just 0.025 nest groups km^{-2} (95% CI 0.006-0.04). There were too few nest groups recorded from which to estimate mean group size, but using a mean of 2.3 weaned individuals (Bermejo 1999), an estimated 774 weaned unidentified apes were present in the PNOK at a mean density of 0.06 km^{-2}. There were too few unidentified ape data from which to determine patterns of distribution. It is likely that the majority of unidentified ape nests were chimpanzee nests, and thus it is probable that there are very low densities of this species in the PNOK.

Elephants

Elephant dung was recorded on 70 of the 73 transects on the systematic survey. Mean encounter rate of dung was 8.57 piles km^{-1} (95% CI 6.89 – 10.67), which gave an estimated dung density of 1,765.1 piles km^{-2} (1,384.4 – 2,250.5). Using a mean degradation rate of 90 days and a mean elephant defection rate of 19 per day, the estimated forest elephant density in PNOK was 1.0 km^{-2}, and a total population estimate therefore of 13,545 individuals.

Elephant were most concentrated in the centre and west of the park, with a strong concentration around the southern Savannahs near to the administrative base of the PNOK (Figure 9). Elephant density was notably low in proximity to population centres notably Sembe, Mbanza, and the Liouesso road region. Elephant density increased significantly with distance from the PNOK boundary (Linear regression: $R^2 = 0.147$, $F = 12.210_{(1,72)}$, $P = 0.0008$).

Figure 9. Forest elephant distribution in the PNOK



DISCUSSION

Great apes

Gorillas

This first complete survey of the PNOK has confirmed that the park contains a huge number of gorillas as identified by numerous studies (Fay and Agnagna 1992, Magliocca and Querouil 1997, Vanleeuwe et al. 1998, Bermejo 1999, Magliocca 1999) and see (Maisels 1996) for full review. What was not know before this survey was the high concentration of gorillas in the south, with very few in the middle and north of the park. The mean estimated gorilla density in this study was similar to that recorded by (Bermejo 1999) who recorded 5.4 weaned gorillas per km^{-2} compared to 3.7 km^{-2} in the present study. Even with the lack of gorillas in the north of the park, the numbers of gorillas in PNOK at the time of this study was spectacular.

The dataset showed the extreme importance of Marantaceae forest as a determinant of gorilla abundance, and there is clearly a strong positive relationship between the spatial distribution of degraded forest as identified from satellite imagery (Figure 2b) and the abundance of gorillas. However there is a considerable difference in the distribution of Marantaceae forest in Figure 2b, and that encountered on line-transects. Figure 10 shows the distance of Marantaceae forest encountered by line-transect compared to the Satellite derived map. Clearly the distribution of Marantaceae forest is not the only factor determining the distribution of gorillas in PNOK, since the transect data indicate that this forest type dominates the vegetation to the north of the park as well as the park. This is supported by highly significant relationship between length of Marantaceae forest recorded per transect and estimated gorilla nest density (Linear regression R^2: 0.149, $F_{(1,72)} = 12.46$, $P = 0.0007$). The low R^2 value shows that Marantaceae forest accounts for just 14.9% of the variability in gorilla abundance.

Hunting is clearly a factor that influences gorilla distribution and one possible reason for the lack of gorillas in the north of the PNOK could have been that gorillas have been hunted to very low abundance by the large human population that lives along the road forming the northern limit of the park. There are however a number of large villages around the entire periphery of the park, including villages known to be large hunting centre. For example, Liouesso on the eastern edge of the park is well known as a major hub for sending bushmeat to the town of Ouesso. A multiple linear regression of gorilla nest density per transect as the dependent variable and 1) total distance of Marantaceae forest covered per transect, and 2) distance of transect centroids to the nearest village, revealed that distance to nearest village was not a significant predictor of gorilla density (Multiple linear regression: R2 = 0.18, $F_{(2.71)} = 7.68$, $P = 0.001$; $t_{(nearestvillage)} = -1.617$, $P = 0.11$; $t_{(Marantaceae)} = 2.849$, $P = 0.006$). Eighty-four percent of the variability in gorilla density is unexplained by these 2 variables.

So what additional covariates might account for the distribution of gorillas in PNOK? Habitat variables, such as bais, swamp forests, and other ecological features will all play a role in determining gorilla abundance, but given the recent history in the region, Ebola, must also be considered. Indeed during the present survey, the Ebola virus was positively identified in the carcasses of three dead gorillas (Figure 11). Oddly however these carcasses were found close to the areas of high gorilla density. Two of the biggest problems in identifying a possible role for Ebola, or any other factor, as an explanatory variable of gorilla distribution in the PNOK is 1) the lack of previously collected systematic data from across the park despite many years and effort in "monitoring", and 2) the fact that current carcass searching techniques are limited in scale and effort. Thus it is difficult to know what gorilla distribution was before the 2005 surveys.

There are however 2 sources of data which do provide some information from previous years; the MIKE survey of 2001, and the 'monitoring" work carried out by the cybertrackers teams since 2001.

Figure 10. The distribution of Marantaceae Forest from ground surveys compared to satellite derived data (the red pixels are indicative of very open canopy forest, secondary forest, or Marantaceae forest)

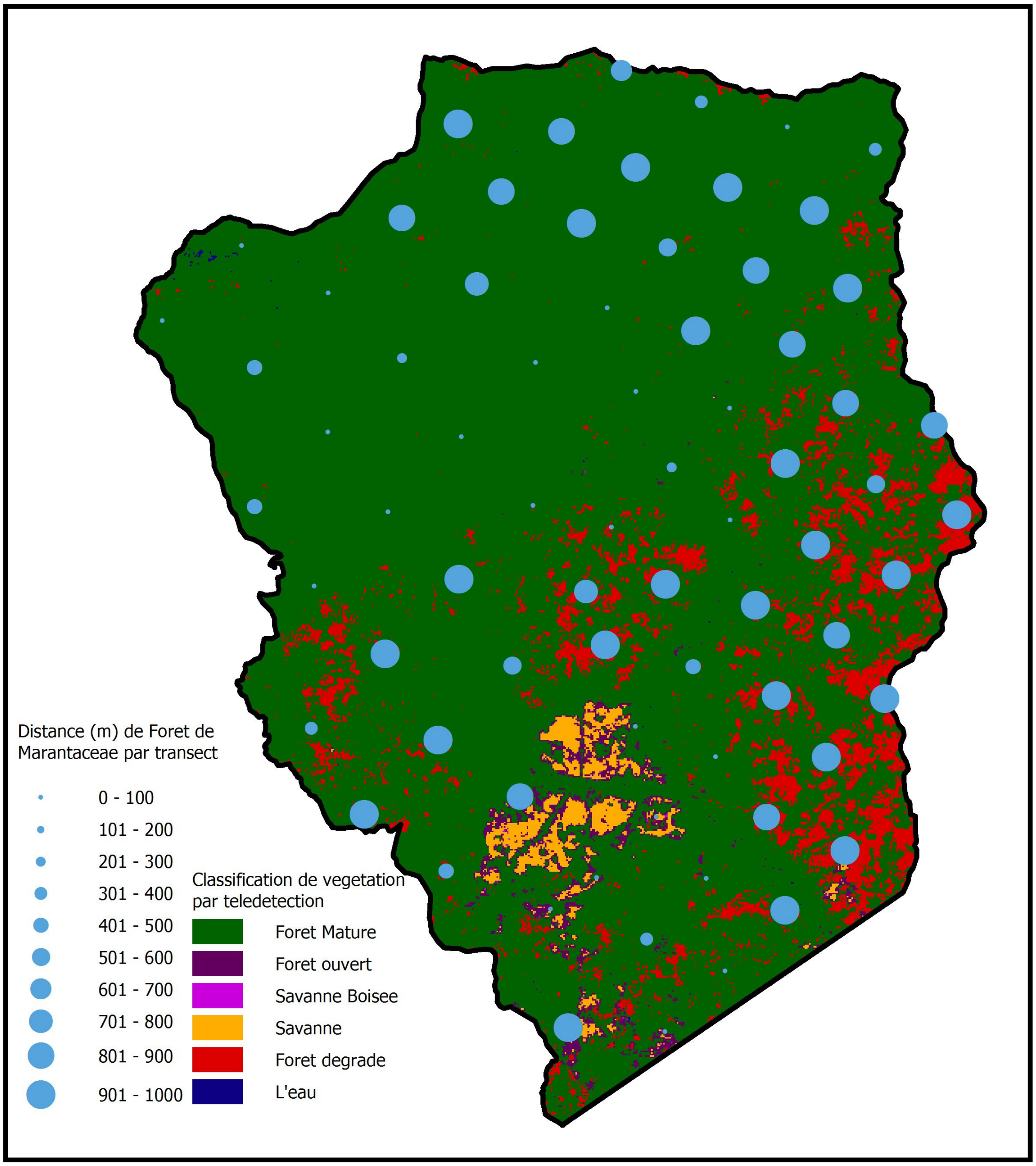
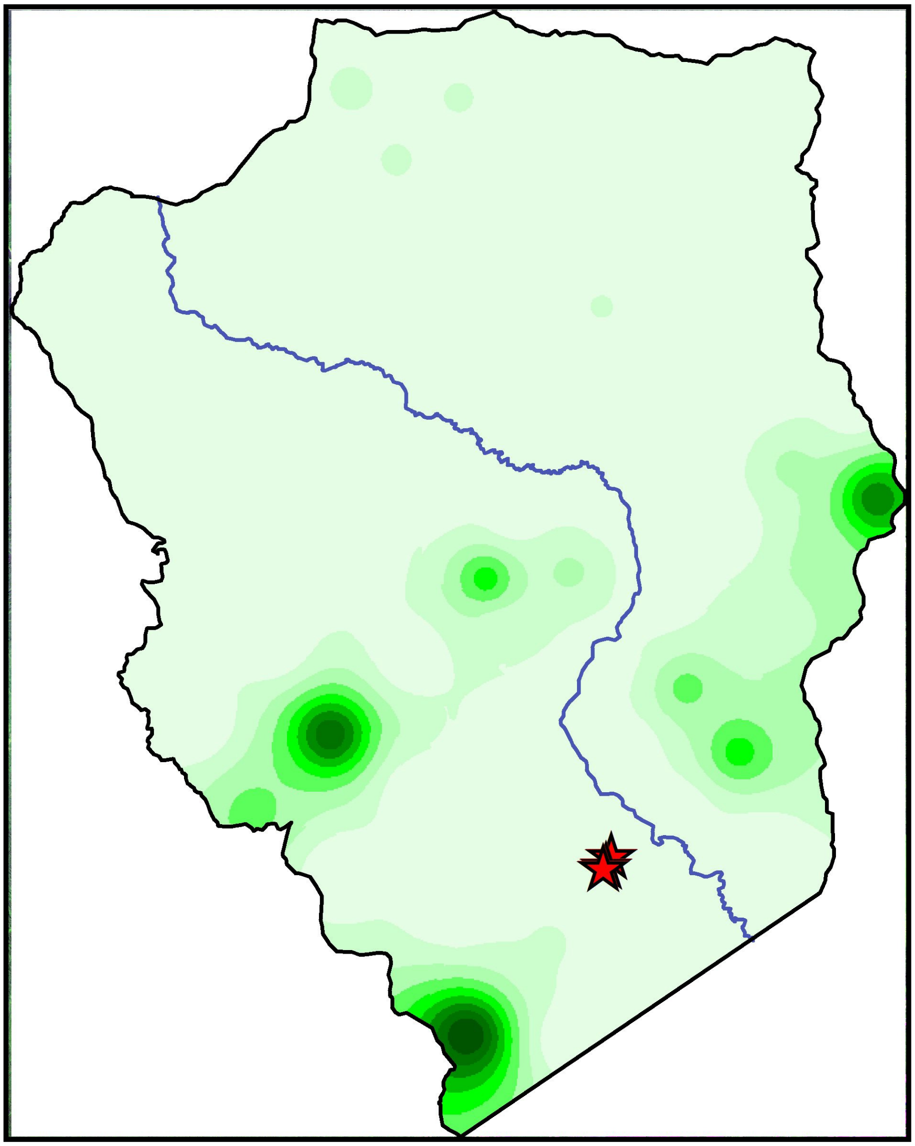


Figure 11. Three carcasses positively infected with Ebola found in June 05, and interpolation of gorilla density



Nest and carcass counts from PNOK cybertracker programme

There is a great difficulty in comparing monitoring data from cybertrackers by region and by year due to the biases inherent in the method and the routes taken. Unfortunately, spatial coverage has been poor in the north of the park, with the exception of 2004, and in no year has there been any coverage of the northwest of the park. It is exactly this region which is the most critical in terms of detecting change in the ape population. One region in central PNOK has had reasonable coverage for three of the four years for which data are available as indicated by region "A" in Figure 12a. Within this area the mean encounter rate of gorilla nests from cybertrackers surveys was calculated for the years 2002, 2004 and 2005 (Figure 12b). The drop in nest group encounter rate between 2002 and 2004 is more than 5 fold, and it remains nearly as low in 2005. Carcass data are available for only 3 years, 2003, 2004, and 2005. Unfortunately the total distance patrolled in 2003 is not available for this report, so an encounter rate of carcasses cannot be calculated. However in 200 of 2003 just 2 gorilla carcasses were found on the extreme western edge of the PNOK, while in 2004 and 2005, 11 and 8 were found on monitoring surveys form 1436 and 388km. The increase in encounter rate of ape carcasses from 2004 to 2005 was more than 2 fold (Figure 13).

Chimpanzees

The estimated density of chimpanzees was extremely low throughout the PNOK. Even if all unidentified apes nests were assumed to be chimpanzee nests the overall density is still two orders of magnitude lower than that estimated by (Bermejo 1999). Potential explanations include observer bias, sampling design bias, or a real decline in the chimpanzee population. It is highly unlikely that the experienced observers in the present study could have been 100 times worse than Bernejo's team, and sample coverage while not dispersed throughout the park in Bermejo's study, was conducted at a reasonable geographic scale, so this is also unlikely. Furthermore, (Bermejo 1995) found high densities of chimps elsewhere in Marantaceae forest, closed canopy forest, and even in march forest. Thus the most reasonable conclusion is that chimpanzees have experienced a dramatic decline in chimpanzee density.

Figure 12 a) Spatial coverage of Cyber-tracker surveys for which data were available, b) encounter rate of gorilla nests in region "A".

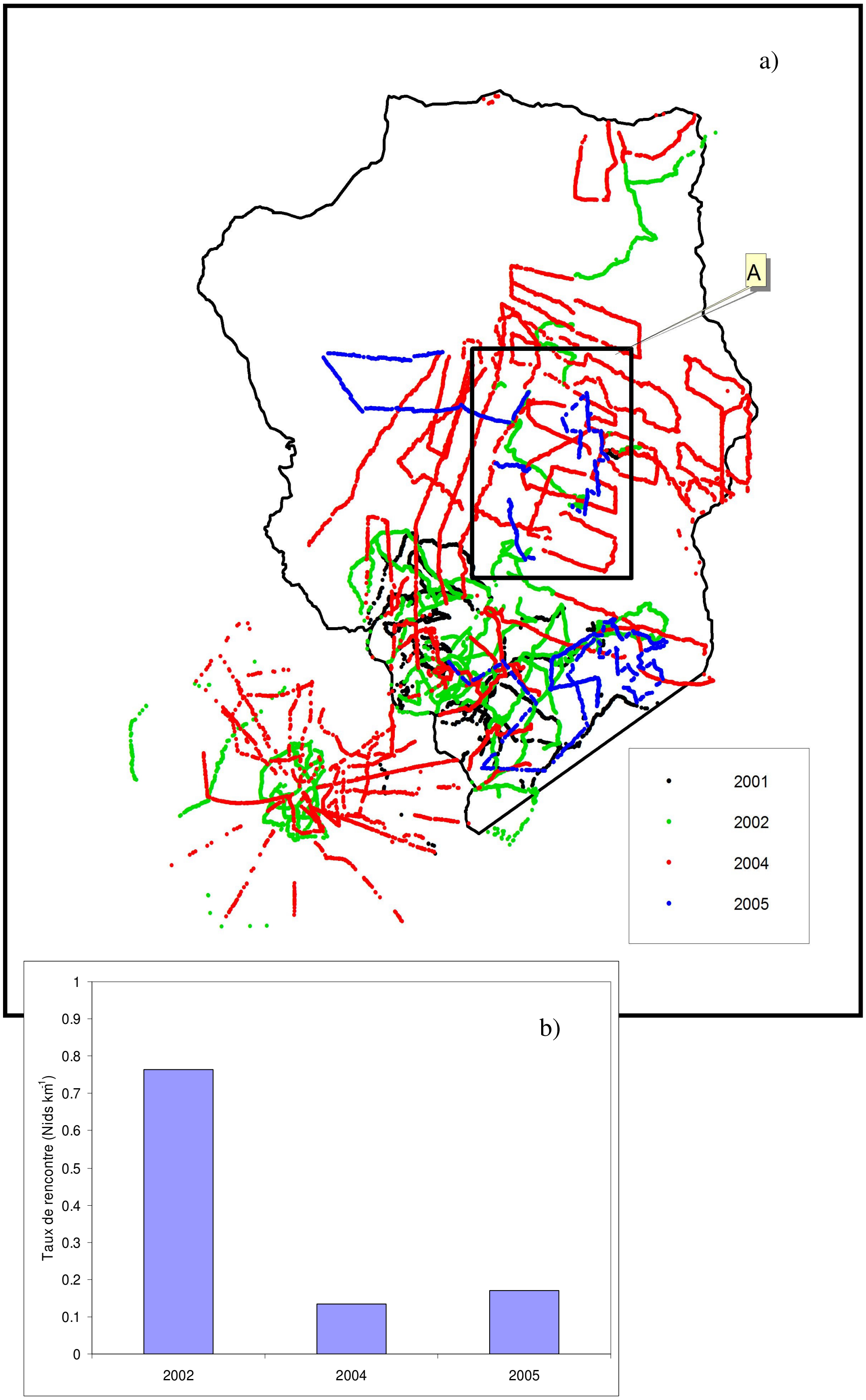
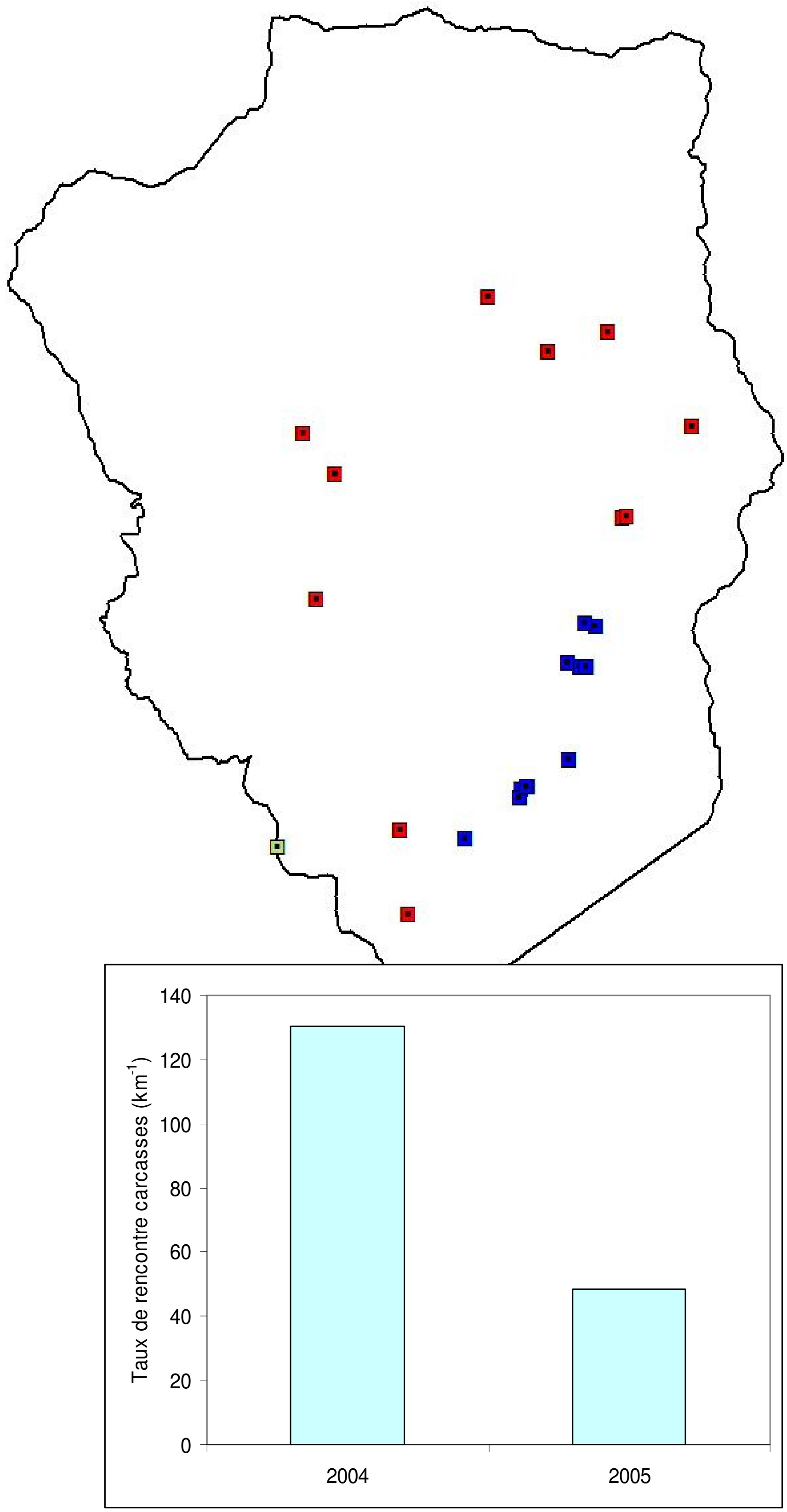


Figure 13. Carcasses recorded on monitoring patrols 2003-2005.



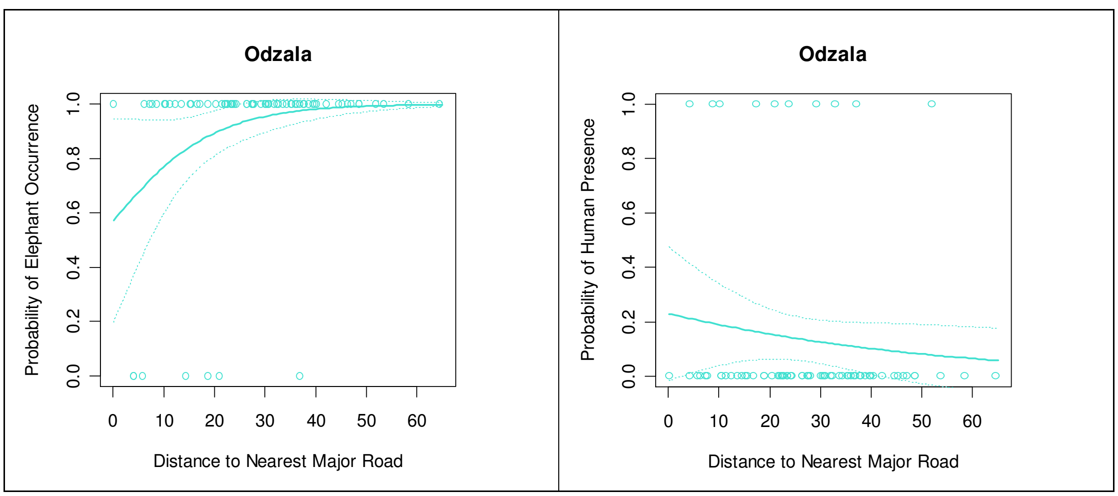
Elephants

Odzala still contains extremely high densities of elephants compared to almost all other sites in central Africa (Blake In press). The excellent habitat with its profusion of bais, and high degree of isolation in the interior of the park, mean that even with relatively high poaching levels, elephants have continued to thrive in the heart of the PNOK. Interestingly there was a significant negative relationship between elephant dung density and the proportion of Marantaceae Forest on line-transects (Spearman's $\rho = -0.354$, $N = 73$, $P = 0.002$).

An analysis completed by (Blake In press) is shown below (Figure 14). The graph reveals that the distance from the nearest road is a significant predictor of elephant abundance (abundance increases with increasing distance from the nearest road), to a distance of ca. 25km, after which increasing distance has a limited impact on abundance. Human sign abundance as observed on line-transects did not decrease significantly with distance from road as had been expected, however the dataset was so small that the ability to detect a trend, even if it did occur, was limited (as evidenced by the wide confidence intervals in Figure 14 below. Three regions where human beings were clearly having a major impact on elephant abundance were in proximity to the villages of Sembe, Liouesso, and Mbanza, which are all known to be elephant poaching centres.

Despite being surrounded by roads and villages, the size of the PNOK means that it is the second most remote forest in central Africa, and is one of the critical conservation aareas for the forest elephant.

Figure 14. The probability of a) elephant occurrence and b) human sign occurrence on line-transects and distance from the nearest road (from Blake et al., in press).



RECOMMENDATIONS

1. The conservation monitoring programme of the PNOK requires thorough analysis and revision. Monitoring datasets are scattered, poorly cleaned and stored, and have never been analysed with a view to detecting change in either animal abundance, poaching activity, or change in conservation state of the PNOK over time in a rigorous way. A coherent conservation monitoring for PNOK should be written up and implemented.
2. A follow-up ape survey should be conducted in the southern half of the park immediately to determine whether there has been any change in either abundance and/or distribution of gorillas. Datasets from PNOK, and survey work in the peripheries of PNOK should be harmonised and included in a single spatial analysis.
3. The full dataset from these surveys and from the PNOK monitoring programme should be made available for in-depth statistical review by an independent team selected by the GOC and partners in PNOK. It is imperative that these data provide as much information as possible on the reasons for the patterns in distribution and abundance seen in apes in PNOK. This work should involve specialists with the following skills: ecology, epidemiology, animal medicine, spatial statistics, and human health.
4. Sensibilisation and preventative measures to inform the public of the possible risks from Ebola should be stepped up in northern Congo in accordance with previous recommendations already following this study.

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