



Master's Thesis

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A Conservation Re-Assessment of the Endangered Zanzibar Red Colobus

Piliocolobus Kirkii



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DEN A.P MØLLERSKE STØTTEFOND



According to the Chinese zodiac calendar, 2016 is the year of the Red Fire Monkey.

A year were people born in the year of the snake, will have an exceptional connection to the monkey.

Lærke N.J. (snake)

PREFACE

This thesis is the result of a 9-month Master's project at the Center of Macroecology, Evolution and Climate at University of Copenhagen, Denmark. This project has been supervised by Professor Neil David Burgess Danish Natural History Museum, Copenhagen University Denmark, and co-supervisor Doctor Katarzyna Nowak, AAAS, USA. The fieldwork conducted in Kiwengwa – Pongwe Forest Reserve was supported by the Department of Forestry and Non-Renewable Natural Resources, Zanzibar. Research permit was issued by the Ministry of State through the Second Vice - Presidential Office of Zanzibar, Stonetown Zanzibar.

In collaboration with my supervisors, I have been building on this project since March 2015. It has resulted in two trips to Zanzibar, in August 2015 and January-April 2016, subsequent four months' total, spent on Zanzibar and mainland Tanganyika.

With this thesis, I will pursue to embrace conservation of an endangered endemic species and what role habitat preservation has in the success of this.



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I am thankful for all the dear friends I made while on Zbar. In my eyes, you are not ranked, for this I am grateful for having crossed paths with every one of you.

The greatest gratitudes I send to my scientific supervisors Neil, and Kate. Thank you, Neil, for starting this project with me, for being the minds behind it, and thanks to Kate for your knowledge about colobus and help on Zanzibar, I would not have been able to complete my field work without it.

At Copenhagen University, my thanks go to CMEC, every one there, the fourth floor and “kagestuen” - no coffee, no cake, no aquarium = no thesis.

I also sincerely thank the grants I have been awarded, Den A.P. Møllerske Støttefond, Det Saxild'ske Familiefond, Dr. Bøje Benzons Støttefond and ‘Nykjærs Familien Legatet’, without this economical support this project would never have been a possibility. Last but not least, my appreciation go to my father Olav Nykjær, thank you for being my extra external advisor, for guidance and counseling, for you and Thea visiting me on Zanzibar, thank you for helping me. To everyone else who has been involved in this project, to my friends, to my family

-Uja Moya Asante Sana

ABSTRACT

Aim: Deforestation and habitat degradation due to forest resource demand from growing human settlements, imposes a severe threat to conservation of endangered species worldwide. To best conserve our remaining wildlife more and more land becomes protected to further inhibit degradation. To evaluate the effects of protection management for an endangered species, we reassess the conservation status of the endemic Zanzibar red colobus (*Procolobus kirkii*), in a government managed forest reserve, prior and past gaining protection status.

Location: All fieldwork was conducted in Kiwengwe-Pongwe Forest Reserve, Unguja Island Zanzibar, United Republic of Tanzania.

Methods: Populations of *P. kirkii* were censused using line transects sampling of three transects. Habitat was sampled along the same transects by measuring 35 5x50 m vegetation plots.

Results: I found that in total the area sampled now likely contained a higher density of colobus than before gazettelement. Groups were encountered more often, but were in average slightly smaller. The habitat had undergone a radical degradation. The density of trees $\geq 2,5$ m in height had decreased 42 % and 58 species found in 2004 were absent in the same area sampled in 2016. The deforestation, species loss and human disturbance was clearly larger towards the reserve rim, closer to growing urban settlements.

Main Conclusions: We found that the habitat degradation had possibly caused a population compression of *P. kirkii*. This increasing animal density in the center of the reserve, furthest from human disturbance from surrounding rural settlements. It is an unfortunate reality for the endangered species, emphasizing the need of engaging local community in conservation management. Conservation is a sociological matter, requiring implementation and support by the local community, for even the best meant management plans to have a sufficient effect. More focus must be turned towards the fulfilling of management goals and follow-ups on issued management plans, to insure implementation and effective conservation.

RESUMÉ

Vores voksende humane population truer tilværelsen for flere arter af vilde primater. Især den øgede urbanisering af det afrikanske kontinent har konsekvenser for flere arter heriblandt den Zanzibar endemiske røde colobus abe, *Piliocolobus kirkii*. Den årlige menneskelige populationstilvækst på 5% og en lokalbefolkning hvor over 80 % er afhængige af ressourcer fra skoven, gør at der hvert år gradvist forsvinder mere af de fragmenterede skove, Zanzibar colobus aben hovedsageligt lever i.

Med denne afhandling undersøger jeg, ved transekt populationsoptælling og vegetationsanalyse, hvorvidt fredning af et af de mest betydningsfulde skovområde, Kiwengwa-Pongwe reservatet, har haft nogen effekt på den deri boende population, samt på den overordnede tilstand af skoven. Jeg gør dette ved at sammenligne data fra 2004, før fredning i 2007, med data indsamlet vinteren 2016.

Jeg fandt at der, i det afgrænsede prøveområde, med al sandsynlighed var en større tæthed af aber i 2016, dog med en hvis usikkerhed. Det viste sig dog at, aberne generelt bevægede sig i mindre grupper og at der var signifikant forskelle i hvor aberne befandt sig i højere densiteter både mellem de to år og inden for hvert år. Vegetationsanalyse viste at, densiteten af træer var faldet signifikant ved alle tre transekter. Der var sket et skift i, at der nu blev fældet signifikant flere træer ved transekt B det nordlige transekt, samt signifikant færre træer ved transekt K3, det sydlige transekt. Af de 119 arter fundet under vegetations analyse i 2004, blev 58 arter ikke fundet ved samme analyse i 2016 hvor totalt kun 75 arter blev fundet. Der var en klar sammenhæng mellem hvor der var en større menneske aktivitet i skoven, med hvor flere arter var forsvundet, ved brug af flere parametre som proxy for menneskelig aktivitet.

Ud fra den forringede tilstand af skoven, skiftet i hvor der flest aber blev observeret, samt den formindskede observerede gruppestørrelse antager jeg, at det forøgede estimerede totale antal aber skyldes *populations kompression*, hvor individer fra andre mere forstyrret dele af skoven er indvandrede til dette undersøgte område, resulterende i en kunstig forøgelse af populationstallet. Dette er en kedelig realitet for den truede aber og viser hvor vigtig, inkludering af lokalbefolkningens behov og tilgængelige ressourcer er, i naturbevaring og forvaltning.

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LIST OF ABBREVIATIONS AND ACRONYMS

AOD	Animal-to-Observer Distance
AIC	Akaike Information Criterion
CF	Community Forest
CFMG	Community Forest Management Groups
CITES	the Convention on International Trade in Endangered Species
CoFMA	Community Forest Management Agreement
DBH	Diameter at breast height
DFNRNR	Department of Non-renewable Natural Resources
DS	Distance Sampling
EACF	Eastern Arc Mountains and Coastal Forests of Tanzania and Kenya Hotspot
ER	Encounter Rate
FR	Forest Reserve
ICDP	Intergraded Conservation Development Projects
JCNP	Jozani - Chwaka Bay National Park
KP	Kiwengwa – Pongwe Forest Reserve
KPFR	Kiwengwa - Pongwe Forest Reserve
NGO	Non-Governmental Organization
NT	Near Threatened
PA	Protected Area
PD	Perpendicular Distance
VCC	Village Conservation Councils
WM	Whiteside Method

INTRODUCTION

Of the 25 wild primates listed as the world's most endangered, 10 are from central Africa, with some genera being highly represented on this list (Schwitzer et al. 2015). In the case of the red colobus genus (*Piliocolobus sp.*) several species are found in populations with less than 5000 individuals remaining. The *Piliocolobus* genus holds many endemic species often restricted to very small patchy habitats, opposing a large threat of extinction to several of these unique species (Struhsaker 2005). *Piliocolobus kirkii* (commonly known as Zanzibar red colobus) is endemic to Zanzibar and threatened of extinction by factors imposed by a rapidly increasing human population (Struhsaker & Siex 2016). Zanzibar holds one national park where the occurrence of *P. kirkii* is well studied and protected. But other, less prosperous, protected areas lack the same engagement and follow-up on implementation and efforts in conservation management, despite near equivalent importance for Zanzibar wildlife conservation.

In the period of 2004-2005 Dr. Katarzyna Nowak studied the behavioral and demographic flexibility of *P. kirkii* in Kiwengwa – Pongwe (Nowak 2007). Since then the Kiwengwa – Pongwe forest has gained status as forest reserve. The main purpose of this study is, to investigate how/if the status as protected area has had an effect on the population of *P. kirkii* and its habitat in Kiwengwa-Pongwe Forest Reserve.

I will do this by:

- 1) *Comparing population and habitat data prior to protection of Kiwengwa-Pongwe Forest Reserve, with data collected in 2016, almost 10 years past gazettelement. I will investigate both between- and within sampling year variations.*
- 2) *Investigating influences on habitat and population, with proxies for human disturbance, to assess the human involvement in the conservation of this species.*
- 3) *Assess the possible correlations between investigated parameters, to pursue a qualified estimation and overall picture, of the conservation status of this endangered species and the forest reserve, to understand the effectiveness of conservation management in a developing country.*

BACKGROUND

The fragmented forests of Zanzibar are part of a strip of coastal forest mosaics, from southern Somalia to Mozambique, known as *The Eastern Arc and Coastal Forest of Tanzania/Kenya hotspot* (EACF) (Burgess et al. 1998). This area is one of 25 worldwide biodiversity hotspots which are characterized by being, places of conservation top priority, for having exceptional concentrations of endemic species, undergoing exceptional habitat loss (Myers et al. 2000).

The EACF hotspot is by far the hotspot with the highest species to area ratio, both concerning endemic plants and vertebrate species, and is among the top eight hottest hotspots in terms of five priority factors: no. endemic plants, no. endemic vertebrates, endemic plants to area ratio, endemic vertebrates to area ratio and remaining primary vegetation as % of original extent (Myers et al. 2000). The Zanzibar archipelago is included in the hotspot due to high levels of strictly endemic plants, butterflies, bird, and the endangered primate, the Zanzibar Red Colobus, *Ptilocolobus kirkii* (Gray 1868) (Burgess et al. 1998).



Figure 1 The location of *The Eastern Arc and Coastal Forest of Tanzania/Kenya hotspot*. The red line shows the area considered within the hotspot. Map modified from: (Gereau et al. 2016; Gaba 2010).

PILIOCOLOBUS GENUS

The Zanzibar red colobus is endemic to the Ugunja, Uzi and Vundwe Islands of the Zanzibar archipelago. It is of the African genus of colobi monkeys known as red colobus (*Piliocolobus*). They are of the old-world monkey family (*Cercopithecidae*), known for their *classic* monkey looks, with long tails, limbs and functional hands and feet (Groves 2007). All African colobuses can be recognized by having their thumbs totally reduced or apparent as small stumps, as they are on the Zanzibar red colobus (Struhsaker 1975; Groves 2007).

All *Piliocolobus* species are distributed around equatorial Africa from Senegal to Zanzibar, with species ranges being allopatrically divided (with the exception of a putative hybrid zone in central African region) (Struhsaker 1975; Struhsaker 2005; Davies & Oates 1994; Groves 2007; Oates & Ting 2015).

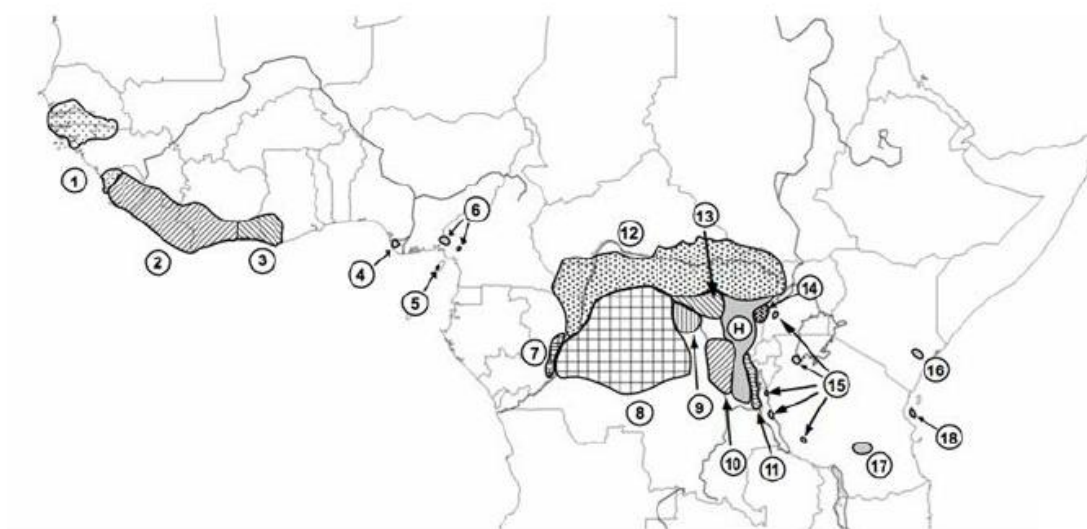


Figure 2 Distribution of the 18 presently recognized taxa of red colobus monkeys.

1: *P. temminckii*, 2: *P. badius*, 3: *P. waldroni*, 4: *P. epieni*, 5: *P. pennantii*, 6: *P. preussi*, 7: *P. bouvieri*, 8: *P. tholloni*, 9: *P. parmientieri*, 10: *P. lulindicus*, 11: *P. foai*, 12: *P. oustaleti*, 13: *P. langi*, 14: *P. semlikiensis*, 15: *P. tephrosceles*, 16: *P. rufomitrat*, 17: *P. gordonorum*, 18: *P. kirkii*. 'H' is the putative hybrid population in the eastern Democratic Republic of Congo. Map: Oates & Ting 2015.

Taxonomy of *Piliocolobus* species has undergone several changes over time. It has over the last 40 years changed several times ranging from olive, red and black-and-white colobus in one genus, red colobus only holding one taxa, to the current recognized deviation into three separate genera, with 18 taxa of red colobus (Grubb et al. 2003; Oates & Ting 2015). Several of these taxa are

restricted to very small patchy habitats (see Figure 2) (Oates & Ting 2015; Groves 2007). In general, the colobus taxonomy is somewhat a gray area severely lacking a consensus in the field of genus/species classification especially for the red colobus (N. Ting 2016, personal comment, 2 November, e-mail correspondence). Six taxa of *Piliocolobus* have repeatedly been included in the IUCN SSC Primate Specialist Group's lists of the world 25 most endangered primates from 2000 - 2016. (Mittermeier et al. 2007; Mittermeier et al. 2009; Mittermeier et al. 2012; Schwitzer et al. 2014; Schwitzer et al. 2015).

The Miss Waldron's red colobus (*Piliocolobus badius waldroni*) was by 2000 already announced extinct (Struhsaker 2005; Mittermeier et al. 2007). In 2007, IUCN added three *Piliocolobus* to their list of top endangered species from 2006 – 2008 (Mittermeier et al. 2007). A total of three *Piliocolobus* species are ranked 'critically endangered', seven species ranked 'endangered' and two species as 'near threatened' (IUCN 2016). Only one species, the Oustalet's Red Colobus (*Procladius rufomitatus oustaleti*) is fairly common, illustrating a rapid decline of several *Piliocolobus* species within very few years (Mittermeier et al. 2009). The IUCN primate specialist group underline the importance of bringing more focus to this genus, as they are in urgent need of attention from conservationist and researchers:

"It is significant that there are three red colobus monkeys on the 2006 – 2008 list — there could (should) undoubtedly be more... need for further research and urgent conservation measures for the entire genus" (Mittermeier et al. 2007).

Struhsaker (2005) investigated the conservation status of all endangered red colobus and concluded that hunting, habitat degradation, fragmentation and loss, *and* possible intrinsic factors following as an aftermath, are the greatest risks to survival of red colobus monkeys (Struhsaker 2005).

Piliocolobus are in general known to by a rather shy, arboreal living species normally habituating tropical and lowland forests (Struhsaker 1975; Davies & Oates 1994). Though the colobus is most commonly restricted to wooded habitats, the different species have shown a wide variety of adaptation to other habitats (Davies & Oates 1994). They have been found to also inhabit other less forest like habitats and more "open habitat", like gallery forests with interrupted canopy, and even wooded savannahs, mangrove swamps and farmlands (Davies & Oates 1994; Struhsaker 1975; Galat-Luong & Galat 2005).

PILIOCOLOBUS KIRKII

Being endemic to Zanzibar separated from mainland Tanzania (Tanganyika) by the approximately 40 km wide Zanzibar Channel, *P. kirkii* has a restricted ability of deviations in distribution range. *P. kirkii* can be distinguished from its nearest relatives, the Udzungwa red colobus (*P. gordonorum*) by a distinct pelage color and pattern, the slightly different acoustics of male calls, and reduced size in accordance to the effects of *the island rule*, on island insular mammals (Nowak et al. 2008; Groves 2007).



Figure 3 Zanzibar red colobus, *Piliocolobus kirkii*, adult male photographed in Jozani – Chawaka bay National park. They can be recognized by their characteristic chestnut red backside, crown and exceptional long tale with color lightened towards tip. They have white head, limbs and ventral side, with black face, shoulder region, lower part of arms and legs, hands and feet. Males can be distinguished by their broader skulls and slight sexual dimorphism. The shoulder area and face is lined with long white hairs sometimes resembling the classic look of a mad scientist. Photo: Lærke Nykjær Johansen.

The latest estimations declared less than 2000 individuals remaining, with population trends still declining (Struhsaker & Siex 2016). This should qualify *P. kirkii* as one of Tanzania's primates of greatest conservatory concern (Davenport et al. 2013; Struhsaker 2005).

The highest numbers of *P. kirkii* is found in and around the combined tropical ground water, coral rag and mangrove forests of Jozani - Chwaka Bay National Park (abbreviated JCNP) (see Figure 4)(Struhsaker & Siex 2016). The Kiwengwa - Pongwe Forest Reserve (abbreviated KPFR or KP) is the second most important forest area for sustainable colobus populations. It is the second largest continuous forest area on the island and simultaneously the northern border of their distribution range.

South of Jozani - Chwaka Bay National Park the colobus populations inhabit both protected and unprotected species-supportable habitat mosaics, scattered to the Kungwi Community Forest, secondary forests, shrubs, shambas (shambas are areas of agricultural purpose) and the mangrove swamp forests of Uzi and Vendwe Island (Siex & Struhsaker 1999b; Siex & Struhsaker 1999a; Nowak et al. 2009).

The 2013 list of Priority Primate Areas mentions both Jozani - Chwaka Bay National Park, Kiwengwa – Pongwe Forest Reserve and the unprotected/unmanaged forest and mangrove swamps of Uzi and Vundwe Islands, as to be of special interest for the protection of the endangered Zanzibar red colobus (Davenport et al. 2013). These forests are under different levels of management, whereof no official management plans for Uzi and Vundwe Islands are currently present. The area has several times been proposed as an area worthy of gazetting and is highly threatened by the nearby growing human settlements. (Nowak 2013; Nowak & Lee 2013; Davenport et al. 2013; Nowak et al. 2009).

Habitat management

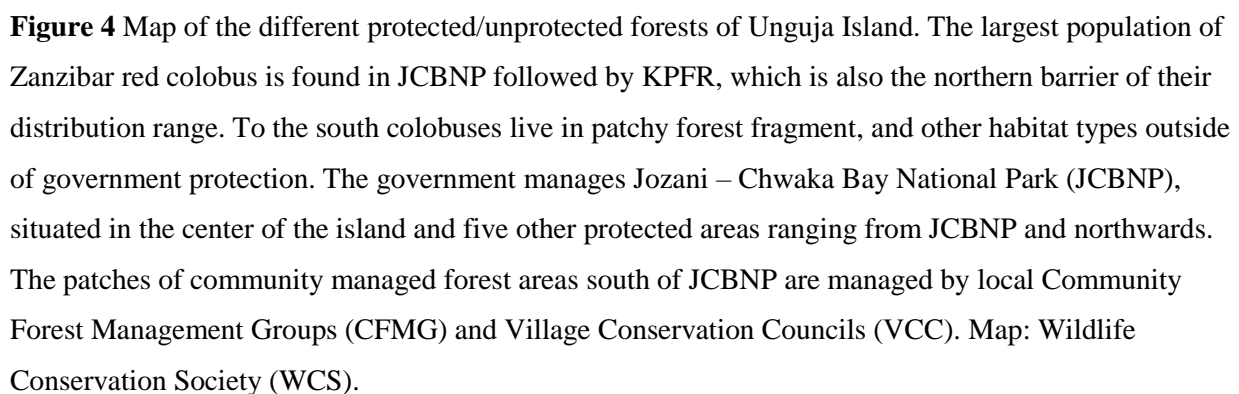
Zanzibar has four forest types listed after level of protection; National park (NP), Forest Reserve (FR), Community forest (CF) and Unprotected forest / plantations (Figure 4).

Largest is Jozani – Chwaka Bay National Park, a 50 km² area protected in 2004 and managed by Ministry of Agriculture through the Department of Non- Renewable Natural Resources (DFNRNR) (formerly known as Department of Commercial Crops Fruit-trees and Forests (DCCFF)) (Ministry of Natural Resources and Tourism 2014). Conservation management on Zanzibar, is based on the holistic community integrating conservation approach, known as the

“New Conservation Debate” (Minteer & Miller 2011). JCNP is surrounded by a buffer zone where villagers and farmers from the surrounding nine villages, are allowed to collect their needed natural resources, and continue agricultural farming, managed by local community based natural resource management committees. This approach to allow locals a sustainable use of needed natural resources surrounding the national park, *and* to ensure the best possible conservation of endangered flora and fauna biodiversity (Saunders 2011). Within the boundaries of the national park there is complete protection of all flora and fauna and no resource extraction of any kind is allowed (hunting, charcoal and limestone excavation, timber and firewood collection and so on).

Forest reserves as Kiwengwa – Pongwe Forest Reserve are protected areas of special interest due to conservation, biodiversity or other interests, and are also under government management. They have no entrance limitation; you are allowed to use the forest for recreational purposes and for extraction of natural resources in agreement with the local community council.

The smaller community forests fragment on the southern part of Unguja island, are based on the ideas behind new generation alternative conservation approach called Integrated Conservation Development Projects (ICDP). They try to integrate local communities in conservation of their natural surroundings, having a developmental and beneficial payoff for the community. An agreement known as the Community Forest Management Agreement (CoFMA) between the government, NGO's of interest and the local villagers, establishing local community based organizations (Community Forest Management Groups (CFMG)) and Village Conservation Councils (VCC)) responsible for forest- and natural resource management. This gives the local community the inclusive rights to the forest management, forest resource utilization and shared benefits accrued from forest resources at community level. Simultaneously fulfilling conservation goals of NGO's, conservation advocates and others interest groups (Rabe & Saunders 2014; Hassan & Said 2011; Ministry of Natural Resources and Tourism 2014).



Main threats of *Piliocolobus kirkii*

Loss of habitat and habitat degradation is recognized as the greatest cause to the decreasing *P. Kirkii* population (Siex and Struhsaker 2016).

The majority of Zanzibar's human population still live a somewhat simplified lifestyle, dependent on forest products (Siex 2011). Up to 92% being depend on wood- or charcoal fires as only source of energy for cooking (National Bureau of Statistics 2014). This is estimated to cause a yearly demand of fuelwood exceeding 1,5 million m³, triggering an estimated yearly over harvest of wood approximately 800.000 m³ (Ministry of Natural Resources and Tourism 2014). These estimates are based solely on demands for fuelwood, not including the wooden furniture industry and wood for housing constructions etc., which certainly contribute a great deal, as the majority of Zanzibar's human population live in houses made using a wooden frame or palm thatch roofs on wooden roofing beams. In addition to use of trees for fuel, houses and furniture it has been estimated that more than 500 ha coral rag forest was cleared to make room for agricultural fields in 2007 alone (Ministry of Natural Resources and Tourism 2014). With a yearly population growth of ~3 % and a 2% yearly immigration rate, the agricultural needs are likely also steadily increasing every year (National Bureau of Statistics 2014). During interviews of local civilians in 2011 over 66 % of respondents answered that the rate of deforestation in their area was high / very high and that the majority of the needed forest products in their community came from government protected areas (Hassan & Said 2011).

Consequences of endangerment

It is widely believed that the Zanzibar red colobus has embraced using secondary habitat types, as a necessity, due to the lack of primary habitat, or due to habitat insufficiency (Nowak 2013; Nowak & Lee 2013). Some populations have been shown to spend up to 85% their time in the mangrove forest (*Rhizophoraceae sp.*) as a place of refugee from the frequent human disturbances and forest degradation of the adjacent coral rag forest, where the populations previously roamed (Nowak 2013).

Like other red colobus under the pressure of habitat disruption, the *P. kirkii* has also adapted it's folivorous diet to include secondary plant species and some fruits, possible because of the insufficient amounts of favored foods available (Nowak 2008; Siex & Struhsaker 1999a). *Piliocolobus* normally get their supply of water through their foliage diet, but the embrace of mangrove leaf with a higher salinity, to their diet has resulted in a frequent water drinking behavior

(Nowak 2008). Groups with more primary forest available, use mangrove forest less for foraging and equally drink water less frequently (Nowak 2008). This emphasizing that the consumption of mangrove leaves and therefore necessity of drinking water, not being a favored food source but a bearable adaption to the refuge life.

Groups living in close proximity to human settlements, in shambas or near plantations, have acquired the behavior of eating charcoal, due to phenolic acids and other organic compounds in leaves of species non-native to Zanzibar (Struhsaker et al. 1997). The charcoal apparently absorbs these compounds in exotic species like mango (*Mangifera sp.*), compounds which are otherwise toxic in higher concentrations (Struhsaker et al. 1997).

Adaptations towards a change in habitat is also seen in their social structure and foraging strategies. *Ptilocolobus* generally live, forage and travel in large multi-male/female troops of 15-80 individuals, but in habitats of poorer quality and fewer food species present, these large groups are not sustainable (Struhsaker 1975; Struhsaker et al. 2004). *P. kirkii* and other colobuses have coped with this by converting their social structure to a *fission-fusion behavior*, where the main group splits into two or more subgroups when foraging (Struhsaker 2000; Struhsaker et al. 2004; Siex & Struhsaker 1999b; Galat-Luong & Galat 2005). This intergroup fragmentation happens as a reaction to a low density or patchy distribution of available foods, presumably to reduce interspecific competition and increase foraging efficiency (Nowak 2007). On the down side the protection from predators is lower in small groups, but the near absence of any predators on Zanzibar imposes a very little predation pressure (Nowak et al. 2008).

There is very little knowledge about any instances of human poaching of Zanzibar red colobus. Possibly due to the human population being 98% Muslim, and therefore generally not being prone pursuers of bush meat (In personal conversation with locals, February 2016). A research project running from 2010–2014 regarding the conservation and management of Eastern African costal forest, listed hunting as the second largest threat to the Zanzibar wildlife after need for agricultural lands and wood fuel (Ministry of Natural Resources and Tourism 2014). The report implies that there *is* hunting on monkeys, but does not elaborate on the extent of this (Ministry of Natural Resources and Tourism 2014). It has been suggested that the monkeys have become subjects to hunting by immigrants from the mainland and other countries, and not by the native Zanzibarians. Colobus confiding to larger groups not embracing fission-fusion behavior would presumably not

be protected against human hunting as larger populations are noisier and therefore easier for people to detect. *P. kirkii* has been a protected species since 1919 and listed in Appendix 1 in CITES, which means all hunting and trading of the species is illegal (Nowak et al. 2008; CITES 2016). This protection status possibly hesitating locals in sharing knowledge of any illegal handling of the species.



Figure 5 Other colobine species are very threatened due to hunting by humans and other predators. Chimpanzee (*Pan troglodytes schweinfurthii*) feeding on a Ugandan red colobus (*Piliocolobus rufomitratu tephrosceles*). In Kibale Forest National Park local populations of red colobus are going extinct, estimating a total population drop of 89% mainly due to over predation by chimpanzees (Lwanga et al. 2011). Photo: Alain Houle.

P. kirkii groups living in proximity of shambas and feeding on unripe plantation coconuts (*Cocos nucifera*), thereby creating conflicts with local farmers, has caused chasing, trapping and poisoning of the monkeys to keep them out of crops. Research from 1999 by Siex and Struhsaker showed that the red colobus' consumption of coconut actually promoted the net coconut harvest, and this should have put an end to this pursuing threat, and farmers demanding economic compensation for nonexistent colobus crop raids (Siex & Struhsaker 1999a; Rabe & Saunders 2014).

METHODS

In the period 2004 – 2005, Dr. Katarzyna Nowak conducted fieldwork in Kiwngwa – Pongwe forest, before FR status. To simplify comparison possibilities, data collection methods have largely followed Dr. Nowak's methods. Prior to engaging fieldwork, the forest reserve was visited in August 2015 to judge the state of the transects and assess which transects could be reused.

Study Site

Kiwengwa – Pongwe Forest Reserve (Lat.: 06°00'43" S, Lon.: 039°22'01" E) is located in the Northeastern district of the main island Unguja in the Zanzibar archipelago. It is a natural forest situated only a few hundred meters from the coast, following the coastline from Pongwe to Cairo, covering a total of 33 km². The vegetation type ranges from high coral rag with a canopy height of up to 30 m to shrubs and cultivated grounds (see Appendix 1).

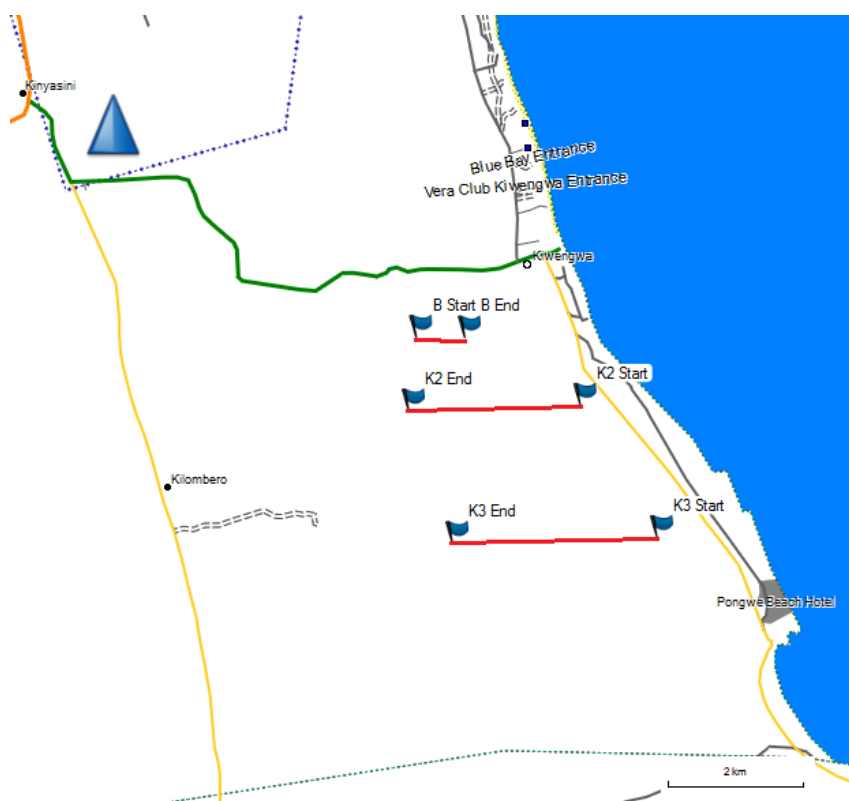


Figure 6 Location of the three transects used during transects walks. Transect K3 and K2 are placed parallel 2 km apart running from edge to edge of the forest reserve. Transect B is located close to the Mchekeni Caves visitor center, a place of higher core forest due to the water catchments in the caves. Transect walks were conducted in the direction Start - End. See Appendix 1 for additional map of study area.

Monkey census

Census of monkeys in Kiwengwa-Pongwe Forest Reserve was completed using transect walks. Prior to initiation of fieldwork I attended primate observation training in Udzungwa Mountains National Park, mainland Tanzania. Observation techniques were trained by census of *P. kirkii*'s nearest relative *P. gordonorum*, *C. mitis* (Sykes' monkeys who frequent associate of *Piliocolobus*) and *Colobus angolensis* (black and white colobus, sister genus to red colobus). Training was led by Dr. Francesco Rovero.

Transect walks in KPFR were conducted from January - April 2016, during the short winter dry season. Three transects B, K2 and K3 were traversed during census.

- **Transect B** (S5° 59.974' E39° 21.596' - S5° 59.981' E39° 21.983') north transect, 0,7 km long, located close to the Mchekeni caves visitor center.
- **Transect K2** (S6° 00.513' E39° 22.901' - S6° 00.559' E39° 21.537') middle transect, runs parallel 2 km north of K3 and has a length of 2,5 km.
- **Transect K3** (S6° 01.559' E39° 23.510' - S6° 01.606' E39° 21.884'), is the most southern transect with a length of 3 km, located 4 km from the southern edge of the reserve.

All transects run in an East – West direction at 169°.

Walks were initiated at 06:30h. (SD 0.006). This start time was chosen in order to be methodically consistent with the data collection from 2004-2005 and guidelines for observation of diurnal primates. (National Research Council 1981; Whitesides et al. 1988). The transects were traversed at a pace of 1 – 1½ km h⁻¹ starting at forest rim and moving inwards (Transects K3 and K2 in an East – West direction and transect B in a West – East direction).

During transect walks all audial and visually detected encounters with humans, dogs, human disturbances, *P. kirkii* and sykes' monkeys (*Cercopithecus mitis ssp. albogularis*) were notated. All human-related encounters, audio and visual detections, and monkeys detected by audially, were allowed 1 min stationary. Sightings of *C. albogularis* groups were allowed 5 minutes stationary and encounters of *P.kirkii* groups or mixed *P.kirkii* and *C. albogularis* groups were allowed 10 minutes stationary. Detection angles and sighting distances were detected using a field compass and a Berger & Schröter Range Finder, or in some cases visually estimated. Locations were defined as meters from transect start and all sightings of monkeys were also marked with a GPS waypoint on a Garmin ETREX 10 GPS.

Most traverses of transect B were conducted by me alone, all other walks were accompanied by field assistant Mtumwa Simai. Mtumwa is an experienced monkey observer, with a great knowledge of the terrain and safety in KPFR. Therefore, we concluded it would benefit detectability being two observers despite the possible slightly enhanced noise factor.

In cases of shorter rains, census was paused maximumly 30 minutes per walk. In case of rainfalls longer than 30 minutes total, the transect was abandoned until the following day. An individual transect was given a rest period of 72 hours between two repetition, to avoid monkeys being influenced by our presence, (Minimum recommended rest period of 36 hours (Whitesides et al. 1988)). A total of 12 census walks of each transect were completed.

Disturbance

During census walks all human disturbances detected were denoted. Locations were noted as meters from transect start and all disturbances except audio detected disturbances (like with monkey encounters) were also marked with a GPS waypoint. Detected disturbances include:

- Fresh cut trees
- Wood bundles
- Human encounters
- Wood piles, firewood, poles etc.
- Encounters with dogs (with or without human accompaniers)
- Manmade forest clearings
- Wood cutting stations
- Trash and waste dumping
- Audio detected woodcutting ex. ax, saw or chainsaw
- Detection of humans talking or walking in forest

See Figure 7 for examples of disturbances found under transect walks.

Some areas had no encountered human disturbances, because audio detected disturbances ex. hearing use of axe or chainsaw, the precise location of the disturbance can be flexible. The location where the disturbance was heard most clearly was noted as the location of the disturbance. This also applies for audial detected monkeys.



Figure 7 Pictures of human disturbance observed under transect walks. A: woodcutting station at transect K2. B: Cycad (*Encephalartos hildebrandtii*) cut for access to trees on transect B. C: Area of newly cut trees at transect B. D: poles of wood laying on transect K2. E: wood bundle found at K3. F: Waste dumped at transect K2. Photos by: Lærke Nykjær Johansen.

Vegetation sampling

Data for vegetation analysis was collected in 5×50 meter plots. Vegetation plots were placed at the start of each transect (0 m) and each 200 meters for transect K2 and K3, and each 100 meters for transect B, following locations from 2004. For highest similarity between vegetation data collected in 2004 and 2016, speciation was conducted by local botanist Tahir Abbas Haji, who also assisted in 2004.

Within each plot species and Diameter at Breast Height (DBH = 130 cm) was registered of all trees, shrubs, bushes and lianas with a height $\geq 2,5$ meters. Vegetative disturbances were registered, by measuring DBH and species of all trees cut by human activity.

Data was collected from a total of 35 plots. 7 plots on transect B, 13 plots on transect K2 and 15 plots on transect K3. The plot area 400 meters down transect K3 was not examined in 2004 because of a previous wildfire. It has because of this been excluded from further data analysis. Resulting in a total of 34 plots used in data analysis.

DATA ANALYSIS

Data were analyzed using Microsoft Excel with XLSTAT and Analysis ToolPak add-ons. Graphs and statistic tester were calculated using Graphpad Prism version 6. DISTANCE version 6.2 was used to calculate *P. kirkii* population estimations.

Distance sampling (DS)

The program DISTANCE was used to estimates population densities, group sizes and number of animals within sampling area, based on perpendicular distances. DISTANCE makes these estimates based on a detection function $g(x)$, modeled to best fit the distribution of perpendicular distance data entered. By incorporating an observer's decrease in ability to detect a given animal over distance, DISTANCE estimates a density within the sampled area (Thomas et al. 2010). A half-normal key function and a half-normal key function with a cosine adjustment were selected based on lowest Akaike Information Criterion (AIC), to best describe observation distance distributions (Chosen model 2004 AIC 394,93 < 355,81 and for 2016 AIC: 372,72 < 395,32; 396,36). Distances entered were perpendicular distances to estimated center of group, if no estimation to group center was possible, perpendicular distance to first observed animal was used. Group sizes were number of monkeys observed including lowest estimated other individuals in group, based on movement etc.

The perpendicular distance (PD) is the shortest distance from transect to observed animal, calculated by basic trigonometry. As few animals are observed in an angle to the transects, elongating the measured distance from observer to animal, the following mathematical formula is used to calculate perpendicular distance:

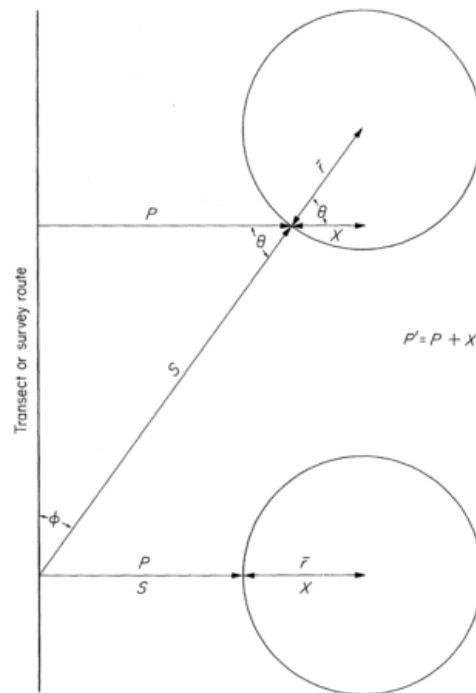


Figure 8 Techniques for observing primates during transect sampling explaining relationship between sighting angle and distance of observed animal in group, and shortest distance to transect sampled. P = perpendicular distance from transect to first observed animal, $\bar{r} = \frac{1}{2}$ mean group spread, θ = sighting angle and S = sighting distance.

$$P = S \times \sin(\theta)$$

S = Sighting distance

θ = Sighting angle

Whiteside method (WM)

For alternative estimations of population densities, sighting distances were also calculated using Whiteside method. The Whiteside method estimates an adjusted perpendicular distance P' , to calculate perpendicular distance including average group spread as a variable (Whitesides et al. 1988).

$$P' = P \left(1 + \frac{\bar{r}}{S}\right)$$

P = perpendicular distance to first observed animal

$\bar{r} = \frac{1}{2}$ mean group spread

S = sighting distance to first observed animal

Using the Whiteside method, the detection function to best fit the distribution of data was, for 2004 a half normal key function (ACI 371,53<372,31) and for 2016 a half-normal key function with a cosine adjustment (ACI 423,96<424,31).

Population structure

Encounter rates from and cluster size was analyzed using a two-tailed Mann-Whitney U test, to test for different encounter rates and cluster sizes on same transect, and between the two sampling years. To test for significant difference between transects within one sampling year, Kurskall-Wallis tests, and a Dunn's multiple comparison test were used. To test for bias in sampling effort due to difference number of repeated walk at each transect in 2004 a Chi square test. I did not find a sampling bias ($\chi^2=2,93$, DF=2, p=0,23).

Vegetation analysis

To test if the vegetation data followed normal distribution, I used D'Agostino & Pearson omnibus normality test. To compare vegetative differences at each transect between the two years, I used a Pairwise Student's T – test. For testing differences between DBH of trees cut compared to DBH of live stems in plot, I used a Wilcoxon matched-pairs signed rank test. To test if there was a significant difference between the transects within the same year, I used a one-way Anova on plot mean DBH, and a Kurskal-Wallis test on mean number of stems in plot, mean cut stems per plot, proportion of cut stems per plot and mean DBH of cut stems. To test if transects within one sampling year varied, I used a Dunn's multiple comparison test.

Correlations

To test for correlations between parameters of geographical, population, vegetation and human disturbance related character, a Spearman's correlation test and linear regression tests were used.

Mapping

To construct maps, I used QGIS V. 2.12.1 with a GRASS V. 6.4.4. extension. Digital satellite photos were generated from Google earth version 7.1.2.2041 (Google Inc. 2016). Data layers from 2015 are generated mathematically from satellite pictures, where similar objects/structures are assigned the same color.

RESULTS

Population analysis

AIC was lower for 2004 results generating a better fit detection function $g(x)$, for the observation data using both perpendicular distance calculation methods (ACI; 2004 DS: 353,84 WM: 371,53, 2016 DS: 394,92, WM: 423,96). Both methods estimated densities (groups/km²) larger in 2016 than in 2004, but also with higher standard errors (Density; 2004 DS: 6,49±1,48, WM: 4,60±1,17, 2016 DS: 12,95±5,36, WM: 6,42±3,42). The estimated average group sizes vary very little between years of the same method, but groups were calculated to be approximately one individual larger using Whiteside method (DS: 2004: 6,56±0,49, 2016: 7,66±1,15, WM: 2004: 7,66±1,15, 2016: 7,10±0,87) (table 1 and 2).

Table 1 Population estimates from Distance sampling with standard error

	AIC	DENSITY GROUPS/KM ²	INDIVIDUAS /KM ²	GROUP SIZE	N COLOBUS IN AREA
2004	353,84	6,49 ± 1,48	40,03 ± 10,16	6,56 ± 0,49	240 ± 60,92
2016	394,92	12,95 ± 5,36	87,66 ± 37,88	6,77 ± 0,84	526 ± 227,31

Table 2 Population estimates from Whiteside method with standard error

	AIC	DENSITY GROUPS/KM ²	INDIVIDUAL S / KM ²	GROUP SIZE	N COLOBUS IN AREA
2004	371,53	4,60 ± 1,17	35,30 ± 10,41	7,66 ± 1,15	212 ± 65,52
2016	423,96	6,42 ± 3,42	45,62 ± 24,92	7,10 ± 0,87	274 ± 149,63

Encounter rate

Encounter rates for 2004 and 2016 were calculated as average numbers of colobus groups encountered per kilometer traversed. The average encounter rates for 2016 (2016 B: $1,79 \pm 0,65$, K2: $0,80 \pm 0,74$, K3: $0,42 \pm 0,25$) are in general higher on all transects than in 2004 (2004 B: $0,83 \pm 1,29$, K2: $0,46 \pm 0,15$, K3: $0,30 \pm 0,30$),

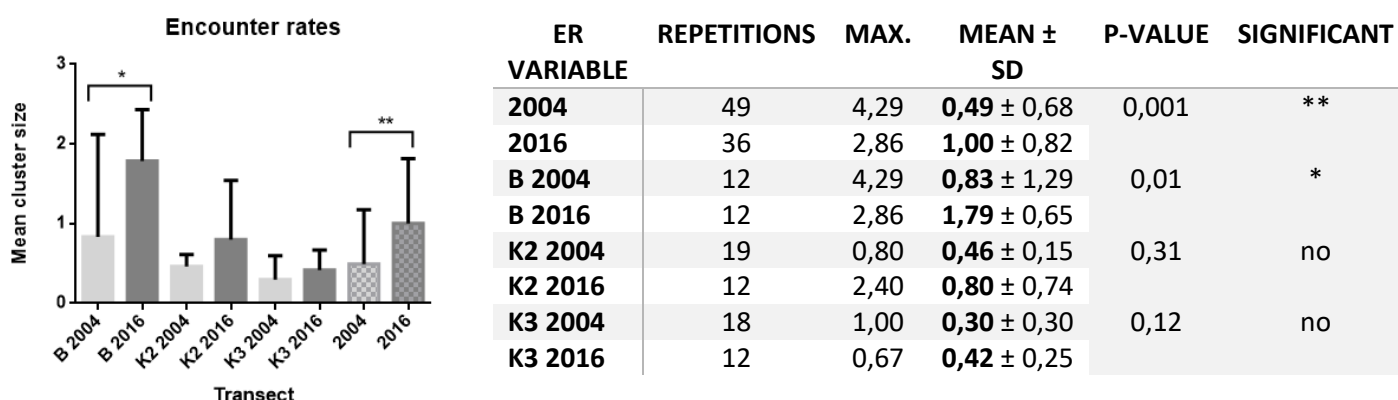


Figure 9 Encounter rates for all three transect in 2004 and 2016

several of the transects also showing a larger variance. A Mann-Whitney U test showed a significant difference between the overall encounter rate of 2004 and 2016 (Mann-Whitney U=527, $p < 0,001$) and also a significantly higher encounter rate on transect B in 2016 than in 2004 (Mann-Whitney U=30, $p = 0,01$). There was not found a significant difference in encounter rates on transect K2 and K3 between 2004 and 2016 (Mann-Whitney U: K2=91,50, $p = 0,031$, K3=75, $P = 0,12$).

Multiple comparison of encounter rates within each sampling year determined, significantly more colobus encounters at transect K2 than at K3 in 2004. Within 2016 encounter rates were significantly higher at transect B as shown in Table 3.

Table 3 Comparison of encounter rates within each sampling year.

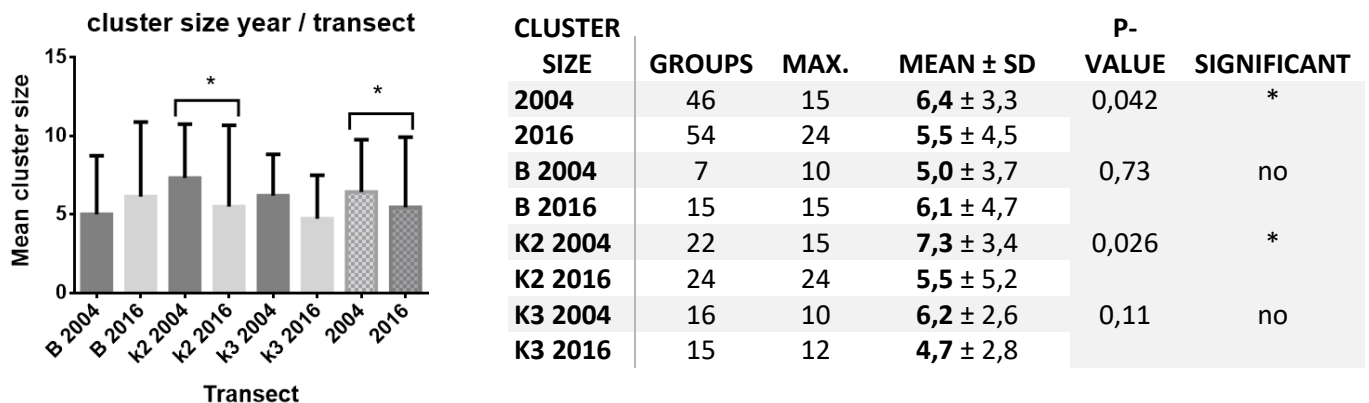
KRUSKAL-WALLIS TEST ON ENCOUNTER RATES 2004		SIGNIFICANT	SUMMARY
P - VALUE	0,0027	Yes	**
DUNN'S MULTIPLE COMPARISONS TEST	Mean rank diff.	Significant	Summary
K2 2004 VS. K3 2004	15,56	Yes	**
K2 2004 VS. B 2004	9,333	No	ns
K3 2004 VS. B 2004	-6,222	No	ns
KRUSKAL-WALLIS TEST ON ENCOUNTER RATES 2016		Significant	Summary
P - VALUE	< 0,0001	Yes	****
DUNN'S MULTIPLE COMPARISONS TEST	Mean rank diff.	Significant	Summary
K2 2016 VS. K3 2016	5,5	No	ns
K2 2016 VS. B 2016	-13	Yes	**
K3 2016 VS. B 2016	-18,5	Yes	****

Group size means

The largest mean size of groups observed classified by transect, was in 2004 found at transect K2 ($M=7,3$, $SD\pm 3,4$) and in 2016 on transect B ($M=6,1$, $SD\pm 4,7$). Average cluster sizes were larger at both transect K2 and K3 in 2004 (2004 $M\pm SD$: $K2=7,3\pm 3,4$, $K3=6,2\pm 2,6$) than in 2016 (2016 $M\pm SD$: $K2=5,5\pm 5,2$, $K3=4,7\pm 2,8$). The smallest average cluster size was in 2004 at transect B ($M=5,0$, $SD\pm 3,7$) and in 2016 at K3 ($M=4,7$, $SD\pm 2,8$). A Mann-Whitney U test confirmed a significant difference in mean cluster size, being lower in 2016 ($M=5,46$, $SD\pm 4,48$) than in 2004 ($M=6,43$, $SD\pm 3,32$) (Mann-Whitney U = 949, $p = 0,04$). A Mann-Whitney U test also showed that the average cluster size has dropped significantly on transect K2 (Mann-Whitney U = 163,5, $p=0,03$) but had not changed significantly at transect B (Mann-Whitney U = 47, $p=0,73$) or K3 (Mann-Whitney U = 79, $p=0,11$). Within each sampling year, there was not found a significant difference in cluster size between the transects (Kruskal-Wallis test; DF (2004) = 45, DF (2016) = 53, P (2004) = 0,29, P (2016) = 0,8).

A total of 45 *P. kirkii* groups were observed in 2004 versus 54 in 2016. Singletons and smaller groups were observed more frequently in 2016 than during census in 2004 (Appendix 4). In 2004 6 observations (13%) were singletons or doubletons. In 2016 15 observations (28%) were singletons or doubletons. Singleton observations were most frequent at transect K2 both years. Transect K2 was overall the transect with most observations, holding 22 observations in 2004 (48% of all observations in 2004) and 24 observations in 2016 (44% of all observations in 2016). The largest group observed in 2004 ($N = 15$) was observed at transect K2, likewise the largest single group of colobus observed in 2016 ($N = 24$) was also observed at transect K2.

Figure 10 Cluster size means + 1 SD of each transect and overall mean for 2004 and 2016 and Mann - Whitney U test.



VEGETATION ANALYSIS

A total of 9293 and 5428 live stems were measured within the 34 analyzed vegetation plots in 2004 and 2016. This is a reduction of 41,6% in forest density over the 12 years between samplings. The average number of stems in each plot has dropped significantly between the two sampling years (Pared T-test=6,83, DF=33, $P < 0,0001$), and at all three transect (Pared T-Test: B: $T=3,2$, DF=6, $P=0,0186$, K2: $T=6,97$, DF=12, $P < 0,0001$, K3: $T=3,67$, DF=13, $P=0,0028$). Stem density has dropped notably most at transect K2, and least at transect B (Figure 11A). Average total diameter in each plot has undergone the same significant reduction as stem density (Pared T-test=6,52, DF=12, $P < 0,0001$), shown in Figure 11B. The reduction in diameter is more significant than the reduction in mean number of stems at transect B (Pared T-test=5,35, DF=6, $P=0,0017$). The number of cut stems in each plot averaged for each transect, is highest at transect K3 in 2004 and descending to transect B with fewest average cuts per plot. In 2016 there is an opposite tendency with most cuts per plot at transect B and fewest at transect K3 (Figure 11C) (Pared T-Test: B: $T=2,83$, DF=6, $P=0,03$, K2: $T=0,89$, DF=12, $P=0,4$, K3: $T=2,26$, DF=13, $P=0,04$). The shift in where more cut stems were observed more or less equalizes each other. The year average for 2004 and 2016 are very close to each other not significantly different (pared T-test=1,8, DF=33, $P=0,08$). It is also worth noticing that the variance in the data is considerably higher at K2 and K3 in 2004 than in 2016.

The diameter sum of cut trees follow the same tendencies as number of cut stems in each plot being significantly larger at B 2016 (pared T-test=6,42, DF=6, P=0,0007) then anywhere else (Figure 11D).

Because the stem densities vary so significantly between the two years, comparing proportions of cut trees of plot total stem density may be more descriptive to illustrate vegetative disturbance levels. Here we find no significant difference between the two years in proportion of cut stems in plot, though 2016 is a fraction higher (Wilcoxon=177, P=0,13) (Figure 11E). The number of cut stems removed from each plot compared to how many live stems are found within the same plot is on average significantly higher on transect B in 2016 than in 2004 (Wilcoxon=28, P=0,016). At transect K2 the proportion is higher in 2016 and at K3 it is lower, but here neither are significant (Wilcoxon: K2: W=49, P=0,09, K3=-17, P=0,63). Comparing diameter proportions, also here there is a significant difference in proportions at transect B (Wilcoxon=28, P=0,016). The mean is larger in 2016 at K2 (M=0,19 SD=0,13) and K3 (M=0,16 SD=0,15), but the difference is not significant (Wilcoxon: K2 W=31, P=0,3, K3 W=15, P=0,67). Overall the proportion is larger in 2016 than in 2004. The variance at the different transects is here also fairly large (Figure 11F).

Significant results of multiple comparison of the above-mentioned parameters within sampling years are summarized in Appendix 5, including results and further analysis with Dunn's multiple comparison test, if Kruskal-Wallis test showed a significant result.

In 2016 there is only found a within year difference in total diameter of cut trees. The total diameter of cut trees at transect B is significantly bigger than the total diameter of cut trees at transect K3. In 2004 transect B is significantly different from one or both transects at several parameters. Transect B has significantly less stems per plot than transect K2 and K3. K3 has significantly more cut stems per plot than transect B, and the total diameter of cut trees in plot is significantly lower at transect B than at transect K2. The average DBH proportion of cut trees of plot total DBH was significantly lower at transect B in 2004. Average proportion did not vary between transect K2 and K3.

Species composition and abundance

A total of 141 species of trees, shrubs and lianas were found in the two sampling years. 119 species in 2004 and 75 species in 2016, totaling 61 species shared between the two sampling years. 58 species found in 2004 were not found in 2016, and 14 new species were found in 2016 (a total

species list can be found in Appendix 7). Of the 58 species not found in 2016, 6 have only been identified to genus level. Five species are only known by local Swahili name and do not yet have a scientific name. 14 stems or stumps, out of a total of 6226 live and dead stems measured where unknown or unidentifiable in 2016, and 63 out of 10440 in 2004. In both cases an identification rate of >99%. In average 5,9 fewer species were found in each vegetation plot. Some species more common in 2004 have been lost from several plots. One of the more common species *Euclea schimperi* has disappeared from 22 of 34 plots. 30 of the 58 species not found in 2016 were locally rare only found in a single vegetation plot. The plot that had undergone the highest species decline is the rim plot (B0000) from 0-50 m at transect B (N= 11) followed rim of transect K2 (K22400) (N=9).

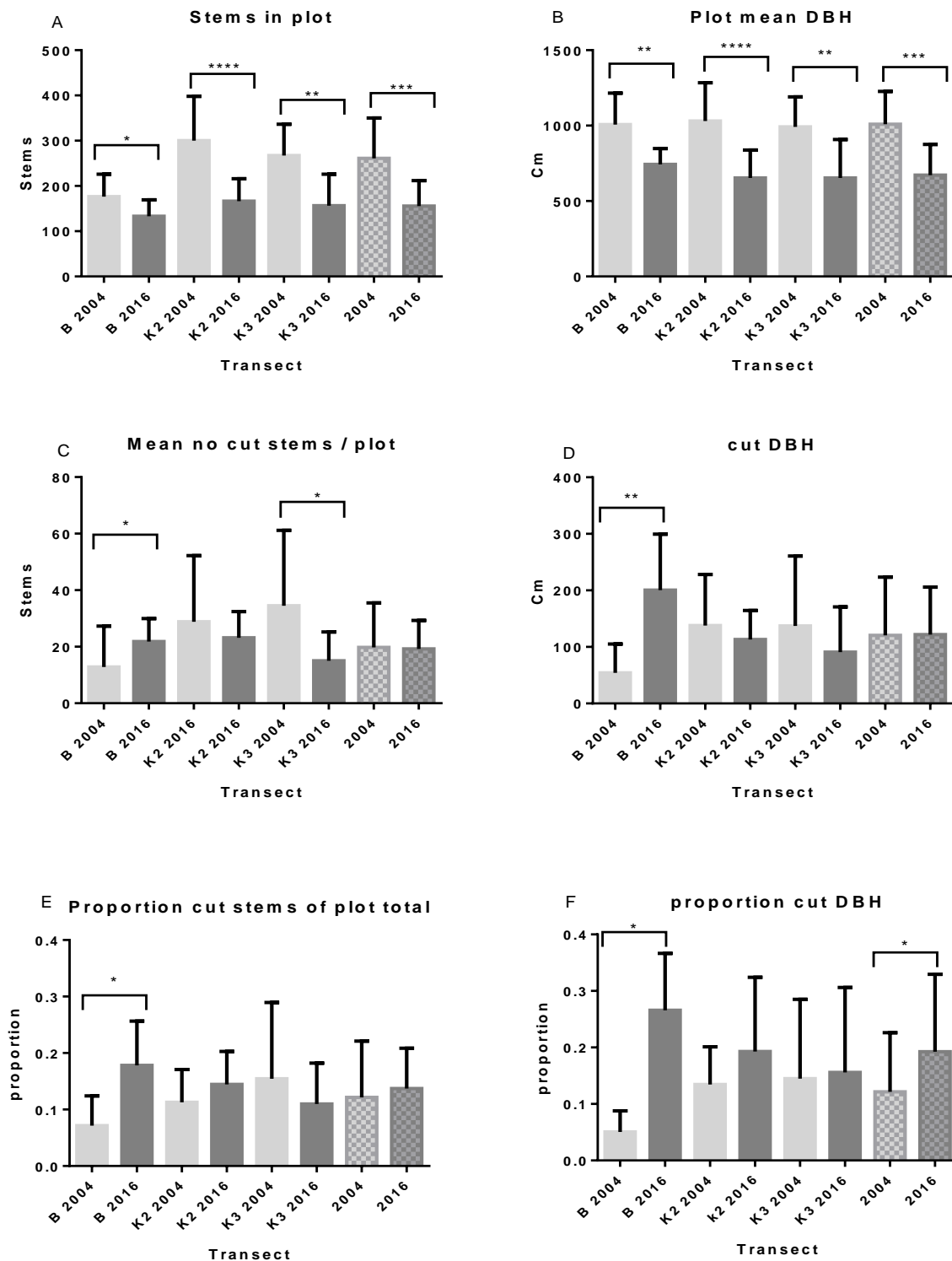


Figure 11 Results of vegetation analysis. A: analysis of average number of stems in plot B: average total DBH for each plot C: Mean number of cut stems per plot D: Average DBH of total cut stems in plot E: average no of cut stems in plot of plot total number of stems F: average DBH of cut stems compared with plot total DBH.

CORRELATIONS

At total of 19 parameters of interest covering, *P. kirkii* abundance (*P. kirkii* abbreviated as colobus), vegetation quality, disturbance indicators, food species availability, geographical parameters and DBH measurements where analyzed for correlating effects in the spearman's correlation map in Figure 12. Correlation range from positive correlation to negative correlation in a red – blue scale. Of the 361 comparison of parameters, 47 significant positive and 14 significant negative correlations were found. Correlations summary of correlation parameters and significant correlations can be found in appendix 8.

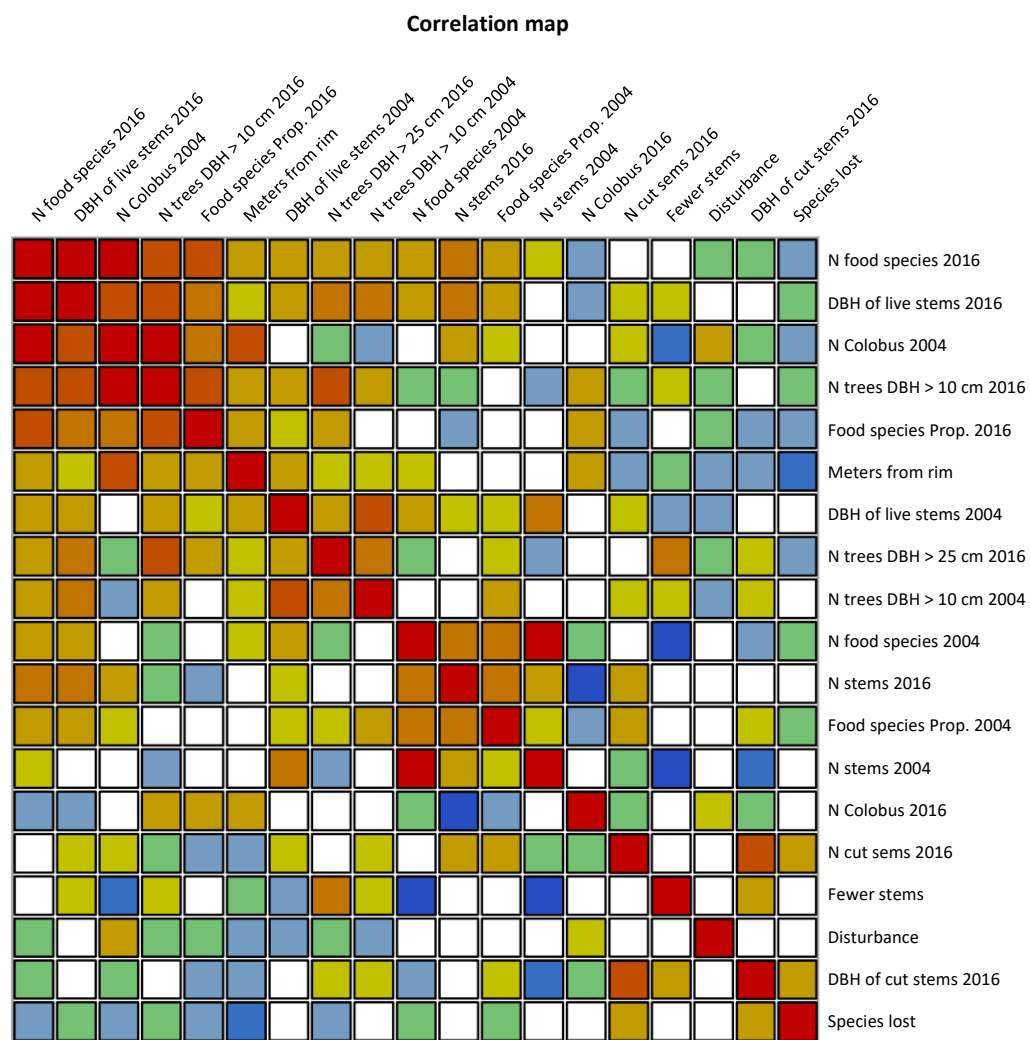


Figure 12 Correlation map on 19 variables. Correlation range +1 to -1 in a red to blue color scale. White is correlations between -0,1 - +0,1, yellow and green are respectively +0,1 - +0,2 and -0,1 - -0,2.

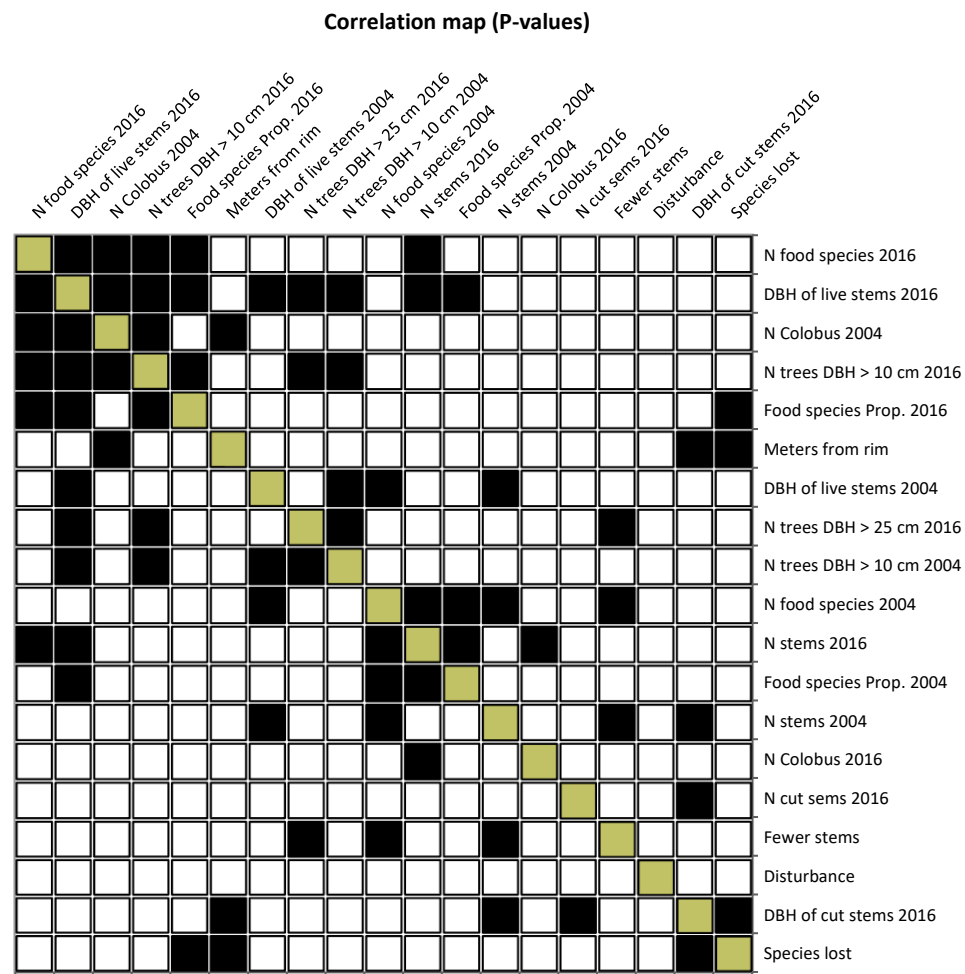


Figure 13 Significance levels for correlation mad. Black squares represent a significant relationship between the two variables.

HUMAN DISTURBANCE

Human disturbances recorded along transect while traversed during census are showed in Figure 14. There has been an increase in level of disturbance along forest rim at approximately 0 m and 3000 m.

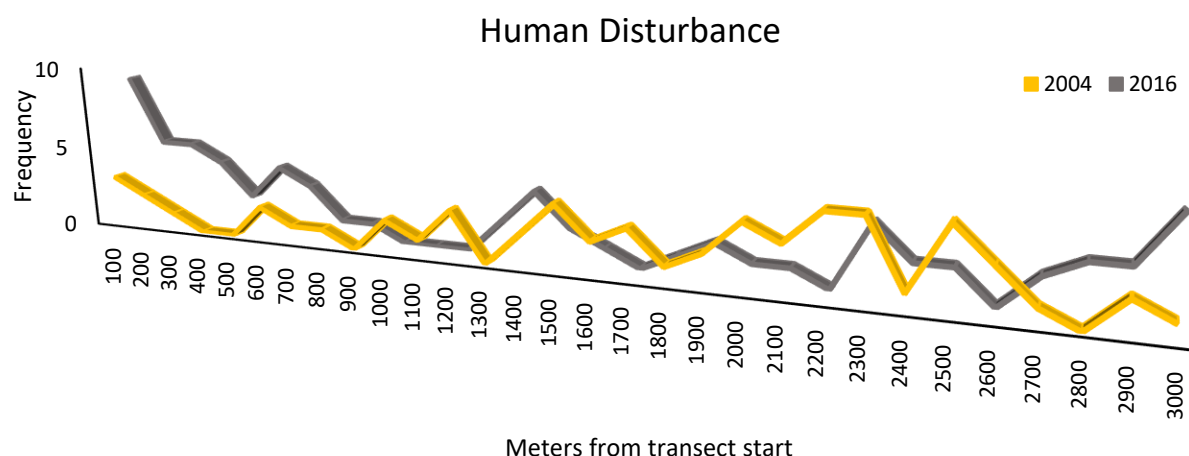


Figure 14 Frequency of human disturbances recorded along transect walks.

Linear Regression

The location of observed human disturbances and *P. kirkii* monkeys can best be described as distance 0-1500 m from forest rim, 1500 m being furthest from any forest border/rim. The linear regression fit to best describe the tendencies observed in locations of humans and *P.kirkii* monkeys, shows that humans were more frequent closer to forest border and colobus being more frequent the further you get from forest rim. The linear regression has a better fit description of the tendencies in location of human disturbances, describing 32% of the data whereof only 10% of the large variation in colobus data can be describe by a linear relationship to location.

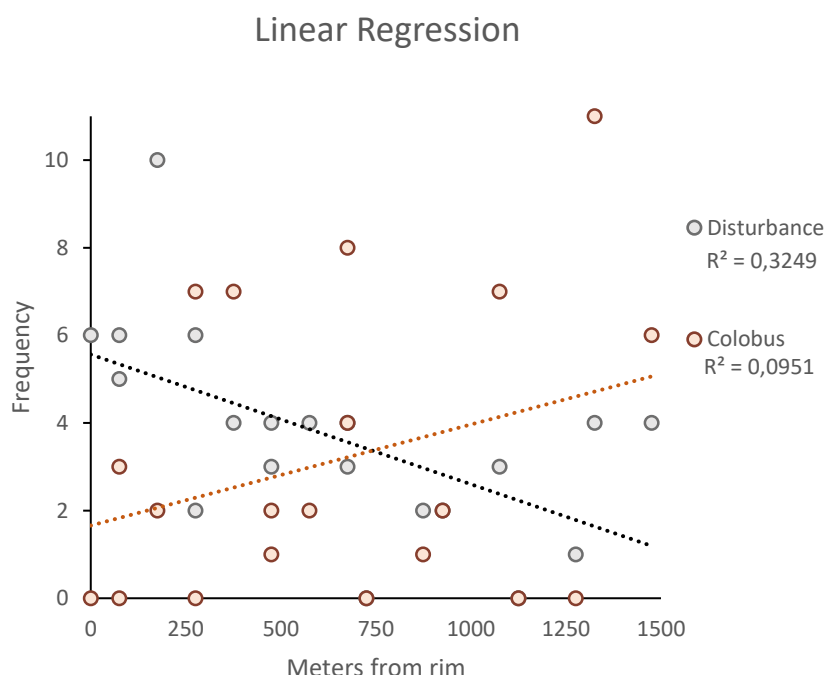


Figure 15 Linear regression on located observed colobus and human disturbances at K2 and K3.

The relationship between human disturbance and vegetative changes were further analyzed with linear regression tests. All four linear regressions are fairly scattered, but some assumptions can be made on the found. There was not found a relationship between the number of species that had been lost from a plot and the fluctuations in the number of stems in plot. Comparing the number of stems cut in a plot with number species lost from plot, there is a relatively clear tendency towards more species not being found where plots had been subjected to a higher level of woodcutting. There was a linear negative relation between how deep in the forest reserve the vegetation plot was (e.g. meters from rim or forest edge) and how many species were not re-found in the plot. More species have been lost at the forest edges than at the core of the forest. Also, when comparing disturbances encountered during transect walks and species lost in same area there was found a positive tendency describing the relationship. Encountered human disturbances are only registrations from 2016 and include all transects. Some areas had no encountered human disturbances, but because audio detected disturbances ex. hearing use of axe or chainsaw, humans talking and dog barking, the precise location of the disturbance can be flexible. The location where the disturbance was heard most clearly was noted as the location of the disturbance. This contributes some of the variation in the regression relationship which explains approximately 9 % of the variation in the data. The regression between cut stems, meters from rim and species loss describe respectively 12 % and 24 % of the variation.

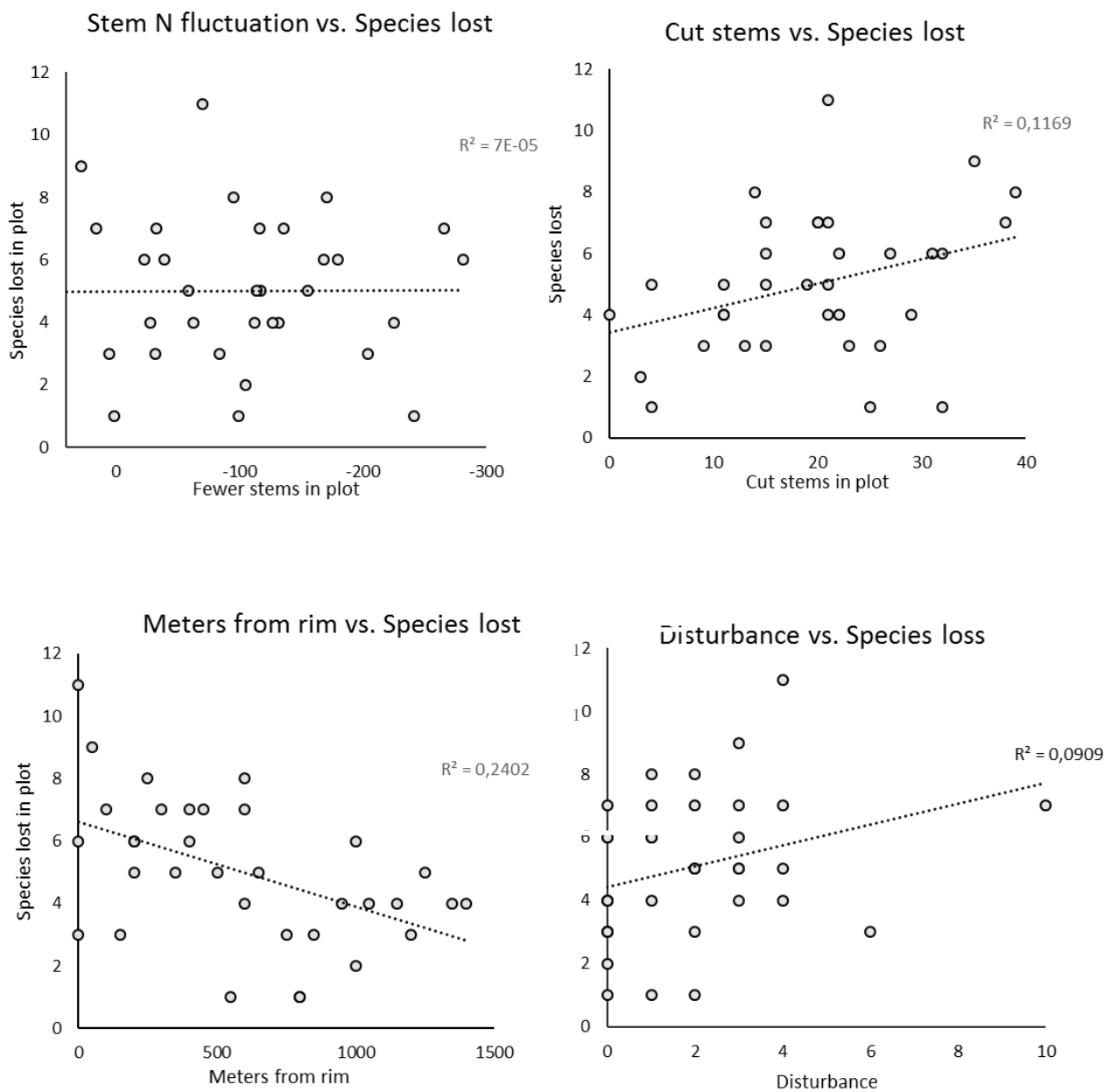


Figure 16 Linear relationships between the different parameters that are used as a proxy for human disturbance.

DISCUSSION

In this thesis, I studied *P. kirkii* along three transects. I estimated population density and structures, and will in this discussion summarize and outline how these findings correlate to habitat and human disturbances, in the two sampling years. Furthermore, I will discuss what alternatives approaches could improve this work and also relate my findings to other relevant studies.

Both methods for estimation of *P. kirkii* density, showed a higher density in 2016 than in 2004. This is consistent with the significantly higher encounter rate also in 2016. The overall significant difference in encounter rate is largely due to the large difference in ER at transect B.

The within year comparison of transects ER, showed that the colobuses (*P. kirkii* implied) in 2004 were encountered more often in the area around transect B over transect K3, and transect K2 over transect B, but there was only found a significant difference between K2 and K3. In 2016 colobuses were much more frequently observed at transect B than anywhere else in the studied area. ER was still higher at K2 than at K3 but statistically not significant. Finding collectively emphasizes a shift in where colobus roam in higher numbers and prioritizing of area from north to south, transect B to transect K3, becoming more pronounced in 2016.

Together with population estimates, this implies that there has been an overall increase in colobus abundance, and the increase is most pronounced at transect B in the Mchekeni area.

DISTANCE SAMPLING

The two calculation methods used to estimate population density, generated quite difference population estimations, though with uncertainties both methods estimated a higher colobus density in 2016 than in 2004. This is consistent with the significantly higher encounter rate also in 2016, but the encountered groups were also significantly smaller, on average by one individual.

It is generally accepted by primatologist that a minimum 60-80 observations are required for proper populations estimations (Marshall et al. 2005). The total observations for both years fall far shorter then general requirement, making population estimates based on an inadequately small dataset.

Secondly there is in both sampling years a very low detection within the first 5 m from the transect. This could imply violation of the two first assumptions in line transect surveys 1) that all animals on transect (0m distance) are detected, 2) that animals do not move before detection (National Research Council 1981). I cannot argue against these possible violations, but as this lack in observation has occurred equally in both sampling years, it should not be consequential for the comparison of the data. This neglect in observations in close proximity to the transect could be because of misted or bad observation skills, but it could also plausibly be because the colobus in general stay further away from the transects. This because the transects in 2016, obviously were used relatively often by locals as a common path for entering and exiting the forest (personal observation). Only short parts of the transects had to be reopened at the start of the field work. This mostly being parts of lower vegetation and shrubby areas, probably of less interest for the locals to gain access to. To decrease accessibility for local use, the path width had been kept to a minimum. This also mean that it can be difficult to survey without generating any sound when, due to dens understory brushing against legs. As transect walks were conducted during dry period, where forest floor leaf litter was extremely dry generating noise despite an effort tiptoeing on more solid rocky underlay. Colobus could possibly have detected our sound and fled to a further distance why using animal-to-observer distance (AOD) in this case possibly could have been a better approach for calculation of detection functions. There is an ongoing scientific discussion on which method should be used to estimate population densities (Hassel-Finnegan et al. 2008). Both methods used in this study were based on perpendicular distance, but animal-to-observer distance have been used when surveying populations in JCNP (Siex & Struhsaker 1999b). Due to the low detection, nearest to the transect, of that ever reason this is caused, it could in the future be a possible better approach using AOD also when sampling in KP.

The densities calculated for 2016, showed a large variance, why the results should not be interpretation as definite populations sizes, but implied estimations. As the results are higher in 2016 using both calculations, I have chosen to interpret the results suggesting that the sampled area in KPFR holds an undefined, but slightly density of colobus now then in 2004. The inaccuracies are also likely due to the reduced data set.

GROUP SIZE

Singleton or doubleton observations had become more common in 2016. Observed groups were overall significantly smaller in 2016 than earlier observed. Even with the observation of the exceptionally large group at transect K2 (N=24) during 2016 survey, the average group size at transect K2 was significantly smaller than in 2004.

Earlier studies have shown large fluctuations in cluster size between forest core and edge, and have therefore been estimated separately (Nowak 2007). The smallest ever reported population size for *P. kirkii* of average 5,5 individuals, was from observation of edge groups in KPFR (Nowak 2007). The fact that the 2016 overall mean population size (core and edge forest of all transects together), is equal to the lowest earlier reported, is somewhat worrying for the conservation status of *P. kirkii*. To why this is worrying I will elaborate on later in the discussion.

Methodically the data from 2004 was collected over a 12-month span covering all seasonal changes, where 2016 data was collected over a 3-month span within one season, weakens the reliability of comparisons. And indeed, the collection over a longer time span would give a more precise population estimate despite seasonal changes. The 2016 data were as mentioned collected during the winter dry season, where infant recordings in Kiwengwa peak (Nowak & Lee 2011). This means 2016 population estimates and cluster size averages in fact may be overestimated due to a possibly higher infant rate. Earlier studies also imply a lower infant survival rate in KPFR and other more disturbed habitats, compared to population living in stable habitats in JCNP, or with access to refuge in mangrove forests, also emphasizing that the very low average group size still possible could be an overestimation (Nowak & Lee 2011; Siex & Struhsaker 1999b).

Group size is largely determined as a compromise between foraging investment, resource availability and protection from predators in larger numbers (Struhsaker 2000). As we know there are hardly any larger predators on Zanzibar, and hunting upon colobus is restricted, this therefore not imposing a necessary limitation to minimal population sizes. Investigation of *P. gordonorum* group size showed a significant decrease in population size in human disturbed areas (Marshall et al. 2005). Human encounters in KP during census has increased at forest rim, but using N cut stems per plot as a proxy for disturbance, there was not found a significant difference between the two sampling years, though there has been a shift from transect K3 to B in location of greatest number

of stems harvested. As colobus are highly social animals, where population sizes have earlier been reported this low, it has been addressed as the possible minimum bearable limit of red colobuses essential ecology and requirement for social interaction (Marshall et al. 2005).

Variation in group size has also increased at all locations which could indicate a home range overlap between populations of different sizes. As this could compromise safety of smaller groups, I suspect the local variation in group size may be caused by smaller groups representing foraging parties that have split from larger social groups.

Fission-fusion behavior has earlier been observed in KP, where groups in core forest showed to split into ≥ 2 foraging subgroups in 72% of observations (Nowak & Lee 2011). Adaptation to fission-fusion behavior has been documented in several *Ptilocolobus* species, to increase foraging yield and decrease intergroup competition, in habitats with clumped food resources, low species diversity and large home ranges needed to cover dietary requirements (Marshall et al. 2005; Nowak 2007; Struhsaker 2000; Struhsaker et al. 2004) *P. gordonorum* display fission-fusion behavior in heavily human disturbed areas, as such a displayed flexible group structure may be a necessary adaptation to living in an inadequate human dominated habitat (Nowak & Lee 2011; Marshall et al. 2005).

Where colobuses were observed more frequently in KP, cluster size also tend to be larger, indicating a habitat able to sustain more colobus, as mentioned group size is simultaneously largely determined by habitat quality (e.g. food available ect.) (Siex and Struhsaker 1999b; Struhsaker 1975). Arguing that the decrease in population size observed in KPFR could be an indicator of a reduced habitat quality and increase in disturbance.

Also, this could imply that *P. kirkii* in KPFR indeed do prefer higher coral rag forest as main habitat, but can embrace other habitat types, if conditions are right and if there is a sustainable diversity in available food sources. This is supported by an investigation by Siex (2011) where five different habitat types between KPFR and JCNP, where examined only finding *one* sign of *P. kirkii* presence outside high coral rag forest, opposed to 27 within (Siex 2011). These tendencies were furthermore consistent throughout investigated areas on the whole island.

VEGETATIVE OUTCOMES

Vegetation analysis showed that the forest density and likewise mean DBH has dropped significantly most at transect K2. In 2004 there was a significant higher amount of woodcutting at transect K3 than anywhere else. This has decreased significantly and there has instead been a significant increase in wood harvest at transect B. In most places of the forest, the stems harvested by woodcutters are thin, rarely with a diameter above 5 cm, purposely to make small household fires for cooking. During walks at transect B we observed harvest of very large trees, much more frequent than at other transects, which is also indicated by the bias between number of cut stems and the very high DBH of cut stems at transect B. This is why several factors for vegetative human disturbance have been included in the vegetation analysis, and to investigate if there was a bias in tree harvested in comparison to mass and density available the two proportional differences (proportion of cut stems of total stems in plot and proportion cut DBH of plot total DBH). The results showed bias at transect B possibly because of the easier transportation of larger trunks by accessing to the forest from the road to the Mchekenji caves visitor center.

Of the species found and not re-found not much is to be said about their conservation state as very few species have been evaluated by any conservation agency. Of the eight species evaluated by IUCN or CITES, *Encephalartos hildebrandtii* is the only one under concern, listed as near threatened (NT) with declining population size (Bösenberg 2010). Special notice has been made to sub-population rapidly being destroyed on Zanzibar, due to the growing demand for agricultural grounds, tourism and local urban development (Bösenberg 2010). During census, we experienced several cases of *E. hildebrandtii* that had been cut to gain access to trees behind the cycad.

Of other evaluated species, *Erythrococca berberidea* is listed as of least concern, due to great protection in South Africa. Subpopulations of *E. berberidea* in Tanzania are considered threatened due to continuous degradation of habitat in protected areas, but this concern seems to be focused on two forest reserves in proximity of Dar es Salaam and does not list any detail on Zanzibar distributions (IUCN SSC East African Plants Red List Authority 2013a).

Of specimens only identified to genus level *Turraea* has 29 species whereof five have been evaluated by IUCN. Four species are listed as vulnerable, endangered or critically endangered. Due to distribution, endemism and ecology, the species found in KPFR is undeniably, not one of

the threatened species. The species could likely be *Turraea mombassana* a very common shrub in costal forest shrub land forest, or *Turraea floribunda* a species which was found in 2016 (IUCN SSC East African Plants Red List Authority 2013b).

In 2016, 19 individuals of *Dovyalis macrocalyx* were registered. I suspect that the unknown *Dovyalis* species found in 2004 is also *D. macrocalyx* a relatively common species in fringing forest but with no previous official records in Zanzibar (Hyde et al. 2016).

Psychotria bibracteatum and *Psychotria goetzei* were both found in 2004 and 2016. A third unknown *Psychotria* was also found in 2004. *Psychotria* has a very long list of IUCN evaluated species. Several critically endangered. It is not possible to determine which species the sample from 2004 is, or if it is endangered or not. Other evaluated species that have not been identified to species level do not have any threatened or endangered species with a likely range on Zanzibar. The main concern should be focused towards conservation of *E. hildebrandtii* as it also is an important *P. kirkii* food species and is occasionally excavated for ornamental purposes in hotel gardens. More knowledge on species distribution on Zanzibar and a thorough investigation or publication of collected data is desirable to further investigate if the consequences of the ongoing wood cutting on Zanzibar for floral species composition.

Human disturbance showed to have a negative interference on species composition. Plots were placed as precise as possible in the same locations to analyze species composition in a capture - recapture method. As several new species were found in 2016 which were not present in 2004, there is a high chance some of these *new* species have the same functional traits and a species turnover has occurred. Even taking this into consideration the species richness has still dropped considerably and probably most remarkable is, that richness has dropped in accordance to increasing human activity.

CONSEQUENTIAL RESULTS

Food species availability showed a positive correlation *P. kirkii* location, though not significant. Correlations with distance to rim and abundance of larger trees outline that food is patchy distributed in core forest with bigger trees and in more shrubby areas, where smaller groups were encountered, believed to be foraging parties. This also explains why correlations and linear regressions with location of colobus are weak or not significant. Encounter rate and group size was higher in higher coral forest, but shrubs were occasionally visited, splitting correlations.

Shrubby areas are often closer to higher levels of disturbance and I believe this reflects on the relation to colobus habitat use. Seasonal changes in available foods is larger in coral rag forest than in cultivated shambas. This has elsewhere led to extremely inflated population densities of 550 individuals/km² (Siex & Struhsaker 1999b). This has earlier been misinterpreted as a habitat preference where I support the original findings concluding that this is an exceptional case only possible because of dietary diversity requirement satisfied in the adjutants NP, as *Piliocolobus* have high dietary diversity requirement (Siex & Struhsaker 1999b; Siex & Struhsaker 1999a; Onderdonk & Chapman 2000). Colobuses were occasionally observed in smaller groups closer to forest edge right after sunrise. During return from transect walks at midday, groups had often retreated to the core forest for midday rest in the shade of the greater canopy cover. As these observations were outside of census they have not been included in the analysis but does nonetheless point out some population behavioral tendencies.

During studies in 2004 two adjacent transects, K1 and K4 were also traversed. These transects were not used during this recent study as they were not revivable. They would have required a lot of work clearing the transects possibly having greater consequences for the forest and was also prohibitive due to time limitations. The area around transect K1, located north of the main road to Kinyasini, has been completely cleared of higher coral forest and is now a patchy shrub forest. Interviews with locals and investigation of the area showed no signs of colobus monkeys living in this area. The increase of both colobus and wood cutting at transect B in Mchekeni, located south of the main road may have happened as a reaction to the degradation of the northern transect K1 area.

With disturbance in general being higher towards forest rim it could indicate the forest reserve being degraded from forest borders and inwards, causing a higher deforestation from north and south edge of the forest reserve, where transect K1 and K4 were located. Areas at the north and south boarder have previous been proposed as “high protection zones” because of being crucial for continued survival of Zanzibar wildlife, and experiencing extensive threat, demanding excessive protection (Siex 2011).

Population estimates predicted an advancement in total abundance of colobus within the sampled area, which is not consistent with the tendencies in group size, vegetation and disturbance, why I can only argue that the elevated population size, could be a result of population compression from north, south and rim inwards. Population compression is a phenomenon within *Piliocolobus* history and has earlier been predicted in *P. kirkii* in other areas of Zanzibar (Nowak 2007). Population compression occurs as a result of habitat loss or degradation, causing inflated population densities by immigration to more adequate habitats (Struhsaker 2010). Without vegetation analysis population densities, can be a very misleading indicator of habitat quality (Siex & Struhsaker 1999b).

I believe the population compression is due to immigrations from these northern and southern areas of the reserve, to Mchekeni and core forest areas.

Because of the simultaneous high human and colobus activity at Mchekeni, the general picture from transect K2 and K3 of colobus preferring less disturbed central/core areas of the reserve and humans dispersing with opposite tendencies, cannot be transferred to Mchekeni. Additionally, as transect B being so short and the ecological structure of the forest in this area being quite different from the overall compositions the tendencies in this area understandably very from the rest of the transects. The vegetative indicators of human disturbance observed at transect B, specifying a rising human-colobus conflict, between where monkeys are more abundant and the increased human activity.

MANAGEMENT STATUS

As mentioned, The 2013 list of Priority Primate Areas, listed Kiwengwa – Pongwe Forest Reserve as of special interest for the protection of the endangered Zanzibar red colobus (Davenport et al. 2013). In general, there is an array of different boards, groups, organization and councils to manage and oversee the nature and conservation of Zanzibar, embracing the importance of integrating the local community and their needs in conservation management. This new generation approach of conservation management is well organized, but it appears that the lack of sufficient funds leaves most agreements and projects, started by the administrative parties, not able to be integrated at community level. During my time in Kiwengwa I did not once experience any signs of community and conservation cooperation, nor did the established collaborations in JCNP, show any functional commotion when visiting the park visitor center. This implying a lack in implementation of conservation strategies. The majority of communities surrounding the PA's are highly dependent on forest related labor, having nonexistence secondary income opportunities. This gives the community based organizations (and the government) managing the areas, little ability of inducing sustainable change in the natural resource harvest from the forests, causing the continued degradation (Hassan & Said 2011). Tanzania generally experiences a lack in active and adequate management of government protected forests. High density human settlements adjacent to government protected area, consequently linger, a lower conservation success than in unmanaged forest in low density of human settlements areas (Davenport et al. 2013).

CONCLUDING REMARKS

In this study of the endangered *P. kirkii*, in Kiwengwa-Pongwe Forest Reserve. Habitat protection has not (or at least not yet), had the anticipated conservation effects. We did find a possibly higher total density of *P. kirkii* and a higher encounter rate, but these results were based on a dataset of fewer observations than what is generally required for population estimates. We also only sampled a more central section of the forest reserve, where wildlife is more secluded from disturbing human activity. Comparing the in general very low average group sizes, the significant reduction in group size between the two sampled years, the shift in location, the decreased forest density, and the avoidance of human activity, I can only conclude that the colobuses are still suffering habitat loss forcing to compress furthest from humans, in safety of the patches of higher coral rag that still remain.

For conservation management to have an impact here, I believe that the root to the problem has to be addressed. In Kiwengwa – Pongwe the problem imposing the largest threat to the reserve wildlife, is the surrounding human settlements being so dependent on forest products, particularly fuelwood. This is a socioeconomic concern caused by lacking affordable alternatives, to illegal but cheap, wood collection in the reserve. It has little effect creating rules and regulations through management, if the people you are affecting by this, have so limited resources that they have no ability to follow conservation attempts, and a reassessment of the conservation management implementation is critical needed.

Before the Zanzibar collective society can support a more prosperous community, commonly affording alternatives to fuelwood, I do not believe that despite community including management strategies, we will see a positive effect on the conservation of the Zanzibar endemic *Piliocolobus kirkii*.

FURTHER RESEARCH

For a more thorough re-assessment of the conservative state of KPFR, reopening of transects K1 and K4 should be considered. The doubts of what consequences this might have, creating easy access routes through the forest also beneficial for wood cutters, might indeed not be that great if the areas of the forest already have undergone a great degradation. We did consider doing it for this study, but the time restrictions did not allow the time for it, nor would I have been able to conduct enough repetitions of each transect within the time limit. Conducting this amount of field research for one researcher within three months is not recommended, lenition of time restrictions allowing additional rest days and increasing repetitions would enable further representative results.

Starting a long-term research project on all four transects, like they have in JCNP, with repeated walks several times yearly, would also create a great opportunity of following the changes in habitat quality and population densities, as long-term monitoring is the most reliable monitoring method (Hassel-Finnegan et al. 2008). Because of the easier access and a functional forest office, most ecology and conservation research is based in JCNP. Establishing long term monitoring program would not only benefit KPFR, but would also provide diversity to Zanzibar based biological exploration, this not only addressing *P. kirkii*, but the broad spectra of Zanzibar's idiosyncratic flora and fauna.

Investigating the surrounding settlements yearly requirement of forest related resources would also greatly apprise KPFR's coming future. It could possibly become the support gaining the needed attention upon the assessment of the forest reserves conservation status.

One of the things that in my opinion could be most interesting to research from here on, is the established wildlife corridors. In 2011 wildlife corridors were establish to strengthen the terms of representativeness and connectivity of PA in order to preserve ecology and evolutionary processes necessary for a continued survival of the unique Zanzibar flora and fauna (Siex 2011). So far there has not been any thorough research investigating if the corridors are being used or fulfilling the purpose of engagement.

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APPENDIX

Appendix cover additional material outside of the original thesis, which I find relevant for the greater understanding of this study.

Appendix 1 – Study site map

Figure 17 Map of area surrounding The Kiwengwa – Pongwe Forest Reserve. The reserve border is outlined in white. A total of 10 local villages border the reserve. Transects start and end points are marked with flags and red line. Yellow line marks main road.



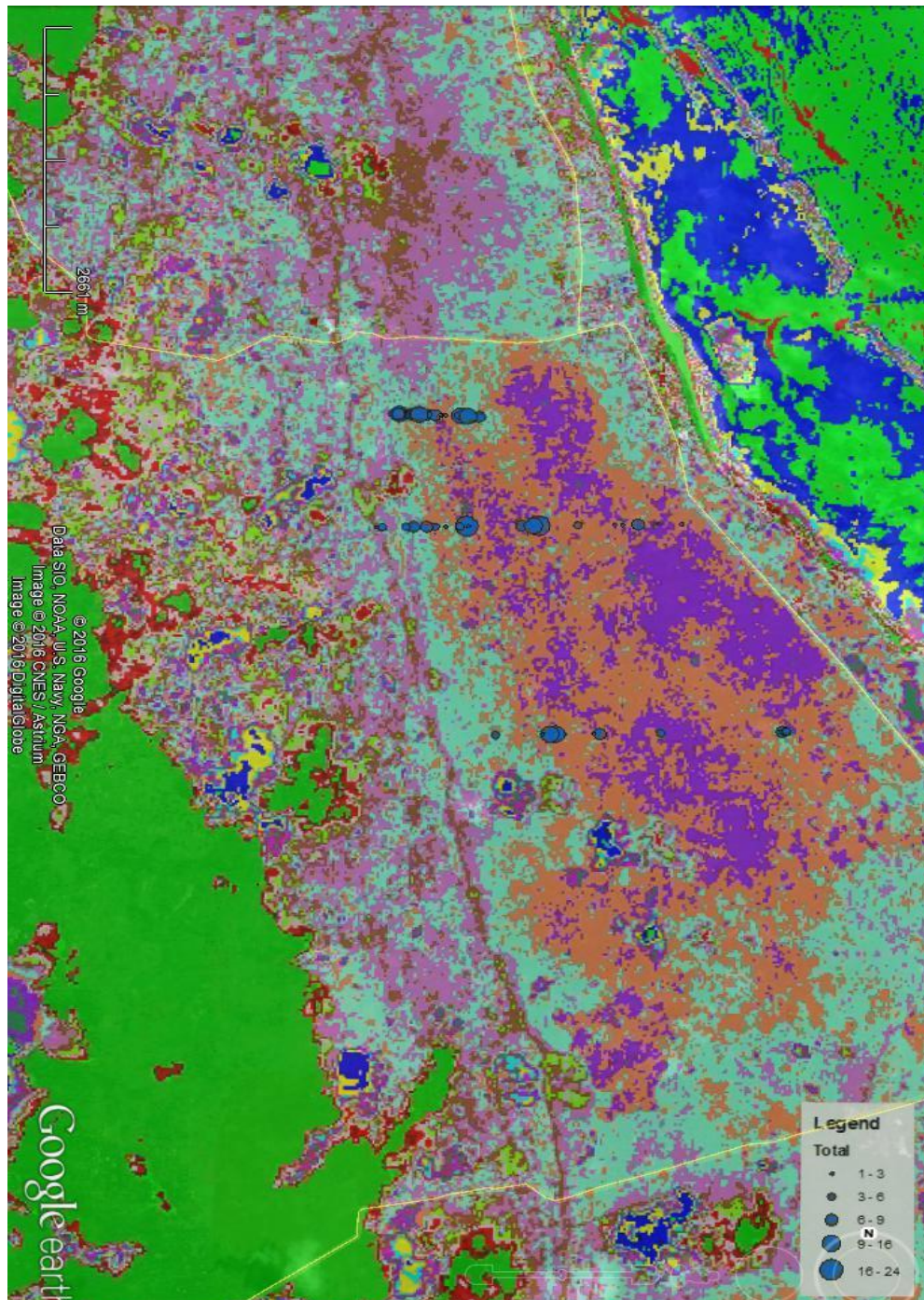
Appendix 2 - Colobus and food species maps

Figure 18 Satellite photo of study site with descriptive layer added. The layer colors are assigned by a mathematical model giving similar areas the same color based on aerial footage. Data on colobus group size encountered on each transect, as blue circles. Data layer is from 2014.

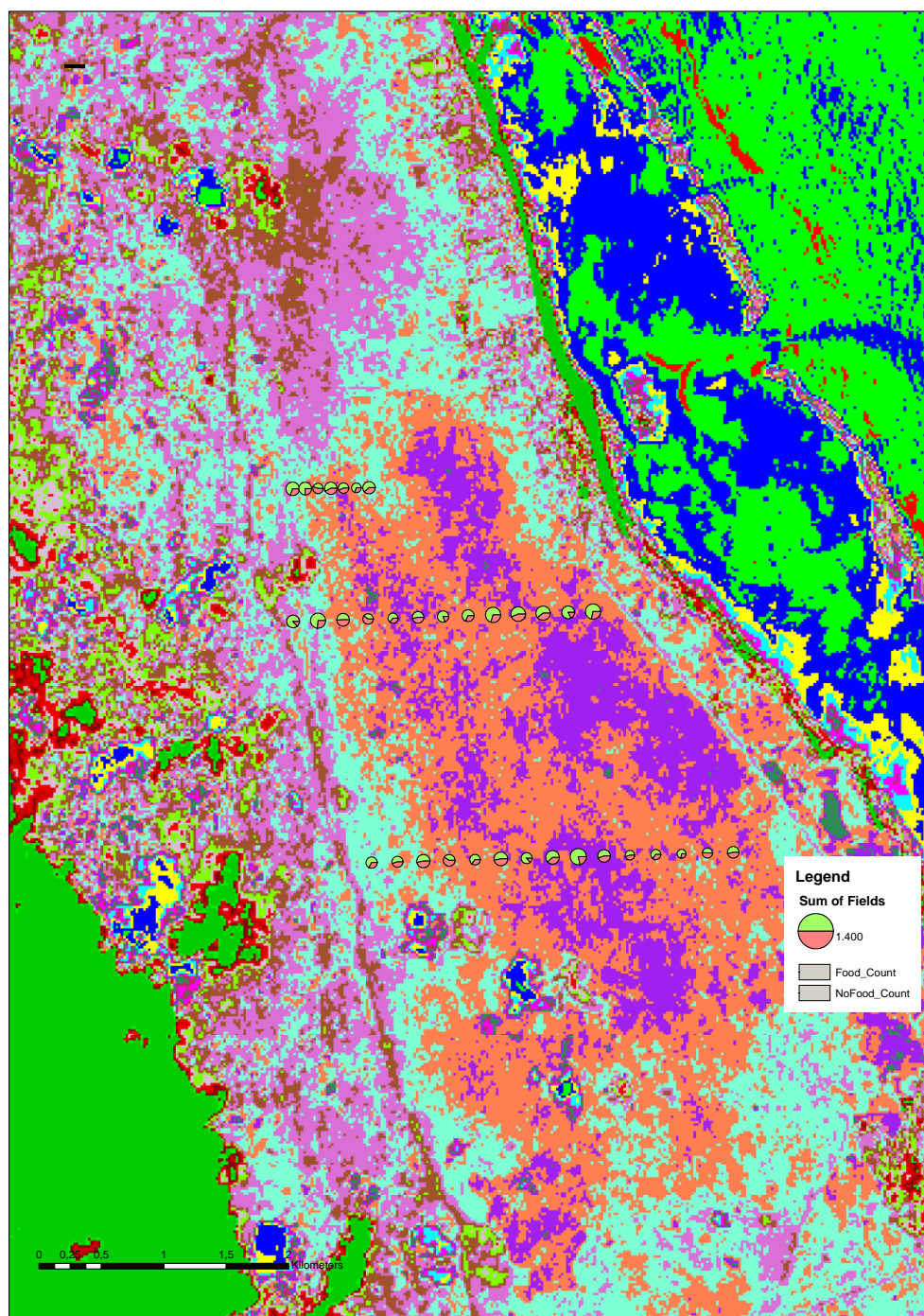


Figure 19 Satellite photo of study site with descriptive layer added. The layer colors are assigned by a mathematical model giving similar areas the same color based on aerial footage. Data on proportion of colobus food species within each plot. Diagram size reflecting plot total stem number.

Appendix 3 – Detection functions $g(x)$

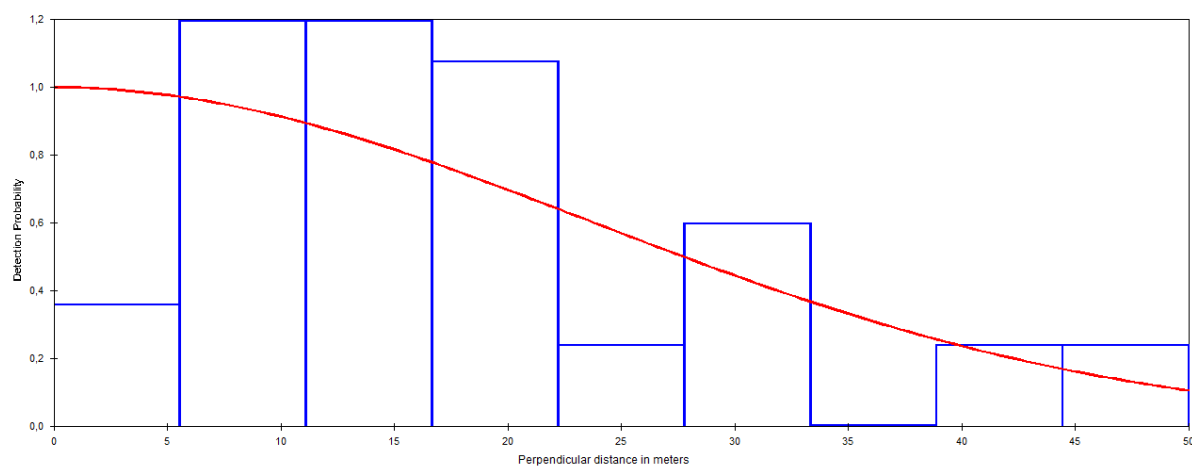


Figure 20 2004 Observation distances and detection function $g(x)$ Distance sampling method

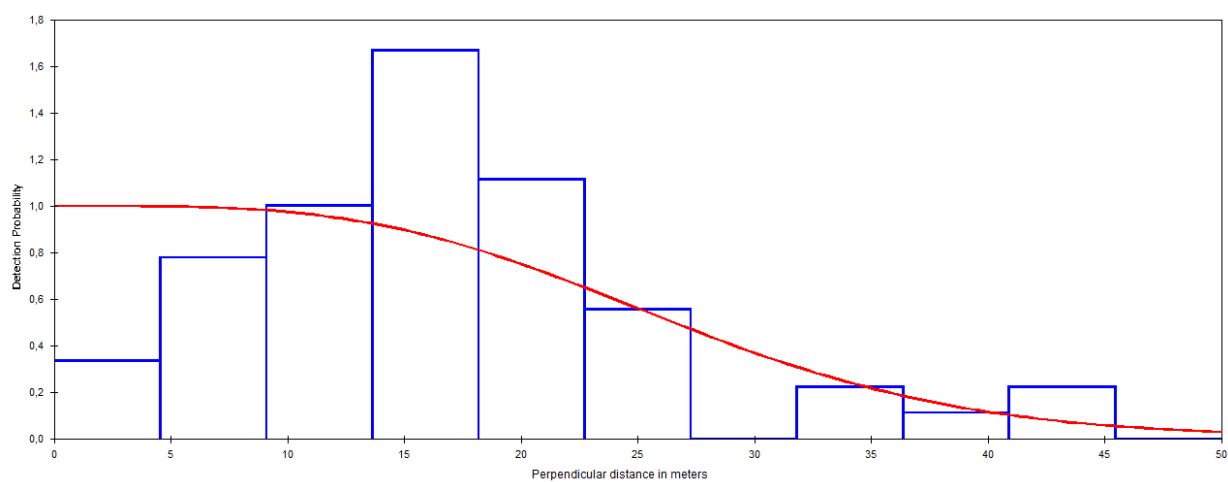


Figure 21 2016 Observation distances and detection function $g(x)$ Distance sampling method

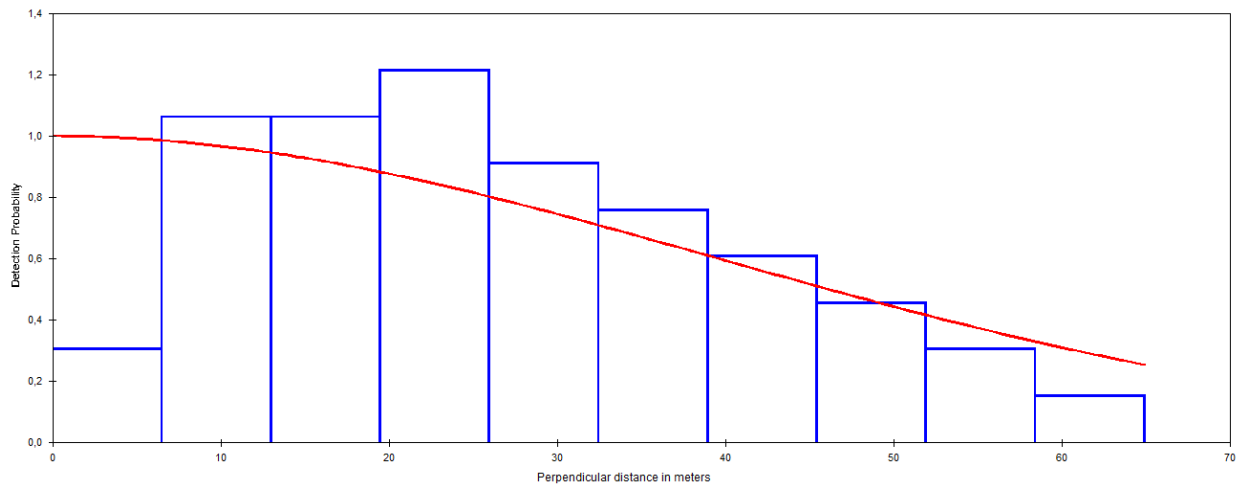


Figure 22 2004 Observation distances and detection function $g(x)$ Whiteside method.

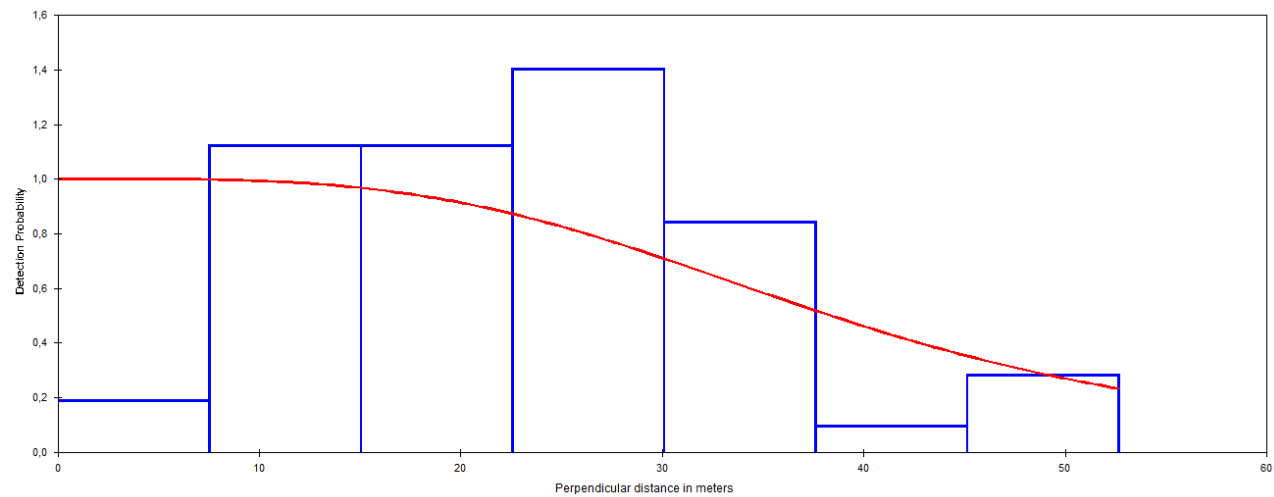


Figure 23 2016 Observation distances and detection function $g(x)$ Whiteside method

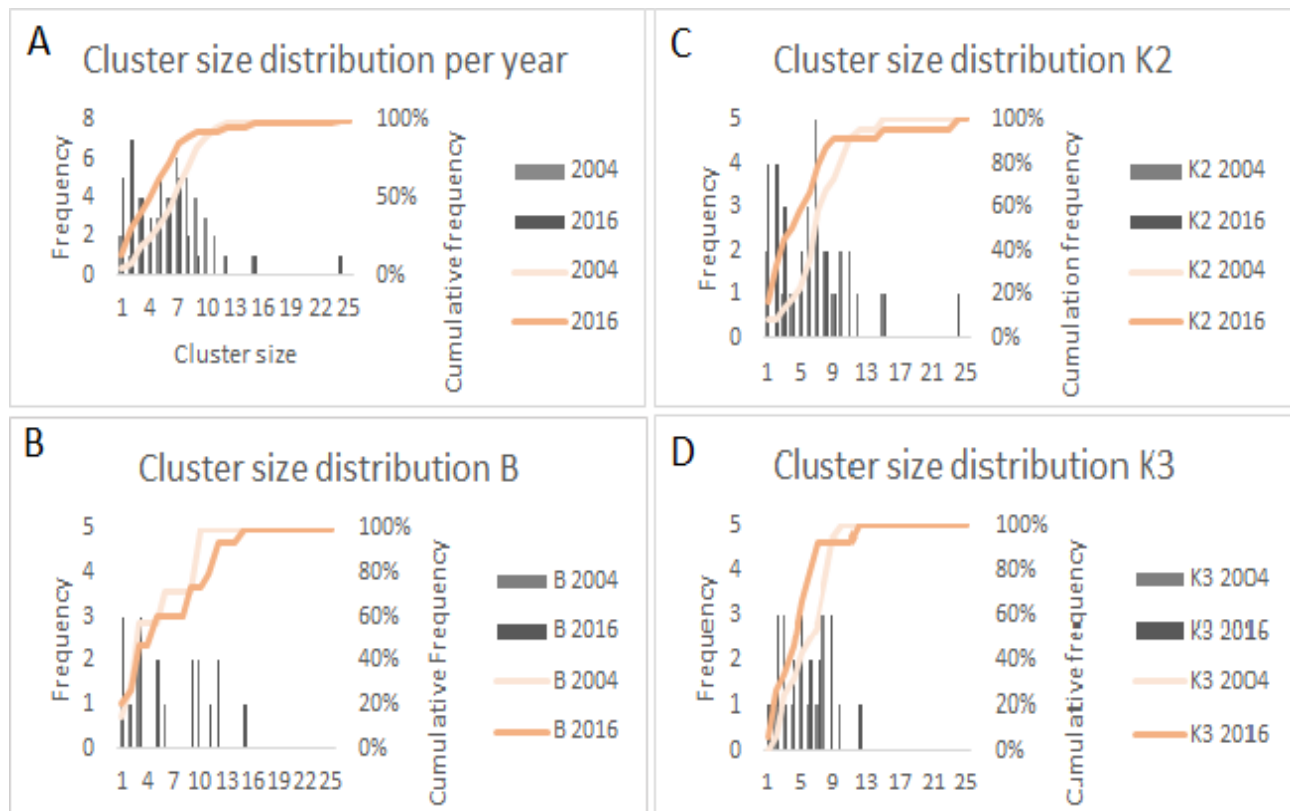
Appendix 4 – Cluster size distribution

Figure 24 Frequencies and cumulative frequencies distribution and sized of clusters observed in 2004 and 2016 overall and by transect.

Appendix 5 - Statistics

Table 4 Pared students t-test for paired samples on vegetative differences between 2004 and 2016. Wilcoxon matched-pairs signed rank test for proportion of cut stems DBH out of plot total.

	Mean 2004	Mean 2016	T(DF=33)	P-value	Significant
<i>Stems in plot</i>	261,21 ± 87,84	155,62 ± 55,66	6,83	<0,0001	***
<i>Plot total DBH</i>	1009,4 ± 217,8	671,68 ± 203,7	8,15	<0,0001	***
<i>No. cut stems in plot</i>	27,88 ± 24,15	19,53 ± 9,96	1,8	0,08	No
<i>Total DBH of cut stems in plot</i>	120,45 ± 103,06	121,97 ± 83,74	-0,062	0,95	No
<i>Proportion of cut stems in plot</i>	0,12 ± 0,1	0,14 ± 0,07	0,7	0,49	No
<i>Proportion cut stems DBH in plot</i>	0,12 ± 0,1	0,19 ± 0,13	W=281	0,015	*

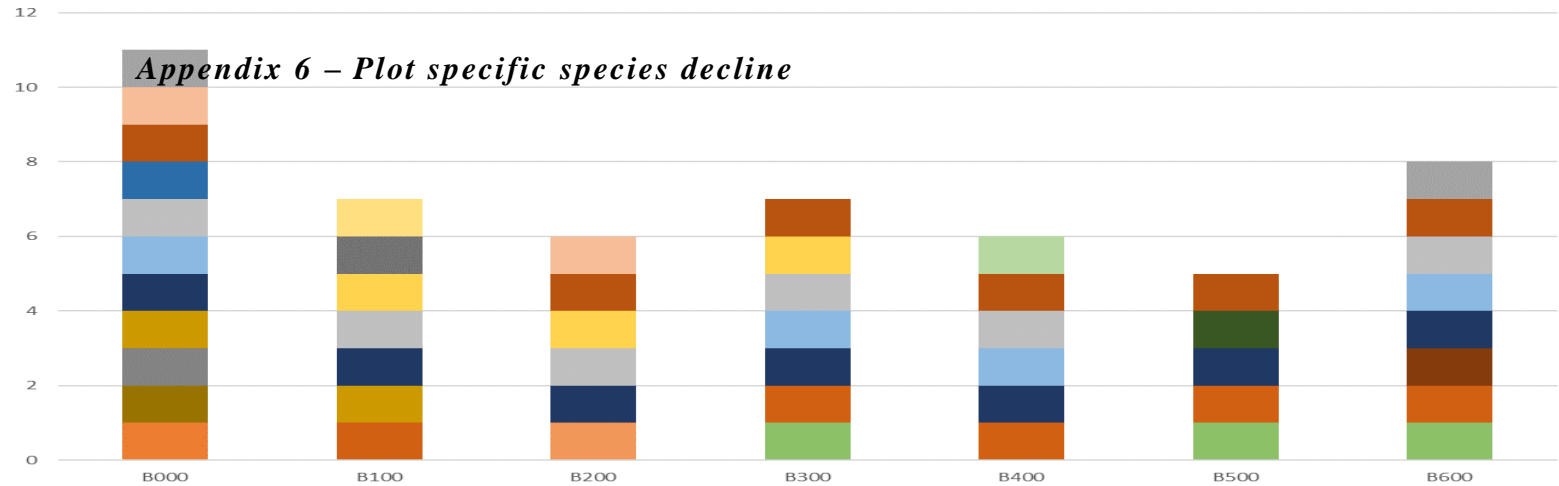
Table 5 Pared students t-test for paired samples on wood harvest at different transects between 2004 and 2016. Wilcoxon matched-pairs signed rank test for proportion of cut stems DBH out of plot total.

	Transect	Mean 2004	Mean 2016	DF	t-value	p-value	Significant
<i>Stems in plot</i>	B	176 ± 49,8	133 ± 36,6	6	3,19	0,018	*
	K2	300 ± 97,8	167 ± 49,9	12	6,97	<0,0001	****
	K3	267 ± 69	157 ± 69,5	13	3,67	0,0028	**
<i>Plot total DBH</i>	B	1007 ± 208,7	742,9 ± 105,8	6	5,35	0,0017	**
	K2	1030 ± 254,5	653,1 ± 184,7	12	6,52	<0,0001	****
	K3	991,4 ± 199,3	653,2 ± 255,2	13	4,09	0,0013	**
<i>No. Cut stems in plot</i>	B	12,86 ± 14,46	21,86 ± 8,09	6	-2,83	0,03	*
	K2	28,85 ± 23,37	23,15 ± 9,25	12	0,89	0,39	No
	K3	34,50 ± 26,65	16,15 ± 9,64	13	2,17	0,04	*
<i>Total DBH of cut stems in plot</i>	B	54,21 ± 50,84	200,60 ± 98,91	6	-6,42	0,001	**
	K2	137,95 ± 90,24	113,14 ± 51,22	12	0,95	0,36	No
	K3	137,31 ± 123,61	90,85 ± 80,07	13	1,05	0,31	No
<i>Proportion of cut stems in plot</i>	B	0,07 ± 0,05	0,18 ± 0,8	6	4,37	0,0047	**
	K2	0,11 ± 0,6	0,14 ± 0,06	12	1,58	0,14	No
	K3	0,15 ± 0,14	0,11 ± 0,07	13	0,99	0,34	No
<i>Proportion cut stems DBH in plot</i>	B	0,05 ± 0,04	0,27 ± 0,01	6	W=28	0,016	*
	K2	0,14 ± 0,07	0,19 ± 0,07	12	W=31	0,3	No
	K3	0,16 ± 0,14	0,16 ± 0,15	13	W=15	0,67	No

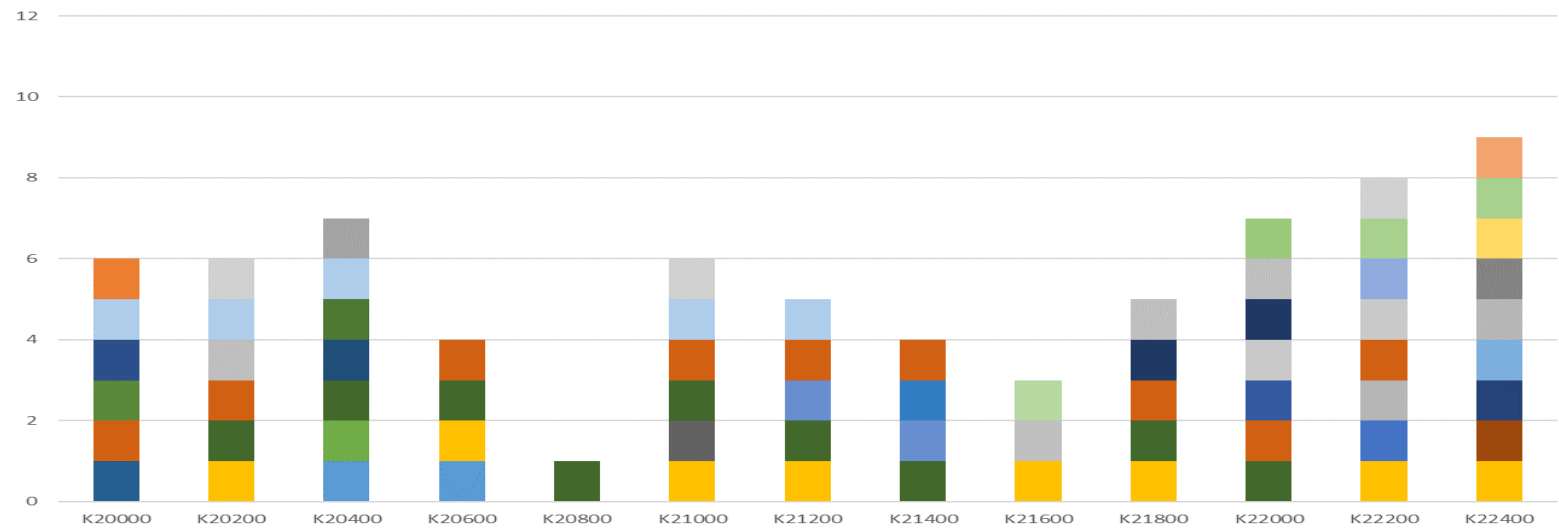
Table 6 Kruskal – Wallis and Dunn’s multiple comparison test summarized. Only including significant result from Kruskal-Wallis for further analysis with Dunn’s multiple comparison test.

Multiple comparison test results summary							
Stems in plot				No. cut stems in plot			
Kruskal-Wallis test	P-value	Significant?	Summary	Kruskal-Wallis test	P-value	Significant?	Summary
2004	0,0102	Yes	*	2004	0,019	Yes	*
Dunn's multiple comparisons test	Mean rank diff,	Significant?	Summary	Dunn's multiple comparisons test	Mean rank diff,	Significant?	Summary
B 2004 vs. K2 2004	-13,77	Yes	**	B 2004 vs. K2 2004	-11,05	No	ns
B 2004 vs. K3 2004	-11,32	Yes	*	B 2004 vs. K3 2004	-12,46	Yes	*
K2 2004 vs. K3 2004	2,453	No	ns	K2 2004 vs. K3 2004	-1,415	No	ns
Cut stems DBH				Proportion cut stems DBH of total			
Kruskal-Wallis test	P-value	Significant?	Summary	Kruskal-Wallis test	P-value	Significant?	Summary
2004	0,0188	Yes	*	2004	0,0058	Yes	**
2016	0,0232	Yes	*	Dunn's multiple comparisons test	Mean rank diff,	Significant?	Summary
Dunn's multiple comparisons test	Mean rank diff,	Significant?	Summary	B 2004 vs. K2 2004	-14,78	Yes	**
B 2004 vs. K2 2004	-12,87	Yes	*	B 2004 vs. K3 2004	-11,43	Yes	*
B 2004 vs. K3 2004	-10,43	No	ns	K2 2004 vs. K3 2004	3,352	No	ns
K2 2004 vs. K3 2004	2,44	No	ns				
B 2016 vs. K2 2016	8,615	No	ns				
B 2016 vs. K3 2016	12,64	Yes	*				
K2 2016 vs. K3 2016	4,027	No	ns				

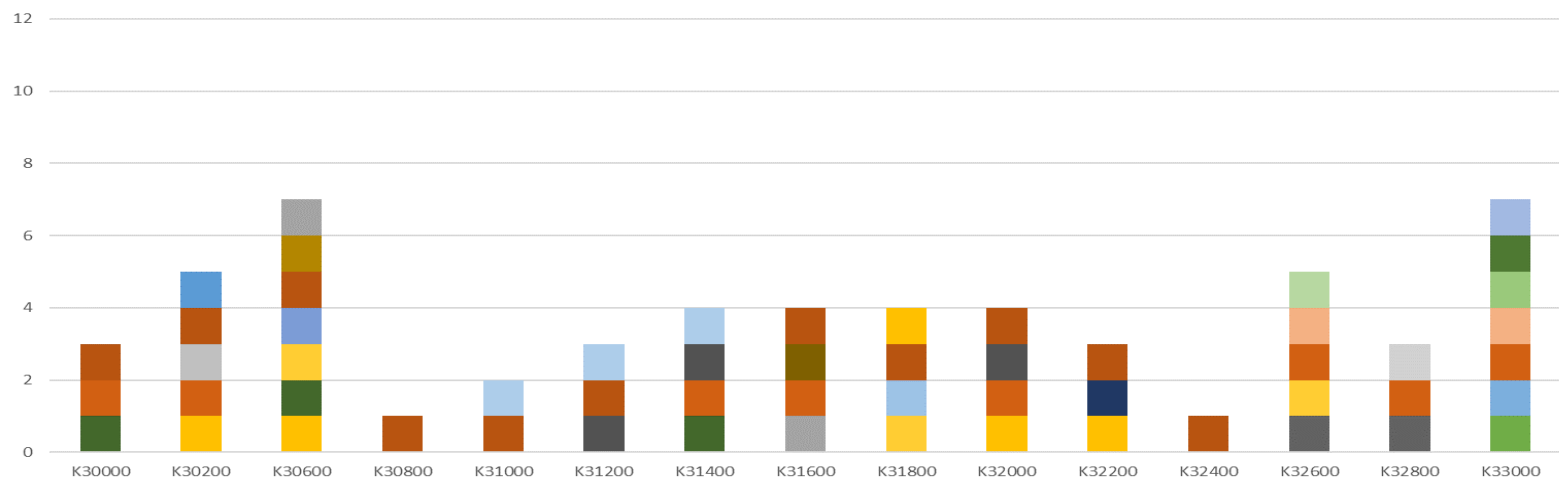
Lost species
Transect B



Transect K2



Transect K3



- | | | | | | |
|-------------------------|-----------------------|--------------------------|-------------------------|--------------------------|--------------------------|
| Adenia gummifera | Albizia glaberrima | Allophylus aldabricus | Ancylobotrys petersiana | Camptolepis ramiflora | Carpodiptera africana |
| Cassytha filiformis | Citrus sinensis | Clerodendrum glabrum | Clerodendrum myricoides | Cocos nucifera | Cremaspora triflora |
| Deinbollia borbonica | Dichrostachys cinerea | Dioscorea sansibarensis | Diospyros abyssinica | Diospyros ferrea | Dovyalis spp. |
| Erythrococca berberidea | Euclea schimperii | Ficus exasperata | ficus natalensis | Grewia mollis | Hensia zanzibarica |
| Ixora narcissodora | Lantana camara | Lepisanthes senegalensis | Mangifera indica | Manilkara sulcata | Margaritaria discoidea |
| Maytenus heterophylla | Mfuka duri | mkomba | mkuni | Monothotaxis trichocarpa | mpanduka female |
| Mrabundi | Musa sp. | Mystroxydon mombaciana | Pavetta gerstneri | Phyllanthus reticulatus | Pittosporum viridiflorum |
| Psiadia arabica | Psychotria spp. | Rausonia lucida | Senna spp. | Stadmania oppositifolia | Sterculia rhynchocarpa |
| Strychnos spinosa | Strychnos spp. | Synaptolepis kirkii | Tarenna pavettoides | Thylachium densiflora | Trema orientalis |
| Tricalysia microphylla | Tricalysia ovalifolia | Unknown climber species | Ziziphus robertsiana | | |

*Appendix 7 - Species list***Colobus food species
highlighted**

Adenia gummifera	Cussonia zimmermannii	Grewia mollis
Albizia glaberrima	Dalbergia vacciniifolia	Harrisonia abyssinica
Allophylus aldabricus	Deinbollia borbonica	Hensia zanzibarica
Allophylus parvillei	Dichrostachys cinerea	Hoslundia opposita
Allophylus rubifolius	Dioscorea sansibarensis	Ixora narcissodora
Allophylus sp.	Diospyros abyssinica	Jasminum fluminense
Ancylobotrys petersiana	Diospyros consolatae	Jusminum mauritianum
Annona senegalensis	Diospyros ferrea	Lannea schweinfurthii
Apodytes dimitiata	Diospyros natalensis	Lantana camara
Aporrhiza paniculata	Dodonaea viscosa	Lawsonia inermis
Berchemia discolor	Dovyalis macrocalyx	Lecaniodiscus
Bersama abyssinica	Dovyalis spp.	fraxinifolius
Blighia unijugata	Drypetes natalensis	Lepisanthes senegalensis
Bridelia cathartica	Ehretia amoena	Leptactina platyphylla
Bridelia micrantha	Encephalartos	Ludia mauritania
Camptolepsis ramiflora	hildebrandtii	Macphersonia gracilis
Carpodiptera africana	Erythrococca berberidea	Mallotus oppositifolius
carpolobia goetzei	Euclea natalensis	Mangifera indica
Cassytha filiformis	Euclea racemosa	Manilkara sulcata
Cathium mombassica	Euclea schimperi	Margaritaria discoidea
Citrus sinensis	Eugenia capensis	Maytenus andata
Clausena anisata	Euphorbia nyikae	Maytenus heterophylla
Clerodendrum glabrum	Ficus exasperata	Maytenus
Clerodendrum	Ficus ingens	mossambicensis
myricoides	ficus natalensis	Maytenus spp.
Cocos nucifera	Ficus scasselatii	Mdalasini mwitu
Cremaspora triflora	Ficus sur	Mfuka duri
Croton	Flacourtia indica	Mimusops fruticosa
pseudopulchellus	Flacourtia spp.	Mkekundu
	Flueggea virosa	Mkomba
	Grewia bicolor	Mkuni

Monanthotaxis**fornicata**

Monodora grandidieri

Monothotaxis**trichocarpa**

mpanduka female

Mrabundi

Musa sp.**Mystroxylon****aethiopicum****Mystroxylon****mombaciana****Olea woodiana****Ozoroa obovata**

Pavetta gerstneri

Phyllanthus reticulatus

Pittosporum viridiflorum

Polyspheria multiflora

Polyspheria parvifolia

Psiadia arabica

Psychotria**bibracteatum****Psychotria goetzei****Psychotria sp.**

Rapanea melanophloeus

Rausonia lucida

Rhoicissus revoilii**Rhus longipes**

Rhus natalensis

Salacia elegans**Senna petersiana****Senna sp.****Sideroxylon inerme****Sorindeia****madagascariensis**

Stadmania oppositifolia

Sterculia rhynchocarpa**Strychnos angolensis**

Strychnos spinosa

Strychnos sp.

Suregada zanzibarensis

Synaptolepsis kirkii

Tarennia pavettoides

Teclea nobilis

Terminalia boivinii

Thylachium densiflora

Toddalia asiatica

Toddalia sp.

Trema orientalis

Tricalysia microphylla

Tricalysia ovalifolia

Turraea floribunda

Turraea sp.

Vernonia zanzibarensis

Ziziphus robertsiana

*Unknown**Unknown climber species**Unknown stump**Unidentifiable*

*Appendix 8 - Correlations***Table 7** Correlation analysis statistical parameters

VARIABLE	OBSERVATIONS	OBS. WITH MISSING DATA	OBS. WITHOUT MISSING DATA	MINIMUM	MAXIMUM	MEAN	±SD
DBH OF LIVE STEMS 2004	34	0	34	431,1	1356,2	1009,4	217,8
DBH OF LIVE STEMS 2016	34	0	34	307,9	1097,0	671,7	203,7
N TREES DBH > 10 CM 2004	34	0	34	11,0	44,0	26,4	8,2
N TREES DBH > 10 CM 2016	34	0	34	0,0	27,0	11,5	7,7
N TREES DBH > 25 CM 2016	34	0	34	0,0	13,0	3,3	3,6
N STEMS 2004	34	0	34	116,0	507,0	261,2	89,2
N STEMS 2016	34	0	34	71,0	319,0	155,6	56,5
N CUT STEMS 2016	34	0	34	0,0	39,0	19,5	10,0
DBH OF CUT STEMS 2016	34	0	34	0,0	410,2	122,0	83,7
DISTURBANCE	34	11	23	1,0	7,0	2,8	1,6
FEWER STEMS	34	0	34	-281,0	137,0	-94,1	95,3
SPECIES LOST	34	0	34	1,0	11,0	5,0	2,3
METERS FROM RIM	34	0	34	0,0	1400,0	591,2	419,3
N FOOD SPECIES 2004	34	0	34	63,0	298,0	139,5	57,5
N FOOD SPECIES 2016	34	0	34	14,0	163,0	46,7	26,9
FOOD SPECIES PROP. 2004	34	0	34	0,3	0,7	0,5	0,1
FOOD SPECIES PROP. 2016	34	0	34	0,1	0,6	0,3	0,1
N COLOBUS 2016	34	13	21	1,0	38,0	13,7	10,0
N COLOBUS 2004	34	23	11	4,0	44,0	22,9	12,0

Table 8 List of all positive correlations

Positive Correlations					
N colobus 2004	N food species 2016	N stems 2016	DBH of live stems 2016	N food species 2016	DBH live stems 2016
	Meters from rim		N food species 2016		N colobus 2004
	N trees DBH > 10 cm 2016		N food species 2004		N trees DBH > 10 cm 2016
	DBH of live stems 2016		Food species prop. 2004		Food species prop. 2016
Food species Prop. 2016	N food species 2016	Food species prop. 2004	DBH of live stems 2016		N stems 2016
	DBH of live stems 2016		N stems 2016	N food species 2004	N stems 2004
N stems 2004	DBH live stems 2004		N food species 2004		Food species prop. 2004
	N food species 2004	N trees DBH > 10 cm 2016	N colobus 2004		N stems 2016
DBH of live stems 2016	N colobus 2004		N food species 2016	N trees DBH > 25 cm 2016	DBH of live stems 2016
	N trees DBH > 10 cm 2016		DBH of live stems 2016		N trees DBH > 10 cm 2004
	Food species prop. 2016	N trees DBH > 10 cm 2004	DBH of live stems 2016		Fewer stems
	DBH live stems 2004		N trees DBH > 25 cm 2016	Food species Prop. 2016	N food species 2016
	N trees DBH > 25 cm 2016	N colobus 2016	N stems 2016		DBH of live stems 2016
	N trees DBH > 10 cm 2004	Meters from rim	N colobus 2004	N cut stems 2016	DBH of cut stems 2016
	N stems 2016	Species lost	DBH cut stems 2016	DBH of cut stems 2016	N cut stems 2016
	Food species prop. 2004			Fewer stems	N trees DBH > 25 cm 2016

Table 9 List of all negative correlations

Negative correlations					
N colobus 2016	N stems 2016	Species lost	Meters from rim	Fewer stems	N food species 2004
Meters from rim	Species lost	N stems 2004	DBH cut stems 2016		N stems 2006
	DBH of cut stems 2016		Fewer stems	N food species 2004	Fewer stems
	Food species prop. 2016	N trees DBH > 25 cm 2016	DBH live stems 2004		DBH live stems 2004
Food species Prop. 2016	Meters from rim				

