ASSESSMENT OF CHIMPANZEE (*Pan troglodytes*) POPULATION AND HABITAT IN KWITANGA FOREST, WESTERN TANZANIA

By

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Research report submitted in partial fulfillment of the requirements for the degree of Master of Science in Resource Conservation Biology

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JUNE, 2007

DECLARATION

I declare that this report is my own, unaided work except where acknowledged. It is being submitted for the degree of Masters of Science in the University of Witwatersrand, Johannesburg. It has not been submitted before for any degree or any examination in any other University.

(Signature of candidate)

31st day of October 2007

ABSTRACT

This study examined three aspects: estimation of chimpanzee (*Pan troglodytes*) population size using nest density as a proxy, description of the plant community and assessment of human impacts to chimpanzee habitat in Kwitanga forest, western Tanzania. The overall estimated mean chimpanzee population density was 0.69(0.31–1.54) individuals per km^2 and a mean population size of 15(7-34) weaned individual chimpanzees in the forest. The natural vegetation in Kwitanga consists mainly of miombo woodland, dominated by *Brachystegia-Julbernadia* tree species, poorly developed riverine forest, cultivated land and oil palm plantation. Assessment of the abundance of nesting trees in the landscape revealed that tree species composition along transects were significantly different to nesting sites (trees surrounding the actual tree that contains a nest) (Kolmogorov-Smirnov test: KSa = 2.0148; D = 0.3934: $P < 0.05$). Thirteen tree species were used for nests; the most used species were *B. bussei*, *B. utilis*, *B. mirophylla*, *J. globiflora* and *P. tinctorius*. The assessment on scarcity of nesting tree species in the landscape revealed that such species were abundant by proportion (KSa = 0.5883; D = 0.2308; $P > 0.05$), and species-specific density (Wilcoxon Z-test: Z = - 1.0265; $U_1 = U_2 = 13$; $p > 0.05$). Trees in size classes between 10 cm and 40 cm diameter dominated the forest. The study on size suitability showed that there were significant differences (using ANOVA with Tukey's HSD post hoc test) in tree diameter size among the three groups: transects, nesting sites, and nesting trees. Nesting trees were unique in size to the other two groups. The mean size of nesting trees was larger compared to both nesting sites and transects (27 ± 1.1 cm; 23 ± 0.7 cm and 18 ± 0.5 cm) respectively. Similar differences existed in tree densities between nesting sites and transects (Wilcoxon test: Z = 1.8104; $U_1 = 46$, $U_2 = 61$: $P< 0.05$), with nesting sites presenting higher tree density. These results indicated scarcity in trees of a size suitable for nesting, and nesting materials.. Nesting tree species occur in the landscape, though their sizes and higher tree species density at nesting sites determined nesting location choice and specific nesting tree selection. Tree felling indicated by stumps was the major threat to the availability of suitable nesting trees, with a higher encounter rate of seven (7) stumps per km and contributed 48 % of total human disturbance, followed by established fields in the forest. The analysis on the direction of the major threat to the habitat revealed that, the main road cutting through the forest is a key to tree felling. Encountered stumps declined with increased distance from the main road towards the forest edge, with more stumps in between 0 -100 m ($P< 0.05$; log (Y) = 1.7017 - 0.0007(X); $R^2 = 0.6705$). Such findings implied that the prison inside the forest is a major cause of habitat decline. At least 30 tree species constituted the group of stumps. *Julbernadia globiflora* and *Uapaca kirkiana* were the most felled tree species. High human disturbances implied by higher human activities encounter rates, and overlapping tree size classes between felled and standing trees were the major threats to chimpanzee habitat in Kwitanga forest. High chimpanzee density and population size estimates in Kwitanga forest renders this area a potential for conservation in the Greater Gombe Ecosystem Program. Kwitanga being the largest remaining natural forest near Gombe National Park, it will increase habitat size to allow chimpanzee dispersal and feeding area. Such movements across heterogeneous landscapes would allow long-term survival through reduced competition, increased genetic diversity and ability to absorb minimal environmental shocks.

ACKNOWLEDGEMENT

I am grateful to a number of people whose efforts made this research report a reality. The foremost gratitude extends to my co-supervisors: Drs. Barend Erasmus and Michael L. Wilson for their valid and invaluable contributions across the study period, consisting of supervision, critical review of this work and constructive challenges. Many thanks go to the two field assistants (Hamis Matama and Amani Bunuguye) who worked with me in the forest and Grace Gobbo for her efforts in trees identification. I also would like to thank Dr. A. Piel (University of California) for exposing some papers, Dr. A. Plumptre (WCS-Uganda) for his advice and papers on the subject and Prof. E. Witkowski (Wits) who devoted time to guide me with vegetation studies and papers. This is not limited to a few people but rather to many other individuals at the University of Witwatersrand who provided their criticism and assistance during report development.

I would further like to extend my sincere gratitude to the University of Witwatersrand and the Jane Goodall Institute Tanzania for their financial support and logistic arrangements for this study.

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1.0. INTRODUCTION

Chimpanzee (*Pan troglodytes*) populations worldwide has declined from about 1 million in 1900 to an estimate of 300,000 in 2000 (Butynski, 2003; Pusey et al., in press), and the species has been listed as Endangered species by the IUCN (Butynski et al., 2000; Oates, 2006). Chimpanzees reproduce and mature slowly making them vulnerable because it takes a long time to recover from population crashes (Marchesi et al., 1995; Oates, 2006). The largest chimpanzee populations are found in the equatorial Central Africa (Oates, 2006; Pusey et al., in press), while other chimpanzee populations occur in West coast to as far as Western part of East Africa (Kano, 1971a, b). Chimpanzees are restricted to moist forest and its surrounding forest Savanna regions (Kano, 1971a, and b).

In western Tanzania, chimpanzees inhabit a drier vegetation type of moist Woodland (Moreau, 1945; Suzuki, 1969; Kano, 1971a, b; Goodall, 1986) and Grassland forest mosaic (Goodall, 1986; Massawe, 1992). As such, their habitats were reported from the borders of Burundi to south of Kigoma (Moreau, 1945; Kano, 1971a, b; Goodall, 1986), on shores of Lake Tanganyika to about "20 mile" away from the lake to Mpanda District in the areas of Kugwe-Mahale Mountains Forests (Moreau, 1945). Their distribution extends to the borders of Zambia and Tanzania in Lwazi area as a southern distribution limit (Ogawa et al., 1997).

Chimpanzee habitats across Africa have declined because of forest clearing for timber and agriculture (Marchesi et al., 1995; Oates, 2006). Increase in human population (Chapman et al., 2006; Morgan et al., 2006), fuelwood and charcoal production (Chapman et al., 2006) are other major contributing factors. In addition to habitat reduction, chimpanzee populations have declined because of hunting (Marchesi et al., 1995; Chapman et al., 2006; Morgan et al., 2006; Oates, 2006) and diseases (Chapman et al., 2006; Morgan et al., 2006). It is reported that, in western Tanzania, similar factors have caused habitat decline (Goodall, 1986; Massawe, 1992). Increase in human population size (Goodall, 1986; Population and Housing Census, 2002; Thaxton, 2006) and influx of refugees from Burundi and Democratic Republic of Congo (DRC) (Greengrass, 2000; Pusey et al., in press) constitute another set of contributing factors. Fuelwood collection, charcoal production

(Goodall, 1986; Greengrass, 2000), hunting (Greengrass, 2000) and diseases (Thaxton, 2006) form another set of factors that contribute to chimpanzee population decline in western Tanzania.

As a consequence of these factors, the extent of chimpanzee habitat and as well as the quality of this habitat has declined and become more fragmented from other neighboring communities (Goodall, 1986; Butynski et al., 2000; Chapman et al., 2006; Oates, 2006). They continue to experience human pressure to date. Reduction in size, quality and isolation of habitats increase the risks of long-term survival of chimpanzees. These risks result from increased edge effects and genetic isolation (Marchesi et al., 1995; Davies et al., 2001; Primack, 2002; Pusey et al., in press). Also, the disruption of reproductive units through killing of males that protect and maintain the community leads to decreased survival of remaining individuals (Marchesi et al., 1995) and disease infections (Gillespie et al., 2005; Chapman et al., 2006, Gillespie & Chapman, 2006).

Conservation planning requires an understanding of the extent of chimpanzee distribution, population size and the threats facing them (Balcomb et al., 2000; Blom et al., 2001; Plumptre & Cox, 2006). Such details are essential to establish conservation strategies to protect viable population size (Primack, 2002) of chimpanzees in their natural habitats.

This study focused on estimation of chimpanzee population size, description of plant community and assessment of the level of human impacts to the habitat prior to conservation planning of Kwitanga forest. Description of vegetation structure and composition helps to understand the role of humans in modifying the habitat. Structural information and human activities in an area provide details on the suitability of the habitat, as an indication of human influence on chimpanzee density.

1.1 Research problem and significance of study

Human settlements and population increase, need for farmland, fuelwood, timber and other forest resources, have led to the isolation of most habitats that have therefore become fragments (Goodall, 1986). Small chimpanzee populations are now in fragmented habitat patches near Gombe National Park, examples of which are Mkongoro, Mganza, and Kwitanga forest (Pusey et al., in press).

Early studies in western Tanzania show that there was a general occurrence of chimpanzees in western Tanzania since 1920s (Moreau, 1945; Thomas, 1961; Sugiyama, 1968; Suzuki, 1969; Izawa, 1970; Kano, 1971a, b). Many research works on chimpanzees concentrated in the southern part of the Malagarasi River. This river restricts contacts between northern and southern populations (Ogawa et al., 1997; 2004; Zamma et al., 2004; Nakamura et al., 2005; Moyer et al., 2006).

There is an estimated population of 2000 chimpanzees in western Tanzania. Mahale National Park contains about 1000 in 1613 km^2 and Gombe National Park about 100 in 35 km^2 (Massawe, 1992). About 900 or more chimpanzee individuals live outside protected areas (Massawe, 1992). These areas exist as fragments due to human settlements and resource extraction from adjacent human communities. To date, little attention has been paid to the eastern part of Gombe National Park, where Kwitanga is located to date.

Reports show that smaller, fewer and more scattered chimpanzee populations exist to the northern part of Malagarasi River (Massawe, 1992; Grossman & Mnaya, 2004; Pusey et al., in press). These populations are important for conservation in the Greater Gombe Ecosystem. A broader program focused on chimpanzee conservation, in the adjacent habitat fragments with chimpanzees near Gombe National Park. Gombe National Park harbors small and isolated population in the region, and any efforts towards linking such populations would ensure protection of viable population in the region.

Kwitanga forest is the largest remaining chimpanzee habitat fragment near Gombe National Park, and contains a small chimpanzee population. The forest has not been formally protected and was part of the Luiche Forest Reserve (Massawe, 1992; Pusey et al., in press). This remained relatively unconverted to farmland in the area, due to a prison located inside, while the most of the Luiche Forest Reserve became transformed since the 1970s (Massawe, 1992), and it has thus lost about 80-90% of the original forest cover (Pusey et al., in press). Efforts to protect this forest and secure connectivity to Gombe National Park chimpanzees would add to the total population size, and make this population more viable over time. Small fragments (examples; Gombe National Park-35 km^2 and Kwitanga-~21.8 km^2) cannot support viable chimpanzee populations on their own over a long-term. Their salvation therefore requires existing in a metapopulation, which would allow dispersal of individuals across the landscapes (Chapman et al., 2006).

Prior to my study, Massawe (1992) and Grossman & Mnaya (2004) described the presence of chimpanzee population in Kwitanga forest. Massawe (1992) measured the presence of chimpanzee nests in Kwitanga and Mganza forests both located near Gombe National Park. In the year 2004, Grossman & Mnaya spent a day in the area, reported presence of 52 nests, and approximated five (5) chimpanzees based on nest grouping size. They also interviewed local people who reported to have had sighted 12 individuals. Other reports of the Roots and Shoots Kigoma (a project of the Jane Goodall Institute), reported presence of about six individuals in Kwitanga forest in year 2000.

The information gathered from these early studies, revealed a need for a detailed study in the area. Reports from Massawe (1992) and Grossman & Mnaya (2004) gave the evidence on the presence of relic chimpanzee populations. Local people do not recognise individual chimpanzees and the reported numbers may not be accurate. From the viewpoint of these uncertainties in estimates, this work has then intended to cover the existing gaps on mean chimpanzee population size, and further examine vegetation status and threats to the habitat.

1.2 Objectives and key questions of the study

Prior to conservation strategies, detailed information on population estimates, habitat structure and threats to particular habitat are essential. This study therefore focuses on the following objectives,

1. To estimate the population density of chimpanzees in Kwitanga forest
2. To identify and describe the structure and composition of the plant community
3. To identify and assess level of human impact on this forest

Suitable conservation decisions rely on the availability of information on population estimates and the understanding of the role of humans in modifying forest structure and composition indicated by human signs that remain in the forest. Sources and types of human induced pressure help in designing the best conservation strategy for an area. To achieve the above goals, the key questions were:

1. What is the population density of chimpanzee in Kwitanga forest?

2. What is the vegetation structure and composition in chimpanzee habitat?
3. Which tree species are utilized for nesting?
4. What is the relationship between vegetation structure, cover, and nest location?
5. What are the most severe threats to chimpanzee habitat?

2.0 LITERATURE REVIEW

2.1 Chimpanzee population estimates

A large number of published measures of chimpanzee population density estimates exist from across Africa. These estimates use different calculations (Hashimoto, 1995; Plumptre & Reynolds, 1996, 1997). The estimates form the basis for conservation planning regardless of the methods used in deriving particular estimates. Examples include Plumptre & Reynolds, 1994; 1996; 1997; Hashimoto, 1995; Ihobe, 1995; Marchesi et al., 1995; Furuichi et al., 1997; Hall et al., 1998; Blom et al., 2001; Feury-Brugiere & Brugiere, 2002; Sunderland-Groves et al., 2003; Matthews & Matthews, 2004; Poulsen & Clark, 2004; Moyer et al., 2006; and Plumptre & Cox, 2006. For example, the method used in Poulsen & Clark, (2004) based on nest density multiplied by mean nest group size and dividing the product to mean nest decay rate, based on the formulae established by Tutin & Fernandez in 1984. The current method used in Plumptre & Reynolds, (1996; 1997) uses; nest density estimates divided by the product of nest decay rate and nest production rate. The unit of comparison among sites is the density of weaned individuals per square kilometers.

2.2 Forest composition

Habitat composition and structure of a forest determines the abundance of chimpanzees (Balcomb et al., 2000). This relates to availability of food and nesting materials. Seasonal changes in food abundance influence ranging patterns of chimpanzees in the landscapes (Kano, 1971a; Baldwin et al., 1982; Plumptre & Reynolds, 1994). In forested habitats, chimpanzees have smaller nomadic ranges (about 20 km^2) than in savanna woodland where they have a wider range of about 70-200 km^2 (Suzuki, 1969; Kano, 1971a; Baldwin et al., 1982; Pusey et al., in press). Chimpanzee density in such savanna woodland habitats is always low (Suzuki, 1969), and snapshot surveys in small areas where information about food distribution and abundance are not known is hard. Such short-term surveys in low density areas is likely to lead to an underestimate of chimpanzee populations. (Kano, 1971a; Hashimoto, 1995).

Studies of habitats use different categorization system to investigate the composition and structure of the forest. For example, Marchesi et al., (1995) used ten different habitat types based on structural particularities while Hashimoto (1995) used logged versus unlogged classification. Though different classifications exist, they all aim at addressing the structures and roles of humans in modifying natural chimpanzee habitats.

2.3 Human impacts

Chimpanzees in Africa face many problems such as habitat decline because of forest resource utilization (Marchesi et al., 1995), and forest clearing for timber and agriculture (Marchesi et al., 1995; Oates, 2006). The ongoing human population increase, hunting and diseases are as yet another set of problems to chimpanzee populations (Chapman et al., 2006; Morgan et al., 2006; Oates, 2006). Habitat fragmentation has isolated majority of chimpanzee populations leading to reduced survival (Goodall, 1986; Butynski et al., 2000).

In western Tanzania, the greatest threat to chimpanzees is the habitat loss (Goodall, 1986; Massawe, 1992), which has kept on increasing due to increasing human population size, need for farmland and fuelwood (Goodall, 1986; Population and Housing Census, 2002; Thaxton, 2006). Hunting forms has a very limited contribution to chimpanzee population decline due to traditional taboos of local Tanzanians, though reports have shown that, there are changes in this attitude following the influx of refugees from Congo DRC (Greengrass, 2000). However, according to the existing reports, diseases form another essential devastating threat to chimpanzee populations and are among the major causes of decline in Gombe National Park (Thaxton, 2006). With respect to small chimpanzee population remaining today in western Tanzania, all threats seem equally important and most of the available information comes from protected areas.

3.0 STUDY SITE AND METHODS

3.1 Study site

Kwitanga Forest in the Kigoma region of western Tanzania is located between 4º 42.676' S and 4º 46.921' S, and 29º 49.127' E to 29º 47.146' E. The forest is about 15 km east of Gombe National Park and 23 km northeast of Kigoma town (Figure 1). The altitude ranges from 976-1183 m above sea level (Grossman & Mnaya, 2004).

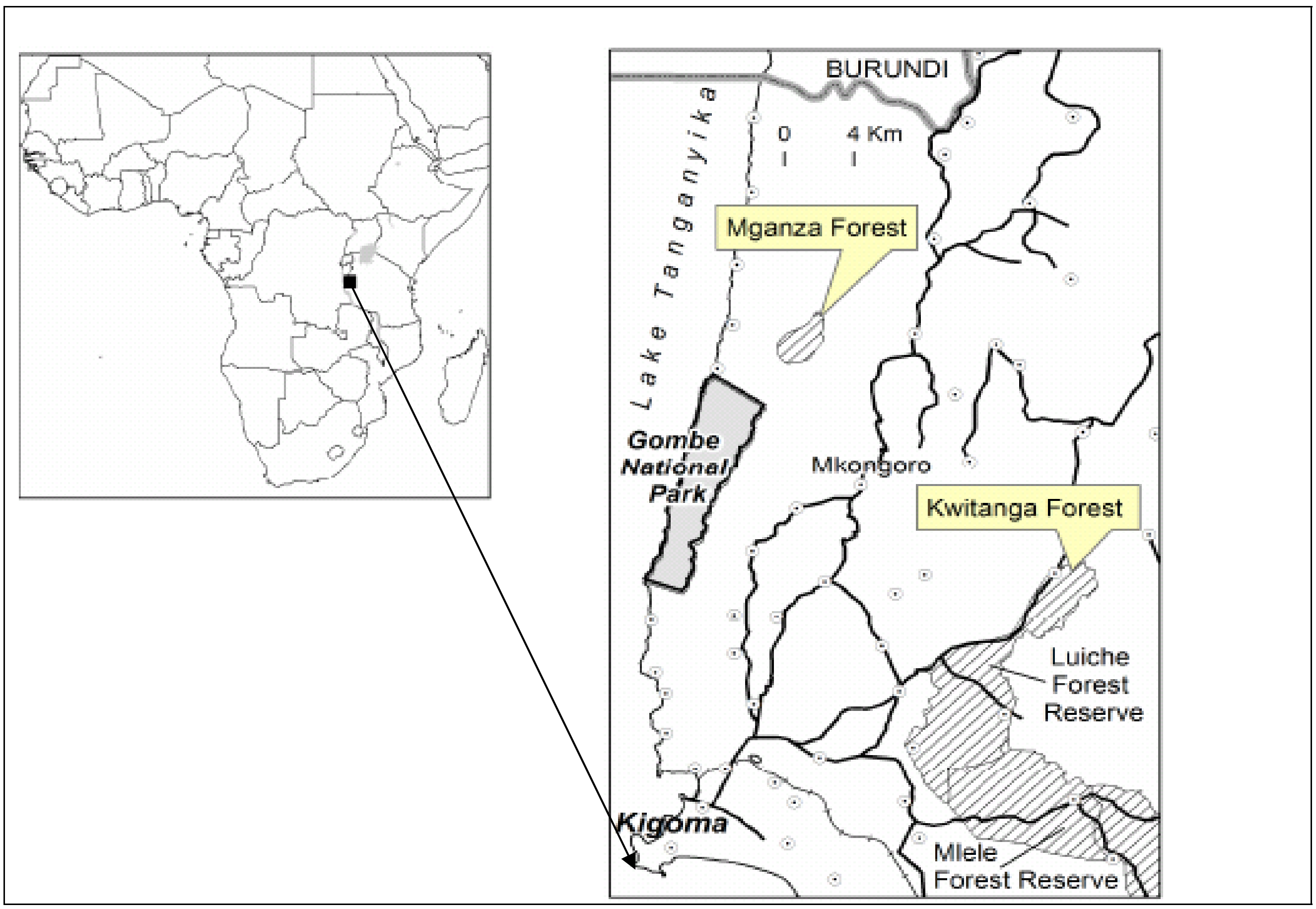

Figure 1 Location of the study site (Source: modified from Pusey et al., in press**)**

In 1972, the size of the forest and woodland in Kwitanga area was 4178 hectares (ha). This figure dropped to 1339 ha in 1999. (Pintea, pers. comm.).

Kwitanga forest contains mainly miombo woodlands of open *Brachystegia-Julbernadia* stands (Goodall, 1986; Malocho, 1998; Grossman & Mnaya, 2004), poorly developed riverine forests, cultivated fields and commercial oil palm plantation. Commercial oil palm plantation covers about (~266 ha).

Annual rainfall ranges from 600 mm to 1500 mm from Gombe National Park located 15 km from Kwitanga. This amount of rainfall may be relatively higher than actual rainfall in Kwitanga, with a bimodal rainfall between October-May being wet as opposed to June-September the dry months. The mean daily temperatures, range from 25^0 C to 28^0 C in wet season (Malocho, 1998) and in dry season from about 27^0 C to 30^0 C (Goodall, 1986).

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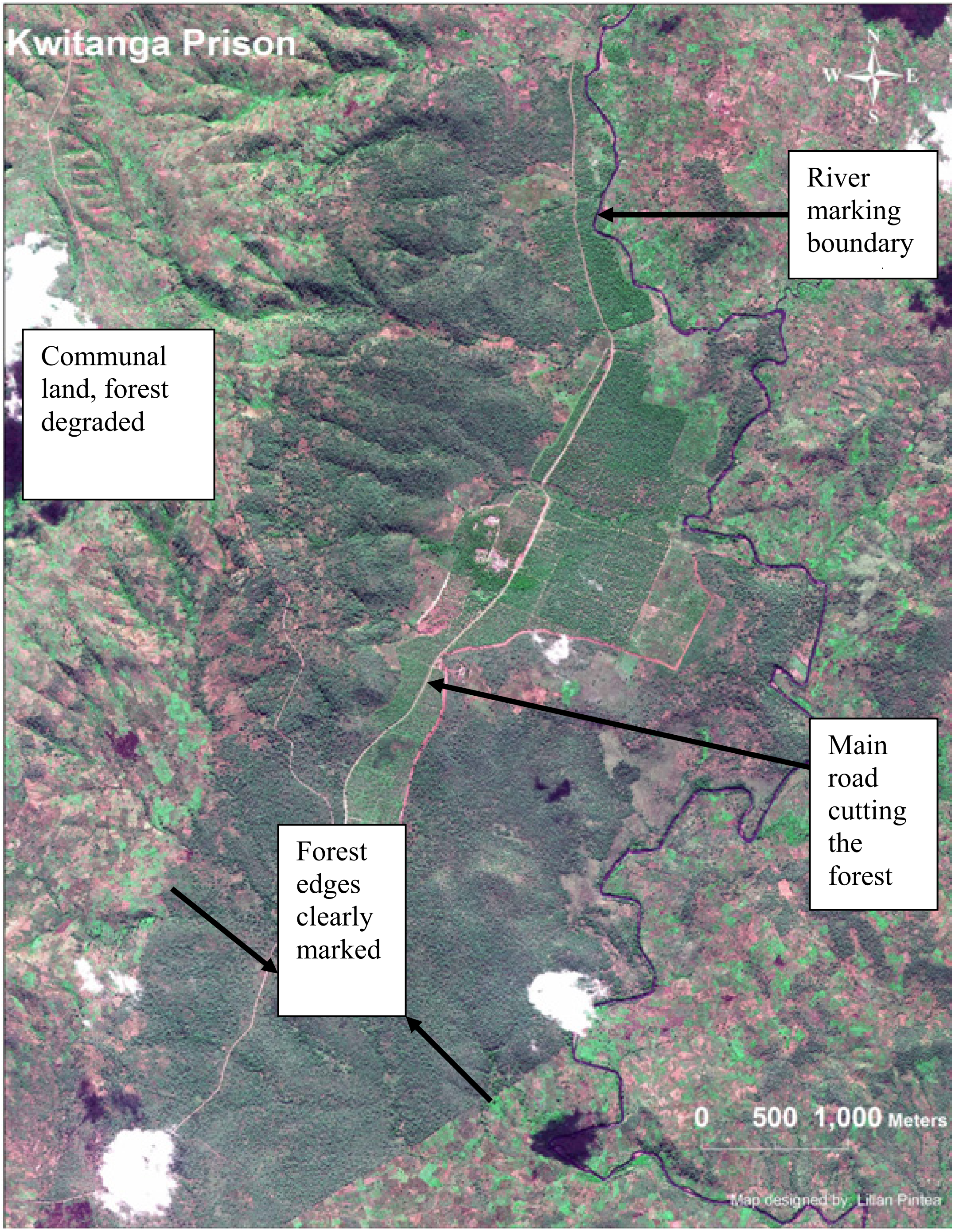

Figure 2 Satellite image of Kwitanga vegetation (Source: Lilian Pintea- the Jane Goodall Institute)

3.2 Methods

Data collection started on 25th of September to 8th of October in 2006, making it a total of two weeks.

3.2.1 General transects design

Transect location was informed by a Quickbird satellite image procured by the Jane Goodall Institute, Tanzania. Natural vegetation is clearly distinguishable from plantations and small-scale agriculture (Figure 2). In order to ensure complete coverage and capturing of fine habitat across varying terrain for the entire forest, transects were set at regular intervals of 500 m, perpendicular to the main north-south access road through the forest.

Thirteen transects were placed within the entire forest, with varying lengths. Transect length was measured by a hip chain which is accurate for variable terrain; GPS locations at the start and end of each transect were also taken (Plumptre & Reynolds, 1997; Moyer et al., 2006). A hip chain was used to determine where to set a vegetation plot along the line at every 100 meters (Moyer et al, 2006). Walking direction was maintained by compass bearing (Hall et al., 1998; Moyer et al., 2006). Alternated sampling direction on each side of the forest between successive days, to achieve random nest encounters in the forest.

3.2.2 Nest sampling theory

Censusing of chimpanzee populations by standard line transect for chimpanzee nests has become commonly used because unhabituated chimpanzees are rarely sighted. They also occur in low densities and have ability to remain silent when an observer passes by (Plumptre & Reynolds, 1997; Plumptre, Cox & Mugume, 2002). Estimates of their numbers depend on nests built every night, once they are weaned (Plumptre & Reynolds, 1997; Plumptre, Cox & Mugume, 2002) Derivation of the mean chimpanzee density uses correction factors for nest production and nest decay rates in a given area (Plumptre & Reynolds, 1997; Ihobe, 2005). It is estimated that a chimpanzee builds 1.09 nests each day (Plumptre and Reynolds, 1997).The overall nest density needs to be divided by 1.09 multiplied by nest decay rate in a given area (Plumptre & Reynolds, 1996; 1997; Ihobe, 2005).

To ensure accuracy in estimates, age-classes of nests enabled researchers to estimate nest decay rates in different areas (Plumptre & Reynolds, 1997; Ihobe, 2005). For example, in Mahale Mountains National Park nest decay rate was 131 days (Ihobe, 2005). Moyer et al., (2006) reported a nest decay rate of 36 days in Gombe National Park, located on lake shore and 97 days for Ugalla forest located inland, and Plumptre & Reynolds (1996) estimated nest decay rate of 45 days in Budongo and 144 days in Kibale forests both located in Uganda.

Density estimates based on nests, report on the number of individuals that do make nests and unweaned juveniles are not included in the estimates (Plumptre, Cox & Mugume, 2002). This method makes use of various assumptions as follows,

- Chimpanzees build individual nests at the age of four years and after weaning (Plumptre, Cox & Mugume, 2002; Matthews & Matthews, 2004).
- Nest density conversion to obtain an estimate of chimpanzee density requires correction factors for nests production rate and nests decay rate (Plumptre & Reynolds, 1997; Plumptre, Cox & Mugume, 2002; Moyer et al., 2006).
- Transects are randomly distributed in relation to nests (Plumptre & Reynolds, 1997).

3.2.3 Nest sampling

On each transect, the GPS (Global Positioning System) location of all nest sightings were recorded. When a nest was sighted from a transect line, the following were recorded:

1. Perpendicular distance between the center of nest and the transect using a tape measure, or alternatively, a range finder where the distance was greater than 30 meters (Marchesi et al., 1995; Plumptre & Reynolds, 1997; Plumptre, Cox & Mugume, 2002)
2. Aging of nests (Plumptre & Reynolds, 1997; Ihobe, 2005)

Aging of nests based on the amount of twigs and leaves present in a nest. The nest classes used for classification were,

1 = New: Leaves in cup of nest all green and cup solid

2 = Medium: Leaves going brown (possibly some green) but nest cup mostly intact

3 = Old: Nest cup disintegrating – most leaves lost and can mainly see gaps between leaves in cup

4 = Decayed: No leaves left (less than 5%) – twigs left only (Marchesi et al., 1995; Plumptre & Reynolds, 1997; Ihobe, 2005; Moyer et al., 2006).

Where nests of different age classes occurred within the same site, each of these nests were scored as separate nest site (Hall et al., 1998; Moyer et al., 2006) and measured separately (Plumptre & Reynolds, 1997; Moyer et al., 2006).

3.2.4 Chimpanzee nest density estimate

Chimpanzee nest density, calculations used standard perpendicular distance techniques based on the computer software DISTANCE 4.1 (Thomas et al., 2004). Analysis started with visual inspection of nest sites perpendicular distances histograms, outside the software DISTANCE 4.1. This aimed to investigate evidence for heaping: existence of observations far from transects (Buckland et al., 1993; Thomas et al., 2004). Data truncation did not occur because all nests in age group 4 were removed from the analysis, making few nests available for the program that require at least 30-40 observations (Buckland et al., 1993; Thomas et al., 2004). Elimination of such points reduces skewness in the results of a detection probability model fitting, which is based on the theory that as distance increases from a transect line; the probability of sighting an object decreases (Buckland et al., 1993). Investigating evidence for heaping requires re-assessing different maximum distances that fit well with nest sighting perpendicular distance data (Buckland et al., 1993; Thomas et al., 2004). After data examination on the evidence for heaping or truncation, the following procedure occurred inside DISTANCE 4.1.

I created an analysis set for each model from the original data set, as a new analysis. This allowed data filtering inside DISTANCE 4.1. Data filtering manipulates the data before reaching the analysis (Thomas et al., 2004). At this stage, setting of the filter to utilize all the data by checking the box referring to grouping data into equal interval was essential. This allowed the use of all the data on nest sighting distances based on the default recommended by the software author (Thomas et al., 2004). The next stage in the analysis was “Model selection”. At this stage, the following sub stages occurred: type of the estimates, survey without stratification because no strata existed in this survey, and selection of the detection function (choosing the model to use and its series expansion). This utilizes only the models available in the software to estimate the density of nests. The variance required settings to estimate variance empirically among other options as the distribution cannot be predicted. The Bootstrapping stage utilized a non-parametric type and resampling at 999. During model selection stage, a single model was set to each data set to examine individual estimates that allowed automated model selection, in a sequential manner using Akaike Information Criterion (AIC). After which the model was set to run and results summarized.

Five models available in DISTANCE 4.1 software were fitted to nesting sites distances. Model fitting used automatic selection of model adjustment terms with sequential selection method, available in DISTANCE 4.1 to estimate nest density (Thomas et al., 2004). These models were Half-normal +cosine, Half-normal + polynomial, Hazardrate + cosine, Hazardrate + hermite and Uniform + cosine, finally their results summarized to examine best model selection.

Selection of the best model that fitted well to the data used the lowest value of "Akaike Information Criterion"-AIC (Buckland et al., 1993; Thomas et al., 2004).

The estimates of mean chimpanzee density used results of a selected model. The different nest density estimates of the models fitted to the data are presented in (Table 2). Chimpanzee density estimates based on the nest density estimates of a selected model used both nest decay rates of 36 and 97 days.

Derivation of weaned chimpanzee densities used mean nest density estimates determined by the best DISTANCE model(s), with the lower and confidence limits.

In this study, no site-specific nest decay rate was available because of logistical constraints. The use of values for nest decay rates and nest production rate from other study sites was necessary. The values were; nest decay rates of 36 days determined in Gombe National Park (Moyer et al., 2006) and 1.09 value of nest production rate per day per individual chimpanzee in the analysis. Studies on density estimates have also used values from other sites to estimate chimpanzee population (examples; Furuichi et al., 1997; Feury-Brugiere & Brugiere, 2002; Sunderland-Groves et al., 2003). Gombe National Park is located about 15 km from Kwitanga forest (Moyer et al., 2006), and is wetter than Kwitanga. This means that Kwitanga forest, may have a shorter decay rate than Gombe National Park because the forest is dominated by miombo woodlands, poorly developed riverine forests and is drier. Ugalla forest is drier though it contains more riverine forests and rivers than Kwitanga and is located inland and further away. Furthermore, the distance between Kwitanga forest and Gombe National Park is shorter (about 15 km) to justify large climatic differences. This is what necessitates more discussions to base the nest densities on decay rates from Gomber

The estimates of chimpanzee population density used mean nest density and the Lower and Upper Confidence limits (UCL) at 95% significance level (see in Results; Table 2). The derivation of minimum, mean and maximum population density estimates used the formula:

Density of Chimpanzees = Density of Nests/ (Nest production rate x mean time for a nest to decay) (Source: Plumptre & Reynolds, 1996; Moyer et al., 2006).

Population size estimate of weaned chimpanzees was calculated by multiplying, density of chimpanzee and total habitat size of 21.8 km^2 (converted from 2182 ha).

3.2.5 Vegetation sampling

Along transects for chimpanzee nest sampling, vegetation was sampled every 100 m using the Point Centre Quarter (PCQ) method for trees. At each sampling point, identified four quarters and the following recorded in each: sampling point number, distance to nearest tree, species name of the tree, and the circumference at chest height (CCH) using a flexible tape measure. Only trees with circumferences greater/or equal to 33 cm (> 10 cm diameter at breast height) were recorded. Tree stumps' circumferences at base were measured regardless of this diameter limitation. Where two trunks originated from the same base, each formed independent measurement and the average of these trunks formed the total trunk size. Measurement of the Vegetation canopy cover used a Foot Candle luxmeter.

Each nest sighting point formed an independent vegetation sampling point. The nest-hosting tree formed a center for the PCQ sampling. The nest-hosting tree was identified to species and its CCH measured. The four quarters were also identified and the same parameters as on transects were recorded.

Therefore, vegetation measurements (study) occurred in three different forms, along transects for chimpanzee nests, at nesting sites (based on sighting of a nest which included a nest hosting tree) and at stump sightings (this utilized the stump closer to the transect line and the nearest neighbors in the four quarters).

A subjective habitat description at vegetation sampling point along transects and at nesting sites was performed. This description was based on forest structure rather than species composition. This form of description allows comparison of habitats and shows the extent to which man in areas where human activities are recorded has modified a forest (Marchesi et al., 1995; Plumptre, Cox & Mugume, 2002). The following forest types were used to classify the forest:

1. Closed Tropical High Forest (>50% canopy closure, trees taller than 15m),
2. Open Tropical High Forest (<50% canopy closure, trees taller than 15m),
3. Closed young/secondary forest (>50% canopy closure, trees shorter than 15m),
4. Open young/secondary forest (<50% canopy closure, trees shorter than15m),
5. Woodland (Trees widely spread and with grass below them),
6. Grassland (greater than 20m radius area of grassland with no trees),
7. Swamp/waterlogged,
8. Bamboo and cultivated land

(Source: Plumptre & Reynolds, 1997; Plumptre, Cox & Mugume, 2002; Moyer et al., 2006).

Analysis of the vegetation data was performed (plant communities on vegetation transect and at nesting sites were described in the same way), as follows;

I. Tree species composition used relative proportions of species at nesting sites and vegetation sampling points. Tree stumps species composition used similar criteria.
II. Size classes of standing trees and stumps were obtained by dividing the circumference at breast height (CCH) and circumference at base (CAB) by π = 3.14 respectively for

comparison among groups and other studies. The derivation of population structures of tree species for both categories depended on these data.

III. Total basal area calculations for each standing tree species and stumps based on the circumference. The formula used to obtain the area (A) was; $A = C^2 /4\pi$ where C refers to CAB and CCH (see subsection II above). The calculations assumed that stumps are round at the cross-sections.

IV. Calculated relative values for density, dominance and frequency as percent proportions of individuals of a species under specific category respectively.

V. Absolute density of a species was calculated as a hectare (10000 m^2) per square of mean distance (D) of a species from a center of sampling point (i.e.; area/D^2), to obtain individuals per hectare.

VI. Preference ratios of nest hosting tree species used specific nest hosting tree density divided by the total tree density in the landscape, to examine the preference for nesting.

VII. Computation of the absolute dominance for each tree species, as a product of mean basal area per tree species, and number of trees (Mueller-Dombois & Ellenberg, 1974). There is more detail to the above descriptions is found in (Mueller-Dombois & Ellenberg, 1974).

VIII. Description of the density of tree felling in the habitat used stump data.

IX. Mean stopping distance from stump sampling points informed how far an individual stump is located from the sampling center, to examine the influence such distance on density estimates.

The above derivations generated an understanding of how much of a given species dominate the forest, and what the links were to trees utilized by chimpanzees for nesting. The following statistical tests were performed prior to which data were checked for the distribution before the choice of the statistical test, using summary statistic method available in SAS version 3.0 (i.e.; assisted in checking for skewness in the data that limits the choice between parametric and non-parametric tests, using SAS 3.0 and 9.1).

- Comparison of the overall tree densities at nesting sites and transects, as well as the abundance of nesting trees in the landscape using specific tree species densities per hectare used Wilcoxon test

- Analysis of the relative abundance of nesting trees in the landscape using species-specific proportions at nesting sites and transects used Kolmogorov-Smirnov test
- Analysis of the difference in tree species composition (by proportion), at both nesting sites and transects to examine species selection employed Kolmogorov-Smirnov test
- ANOVA with a post hoc Tukey's HSD test was used to examine whether tree size classes from transects at nesting sites and nesting trees were similar.

3.2.6 Assessment of human impacts

On the same transects for chimpanzee nest sampling, signs of previous or current human activities were recorded. These were stumps, fields (cultivated lands), pitsaw sites, footpaths, cattle, people, kilns (charcoal producing sites) and temporary camps for poachers or timber harvesters. At every sighting, the following were recorded: the number of each category and perpendicular distances to the center of transect (Plumptre, Cox & Mugume, 2002; Moyer et al., 2006). At each sighting of a tree stump or stumps, a nearest stump to a transect line formed a center for establishment of the PCQ for assessment of neighboring stumps. In each quarter, the nearest stump to the stump at the centre of the PCQ was sampled, and the following parameters were recorded; sampling point, distance of nearest stump, species and circumference at base-(CAB) of each stump (measured on the top of stump).

The analysis of human pressure was based on the following aspects:

- Derivation of Encounter rates per kilometer of signs of human utilization (listed above)s used: total number of counts of all signs and each category divided by total transects length for comparison. This analysis assumes all signs of human use are equal.
- Analysis of harvested tree stump species used all encountered stumps (i.e.; PCQ centers and the neighboring stumps from quarters).
- Analysis of harvested wood density based on complete sets only (i.e.; where all four quarters had tree stumps), because at some sampling points, quarters did not have individuals as a requirement for PCQ (Mueller-Dombois & Ellenberg, 1974). The analysis to investigate the relationships between distance from main road and the number of stumps encountered on transects to study direction of impact employed linear regression test. The numbers of stumps were log-transformed to improve best fit.

4.0 RESULTS

The total transect distance was 16.8 km, with the lengths of each of the thirteen individual transect varying between 0.7 km to 2.0 km (Figure 2).

106 nests were encountered during the study. These nests were in small groups at different stages of decomposition. Larger proportions of nests were in stage (4) followed by stage (3), these stages refer to very old nests that were about to disintegrate (see Appendix 1; Table 1). The largest nest group had 18 nests and the average nest group size was (4) nests, with two nests most commonly encountered (see Appendix 1; Table 1). Most nests encountered were more to the forest periphery than in the central part of the Kwitanga foret (Figure 3).

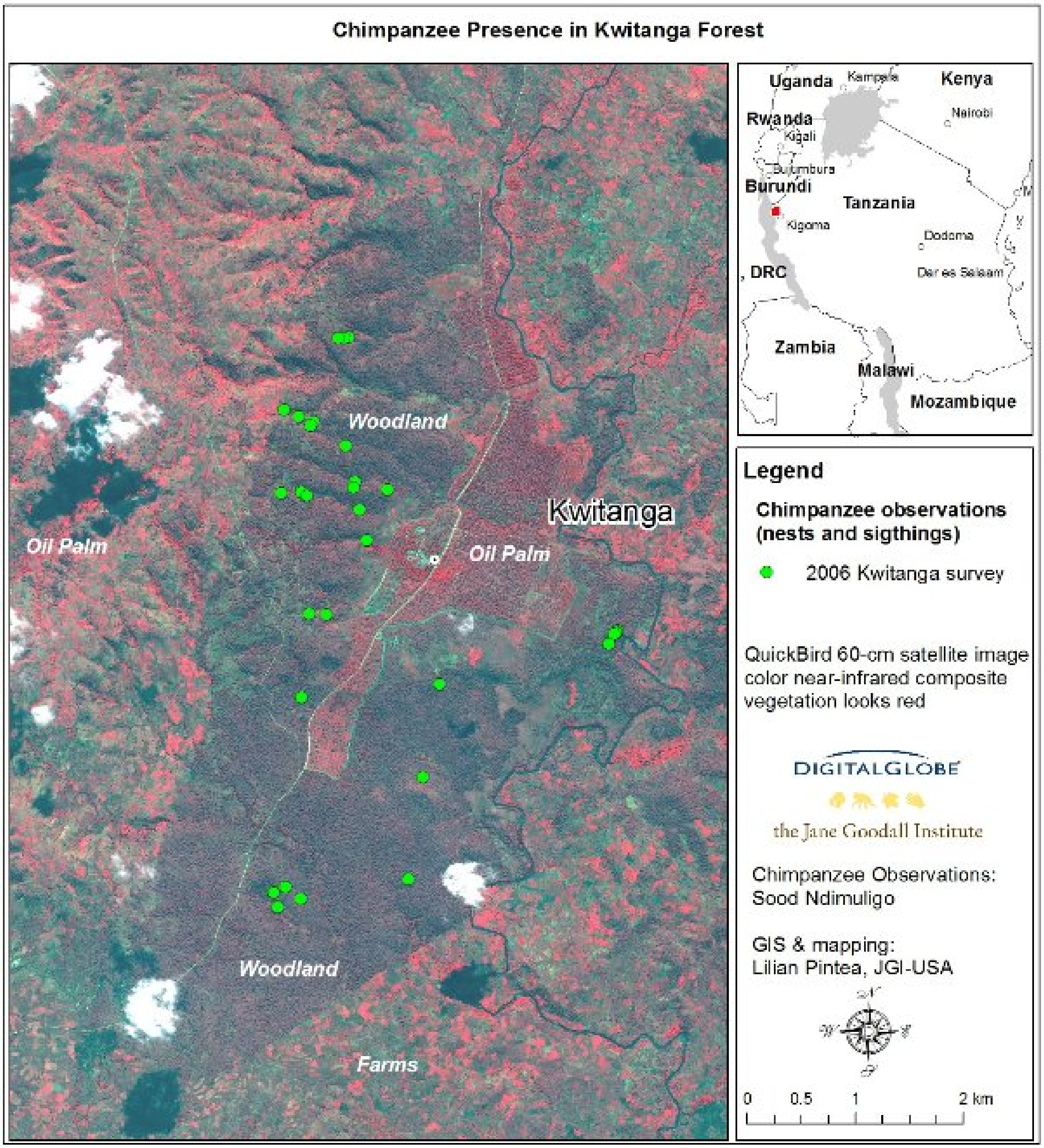

Figure 3 Chimpanzee nest distribution in relation to forest edge

4.1 Nest density, chimpanzee density and population estimates

The Halfnormal Cosine model fitted well to the data. The selection of best model based on the smallest AIC value(s). The values of the Akaike Information Criteria (AIC) of the various models summarized in (Table 2: appendix 1) were not very different from each other. Nest density estimates formed the basis to derive chimpanzee density and population size from the best-selected model (Table 2: appendix 1).

The estimated mean nest density was 27.116 (with 95% lower and upper confidence Intervals (CI): 12.195; 60.293). The estimated mean chimpanzee population densities (at 95% Confidence levels) was; 0.69 km^{-2} (lower CI: 0.31 and upper CI: 1.54 km^{-2}). The estimated chimpanzee population size in Kwitanga forest ranges from a mean of 15 individuals (lower limit of 7 and upper limit of 34 individuals).

4.2 Vegetation structure and composition

158 vegetation sampling points were sampled along transects, located at every 100 m, followed by a subjective "habitat type" description at each 100 m. Woodland forest type occurred in 120 sampling points (76 %) and Open young forest type in 38 sampling points (24 %) respectively (see method; section 3.4). Nesting sites occurred exclusively in woodland (89 nest sampling points) (see criteria in method; 3.4).

Tree canopy cover was similar along transects and nesting sites as measured by Foot Candle Lux Meter. The vegetation sampling points and nesting sites were not different in amount of light through tree canopy. Therefore, since vegetation canopy cover as measured by Candle luxmeter did not vary across the study site it was not used in subsequent analyses.

4.2.1 Composition

61 tree species were encountered, of which 12 we were unable to identify. The most common species (by decreasing proportion) were *Brachystegia bussei*, *Julbernadia globiflora*, *Brachystegia utilis*, *Uapaca kirkiana*, *Pterocarpus angolensis*, *Diprorhynchus condilocarpon* and *Combretum collinum.* In contrast to transects, 46 tree species were encountered at nesting sites, of which 9 were not identified. The dominant tree species were *B.bussei*, *B.utilis* and *B. microphylla*. *Julbernadia globiflora* was less frequent at nesting sites (see Appendix 1: Table 3). In total, 74 tree species were encountered during the study (see Appendix 1: Table 4).

Tree species composition on transects and nesting sites (by percent proportions) were significantly different (Kolmogorov-Smirnov test: KSa = 2.0148; D = 0.3934: $P < 0.05$).

4.2.2 Abundance of nesting trees in the landscape

Only 13 out of 74 total tree species supported nests during the study. Each tree species supported varying number of nests. These trees were; *B.bussei*, *B.utilis*, *B.mirophylla*, *Julbernadia globiflora* and *Pterocarpus tinctorius,* so were their density compared respectively (Table 5).

Known nesting tree species, were also encountered along transects, though had different mean tree densities along transects than at nesting sites: 16.6 ± 5.5 trees per ha and 31.5 ± 10.1 tree per ha respectively. However, there were no significant differences in their overall density (Table 5) (Wilcoxon Z-test: Z = - 1.0265; $U_1 = U_2 = 13$; $p > 0.05$) and respective species proportions (Kolmogorov-Smirnov test: KSa = 0.5883; D = 0.2308; $P > 0.05$) in (Figure 4).

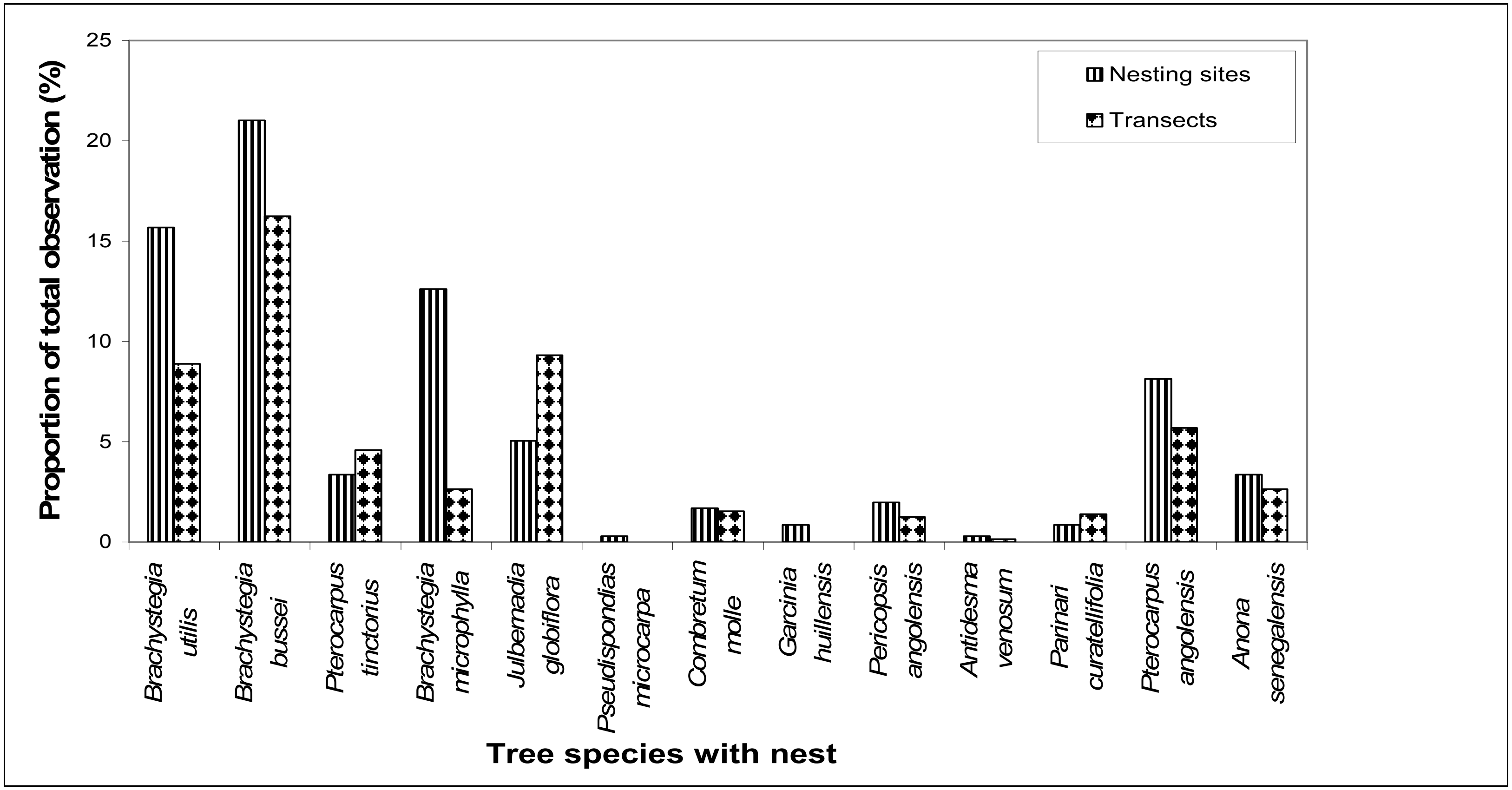

Figure 4 Comparing nest hosting tree species occurrence in the landscape, showing occurrence of same species on transects and at nesting sites

The preference ratios of nest hosting tree species revealed that *Brachystegia bussei, Julbernadia globiflora and Brachystegia utilis* were highly selected for nesting in the landscape (Figure 5).

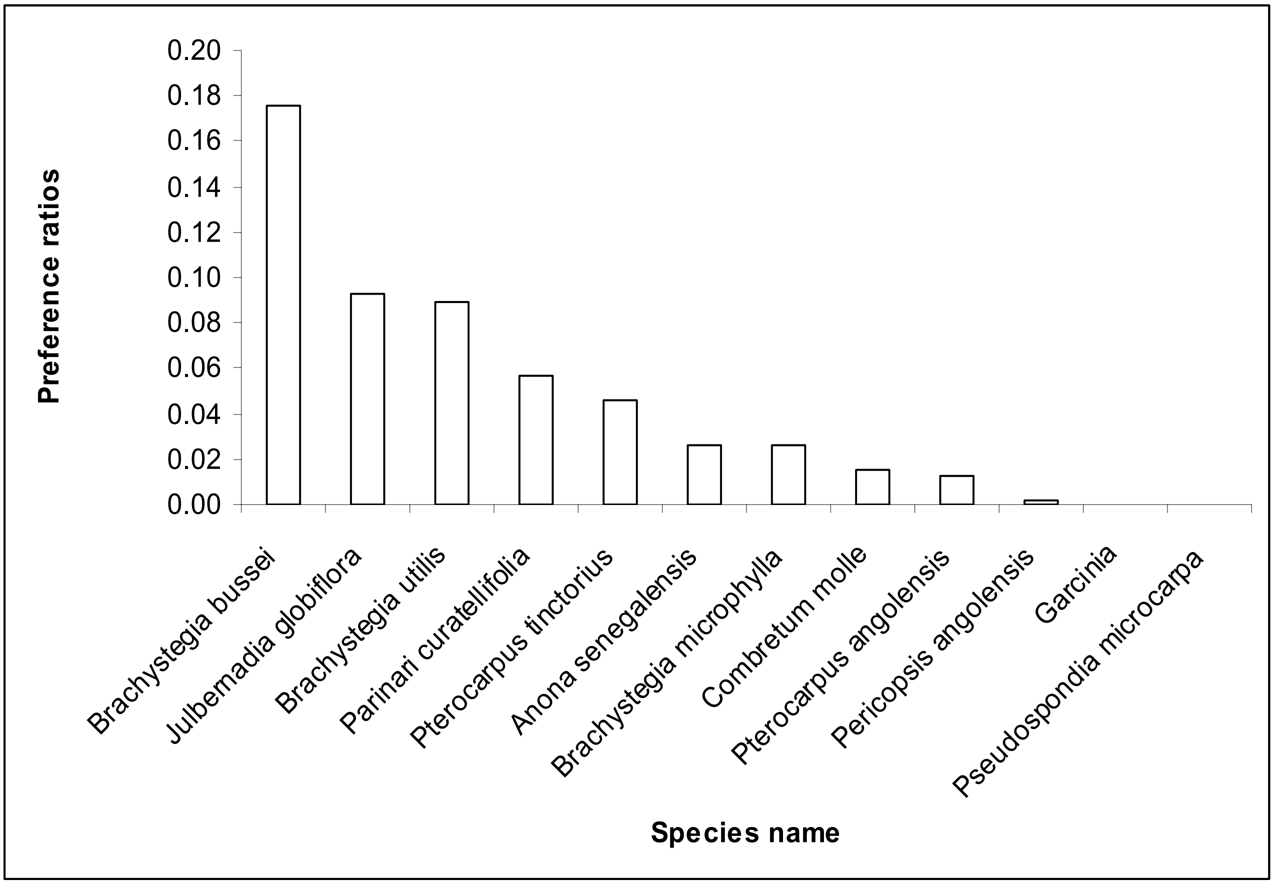

Figure 5 Preference ratios of nest hosting tree species in the landscape

4.2.3 Structure

The overall tree diameter (after conversion from circumference) size in the forest was dominated by smaller individuals. 94.13 % of sampled tree individuals ranged from 10 to 40 cm, of which 69.51 % occurred between 10 and 20 cm (Figure 6). At nesting sites 94.1 % of tree species ranged from 10 to 40 cm of diameter, which was similar to trees used for nesting in which 93.94% were in between 10-40 cm of diameter with 48.88% falling in arrange from 10-20 cm (Figure 6). In general, the highest percentages were in a size class between 10 and 20 cm in all categories, and 50 cm diameter was the upper limit.

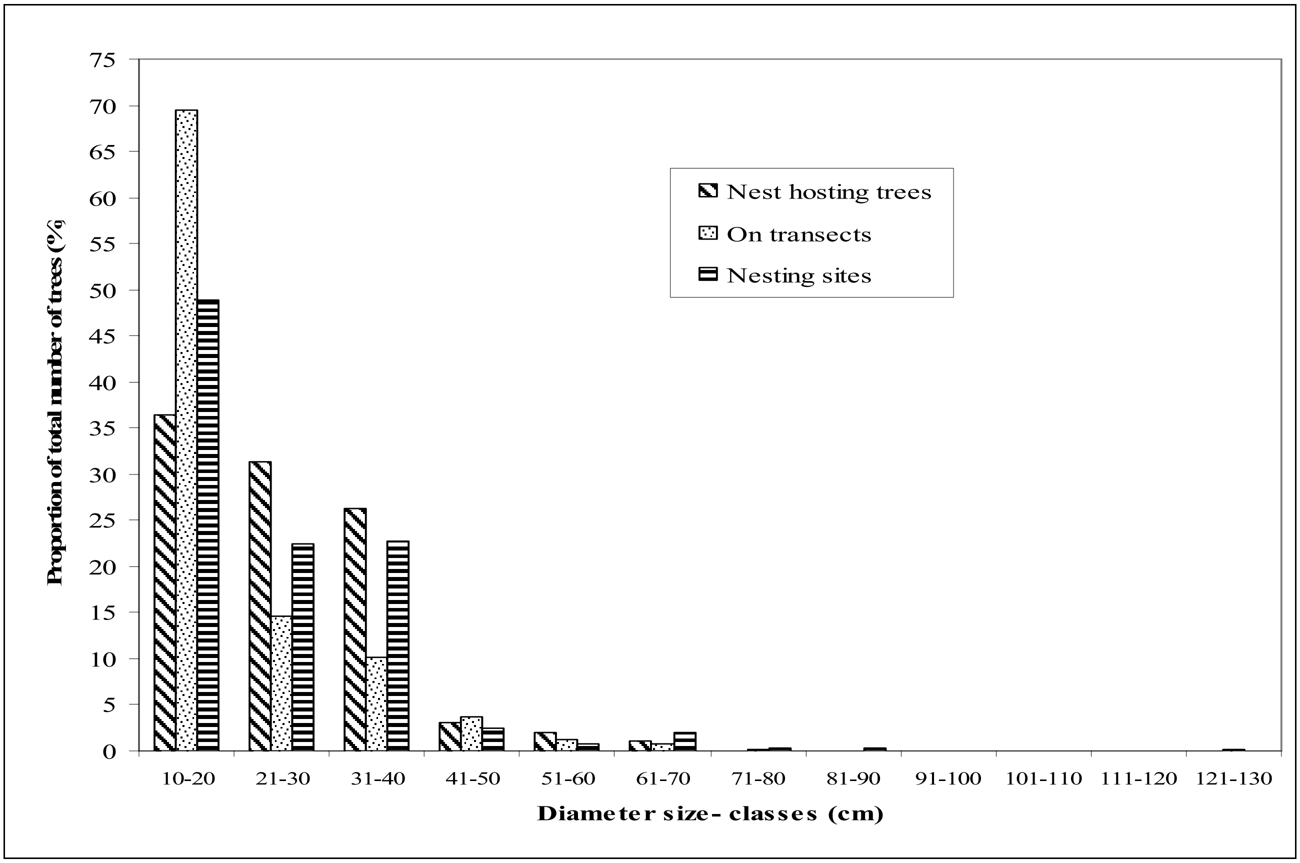

Figure 6 Comparison of tree size classes on transects, nesting sites and nest hosting trees (cm)

The mean diameter size classes of trees along transects was 18 ± 0.5 cm, while at nesting sites was 23 ± 0.7 cm and nest hosting trees, had a mean diameter of 27 ± 1.1 cm (Table 6).

Diameter size classes of trees were significantly different between the pairs, using ANOVA with a post hoc Tukey's test summarized in (Table 7). None of the pairs indicated similarity in size.

Along transects, the overall total tree density was 387.61 trees per ha, that ranged from 0.54 to 62.99 trees per ha (see Appendix 1: Table 8).
The most common tree species were *Brachystegia* species (by total) and *Julbernadia globiflora,* followed by *Uapaca kirkiana, Diprorhyncus condilocarpon* and *Combretum collinum*. The mean basal area of tree species ranged from 0.14 to 20.38 m^2. (see Appendix 1: Table 8).
Relative density of the different tree species ranged from 0.13% to 15.56 % and relative dominance ranged from 0.03 to 21.03 %. Absolute dominance of various tree species varied between 0.08 to 49.59 m^2 per ha (see Appendix 1: Table 8).

At nesting sites, the overall total tree density was 544.89 tree per ha, in a range from 1.53 to 114.47 tree per ha. The mean basal area of tree species varied from 0.15 to 4.05 m^2 (see Appendix 1: Table 8).

Relative densities (as %) varied from 0.28 to 21.07, while relative dominance varied from 0.05 to 31.53%, and species absolute dominance ranged from 0.23 to 10.31 m^2 per ha (see Appendix1: Table 9).

Nesting sites had larger mean tree densities than on transects (Table 10). Overall tree density on transects and nesting sites were significantly different (Wilcoxon-Mann Whitney test: $Z = 1.8104$; $U_1 = 46$, $U_2 = 61$: $P < 0.05$).

4.3 Threats to chimpanzee habitat

Evidence of human activities in the forest was recorded during the study. Tree stumps encounters were more often in the forest than other forms followed by fields and pitsaw sites (Figure 7).

In total, the encounter rate of human signs were 14.71 per km. Tree stumps had the highest encounter rate, followed by fields, pitsaw sites and footpaths respectively (Figure 7).

Tree cutting was not linked with charcoal making, because kilns were less common than stumps, and not associated with stumps. Other forms of human signs categories were encountered less often (Figure 7).

Along transects, stumps were mostly encountered within 100m of the main road. In distances further than 100m from the main road, percent stump encounters declined. A linear relationship existed between the log transformed number of stumps (Y) and distance (X) from road ($P< 0.05$; $\log (Y) = 1.7017 - 0.0007(X)$; $R^2 = 0.6705$). The incidence of tree felling was a function of distance from the main road that cuts through the forest.

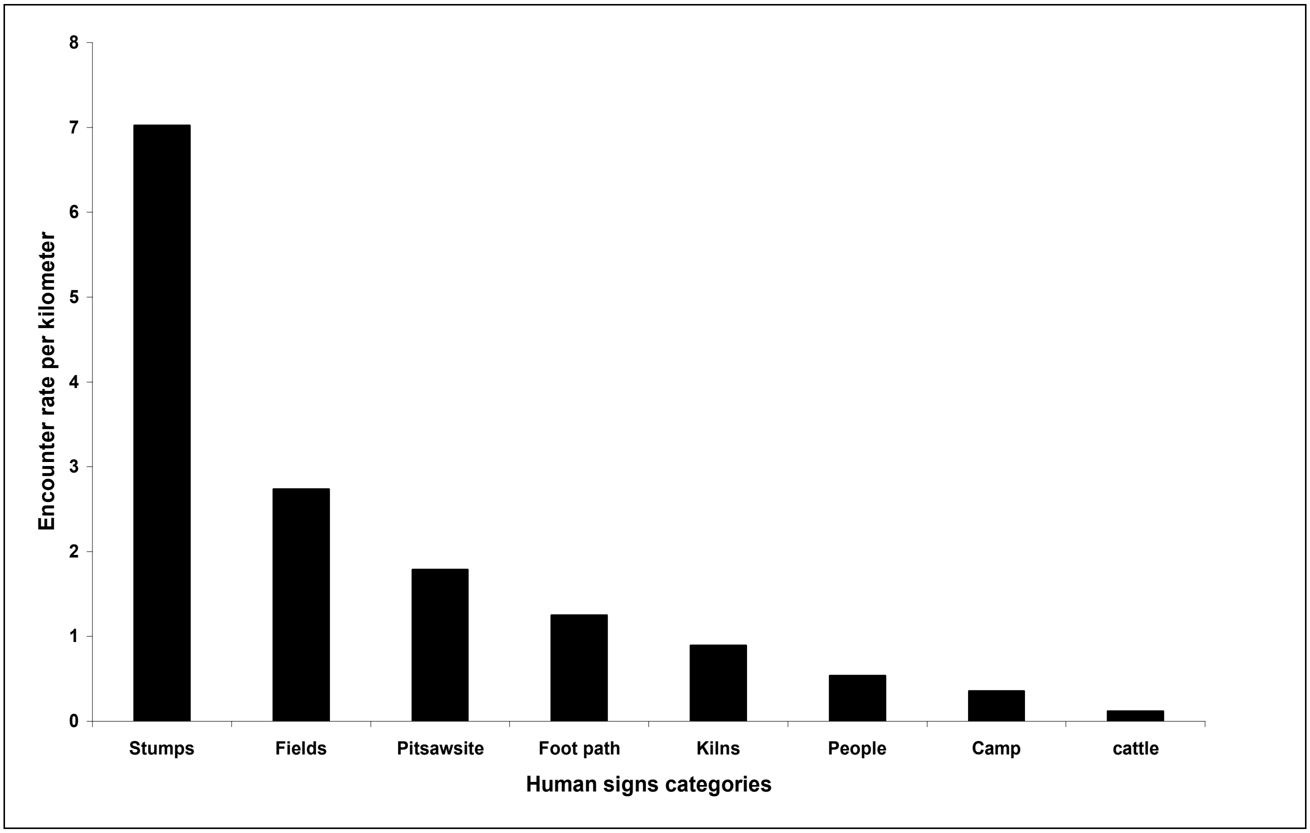

Figure 7 Comparison of human activities by encounter rates

4.3.2 Harvested wood species

315 stumps were recorded, this number includes the stumps that formed the centre reference point for the PCQ sample. There were 34 complete sampling points (where four neighbor stumps existed, one in each PCQ quarter) out of 117, which is 29.01% of total sampling points. Incomplete sets in some PCQs were related to absence of neighboring stump(s) such that stumps did not occur in all four quarters, old age, and understory shrubs that affected visibility from the transect line.

The mean stopping distance from the PCQ center to the neighboring stump(s) was 9 ± 0.7 m with a variance of 31 m. In this study, searching of stumps did not occur and the reported data refer to ones directly encountered than searching due to the limitation in the method (Mueller-Dombois & Ellenberg, 1974).

Stumps belonged to at least 30 species and were identified using bark and/or resprouting leaves. Eighteen stumps were not identified due to absence of signs of resprouting for identification (grouped as unidentified stumps). During the study, age estimation of stumps was not performed. *Julbernadia globiflora*, *Uapaca kirkiana, Pericopsis angolensis, Pterocarpus tinctorius and Pterocarpus angolensis* species had highest percent proportions of encounters respectively, with exception of unidentified group (Figure 8).

Density of stumps was calculated for the complete sets (number of sampling points equals 34). It is accepted that samples greater than twenty (20) are considered large (Mueller-Dombois & Ellenberg, 1974).

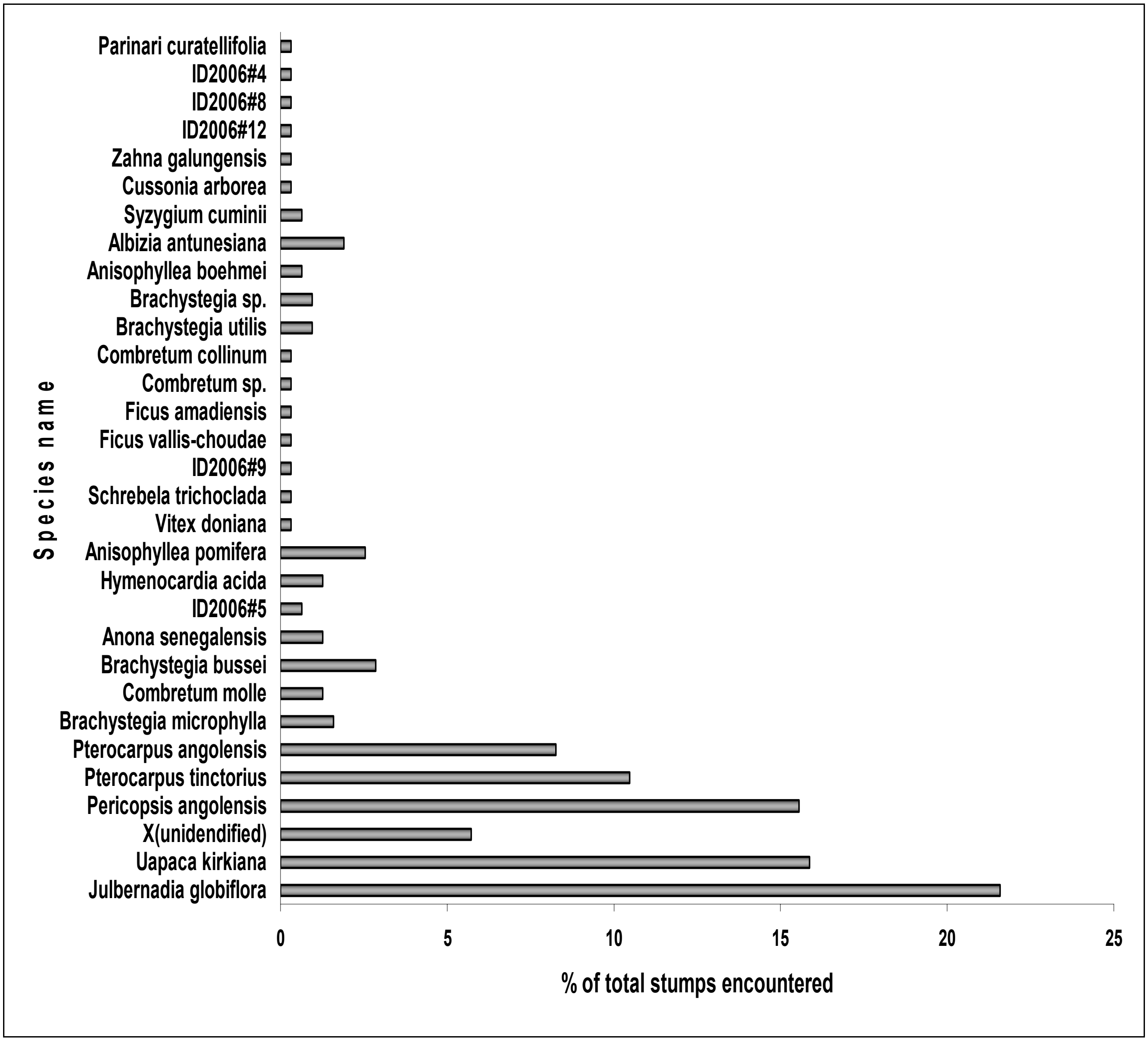

Figure 8 Percent proportion of total harvested tree stumps encountered

4.3.3 Harvested wood structure

Diameter size classes of stumps ranged from 10.5 to 98.7 cm for complete sets (n = 136), where n is the number of stumps in 34 times 4 quarters, and from 10.83 to 164.33 cm for individuals that formed PCQ centre points regardless of complete four quarters (n= 117). Mean diameter for complete sets was 26 ± 1.6 cm as opposed to 54 ± 3.4 cm for sampling centers.

The overall ranges of diameter size classes had more individuals in the 10-40 cm size class, above which individuals started to decline and gaps started to appear above 110 cm. Sampling centers had broader range of diameter than ones at complete sets (Figure 9).

The overall stump density was 123.48 tree per ha, that varied between 0.91 and 37.23 stumps per ha. *Julbernadia globiflora* and *Uapaca kirkiana* had the highest densities per ha, with exception of the unidentified stumps (see Appendix 1: Table 11).
The mean basal area at base ranged between 0.11 and 5.81 m^2. The relative density of different tree species (in %), ranged from 0.74 to 30.15. Relative dominance ranged from 0.08 to 41.11 %, with many falling into a range from 0.08 to 8.82%. The frequent stump species were; *Julbernadia globiflora*, *Pterocarpus tinctorius* and *Uapaca kirkiana* (see Appendix 1: Table 11).

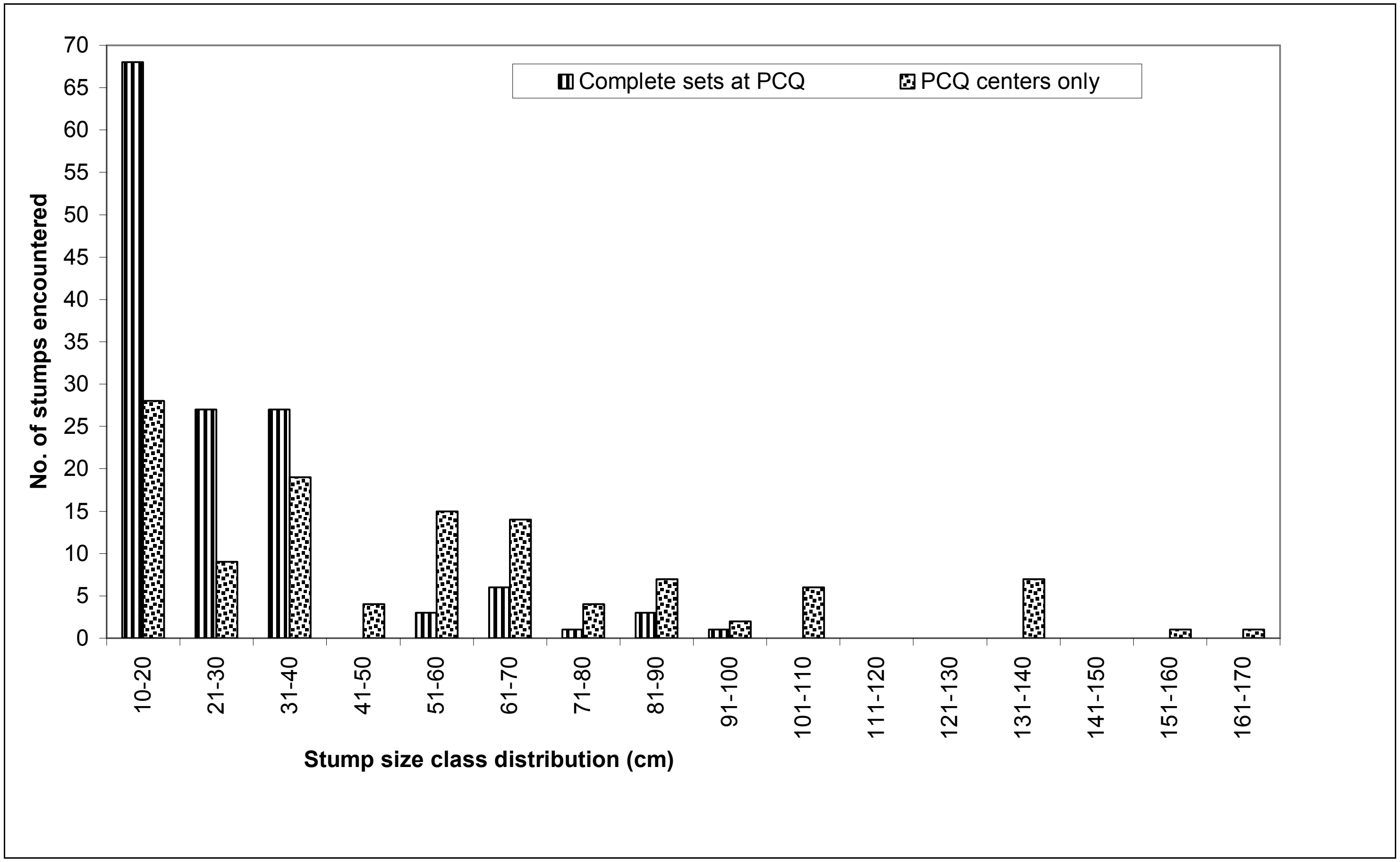

Figure 9 Comparison of tree stump size class distribution for complete sets and centers

5.0 DISCUSSION

5.1 Chimpanzee population density estimates

The results showed a mean chimpanzee population density of 0.69 (95% Confidence intervals of 0.31, 1.54) individuals per km^2. The estimated mean chimpanzee population size was 15 (lower limit 7 and upper limit 34) individuals in Kwitanga forest (Table 12). The results of the models fitted nest sighting distances to estimate chimpanzee nest density had very similar AIC values (Table 2) implying robustness of model selection and accuracy in estimates.

The reports by Grossman & Mnaya (2004) estimated presence of five individuals based on nest group size. In my study mean nest group size was 4 nests, and the largest nest group size had 18 nests (Appendix 1: Table 1). Further second hand information reports of four prison staff reported sighting of four individuals each before the start of this survey, and one person reported sighting of two adult individuals in June 2006. Grossman & Mnaya (2004) reported 12 chimpanzees, a number obtained from interviews with local people. Information available at the Jane Goodall Institute (JGI) - Tanzania, reported the presence of 15-20 chimpanzees in Kwitanga forest. The very recent second hand information at JGI-Tanzania reported 10 individuals based on the details from Chimpanzee tracker organized by the Roots and Shoots program around Kwitanga forest in 2006. The mean chimpanzee population estimates of this study (Table 12) fall in the ranges of all the second hand information reported, and increases confidence in my empirical results.

Kwitanga forest may not be the central habitat for the observed chimpanzees. Results of this study revealed most nests at the final decomposing stage four (see Appendix 1; Table1). This could imply that chimpanzees found in this area are the ones that only visit during a particular season based on certain food availability. The habitat probably provide food supply in certain times of the year, thus chimpanzees seasonally visit this fragment. Large numbers of nests encountered were close to the forest edges near communal lands, on either side of the forest (Figure 3). This could imply higher human disturbance from the forest center where prison activities (mostly natural resource extraction and agriculture) are intense. The intensity of human disturbance to the forest is high

(Figure 7). Furthermore, the study showed that the centre of the forest is more disturbed because tree felling was intense in the shorter distances from the main road that cuts through the forest. High densities of nests near the forest edge close to communal lands may mean that chimpanzees are avoiding the prison activities that were intense in shorter distances and with high encounter rates (Figure 7). This makes chimpanzees to utilize forest peripheral remaining areas for nesting and the adjacent transformed landscapes on communal lands. Thus, I speculate that the prison has massive impact on the forest especially closer to the road, leading to avoidance of such areas for nesting by chimpanzees.

Furthermore, chimpanzees probably range widely in the landscapes and happen to nest in Kwitanga forest edges upon re-visiting during certain times of the year following the presence of particular food supply. This allows chimpanzees to utilize both Kwitanga and the neighboring forest fragments on communal lands that may have some remaining forest pockets with potential food supply yet unknown. In support to this, there is evidence of chimpanzee nests in nearby Mkongoro about 7-8 km (see Figure 1 and 10) communal land (Ndimuligo, unpublished data; Pusey et al., in press) that may have been made by the wide-ranging chimpanzees in between Gombe National Park and Kwitanga forest. Massawe (1992) also reported nests on cultivated fields with sparse trees. Thus, chimpanzees probably utilize this forest by re-visiting fixed feeding points during certain periods of the year.

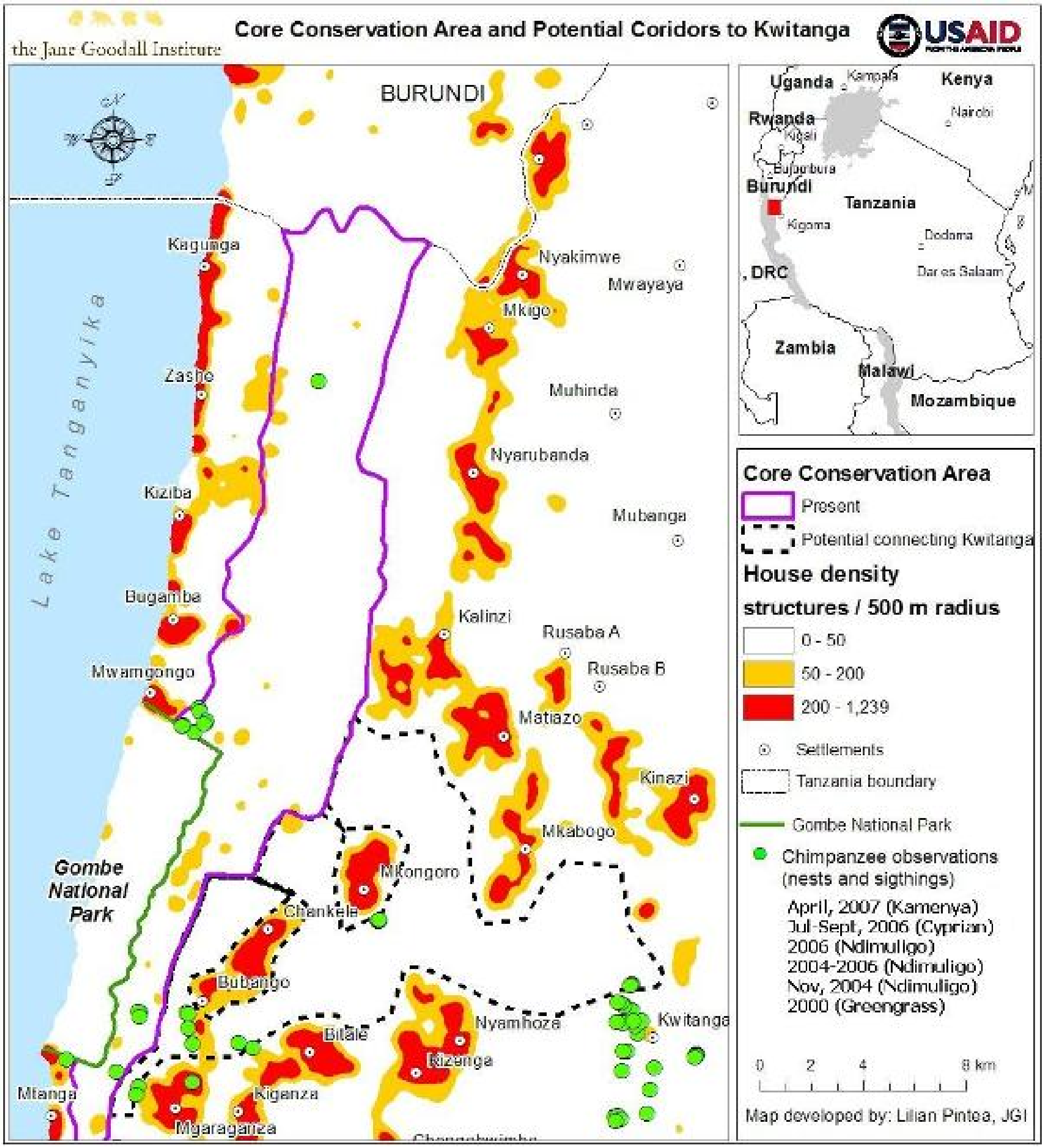

Figure 10 Chimpanzee distributions across the landscapes bordering Kwitanga forest

Seasonal abundance of *Brachystegia bussei* beans determined chimpanzee movements between Filabanga and Kasakati areas, adjacent to each other in western Tanzania between June and August (Suzuki, 1969; Kano, 1971a). Chimpanzees tend to re-visit patches seasonally in response to food cycles (Plumptre & Reynolds, 1994; Hashimoto, 1995). It is possible that cimpanzees in Kwitanga do utilize the adjacent forest pockets in human transformed landscapes.

The mean density of chimpanzee in Kwitanga forest was high compared to most of the other sites summarized in (Table 12) based on the nest decay rate determined in Gombe National Park.

Kwitanga forest harbors high chimpanzee density despite of its history of disturbance. This forest remained unprotected for a long period. The forest has experienced continuous pressure from humans since 1970s to the present, following the National Plan towards resettlement. These events led to its isolation from the larger Luiche Forest Reserve (Massawe, 1992) yet continue to support high chimpanzee density (Table 12).

Forest resource utilization through fuelwood and timber harvesting indicated by higher human activities encounter rates of stumps and pitsaw sites (Figure 7) revealed evidence for logging in this forest. However, the relatively high chimpanzee density estimate in Kiwtanga might relate to the presence of adjacent forest patches that allow movements on seasonal basis. Most nests were in small mean group size (Appendix 1: Table 1) and were encountered near the forest edge to communal land (Figure 3). The results indicated that the forest is highly disturbed (Figure 7) and the chimpanzee utilize mainly the peripheries of the forest.

Hashimoto (1995) and Plumptre & Reynolds (1994) reported similar findings of high chimpanzee density in a transformed habitat. They reported no decline in chimpanzee densities in Kalinzu and Budongo Forests, both in Uganda. They suggested that logging occurred in small compartments, allowing the existence of habitat mosaics that allowed chimpanzee to move betweenin response to food cycles and large forest sizes that unaffected by logging concessions. Their conclusions were based on the historical information of logging. In the previously logged habitat, tree regeneration and the unharvested tree species can still support high chimpanzee density. The evidence on human activities encounter rate in Kwitanga forest (Figure 7) high human impact on the forest. This habitat fragment remains as an island with the adjacent habitat highly transformed to shorter and sparsely distributed trees (Figure 2). This study reports the current state of human disturbance to chimpanzee habitat, which continues to date. The evidence on nest group sizes**,** more nests in the very old stages (Table 1) and large proportion of nests by the forest edge (Figure 3) apparently support the idea of chimpanzee movement between patches. Further evidences on the presence of nests near this patch in Mkongoro (Figure 1 and 10) on communal land about 7-8 km (Ndimuligo, unpublished data; Pusey et al., in press). This supports also the idea on chimpanzee movements across the landscapes especially in the miombo woodlands where chimpanzees require a large range size about 70-200 km^2 (Suzuki, 1969; Kano, 1971a; Baldwin et al., 1982; Pusey et al., in press). Such movements could have led to high chimpanzee density estimates in Kwitanga forest following presence of potential foods in certain times of the year unknown to date. This apparent statement provides a need for a detailed study of chimpanzee movements in these human dominated landscapes.

Many studies reported the negative effects of logging on chimpanzee densities. Examples from; Lekoumon, Zaire (Idani, 1994), Southwestern Congo (Ihobe, 1995), northeastern Congo (Kano & Asato, 1994), Ivory Coast (Marchesi et al., 1995), Petit Loango Reserve, Gabon (Furuichi et al, 1997), and Kibale National Park, Uganda (Chapman & Lambert, 2000), reported decline in chimpanzee densities as a result of logging and other human disturbances. In Kwitanga the scenario was different from these findings.

Chimpanzees are long-lived and any negative effect that recent habitat transformation might have on the population numbers will take a while to manifest, especially if nest densities can only provide estimates of weaned individuals. Furthermore, the brief infrequent surveys do not capture this lagged effect of logging on chimpanzee densities in an area (Plumptre & Reynolds, 1994).

However, the use of estimates of nest decay and nest production rates from other sites, may lead to errors in estimates (Hashimoto, 1995; Marchesi et al., 1995). This is due to the difference in ecological conditions between sites (Plumptre & Reynolds, 1996; 1997; Poulsen & Clark, 2004; Morgan et al., 2006). In this study, no attempt to determine such site-specific values was afforded due to logistic constraints. Therefore, the use of the values from other sites was unavoidable and errors of this type may provide erroneous estimates (Hashimoto, 1995).

In addition to this, the shape of nest decay curve follows an exponential pattern. In such pattern the duration of nests to qualify for the next age class, vary considerably. Nests of age class 1 and 2 take shorter time than 3 and 4. Such patterns in decay rates depend on ecological conditions in a particular habitat, species used for nesting, altitude, and exposure to sun (forest canopy cover). This limits the model to utilize different nests of varying age classes rather than age specific estimates. The estimates of chimpanzee density do not report this effect and all decisions use the overall estimates.

5.2 Vegetation structure and composition

The study aimed at describing the structure and composition of plant community in Kwitanga forest, revealed that, *Brachystegia-Julbernadia* species dominated the forest (Table 3). Kwitanga is miombo woodland forest (Chidumayo, 1987; Backéus et al., 2006; Banda et al., 2006; Luoga et al., 2000; 2002; Caro et al., 2005). This vegetation type falls into Zambezian savanna type (Chidumayo, 1987; Luoga et al., 2002).

5.2.1 Structure

This study showed that trees of small size classes dominated the entire Kwitanga forest. Most of the trees were in size classes ranging from 10-40 cm in all categories (Figure 6). Humans harvested similar tree sizes, with harvested trees presenting broader size range (Figure 9). The trend in size class distribution implied continuous disturbance or early clearing because of the rarity of individuals above 40 cm (Figure 6). The presence of gaps in size distribution in harvested trees (Figure 9) provides preliminary evidence for alternating harvesting periods and size selection. Such size structure distribution of standing trees may result from the alternating harvesting periods (Figure 6). Long and ongoing selective harvesting could have led to small individual size classes, leading to a sudden drop above 50 cm size classes (Figure 6).

The results of this study were similar to results from studies in East-central Tanzania, (Backéus et al., 2006) and Zimbabwe (Vermeulen, 1996), where tree size distribution for the study communities had many individuals in the size classes ranging from 10-40 cm dbh and reported few individuals above 50 and 40 cm respectively.

Backéus et al., (2006) in East-central Tanzania reported a similar drop of individuals in size classes above 50 cm. Furthermore, high dominance of small tree size classes, implied cutting of larger trees (Backéus et al., 2006), through selective logging which was the same for Kwitanga forest where larger stump size ranges and the size of sampling centers were observed (Figure 9). However, size class distribution dominated by juvenile class (from 10-50 cm) has been considered as healthy (Banda et al., 2006; Backéus et al., 2006). Therefore, if tree felling stops, there are chances for the forest to recover from such human pressure.

In contrast to Kwitanga forest, Game Controlled Areas and Katavi National Park contained more individuals of >50 cm dbh than open areas (where access is not strongly restricted) which had most individuals in the classes from 40-50 cm of dbh (Banda et al., 2006).

The mean diameter size classes of standing trees were 18 ± 0.5 cm for transects, 23 ± 0.7 cm at nesting sites and nesting trees had 27 ± 1.1 cm (Table 6). The overall density of trees at nesting sites was higher than on transects (Table 10). Density determines the amount of trees per unit ha in an area. The denser the trees the high the canopy cover and twigs that form nesting materials. This phenomenon indicates that chimpanzees selected nesting location in dense sites for nesting.

However, the vegetation structure measurements are biased due to the 10 cm dbh cutoff , used to concentrate on the trees of a size that chimpanzee can nest in. The use of another method may provide a different structure compared to this reported here, but will not be focused on identifying trees of suitable size for nesting.

5.2.2 Abundance of nesting tree species in the landscape

The results of this study (ie. which aimed at investigating trees utilized for nesting) shows that; nesting tree species in the landscape were abundant by proportions and density (see section 4.2.2) and 13 tree species supported nests (Table 5). The common tree species that supported nests were; *Brachystegia bussei, Brachystegia utilis, Brachystegia microphylla, Julbernadia globiflora* and *Pterocarpus tinctorius* (Table 5).

The overall species composition on transects and nesting sites were very different and nesting sites presented higher total species proportions (Table 3). While nesting tree species proportions and densities did not vary across the landscape, their diameter size classes were very different to the ones from transects and at nesting sites. Nesting trees had larger mean diameter size of 27 ± 1.1 cm (Table 6) and uniqueness in size from other sampled trees in the forest (Table 7). Thus, although similar species occur in the landscape, their sizes revealed selection of nesting trees in the forest. Size of a tree determines the ability to support an animal and nesting materials for nest construction. The sizes of harvested stumps had broader overlapping range (Figure 9) and the larger tree density at nesting sites (Table 10) support this argument for nesting sites selection. Higher tree density and large tree diameter size at nesting sites, revealed availability of suitable nesting trees and materials in a chosen nesting location.

The ongoing harvesting is likely to exacerbate the loss of nesting tree species following changes in ecological physical conditions. Such changes can complicate the availability of nesting and food tree species in the landscape resulting from increased edge effects (Davies et al., 2001). In addition, species diversification by harvesters as preferred species decline (Abbot & Lowore, 1999; Luoga et al., 2000) increases risks to the habitat in terms of size and quality. The results of this study showed that, there was an overlap between tree size classes prevalent in the forest (Figure 6) and ones harvested (Figure 9). The ongoing tree felling eliminates food tree species and large enough trees to support nests. The removal of trees affects both food abundance and nesting tree species. In addition to this, tree removal restricts the role of species-species ecological relationships, which has an impact on changing forest physical conditions. Changes in food abundance, nesting trees species and physical conditions could cause local extinction of chimpanzees in Kwitanga forest.

This study revealed that chimpanzees in Kwitanga selected nesting location based on tree size and density. The evidence provided by the overall variation in tree species proportions (Table 3), tree size classes (Table 6 and 7) and higher tree density (Table 10) at nesting sites, are conclusive for selection. Chimpanzees nested on bigger trees at nesting sites, indicating selection at a particular nesting location. Selection of nesting location and preference for a particular size could be a result of decline in nesting materials in the forest and/or disturbance. Therefore, chimpanzees tend to choose nesting location than considered random.

Among 13 tree species encountered supporting nests (Table 5); *Julbernadia globiflora* was not abundant at nesting sites. It constituted the highly preferred species list after *Brachystegia bussei* (Figure 3). This species was heavily harvested (Figure 8); its population might have declined, unlike the *Brachystegia* species that were not encountered more as stumps (Figure 8).

Similar nesting tree species have been reported in other study sites; examples include Nishida (1989) in Ugalla forest, Massawe (1992) in Kwitanga forest and Ogawa et al., (2004), in Wansisi and Makomayo forests, all located in western Tanzania, observed nests in deciduous forest tree species of *Brachystegia bussei* and *Julbernadia* species.

The findings of this study on tree diameter size were contrary to all reported sizes. Kano (1983), in Yalosidi, Congo DRC, reported a mean diameter of 15 cm, and Ogawa et al, (1997) in Lwazi River Area, southwestern Tanzania, reported a mean diameter dbh of 37.0 cm. Freury-Brugiere & Brugiere (2002) in Haut-Niger National Park reported a mean dbh of 31.0 cm. Finally, Basabose & Yamagiwa (2002) reported mean diameter for nesting trees as: secondary forest 35 cm and primary forest 24.9 cm in Tshabati, Kahuzi-Biega National Park. The reported values were larger compared to the ones in Kwitanga forest with the exception of primary forest that had smaller size. It is clear that chimpanzees use bigger trees in other forest. However, in the absence of data on the available tree sizes, it is not possible to conclude whether chimpanzees use the biggest trees available (if they are abundant enough not to incur searching costs) or whether they choose a specific size class.

The results of this study indicated that, choice of nesting location and preference of a certain tree for nesting as a function of size (Table 6), species proportions (Table 3) and density (Table 10). Thus, selection for nesting site location depends on a combination of species composition, size and density in a given site, though size seems to play a major role based on ability to support a nest on it. High species proportion and density determine tree canopy cover and availability of nesting materials. The results further indicated that though such observed nesting trees were abundant in the landscapes (Table 5) yet the overall species composition at nesting sites was higher to ones along transects (Table 3). Such selection for nesting site and preference for nest construction can reflect the scarcity of nesting trees and pressure to the habitat. The results showed that ongoing human activities threaten the abundance of nesting tree species in the landscapes. Among the 30 identified tree stumps with higher proportions (Figure 8), formed a leading list of the encountered nesting tree species (Table 5). This indicates that human activities in Kwitanga forests have a serious impact on habitat structure (size and quality) that pose a negative effect on chimpanzee population.

5.3 Threats to chimpanzee habitat

The major human disturbances observed in the forest were tree felling and plowing for fields (Figure 7). Tree felling had higher encounter rate followed by fields (Figure 7), with the exception of fire that occurred over the entire landscape. Low encounter rates of camps and kilns may apparently account for use-type of trees harvested in the forest, (Figure 7). Probably the harvesters come from shorter distances that make them not to build camps. Further possible reasons include; the Prison management protects the forest from other users over the boundaries to prevent forest destruction through timber production, or there is a scarcity of suitable tree species of reasonable sizes for timber harvesting in the forest. Some prisoners encountered during the study (represented as people in Figure 7), responded to my interview that they form a patrol team that report any destruction around the forest to the prison management.

Tree felling did not account for a higher number of kilns in the forest, implying that charcoal is not widely produced. I would thus speculate that charcoal is not widely produced in the forest, probably due to patrol teams formed by prisoners, encountered (Figure 7) as smoke is easy to detect and the Prison management can take actions. Such speculations form an apparent conclusion that tree felling is for fuelwood use and/or fencing.

Highest total encounter rate of human signs in the forest (14.71 per km), and the individual category's encounter rate (Figure 7) provide an index on the intensity of disturbance to the habitat. Different types of activities have varying influences to the forest, tree felling, and establishment of fields have a significant impact on the structure and composition of tree species.

The potential presence of stumps in fields and camps would have led to more encounters in some quarters. This would affect stump density estimates due to overcrowding in one particular place than others. Furthermore, the observed stopping distance in sampling had a mean of 9 ± 0.7 m and a variance of 31 m in relation to the sampling point. Such long distance is a source of tree density underestimation especially in clumped vegetation stand (Mueller-Dombois & Ellenberg, 1974). Thus results provide an abstraction of the stump density in the forest as an indication of human pressure to chimpanzee habitat.

Slash and burn agriculture noted as fields in (Figure 7) has a serious effect on the quality and size of the habitat. This type of farming involves clearing large areas and burning fires that spread over the landscape. The fields occur as extension of the existing oil palm plantation (Figure 2) and others are located on the forest age, depicting the very dynamic impact on the forest (Figure 1). The fields have short fallow period leading to multiple field development. This leads to subsequent establishment of early successional herbaceous vegetation, which are prone to frequent fires in the landscape in addition to land clearing. Such activities degrade the habitat through tree felling and fires in the area. This type of farming is likely to negatively affects chimpanzee density.

5.3.1 Wood harvesting

At least 30 tree species constituted stumps during this study, out of the 315 total sampled tree stumps (Figure 8). *Julbernadia globiflora* and *Uapaca kirkiana* were the most abundant stumps with high proportions (Figure 8). The use-type of a particular tree species, determines the species and size to be harvested (Vermeulen, 1996; Abbot & Lowore, 1999; Luoga et al., 2002). Suggested reasons for the choice are listed in (Appendix 1: Table 13).

The limitation on the likelihood of correctly identify a stump encountered is related to its state of decay. In the encounters where a stump did not have resprouting part and/or relatively dry bark identification was not afforded, leading to probably fewer species recognized.

The wood of *Julbernadia globiflora* species is known for its good long lasting flame, energy value and less smoke production (Abbot & Lowore, 1999) and easy to cut relative to other species of *Brachystegia-Julbernadia* complex making it more prone to harvesting (Abbot & Lowore, 1999; Luoga et al., 2000; 2004). *Uapaca kirkiana*, has high durability (Ngulube et al., 1995), and used for various purposes for example; building poles, and fuelwood (Ngulube et al., 1995; Abbot & Lowore, 1999; Luoga et al., 2000). Other tree species that constituted the stumps included: *Pericopsis angolensis, Pterocarpus tinctorius and Pterocarpus angolensis* (Figure 8). These tree species produce hard wood timber product used for furniture and house construction (Luoga et al., 2000; 2002; 2004; Caro et al., 2005).

Selective logging targets specific species (Vermeulen, 1996). Preferred tree species become prone to harvesting first until their populations decline (Vermeulen, 1996; Abbot & Lowore, 1999; Luoga et al., 2002), after which diversification is, sort an alternative (Abbot & Lowore, 1999; Luoga et al., 2000). Such choices based on community users' perception for a given species (Abbot & Homewood, 1999), cause a serious decline in habitat composition and structure due to reduced standing stocks of harvested species (Luoga et al., 2002; Caro et al., 2005). Following a decline in preferred species, diversification increases threat to previously advantaged species (Abbot & Homewood, 1999; Luoga et al., 2000; 2002).

Species preference (as indicated by high proportions of some species in Figure 6) has an impact on tree diameter distribution and structure of plant community (see Appendix 1; Table 8 and 9). The highly harvested species decline in the forest because of increased level of disturbances. Such a trend in decline of preferred species favors unutilized species (Luoga et al., 2002).

It was expected to encounter more stumps near the forest edges, under little or no sufficient forest protection. This could provide local adjacent communities unrestricted access to the forest for tree felling. However, during the study tree felling was more intense in shorter distances from the center of the forest, where Prison Camps are located. Thus, I speculate that though the prison provides protection to the forest, it exerts more pressure on the forest. The deviation from expected trend in number of stumps could be due to presence of some forests to which these communities still depend on for fuelwood and/or charcoal production.

In this study, it was evident that tree felling was a function of distance and accessibility. A similar trend was reported by Luoga et al., (2002), in eastern Tanzania where harvesting intensity declined as distance increased from village or forest boundary for both public lands and reserves. Similarly, Caro et al., (2005) reported a decline in tree cuts in Katavi National Park and its extension in southwestern Tanzania, located in remote areas from Mpanda and the villages on south of park. The reported findings were similar to those of Kwitanga forest, where distance was a main driver to tree felling from the prison.

5.3.2 Harvested wood structure

In this study, harvested trees were in small diameter size classes from 10-40 cm, with some individuals in a range above 40cm **(**Figure 9). The existence of a gap at 41-50 cm and higher percentage of individuals above 50-60 cm indicated the role of selective logging, and periodical tree harvesting (Figure 9).

The sizes of live stands and cut individuals were similar, though cut trees had a wider size distribution in the forest (Figure 6 and 9). This could have resulted from the ongoing selective logging. Vermeulen (1996) reported similar trend of felled trees where higher percent proportion of felled trees ranged between 10-40 cm and few individuals above 40 cm in Zimbabwe.

Human disturbances that remove bigger sized classes can produce a wide difference in size class distribution as seedlings/saplings struggle due to fires (Backéus et al., 2006). The indication of such distribution in the smaller size classes of stumps relates to over harvesting, which led to reduced bigger size classes.

Species preference might exist in the area and the species may become prone to harvesting. In this study, *Julbernadia globiflora* and *Uapaca kirkiana* had much higher densities (see Appendix 1: Table 11). Such observation can apparently account for species preference by the user community. Furthermore, larger mean diameter size of sampling centers reflected selective logging in the forest (54 ± 3.4 cm) to the surrounding neighbors in the quarters (26 ± 1.6 cm). Caro et al., (2005) reported a mean size of 30 cm dbh for cut trees in Forest Reserve, in western Tanzania that was contrary to this study and related small size of harvested tree sizes to heavy tree felling for timber in Rukwa region, Tanzania.

Continuous and/or selective logging has a significant influence on the structure of the forest (Backéus et al., 2006). Low values of mean basal area of the standing trees, can be related to logging and clearing of the forest (Backéus et al., 2006), that has longer been occurring in the forest.

5.4 Conclusion and recommendations

This study indicated that choice of nesting location and preference of a certain tree species for nesting as a function of the combination of species proportions (Table 3), size (Table 6) and density (Table 10). While such a combination influences the choice of nesting site, yet the size of a tree is more influential due to the ability to support the animal. Such selection for nesting site and preference for nest construction on particular tree size can reflect the scarcity of nesting trees and pressure to the habitat. The observed high human activities in the forest (Figure 7) threaten the abundance of nesting tree species in the landscapes. Identified tree stumps with higher proportions (Figure 8), constituted the first leading encountered nesting tree species (Table 5) and the highly preffered trees for nesting (Figure 5) formed first class for harvested species (Figure 8) Thus, human activities in Kwitanga forests have resulted in low habitat quality that poses a negative feedback on chimpanzee population this forest can support.

Tree felling structure (Table 11; Figure 9) provide an ideal situation that best conservation approach requires a state of multiple land use with the prison that have for a long period, protected this habitat while utilizing forest resources. This would need to consider particular tree sizes for harvesting to achieve suitable chimpanzee nesting trees. Chimpanzee used large trees for nesting with a mean of 27 ± 1.1 cm thus; large trees need protection. The cautionary note is to ensure the aspect of species harvested (Figure 8) that showed similar species used for nesting (Figure 8) and inter-species relations so that a compromise to maintain physical ecological conditions before the implementation of multiple land use as a conservation strategy in this area exist.

The observed large proportion of old nests (Table 1) indicated that Kwitanga forest is not suitable to sustain a viable population on its own. Evidence of high human activities encounter rates and high tree felling (Figure 7) indicated high forest transformation. However, being the largest remaining forest patch, in the highly transformed landscape matrix of habitats (Figure 2; Figure 10), this forest has a high conservation value. Protection of Kwitanga forest will allow the movements of chimpanzees across the landscapes leading to improvement of chimpanzee population size through increased habitat size, reduced feeding competition, and improved genetic diversity through mixing of these isolated populations in the neighboring landscape. There is evidence of such relic chimpanzee populations in between Gombe National Park, in Mkongoro and Kwitanga (Pusey et al., in press; Ndimuligo, unpublished data). Furthermore, the protection of Kwitanga forest will add total numbers of protected chimpanzees in the region. Conservation efforts that allow connectivity of these habitat patches can improve chances for these isolated populations near Gombe National Park to receive protection and long-term survival of the species (Massawe, 1992; Marchesi et al., 1995; Davies et al., 2001; Primack, 2002).

Future work to understand the ecology of chimpanzees across habitat mosaics in the region and monitor these small chimpanzee populations in the adjacent landscapes is essential in order to generate details on how these small and isolated populations in human dominated landscapes utilize the remaining habitat fragments.

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7.0 APPENDIX 1: TABLES

Table 1 Nest group size and total nests in particular age classes

	Total nests in each age group encountered			
Group size	**1**	**2**	**3**	**4**
1			1	
2				2
2			2	
3				3
2				2
2				2
2			2	
4	2	2		
4				4
1				1
2				2
4			2	2
1				1
3				3
5				5
2			2	
3		2		1
1				1
2		2		
5		3		2
2				2
4		1	2	1
5			2	3
8		3	2	3
11		3	4	4
1			1	
18			8	10
3			2	1
1			1	
2				2
Total	**2**	**16**	**31**	**57**

Average nest group size 3.5(~4)

Table 2 Nest Density Estimates from fitted models to the nest sighting distances

Model name	***# of para***	***AIC***	***Density*** *(No. km^{-2})*	***DLCL*** ***(No. km^{-2})***	***DUCL*** ***(No. km^{-2})***	***DCV*** ***(No. km^{-2})***	***P-value*** ***(for Chi-Square)***
Uniform Cosine	2	179.18	24.227	10.965	53.526	0.396	0.15398
Halfnormal Polynomial	2	180.05	26.52	11.961	60.293	0.398	0.11207
Halfnormal Cosine	2	178.25	27.116	12.195	60.293	0.4	0.20932
Hazardrate Cosine	3	179.68	28.81	10.93	75.941	0.51	0.13178
Hazardrate Hermite	2	179.78	27.672	10.564	72.481	0.5-7	0.10237

Note: Variance estimates are by bootstrap re-sampling of line transects samples. Terms used: LCL is the lower confidence level, UCL is the upper confidence level and CV is the coefficient of variation, 'AIC' is Akaike Information Criterion and D is Density

Table 3 Comparison of tree species on transects and nesting sites

Species	**% of observation on transects(720)**	**% of observation nesting sites(357)**
Brachystegia bussei	16.3	21.0
Julbernadia globiflora	9.3	5.0
Brachystegia utilis	8.9	15.7
Uapaca kirkiana	8.3	0.6
Pterocarpus angolensis	5.7	8.1
Diprorhyncus condilocarpon	5.3	7.6
Combretum collinum	5.0	0.6
Pterocarpus tinctorius	4.6	3.4
Uapaca nitida	2.9	0.6
Brachystegia microphylla	2.6	12.6
Anona senegalensis	2.6	3.4
ID2006#5	1.7	2.8
Combretum molle	1.5	1.7
Uapaca sansibarica	1.4	0.3
Parinari curatellifolia	1.4	0.8
Pericopsis angolensis	1.3	2.0
ID2006#4	1.3	0.3
Anisophyllea boehmei	1.3	1.1
Schrebela trichoclada	0.8	1.4
Combretum sp.	0.8	0.3
Stereospermum galeopsifolium	0.7	0.6
Monotes elegans	0.7	0.3
Dalbergia nitulada	0.7	0.8
Ochna schweinfurthiana	0.6	0.3
Vitex doniana	0.4	0.3
Strichnos sp.	0.3	0.6
Cordia africana	0.3	0.6
Terminalia cf kaisseriana	0.1	0.3

ID2006#12	0.1	0.6
ID2006#11	0.1	0.3
ID2006#10	0.1	0.8
Antidesma venosum	0.1	0.3
Garcinia huillensis	0.0	0.8
Anisophyllea pomifera	0.4	0.3
Steganotaenia araliacea	0.0	0.6
Commiphora habessinica	0.0	0.6
Afrisersalia ceracifera	0.0	0.6
Sterculia quinqueloba	0.0	0.3
Pseudispondias microcarpa	0.0	0.3
Oxyanthus lepidus	0.0	0.3
Margaritaria discoides	0.0	0.3
ID2006#15	0.0	0.3
ID2006#14	0.0	0.3
ID2006#13	0.0	0.3
Flacourtia indica	0.0	0.3
Ficus mucuso	0.0	0.3
Hymenocardia acida	2.4	0.0
Cussonia arborea	2.1	0.0
ID2006#8	1.1	0.0
Syzigium guineense	0.7	0.0
Protea sp.	0.7	0.0
Psorospermum febrifigum	0.6	0.0
Bridelia carthatica	0.6	0.0
Brachystegia sp.	0.6	0.0
Multidendia crassa	0.4	0.0
ID2006#9	0.4	0.0
Albizia antunesiana	0.4	0.0
Acacia polyacantha	0.3	0.0
Vernonia sp.	0.1	0.0
Trichilia sp.	0.1	0.0
Strychnos spinosa	0.1	0.0
Strichnos innocua	0.1	0.0
Sterculia tragacantha	0.1	0.0
Piliostigma sp.	0.1	0.0
Ochna sp.	0.1	0.0
ID2006#7	0.1	0.0
ID2006#6	0.1	0.0
ID2006#3	0.1	0.0
ID2006#2	0.1	0.0
ID2006#1	0.1	0.0
Harungana madagascariensis	0.1	0.0
Grewia mollis	0.1	0.0
Gardenia ternifolia	0.1	0.0
Ficus sp.	0.1	0.0

Table 4 Tree species list (not to author) and their local names of Kwitanga

Scientific name	**Local name**
Brachystegia bussei	ngongo
Julbernadia globiflora	mlembela
Brachystegia utilis	msamba
Uapaca kirkiana	Mgusu
Pterocarpus angolensis	mninga
Diprorhyncus condilocarpon	Msongati
Combretum collinum	Mkukulama
Pterocarpus tinctorius	Mkurungu/msiloti
Uapaca nitida	Mgusuhande
Brachystegia microphylla	mwani
Anona senegalensis	mtopetope
ID2006#5	katunguru
Combretum molle	mlama
Uapaca sansibarica	mgusuhande
Parinari curatellifolia	mbula
Pericopsis angolensis	mninga
ID2006#4	muhongoro
Anisophyllea boehmei	mshindwi njano
Schrebela trichoclada	mfute
Combretum sp.	Mkukulama
Stereospermum galeopsifolium	mtelele
Monotes elegans	mkwabhulo
Dalbergia nitulada ?	muyigi
Ochna schweinfurthiana	mnyago
Vitex doniana	mtunda ugoro
Strichnos sp.	mshongo wa kike
Cordia africana	mkole
Terminalia cf kaisseriana	muhenya
ID2006#12	mgongo
ID2006#11	kamena
ID2006#10	muyama
Antidesma venosum	mzinganziga
Garcinia huillensis	msalasi
Steganotaenia araliacea	mganasha
Commiphora habessinica	mtahwela
Afrisersalia ceracifera	uruzu
Sterculia quinqueloba	mnyelezankende
Pseudispondias microcarpa	mgwiza
Oxyanthus lepidus	jamii ya kahawa pori
Margaritaria discoides	msasilankanga
ID2006#15	mpelele
ID2006#14	mgimbu

ID2006#13	kihororo
Flacourtia indica	ntuligwa
Ficus mucuso	mkuyu
Anisophyllea pomifera	mshindwi
Hymenocardia acida	msagamba
Cussonia arborea	gihondogori
ID2006#8	mgoti
Syzigium guineense	mtimbula
Protea sp.	gihungere
Psorospermum febrifigum	marandula
Bridelia carthatica	kamembe
Brachystegia sp.	mtundu
Multidendia crassa	mgugunwa
ID2006#9	mweza
Albizia antunesiana	mpilipili
Acacia polyacantha	mkaza
Vernonia sp.	mfumya
Trichilia sp.	mbilabila
Strychnos spinosa	mshongo mdogo
Strichnos innocua	mkome
Sterculia tragacantha	mkungwe
Piliostigma sp.	Mfumbe
Ochna sp.	mnyagasozi
ID2006#7	mlalangwe
ID2006#6	mselele
ID2006#3	mgando
ID2006#2	kitagata
ID2006#1	msambala
Harungana madagascariensis	mshaishai
Grewia mollis	msha
Gardenia ternifolia	mtelama
Ficus sp.	jamii ya mkuyu

Table 5 Tree species supporting nests and their respective densities per ha on transects and nesting sites

Species	No. of nests	Density/ha on transects	Density/ha at nesting sites
Brachystegia bussei	30	67.99	114.47
Brachystegia utilis	28	34.45	85.47
Brachystegia microphylla	14	10.23	68.68
Julbernadia globiflora	13	36.07	27.47
Pterocarpus tinctorius	6	17.77	18.32
Combretum molle	2	5.92	9.16
Garcinia	2	0	4.58
Pericopsis angolensis	2	0.54	1.53
Antidesma venosum	2	5.38	4.58
Parinari curatellifolia	2	22.07	44.26
Pterocarpus angolensis	2	4.85	10.68
Anona senegalensis	2	10.23	18.32
Pseudispondias microcarpa	1	0	1.53
Total	**106**	**215.5**	**409.05**

Table 6 Mean tree size classes of trees on transects, nesting sites and nest hosting trees

Location type	No. of Observations	Mean dbh (cm)	Std Error
Nest hosting trees	89	27	1.1
Trees at nesting sites	356	23	0.7
Trees on transects	716	18	0.5

Table 7 Pair comparison of tree size classes among groups and their significance level using Tukey's Studentized Range HSD

Pairs compared	Tukey's HSD Confidence Intervals		Significance
Nest hosting trees Vs. trees at nesting sites	0.6637	7.4257	***
Nest hosting trees Vs. trees on transects	5.5408	11.9538	***
Trees at nesting sites Vs. trees on transects	2.8525	6.5528	***

Key: *** means significant

Table 8 Vegetation structure on transects and species description

SPECIES	Frequency	No. in quarters	No. of trees per ha	Relative Density (%)	Relative Dominance %	Relative Frequency %	Mean basal Area (m^2)	Absolute Dominance (m^2/ha)
Brachystegia bussei	117	0.156	62.99	15.56	21.03	16.25	0.79	49.59
Julbernadia globiflora	67	0.089	36.07	8.91	19.33	9.31	1.26	45.58
Brachystegia utilis	64	0.085	34.45	8.51	11.25	8.89	0.77	26.52
Uapaca kirkiana	60	0.080	32.30	7.98	3.77	8.33	0.28	8.89
Pterocarpus angolensis	41	0.055	22.07	5.45	2.36	5.69	0.25	5.56
Diprorhyncus condilocarpon	38	0.051	20.46	5.05	1.51	5.28	0.17	3.55
Combretum collinum	36	0.048	19.38	4.79	1.18	5.00	0.14	2.77
Pterocarpus tinctorius	33	0.044	17.77	4.39	2.02	4.58	0.27	4.75
Uapaca nitida	21	0.028	11.31	2.79	1.42	2.92	0.30	3.36
Brachystegia microphylla	19	0.025	10.23	2.53	2.34	2.64	0.54	5.52
Anona senegalensis	19	0.025	10.23	2.53	1.14	2.64	0.26	2.69
Hymenocardia acida	17	0.023	9.15	2.26	0.90	2.36	0.23	2.13
Cussonia arborea	15	0.020	8.08	1.99	0.62	2.08	0.18	1.46
ID2006#5	12	0.016	6.46	1.60	0.97	1.67	0.35	2.29
Combretum molle	11	0.015	5.92	1.46	1.17	1.53	0.47	2.76
Uapaca sansibarica	10	0.013	5.38	1.33	1.61	1.39	0.71	3.80
Parinari curatellifolia	10	0.013	5.38	1.33	6.26	1.39	2.74	14.77
Pericopsis angolensis	9	0.012	4.85	1.20	2.94	1.25	1.43	6.93
ID2006#4	9	0.012	4.85	1.20	0.90	1.25	0.44	2.12
*Anisophyllea boehme*i	9	0.012	4.85	1.20	0.88	1.25	0.43	2.07
ID2006#8	8	0.011	4.31	1.06	3.15	1.11	1.73	7.43
Schrebela trichoclada	6	0.008	3.23	0.80	0.67	0.83	0.49	1.57
Combretum sp.	6	0.008	3.23	0.80	1.06	0.83	0.77	2.49
Syzigium guineense	5	0.007	2.69	0.66	0.21	0.69	0.18	0.50
Stereospermum galeopsifolium	5	0.007	2.69	0.66	0.17	0.69	0.15	0.39
Protea sp.	5	0.007	2.69	0.66	0.16	0.69	0.14	0.38
Monotes elegans	5	0.007	2.69	0.66	0.55	0.69	0.48	1.29
Dalbergia nitulada	5	0.007	2.69	0.66	0.17	0.69	0.15	0.41
Psorospermum febrifigum	4	0.005	2.15	0.53	0.13	0.56	0.14	0.31
Ochna schweinfurthiana	4	0.005	2.15	0.53	0.17	0.56	0.18	0.39

Bridelia carthatica	4	0.005	2.15	0.53	0.14	0.56	0.16	0.33
Brachystegia sp.	4	0.005	2.15	0.53	0.88	0.56	0.96	2.07
Vitex doniana	3	0.004	1.62	0.40	0.40	0.42	0.59	0.95
Multidendia crassa	3	0.004	1.62	0.40	0.10	0.42	0.14	0.23
ID2006#9	3	0.004	1.62	0.40	0.10	0.42	0.14	0.23
Anisophyllea pomifera	3	0.004	1.62	0.40	0.57	0.42	0.83	1.35
Albizia antunesiana	3	0.004	1.62	0.40	0.40	0.42	0.59	0.95
Strichnos sp.	2	0.003	1.08	0.27	0.06	0.28	0.14	0.15
Cordia africana	2	0.003	1.08	0.27	0.07	0.28	0.15	0.16
Acacia polyacantha	2	0.003	1.08	0.27	0.07	0.28	0.15	0.16
Vernonia sp.	1	0.001	0.54	0.13	0.20	0.14	0.86	0.46
Trichilia sp.	1	0.001	0.54	0.13	0.06	0.14	0.26	0.14
Terminalia cf kaisseriana	1	0.001	0.54	0.13	0.03	0.14	0.14	0.08
Strychnos spinosa	1	0.001	0.54	0.13	0.03	0.14	0.14	0.08
Strichnos innocua	1	0.001	0.54	0.13	0.03	0.14	0.14	0.08
Sterculia tragacantha	1	0.001	0.54	0.13	0.03	0.14	0.14	0.08
Piliostigma sp.	1	0.001	0.54	0.13	0.03	0.14	0.14	0.08
Ochna sp.	1	0.001	0.54	0.13	0.03	0.14	0.14	0.08
ID2006#7	1	0.001	0.54	0.13	0.03	0.14	0.14	0.08
ID2006#6	1	0.001	0.54	0.13	0.03	0.14	0.14	0.08
ID2006#3	1	0.001	0.54	0.13	0.03	0.14	0.15	0.08
ID2006#2	1	0.001	0.54	0.13	4.65	0.14	20.38	10.97
ID2006#12	1	0.001	0.54	0.13	0.58	0.14	2.53	1.36
ID2006#11	1	0.001	0.54	0.13	0.03	0.14	0.15	0.08
ID2006#10	1	0.001	0.54	0.13	1.12	0.14	4.89	2.63
ID2006#1	1	0.001	0.54	0.13	0.04	0.14	0.16	0.09
Harungana madagascariensis	1	0.001	0.54	0.13	0.03	0.14	0.14	0.08
Grewia mollis	1	0.001	0.54	0.13	0.03	0.14	0.15	0.08
Gardenia ternifolia	1	0.001	0.54	0.13	0.03	0.14	0.14	0.08
Ficus sp.	1	0.001	0.54	0.13	0.09	0.14	0.39	0.21
Antidesma venosum	1	0.001	0.54	0.13	0.03	0.14	0.14	0.08
Total	**720**							**235.80**

Table 9 Vegetation structure at nesting sites with species description

SPECIES	Frequency	No. of trees in quarters	No. of trees per ha	Relative Density (%)	Relative Frequency (%)	Relative Dominance (%)	Mean basal Area (m^2)	Absolute Dominance (m^2/ha)
Brachystegia bussei	75	0.211	114.47	21.07	21.01	31.53	1.31	150.31
Brachystegia utilis	56	0.157	85.47	15.73	15.69	18.69	1.04	89.12
Brachystegia microphylla	45	0.126	68.68	12.64	12.61	15.04	1.04	71.71
Pterocarpus angolensis	29	0.081	44.26	8.15	8.12	3.38	0.36	16.10
Diprorhyncus condilocarpon	27	0.076	41.21	7.58	7.56	2.66	0.31	12.67
Julbernadia globiflora	18	0.051	27.47	5.06	5.04	5.85	1.02	27.89
Pterocarpus tinctorius	12	0.034	18.32	3.37	3.36	3.22	0.84	15.34
Anona senegalensis	12	0.034	18.32	3.37	3.36	1.52	0.40	7.25
Pericopsis angolensis	7	0.020	10.68	1.97	1.96	4.61	2.06	21.98
Combretum molle	6	0.017	9.16	1.69	1.68	0.58	0.30	2.78
Schrebela trichoclada	5	0.014	7.63	1.40	1.40	0.93	0.58	4.44
Anisophyllea boehmei	4	0.011	6.11	1.12	1.12	0.77	0.60	3.68
Parinari curatelifolia	3	0.008	4.58	0.84	0.84	0.99	1.03	4.72
ID2006#10	3	0.008	4.58	0.84	0.84	0.55	0.57	2.63
Garcinia huillensis	3	0.008	4.58	0.84	0.84	0.67	0.70	3.21
Dalbergia nitulada	3	0.008	4.58	0.84	0.84	0.14	0.15	0.67
Uapaca nitida	2	0.006	3.05	0.56	0.56	0.12	0.19	0.56
Uapaca kirkiana	2	0.006	3.05	0.56	0.56	0.19	0.29	0.89
Strichnos sp.	2	0.006	3.05	0.56	0.56	0.14	0.22	0.67
Stereospermum galeopsifolium	2	0.006	3.05	0.56	0.56	0.10	0.15	0.46
Steganotaenia araliacea	2	0.006	3.05	0.56	0.56	0.09	0.15	0.44
ID2006#12	2	0.006	3.05	0.56	0.56	2.59	4.05	12.35
Cordia africana	2	0.006	3.05	0.56	0.56	0.10	0.16	0.47
Commiphora habessinica	2	0.006	3.05	0.56	0.56	0.45	0.71	2.17
Combretum collinum	2	0.006	3.05	0.56	0.56	0.11	0.17	0.52
Afrisersalia ceracifera	2	0.006	3.05	0.56	0.56	0.10	0.16	0.49
Vitex doniana	1	0.003	1.53	0.28	0.28	0.21	0.67	1.02
Uapaca sansibarica	1	0.003	1.53	0.28	0.28	0.05	0.15	0.23
Terminalia cf kaisseriana	1	0.003	1.53	0.28	0.28	0.05	0.16	0.24
Sterculia quinqueloba	1	0.003	1.53	0.28	0.28	0.17	0.53	0.81
Pseudispondias microcarpa	1	0.003	1.53	0.28	0.28	0.53	1.67	2.55
Oxyanthus lepidus	1	0.003	1.53	0.28	0.28	0.05	0.17	0.26

Ochna schweinfurthiana	1	0.003	1.53	0.28	0.28	0.08	0.26	0.40
Monote elegans	1	0.003	1.53	0.28	0.28	0.44	1.36	2.08
Margaritaria discoides	1	0.003	1.53	0.28	0.28	0.06	0.20	0.31
ID2006#5	10	0.028	15.26	2.81	2.80	1.63	0.51	7.78
ID2006#4	1	0.003	1.53	0.28	0.28	0.21	0.67	1.02
ID2006#15	1	0.003	1.53	0.28	0.28	0.22	0.69	1.05
ID2006#14	1	0.003	1.53	0.28	0.28	0.08	0.26	0.40
ID2006#13	1	0.003	1.53	0.28	0.28	0.08	0.26	0.40
ID2006#11	1	0.003	1.53	0.28	0.28	0.05	0.15	0.23
Flacourtia indica	1	0.003	1.53	0.28	0.28	0.30	0.93	1.42
Ficus mucuso	1	0.003	1.53	0.28	0.28	0.09	0.29	0.44
Combretum sp.	1	0.003	1.53	0.28	0.28	0.10	0.30	0.46
Antidesma venosum	1	0.003	1.53	0.28	0.28	0.09	0.27	0.41
Anisophyllea pomifera	1	0.003	1.53	0.28	0.28	0.39	1.21	1.85
Total	357							476.72

Table 10 Comparison of mean tree species density on transects and nesting sites

Label	No. of Observations	Mean (per ha)	Std Error
Transects	61	6	1.4
Nesting sites	46	12	3.4

Table 11 Showing harvested wood species and the associated characteristics

SPECIES	Frequency	No. in quarters	No. of Trees per ha	Relative Density (%)	Relative Dominance %	Reltive Frequency%	Mean basal area(m^2)	Absolute Dominance (m^2/ha)
Julbernadia globiflora	41	0.30	37.23	30.15	41.11	30.15	1.68	62.67
Uapaca kirkiana	34	0.25	30.87	25.00	15.82	25.00	0.78	24.11
X(unidendified)	12	0.09	10.90	8.82	3.67	8.82	0.51	5.59
Pericopsis angolensis	11	0.08	9.99	8.09	9.30	8.09	1.42	14.18
Pterocarpus tinctorius	5	0.04	4.54	3.68	17.32	3.68	5.81	26.39
Pterocarpus angolensis	4	0.03	3.63	2.94	1.60	2.94	0.67	2.44
Brachystegia microphylla	4	0.03	3.63	2.94	2.64	2.94	1.11	4.03
Combretum molle	3	0.02	2.72	2.21	0.77	2.21	0.43	1.18
Brachystegia bussei	3	0.02	2.72	2.21	1.10	2.21	0.61	1.67
Anona senegalensis	3	0.02	2.72	2.21	0.20	2.21	0.11	0.30
ID2006#5	2	0.01	1.82	1.47	3.53	1.47	2.97	5.38
Hymenocardia acida	2	0.01	1.82	1.47	0.17	1.47	0.15	0.26
Anisophyllea pomifera	2	0.01	1.82	1.47	0.48	1.47	0.40	0.73
Vitex doniana	1	0.01	0.91	0.74	0.26	0.74	0.43	0.39
Schrebela trichoclada	1	0.01	0.91	0.74	0.08	0.74	0.14	0.13
ID2006#9	1	0.01	0.91	0.74	0.10	0.74	0.16	0.15
Ficus vallis-choudae	1	0.01	0.91	0.74	0.08	0.74	0.14	0.13
Ficus amadiensis	1	0.01	0.91	0.74	0.13	0.74	0.22	0.20
Combretum sp.	1	0.01	0.91	0.74	0.09	0.74	0.15	0.14
Combretum collinum	1	0.01	0.91	0.74	0.08	0.74	0.14	0.13
Brachystegia utilis	1	0.01	0.91	0.74	0.57	0.74	0.96	0.87
Brachystegia sp.	1	0.01	0.91	0.74	0.70	0.74	1.17	1.06
Anisophyllea boehmei	1	0.01	0.91	0.74	0.19	0.74	0.32	0.29
TOTAL	136							152.42

Table 12 Population density of nest-building chimpanzee estimates by nest counts

Location of study	Estimated density per km^2	Method used	Source
Kwitanga Forest, western Tanzania	0.69(0.31-1.54)	line transect	this study
Budongo Forest, Uganda	1.8	line transect	Plumptre & Reynolds, 1996
Petit Loango Forest, Gabon	0.78	line transect	Furuichi et al., 1997
Tschengo Forest, Congo DRC	0.27	line transect	Ihobe, 1995
Kalinzu Forest, Uganda	2.8-4.7	line transect	Hashimoto, 1995
Côte D'Ivore (National Parks)	1.64	line transect	Marchesi et al., 1995
Filabanga, Western Tanzania	0.2	Direct observation	Kano, 1971
Takamanda, Cameroon	0.1-0.12	line transect	Sunderland-Groves et al., 2003
Northern Congo DRC	0.7(0-1.3)	line transect	Poulen & Clark, 2004
Wansisi, western Tanzania	0.06	line transect	Ogawa et al., 2004
Haut-Niger park, Repub.Guinea	0.52(0.33-0.79)	line transect	Feury-Brugiere & Brugiere, 2002
Kibale N.Park, Uganda	3	line transect	Chapman & Lambert, 2000
Budongo Forest, Uganda	1.3(1.0-1.7)	line transect	Plumptre & Reynolds, 1994
Dzanga-Ndoki N. Park, Central Africa	0.16	line transect	Blom et al., 2001
Goualongo Triangle, Repub. Congo	1.53	line transect	Morgan et al., 2006
Motaba River Area, northeastern Congo	0.3(0.25-0.36)	line transect	Kano & Asato (1994)

Key: The brackets ( ); indicate range of estimates

Table 13 showing characteristics that determine choice of tree species harvested

Use type	Suggested properties of a species	Source of information
Commercial harvesting	Large size, particular hardness and durability	Vermeulen, 1996, Luoga et al., 2002, Caro et al., 2005
Building poles	Small size Have specific features identified by user community, resistance to biodagraders, availability and cultural taboos, Quality of wood	Luoga et al., 2000; 2004 Abbot & Homewood, 1999 Luoga et al., 2000 Abbot & Lowore, 1999
Fuelwood	Small size Flammability and energy produced Easy to chop Quality of flame	Luoga et al., 2000; 2004 Abbot & Lowore, 1999 Luoga et al, 2004 Abbot & Homewood, 1999