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# Seasonal movement patterns and habitat preferences of elephants (*Loxodonta africana*) in Garamba National Park, DR Congo

DIPLOMA THESIS

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Photo by Pavel Hejčl

**Elephant herd in sparse tree bush savannah observed during aerial monitoring.**

# Declaration

I declare that I have written my diploma thesis titled "Seasonal movement patterns and habitat preferences of elephants (*Loxodonta africana*) in Garamba National Park, DR Congo" on my own with a help of literature listed in References.

In Prague: 11th April 2012

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Pavel Hejčl

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# Abstract

Garamba National Park lies in the Congo DR, on the border with South Sudan. During past years, several armed conflicts took place in and around the park. Conditions in the park have changed, and it is important to find out how elephants act under new situation, if the boundaries are sufficient and if management is effective. By this reason five elephants (3 cows, 2 bulls) were fitted with VHF/GPS collars, in May 2009. GPS fixes were sent 3 times a day during period from 31.5.2009 to 10.12.2010. One collar failed after 20.4.2010. Aims of this study were 1) Evaluation of elephant distribution and seasonal movement dynamics; 2) Elephant habitat use and preferences determination; 3) Herd composition and it seasonal fluctuations; 4) Human-elephant conflict area identification.

Average movement distance per day was 6.4 km (± 1.8 km S.E.). Movement distances differ with season. The shortest movements took place in top of wet season and the longest in begining of wet season. Principal and the longest movement in day was at night and in the morning. Home range areas differ with seasons in the same way as movement distances. Average home range area was 1015.73 km$^2$. The most utilized habitat was tall grass savannah, which importance grew with advancing wet season. As well, utilization of tree bush savannah, woodland and forest ecosystems rose in wet season. On the other hand, use of riverine grass and swamps decreased with increasing rains. Average herd size was 6.6 individuals and grown in wet season. Herd aggregations were frequently observed in south part of the park, during beginning of wet season. These aggregations probably affect longer movements made during April and May. Longer night movements were affected by displacement between night and morning feeding place. Raiding on fields was frequently noted during night. Elephant dispersal was not restricted by extensive human population, but places of dense human population and mining areas were mostly avoided. Over difficult conditions and insufficient protection, elephants extended their range, and even are encouraged to move outside the protected area borders.



**Key words**: spatial distribution, home range, diurnal movements, human elephant conflict

## Abstrakt

Národní park Garamba leží v DR Kongo, na hranici s Jižním Súdánem. Během posledních let, v jeho okolí i na jeho území proběhlo několik ozbrojených konfliktů. Proto se situace v parku změnila a je nutné zjistit, jak na změny reagují sloni. Zjistit, jestli stávající hranice praku jsou dostatečné, a management funguje efektivně. Z toho důvodu bylo v květnu 2009 pět slonů (3 samice, 2 samci) označeno obojky s VHF/GPS vysílačkou. Data byla zasílána 3 krát denně, a shromažďována v období od 31.5.2009 do 10.12.2010. Jeden z obojků fungoval pouze od 31.5.2009 do 20.4.2010. Cílem studie bylo $1_)$ Zhodnotit prostorovou distribuci slonů a její sezónní změny (zejména stanovením domovských okrsků (home range)); $2_)$ Zjistit využití a preference biotopů; $3_)$ Stanovit velikost a strukturu stád, $4_)$ Identifikovat konfliktní oblasti lidí se slony.

Průměrně sloni denně urazili 6,4 km (± 1,8 km S.Ch.). Ujité vzdálenosti se lišili mezi sezonami. Nejméně sloni chodili ve vrcholném období dešťů a nejdelší vzdálenosti urazili na začátku období dešťů. Hlavní denní pohyb probíhal v noci a ráno, zatímco odpoledne sloni chodili méně. Velikost domovských okrsků se v průběhu sezon lišila podobně, jako vzdálenosti migrací. Průměrná celková velikost domovských okrsků byla 1015,73 $km^2$. Nejvíce využívaným biotopem byla savana, jejíž využívání roste s přibývajícími dešti. Využití keřové savany a lesů rostlo také s postupem období dešťů. Naopak využívání biotopu bažin a vodní trávy, s přibývajícími dešti a přebytkem vody klesal. Průměrná velikost stáda byla 6,6 jedinců a v období dešťů vzrostla. V období dešťů byly často pozorovány agregace stád v jižní části parku. Tyto agregace zřejmě ovlivňují delší vzdálenosti, ujité v dubnu a květnu. Delší noční pohyb je zřejmě ovlivněn putováním za potravou mezi noční a ranní pastvou, často i do okolí lidských obydlí za pastvou na polích. Distribuce slonů v parku a okolních rezervacích nebyla omezena řídkým lidským osídlením, ale místům velké koncentrace lidí a okolí dolů se sloni vyhýbali. I přes nepříznivé podmínky a ztíženou a nedostatečnou ochranu, sloni za poslední léta rozšířili využívané území a dokonce i často zamíří mimo chráněné území.

**Klíčová slova**: prostorová distribuce, domovský okrsek, pohyby v denních periodách, konflikt lidí se slony

# Table of content

# 1 Introduction

Elephants in the Garamba National Park and adjacent hunting areas (PNG) represent one of the three large mammal species (elephants, giraffes, buffaloes), and they have high population number. According to animal censuses during years elephant numbers rose and declined (Tab. 1) because of civil wars and rebellion armies presence in the park (Smith, *et al*., 1994; Emslie, *et al*., 2006; Amube, 2007; Reid, 2007). Actual number is not known, due to presence of Lord Resistant Army in the park. Population of PNG seems to be one of the best protected and one of the most numerous in Democratic Republic of Congo (Luhunu, 2009). Elephants belong to PNG ecologically and historically (there was a domestication station (Hillman Smith, 1988)). They significantly affect ecosystem and its changing (Western, 1984; Jachman, *et al*., 1991). There is a need to gather as many information as possible about elephants in PNG to effectively protect and manage their population. In addition, PNG population forms genetically intermediate type between forest (*Loxodonta africana cyclotis*, Matschie, 1900) and savannah (*Loxodonta africana africana,* Blumenbach, 1797) elephant species (Roca, *et al*., 2005) and its ecological needs and habits can be distinct from other populations.

*Tab. 1: Estimated elephant numbers gained from aerial or ground censuses conducted in Garamba NP* (Smith, *et al*., 1994; Emslie, *et al*., 2006; Amube, 2007; Reid, 2007).

| Year | 1976 | 1983 | 1984 | 1986 | 1989 | 1991 | 1993 | 1995 |
|---|---|---|---|---|---|---|---|---|
| Estimated number | 22670 | 7742 | 3300 | 4339 | >4065 | 7389 | 8705 | 11175 |
| Year | 1998 | 2000 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 |
| Estimated number | 5874 | 6022 | 5983 | 6948 | 6354 | 1202 | 3800 | 3696 |

Radio and GPS tracking of elephants has been used for a long time in many African countries (Blake, *et al*., 2001; Blake, *et al*., 2003; Ntumi, *et al*., 2005; Douglas-Hamilton, *et al*., 2005; Leggett, 2009 a), but in PNG this was used only once to collar female elephant in 1992 (Hillman Smith, *et al*., 1995 a). Since then collaring technology has made a big step forward with better GPS/radio transmitters and batteries with longer duration, resulting in more accurate and long term observation. Also techniques for movement evaluation have evolved during years, tending to be more precise and accurate (Blake, *et al*., 2003; Osborn, 2004; Douglas-Hamilton, *et al*., 2005; Leggett, 2009 a). In such big area as PNG and its surroundings the GPS tracking is greatly appropriate method to obtain data to understand wildlife movements and habits.

## 1.1 Elephant (*Loxodonta africana* sp.) taxonomy

Elephants belong to order *Proboscidea*, family *Elephantidae*. Recent DNA studies separate African elephants into two distinct species *Loxodonta africana* and *Loxodonta cyclotis* (Roca, *et al*., 2005).

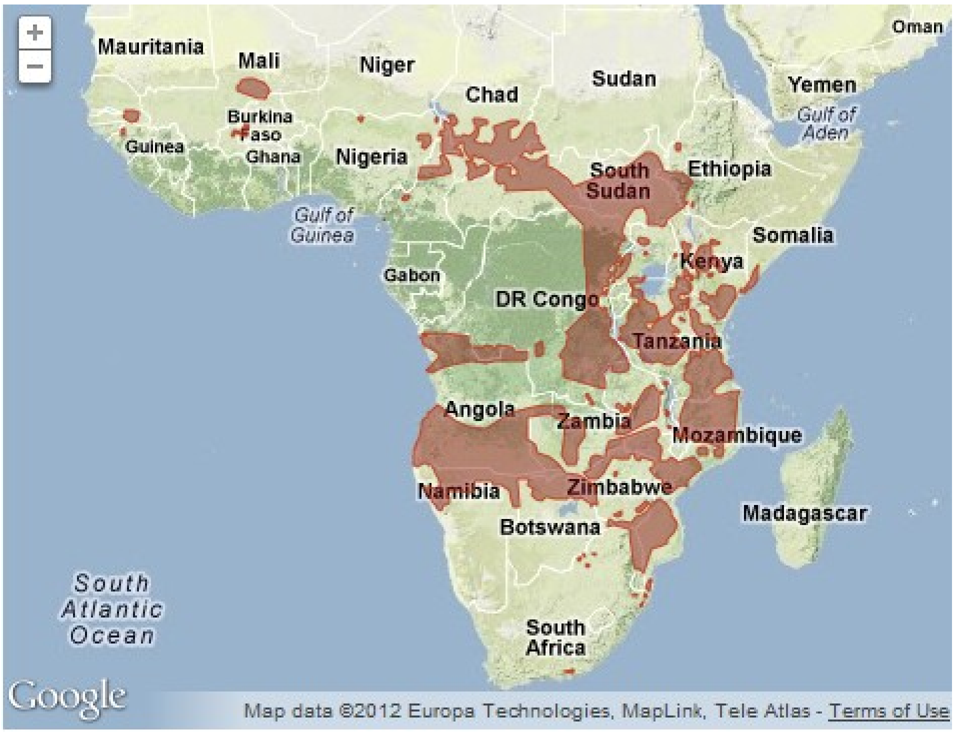


*Fig. 1: Distribution map of African elephant.*
(http://www.edgeofexistence.org/mammals/species_info.php)

But because of occurrence of hybrids with uncertain taxonomic status, African Elephant Database (IUCN) and Wilson and Reeder´s Mammal Species of the World consider African elephant as single species with two subspecies (Wilson, *et al*., 2005; Blanc, *et al*., 2007).

For my study, I will consider PNG elephants as one population (or one species) which has the same ecological pattern, because there are present both subspecies (*L. a. africana* and *L. a. cyclotis*) and their hybrids.

## 1.2 Diurnal activity

Elephants are hind-gut fermenters and so they can feed almost all day and night. They are intermediate feeders and very adaptive in their diet (Beekman, *et al*., 1989). About 75% of the total time elephant spent with feeding, when feeding conditions are good, this can reach around 60% of total time (Beekman, *et al*., 1989; Wyatt, *et al*., 1974). Wyatt, *et al*. (1974) found about 75% of the feeding activity consisted of grazing or feeding at ground level. In Tanzania (Lake Manyara National Park), Beekman, *et al*. (1989) observed during total feeding time 67 % of grazing and 8 % of browsing during wet season and only 28 % of grazing 60 % browsing during dry season. The increased proportion of browsing during dry season and grazing during wet season was also found by Field (1971), Wyatt, *et al*. (1974) and Leggett (2009 b).

Elephant activity is usually observed during the daylight. In PNG habitat utilization and activities of elephants during day were observed by Moss (1990) (Fig. 2). Night observations were done mainly for monitoring of crop raiding. Hillman Smith (1995) discussed night elephant movements from park to hunting areas for to feed on crops or fruits of mango. Nowadays, direct observations are replaced with telemetry data collection (Foley, 2002; Douglas-Hamilton, *et al*., 2005; Leggett, 2009 a).

Wyatt, *et al*. (1974) observed three feeding peaks during the day, first in the morning, second in the afternoon and the third around midnight. The feeding rate tended to increase during the day. Walking took place mainly at dusk. The principal resting period occurred during the small hours of the morning with a shorter resting period in the early afternoon (Wyatt, *et al*., 1974).

Person Wallenius (2010) divided day into four parts: early morning and late afternoon (8:00 to 9:59 h and 16.00 to 17:59 h), late morning (10:00 to 12:59 h) and afternoon from 13:00-15:59 h. Foraging was observed all day, but it was the most performed activity during early morning and late afternoon hours. Early afternoon was also important feeding period. The other common activities were walking and standing. Walking took place mainly during late morning hours (Persson Wallenius, 2010). She also showed males standing without any other activity more time than females.

Leggett (2009 b) who divided day into three periods also observed two feeding peaks in 07:00–11:00 h and 15:00–19:00 h and time for resting and social activities was between 11:00 and 15:00 h. Elephants spent more time walking at the expense of feeding, because of sparsely distributed water sources in the study area (in Namibia) (Leggett, 2009 b).

In South Africa, elephants also showed feeding activity peaks in early morning and late afternoon and during hottest period of day around 14:00 h the lowest activity period was observed (Shannon, *et al*., 2008).

In forest ecosystem the shade provide mild temperatures all day, and so feeding activity does not have to decrease over the hottest part of the day. Then, elephants can satisfy their nutritional needs during the day and lower activity during night (Blake, *et al*., 2001).

With GPS telemetry, we have no possibility to evaluate feeding activity peaks but it is possible to evaluate movement activity during 24 hour day cycle. This is helpful in identifying areas where elephants cross borders of protected areas and how they move outside of them. It was observed that elephants choose to cross unprotected areas especially during night. The speed of movement rise significantly in these areas, probably to diminish conflict with humans (Galanti, *et al.*, 2000; Douglas-Hamilton, *et al.*, 2005; Graham, *et al*., 2009).

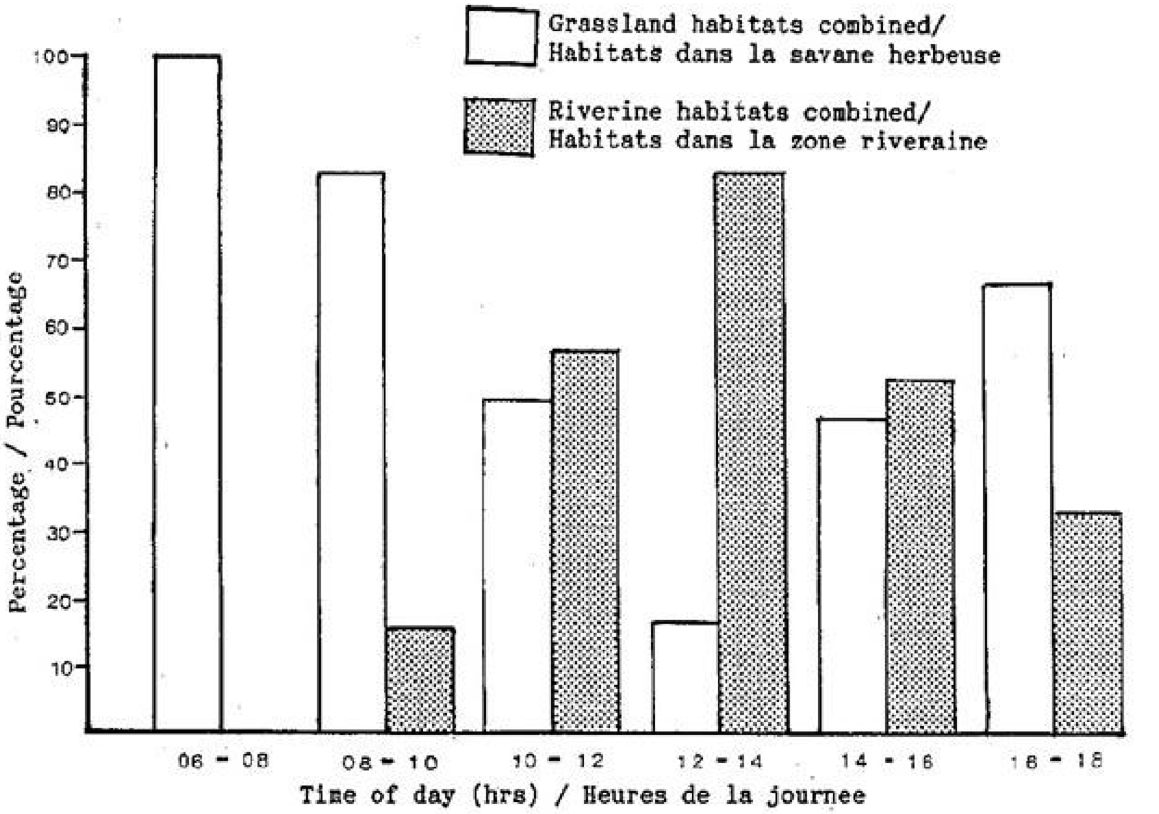


Fig. 2
DIURNAL HABITAT USE BY ELEPHANTS, GARAMBA NATIONAL PARK, APRIL 1990/
UTILISATION DIURNE D'HABITATS PAR LES ELEPHANTS AU PARC NATIONAL DE LA GARAMBA, AVRIL 1990

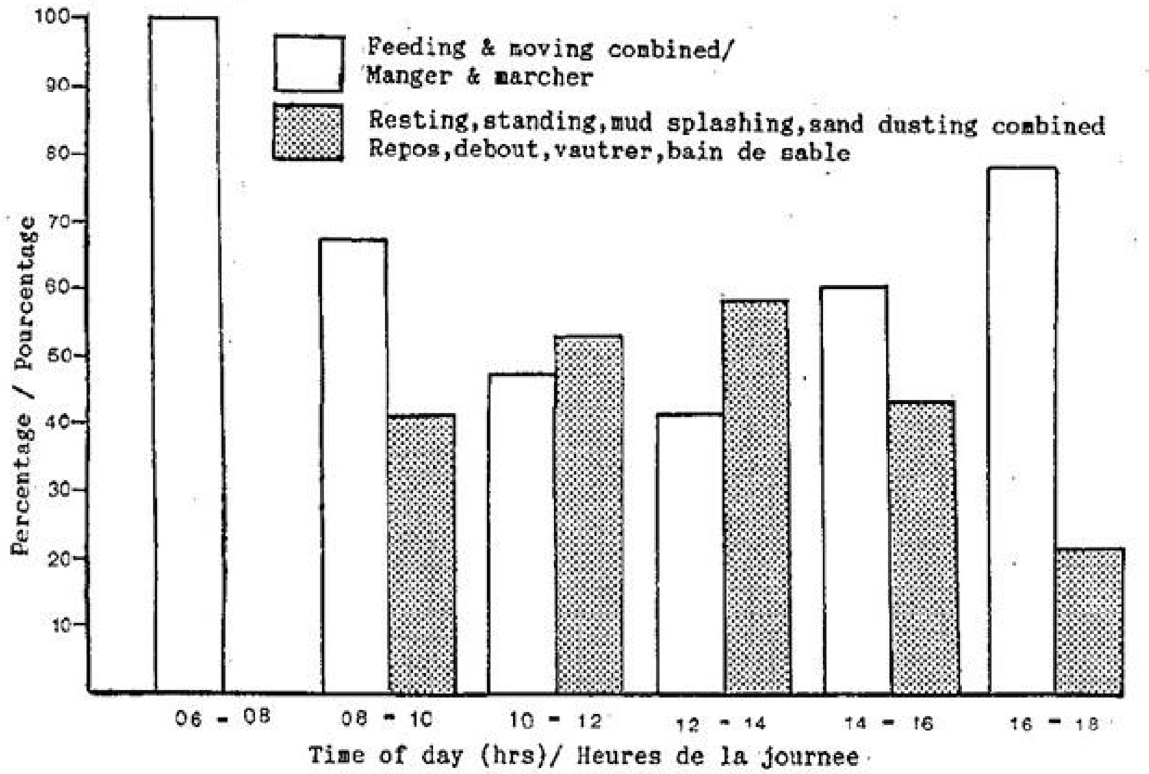


*Fig. 2: Diurnal habitat use and activity of elephants in PNG* (Moss, 1990).

## 1.3 Social behaviour and herd composition

Elephants are migratory animals and have a complex social structure, which influence their spatial distribution. They are not territorial animals but use specific home range areas, changing during particular seasons (Poole, 1996). Females and their offspring form matriarchal family groups, where individuals are relatives. When family is too big, it splits into smaller family groups or several (maximum five) closely allied families can form bond groups (Charif, *et al*., 2005). Adult males live in transient and irregular bull groups or solitary. Bulls during musth, when searching for females to mate with, tend to move more than during non-musth times (Leggett, *et al*., 2003; Poole, 1996).

Groups living in proximity, such as relative families or bond groups, know each other and communicate over long distances. In this context, movements are influenced and regulated by social relations (Wittemyer, 2007; Poole, *et al*., 2008). Wittemyer (2007) showed that social dominance hierarchy between groups play a role in spatial distribution, along with role of resource competition. On the other hand, Charif, *et al.* (2005) found out that patchy distribution of food and water resources, in Amboseli NP in Kenya, during dry season reflects elephant distribution better than coordination between relatives within a clan.

During periods of abundant food resources elephants aggregate into formations as many as 600 animals (Hillman, *et al*., 1983; Hillman Smith, *et al*., 1995 b; Poole, 1996; Amube, 2007). In PNG, such aggregations take place during beginning of wet period in April and May (Hillman, *et al*., 1983; Hillman Smith, *et al*., 1995 b; Amube, 2007). However, Thouless (1996) observed elephants to aggregate also during dry season without overabundance of food resources. Aggregations are connections for a short time. Western (1984) observed that the herd size increase with each rain, and declines progressively through the dry season with decrease in food reserves.

But, bull herd size is smaller during wet season than during dry season. This is probably given by searching for mates (Chase, *et al*., 2009). He also discusses that family group size was not affected by season.

The majority of the elephants in population live in relatively stable matriarchal family groups (Aleper, *et al.*, 2006). The numbers in each family group differ according to age and role of matriarch and probably by environment (Wittemyer, 2005). For example, in Amboseli NP, family group range from three to 22 individuals with a mean of ten. In May 2000, 352 elephants were counted in one large herd (Aleper, *et al*., 2006). In Samburu and Buffalo springs National Reserves, Kenya, median family unit size was nine individuals ranging 3-36 (Fig. 3) (Wittemyer, 2001). Mean group size in PNG during count from 1983 was 4.8 individuals (ranging from 1 to 31), there was one observation of group with 250 individuals in Azande hunting area (Hillman, *et al*., 1983). The rise in group size shows Moss (1990) (Fig. 4). Latter mean group size numbers are accessible from aerial counts from 2006 and 2007, where 11.16 ±1.09 and 13.1 ± 5.2 individuals, were counted in south part of the park during beginning of wet season (Amube, 2007). (Distribution of observed elephants are designed in Annexe 1)

Group size, but also sex and age structure indicate elephant population history and future development (Moss, 1990). When the average age is low and/or if adult females are considerably more abundant than adult males, it refers to recent poaching pressure. It is due to preference to kill mature adults with well developed tusks. Such tuskers are mainly bulls (Wittemyer, 2001; Aleper, *et al*., 2006). Recovery of elephant population after significant decline is a long-term process for more than 20 years (Moss, 2001). Such recovery can be visible on group size numbers in PNG (see above).

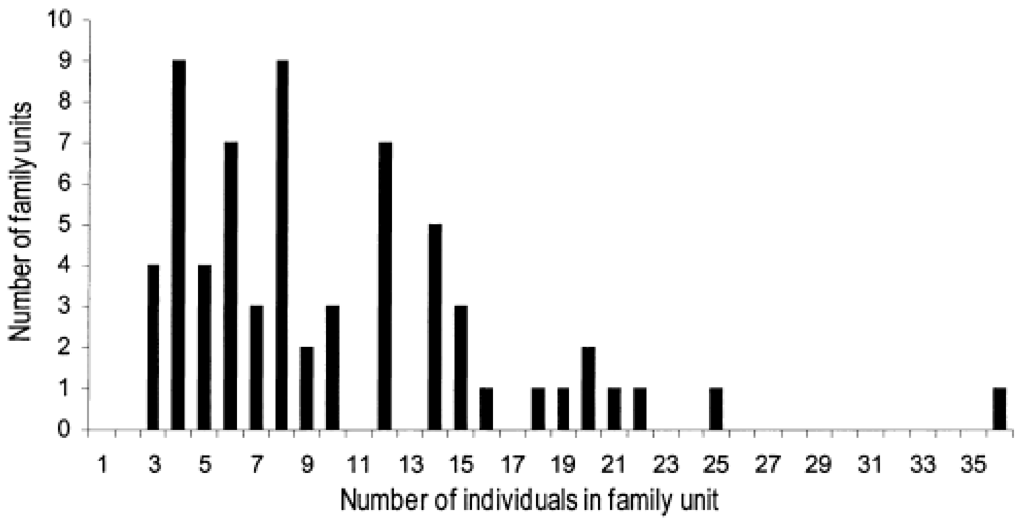


*Fig. 3: Distribution of core family units and its number of individuals in Kenya* (Wittemyer, 2001).

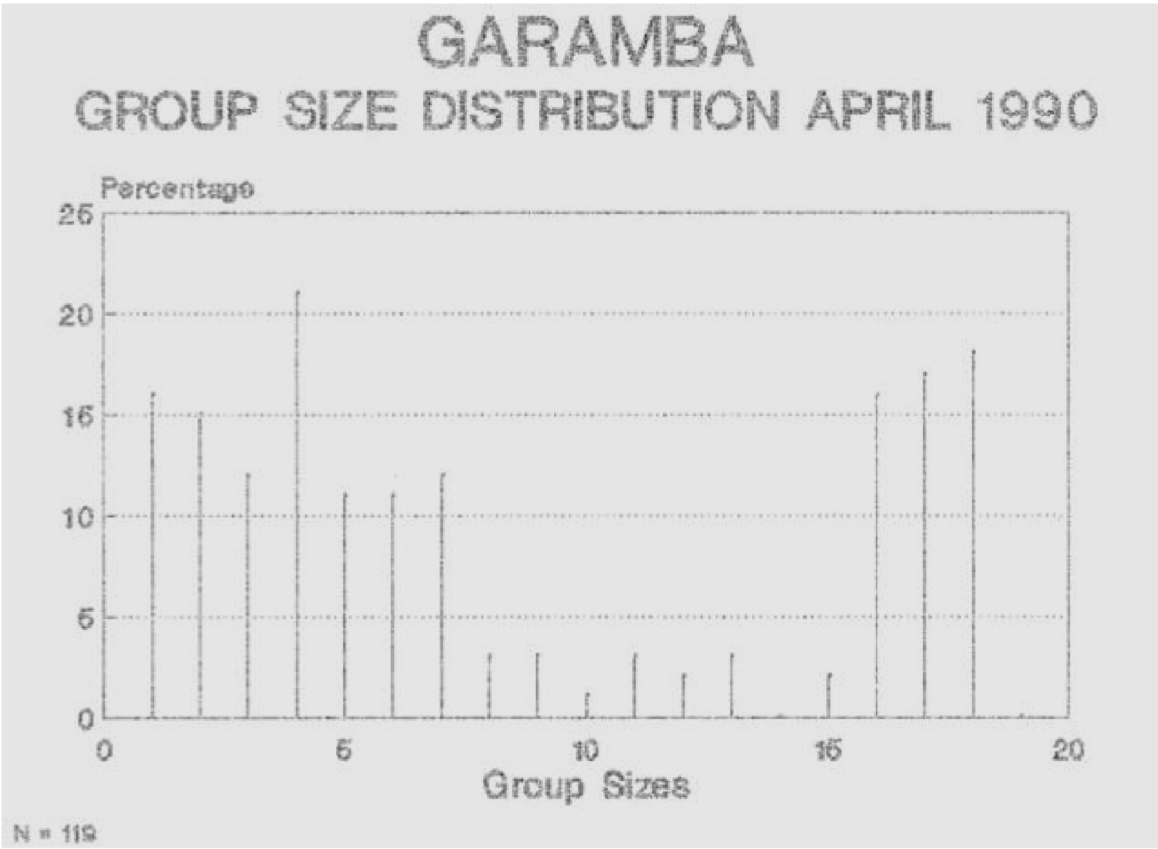


*Fig. 4: Observed elephant group size distribution in PNG* (Moss, 1990).

## 1.4 Elephant movements and habitat preferences

African elephants are distributed almost over whole Africa continent. They disperse into many different zones and habitats ranging from desserts (Blake, *et al*., 2003; Leggett, 2006), open savannahs and woodlands (Osborn, 2005; Mpanduji, *et al*., 2007) to tropical forests (Merz, 1984; Blake, *et al*., 2001). This shows, they can adapt on many different diets and environmental conditions. In smaller scale of particular park or area where elephant population can disperse, the dispersal is limited by resource scarcity or availability in the area. Movements are mainly dictated by water distribution, forage quality and habitat heterogeneity, and change seasonally (Western, *et al*., 1984; Grainger, *et al*., 2005).

Core areas of occurrence during dry season correlate with proximity to permanent water. In places where water sources are scarce, movements are reduced to few kilometres around (Leggett, *et al*., 2003; Charif, *et al*., 2005; Hema, *et al*., 2010). Apparently short movements occur when family herd has young offspring (Stokke, *et al*., 2002; Wittemyer, 2007). Stokke, *et al*. (2002) showed that elephant family groups in Chobe National Park, Botswana, did not move further than 3.5 km from rivers in the dry season and 5 km in the wet season.

Thence, scarce water distribution can negatively influence dispersal. But occasions where river form only permanent water source, dry season range can be bigger than for wet season (Shannon, *et al*., 2006 a). Recent study in Burkina Faso shows that elephants are more clumped during dry season because of lower frequency of water resources. During wet season the dispersal is more random, however it is also clumped into particular habitats. The dispersal is limited by growing and dense human population (Hema, *et al*., 2010).

Where water is abundant and so not limiting resource, dispersal during dry season may be limited by habitat diversity (Grainger, *et al*., 2005). Selected habitats are than with progressively more abundant but less digestible forage (Western, *et al*., 1984). In arid regions where water is rare and forage productivity is low in quantity and quality, elephants need to travel long distances (Lindeque, *et al*., 1991; Blake, *et al*., 2003).

Except extreme arid regions, during wet season water is more common and its influence on the distribution diminishes. Wet season movements are influenced by peak of growing season and higher nutrient content in vegetation. Some authors point that during rainy season elephants are selecting more plant species and perform higher selectivity for grasslands (Kabigumila, 1993; De Boer, *et al.*, 2000). During dry season they switch to higher proportion of browse (Beekman, *et al.*, 1989). This shows that in any area where elephants live they do different way according to environmental conditions (rainfall and water availability, habitat occurrence and distribution).

For example: In Zimbabwe elephants showed any selection in habitat utilisation for *Combretum-Terminalia* woodland and also no selection for riverine woodland and grassland. Positively selected habitat was *Brachystegia-Combretum* bush (Osborn, 2005).

But usually woody species and closed habitats are selected. In Cameroon, elephants significantly preferred forests, bush grasslands and riverine areas and avoided cultivated areas (Hofer, *et al.*, 2004). The importance of riverine vegetation diminishes during wet season, when swamps are the least preferred (Hofer, *et al.*, 2004). Ntumi, *et al.* (2005) studied habitat utilization in Mozambique and elephants there prominently preferred closed canopy habitats as woodlands, forests and riverine thickets, water associated hygrophilous grasslands were also chosen. Despite still green available forage which woody vegetation offers, shade and safe hide can be also important factors driving elephants to search such habitat (De Boer, *et al.*, 2000; Blake, *et al.*, 2001; Ntumi, *et al.*, 2005). During late dry season, woody or forested areas provide still green browse, whereas grasses have reduced palatability (Nicholas, *et al.*, 1995; Ntumi, *et al.*, 2005).

High densities of elephants in Tanzania were typically found near to water related ecosystems swamps and riverine vegetation (open grasslands and those with thick *Accacia kirkii* cover), or near to waterholes (Foley, 2002). Dense and open bushland was significantly focused by elephants, while grassland has not such importance there. However, Foley (2002) observed apparent utilization of alkaline grassland, because this area is not suitable for agriculture (alkaline soils) and so avoided by humans. Other authors pointed out avoidance of alkaline grasslands (Field, 1971; Beekman, *et al.*, 1989).

Some plant species are increasingly selected when having mature fruits (Tab. 2, Hillman Smith, 1988) and elephants travel distances for it (Nackoney, 2006). For comparison of habitat selection, percentages of plant type chosen by elephant in Ngorongoro Crater, Tanzania for wet and dry season respectively: sedges 25.5% and 29%, grass 24.3% and 9%, trees 7.9% and 25.3%, shrubs 6.9% and 19.6% and forbs 35.4% and 17.1% (Kabigumila, 1993).

Forest elephants prefer habitats with undergrowth. Those in Congo basin show preference for mineral holes, not human-used rivers and wetlands (Nackoney, 2006). In heavily disturbed forest in Ivory Coast, elephants fed mostly on trees; the leaves or twigs of 112 species, the bark of 21, the fruits of 54 and the bulbs of 3 species (Theuerkauf, *et al*., 2000). In PNG, elephants select greater range of species during dry season. Lot of mostly used species remain important both seasons. During the wet season many trees attract elephants with their fruits (*Vitex spp., Annona senegalensis, Nauclea latifollia, etc*.) (Nicholas, *et al*., 1995) (For whole information see annexe 2).

Growing season influences raiding on crops. Elephants leave protected areas and feed on fields mainly when crops are about harvest (Hillman Smith, *et al*., 1995 a; Sam, *et al*., 1998).

Preference for particular habitat is important factor and so should be relatively stable. However, De Boer, *et al.* (2000) found that elephant population, which used to feed predominantly in grasslands, switched the preference to woody vegetation because of poaching pressure. When nutrient needs are moderate, habitat preference can be changed. Even to less digestible but closed vegetation which provide hiding place (Foley, 2002).

Sexual dimorphism can play a role on feeding pattern. Males are bigger and can feed and utilize lower quality vegetation. In contrast, females are smaller and need to feed lower quantity of food with higher nutrient content (Barnes, 1982; Stokke, 1999; Shannon, *et al*., 2006 b). It is visible form Shanon, *et al*. (2006 b), who showed males feeding more intensive, and females more selectively. He also observed males browsing less digestible tree parts as roots and medium branches, while females selected leaves, flowers and fruits in higher portion.

*Tab. 2: Plant species eaten by elephants and habitats where given plant species grows* (Hillman Smith, 1988). Total percentages in the diet: for grasses are 37.5 and 49.5, for dry and wet season, woody species 42.6 and 36.8, respectively and rest is represented by shrub species. Plant part abbreviations: W-whole plant, Fr- fruit, L- leaves; Habitat abbreviations: H- tall grass savannah, HV- valley grass savannah, SA- tree bush savannah, ZB- woodland, ZBR- riverine woodland, R- river grass and swamp.

| **Plant species** | **Family** | **Dry season** | | **Wet season** | | **Habitat** |
|---|---|---|---|---|---|---|
| | | **Plant part** | **% of bites** | **Plant part** | **% of bites** | |
| *Eleusine indica* | *Poaceae* | W | 1.2 | W | 0.7 | HV |
| *Eragostis caespitosa* | *Poaceae* | | | W | 1.6 | HV |
| *Eragostis tenuifolia* | *Poaceae* | | | W | 3.2 | HV |
| *Hyparrhenia diplandra* | *Poaceae* | W | 5.2 | | | H/SA |
| *Hyparrhenia niariensis* | *Poaceae* | | | W | 13.4 | H/SA |
| *Hyparrhenia rufa* | *Poaceae* | W | 2.4 | | | H/SA |
| *Imperata cylindrica* | *Poaceae* | W | 4.5 | | | HV |
| *Loudetia arundinacea* | *Poaceae* | W | 13.7 | W | 22.8 | H/SA/R/ZBR |
| *Panicum maximum* | *Poaceae* | W | 2.3 | | | SA |
| *Pennisetum polystachion* | *Poaceae* | W | 1.7 | | | SA |
| *Setaria sphaecelata* | *Poaceae* | W | 3.3 | W | 3.5 | |
| *Urelytrus giganteum* | *Poaceae* | | | W | 1.8 | H |
| *Piliostigma thoningii* | *Caesalpinaceae* | L | 5.4 | L,Fr | 3.2 | H/HV/SA |
| *Combretum collinum* | *Combretaceae* | L | 4.1 | L | 4.8 | SA |
| *Terminalia mollis* | *Combretaceae* | L | 3.9 | | | SA |
| *Alchornea cordifolia* | *Euphorbiaceae* | L,Fr | 7.4 | | | |
| *Bridelia scleroneura* | *Euphorbiaceae* | L | 2.7 | L | 0.5 | SA |
| *Hymenocardia acida* | *Euphorbiaceae* | L | 1.5 | | | SA |
| *Irvingia smithii* | *Ixonthaceae* | L | 1.7 | | | ZBR |
| *Acacia seyal* | *Mimosaceae* | L | 1.9 | | | SA |
| *Acacia siberiana* | *Mimosaceae* | L | 1.9 | | | SA |
| *Ficus sp.* | *Moraceae* | L | 1.7 | | | SA |
| *Lonchocarpus* | *Papilionaceae* | L | 1.2 | L | 1.4 | ZBR/H/HV |
| *Nauclia latifolia* | *Rubiaceae* | L,Fr | 2 | Fr | 3.2 | ZBR/SA/H/HV |
| *Grewia mollis* | *Tiliaceae* | L | 1.7 | L | 0.2 | SA |
| *Vitex doniana* | *Verbenaceae* | L | 4.2 | Fr | 19.7 | H/SA |

## 1.5 Human-elephant confllict

Several authors showed elephants preferably avoiding contact with humans. For example Nackoney (2006) found out that elephants are avoiding human settled areas and roads in forest region of Congo basin. Elephant decision to head toward a river might be based on that elephant being to 1 kilometre away from the river, but a decision for an elephant to avoid a human settlement might be based on a distance of ten kilometres (Nackoney, 2006). In Mozambique, elephants did not use a portion of the reserve, which was inhabited by subsistence farmers. This elephant avoidance is probably given by disturbance by human and by frequent fire presence (De Boer, *et al.*, 2000; Ntumi, *et al.*, 2005). Foley (2002) showed agriculture areas as the least preferred or intentionally avoided habitat. In Zambia, elephants used less frequently habitats along river, which formed only permanent water source in area, because extensive human population lived close to the river (Chase, *et al.*, 2009). Movement speed and timing is different outside and inside the park. GPS radio-collar data showed that elephants are less active during the day when they are outside the national park, to reduce possibility of encounter with humans. Also movement through the migration corridor speeds up to four times faster than movement inside or outside the park (Foley, 2002).

Together with increasing human population, not exploited land is being changed to agriculture land, which is consequently reducing elephant range (Hoare, 1998). Also domestic animals compete for resources with wildlife and affect wildlife distribution (Wittemyer, 2007). Then, the reason of crop raiding can probably be destruction of elephant natural habitats and so insufficient food resources, or insufficient nutrient availability in wild plants especially sodium (Osborne, 1998; Rode, *et al.*, 2006). Furthermore, elephants need to migrate between protected areas, because of mating or seasonally for food. When corridors are not demarcated, elephants need to cross over human settled area (Douglas-Hamilton, *et al.*, 2005). In PNG, de Merode, *et al.* (2000) showed that the low-density presence of subsistence agricultural human populations does not have a significant impact on wildlife distribution.

Sometimes, elephants are not avoiding raiding on crops and even search for food in grain stores or injure and kill people. Crop raiders are especially males or male groups (in 79%) which are more tolerant to human disturbance (Hoare, 1999). Feeding on crops take place most frequently during night and main attraction is the period when crops are maturing or closely before (Hillman Smith, *et al*., 1995 a; Osborne, 1998; Hoare, 1999; Graham, *et al*., 2009). Benefits of taking the risk and feeding on crops, which are more nutritious, are better condition and sexual success (Hoare, 1999).

Rice, cassava, maize and millet are overall planted species in around PNG. The main target species by elephants are cassava, young rice and maize (Anonymous, 1993). The main crop attractant in Ghana was maize and cassava and plantains as well (Barnes, *et al*., 2005). Not only planted crops affect frequency of raiding. Distance from protected area is one of most important factors (Anonymous, 1993; Hillman Smith, *et al*., 1995 a; Barnes, *et al*., 2005). Further aspects attracting elephants are greater farm/field size, higher number of planted crops and distance to nearest field or farm (Barnes, *et al*., 2005).

Finally, most severe human-impact on elephants forms poaching. It has been reducing elephant populations for decades, especially during 1970´s and 1980´s (Smith, *et al*., 1994; Waithaka, 1998). Wildlife abundance in particular areas is negatively associated with proximity to market with bushmeat (de Merdode, *et al*., 2000). After significant poaching period, elephant population is recovering and stabilizing for a really long time (Moss, 2001; Aleper, *et al*., 2006)

Open savannah habitat, north of the river Garamba has been slightly closing because of low presence of animals. By 2004 elephants were avoiding this area due to poaching pressure (Hillman Smith, *et al*., 2005) . Until 2006 poaching pressures pushed elephant southwards and there was higher utilization rate of southern hunting area Gangala na Bodio but from 2007 this started to decline. In 2006, elephants were recorded in hunting area Azande. During ground survey in 2007, elephant presence was confirmed in northern part of the park. These data are showing that late poaching from north stops or at least diminish (Reid, 2007).

## 1.6 Home range

Elephant group or individuals require an area where they can satisfy their needs for food and social patterns. This is part of an area where elephant social unit can move freely and relatively undisturbed (some protected area and areas with low human presence) (Osborn, 2004). Elephants use the area non-randomly and the use and movements are relatively stable and partially repeats year to year. But the utilization may regularly shift in response to environmental changes and conditions (Osborn, 2004). Such utilized area is called home range (HR).

For better idea what home range is, the definition by Burt (1943, *in* Osborn, 2004) can be used: home range is 'the area traversed by the individual in its normal activities of food gathering, mating and caring for young'; Or by Estes (1992 *in* Roux, 2006) where a home range is defined as 'the area occupied by an individual or group, and is determined by plotting the perimeter of points where the individual or group is seen over a period of time'.

However, the HR is not consistent area and it is not possible to say, that elephant use only HR´s area at the same level and does not occur in other place. Stickel (1954) notes that the edges of range should be seen as diffuse and estimations rather than sharply defined (*in* Osborn, 2004). The concept of home range is complex and more respond to area of highest probability of elephant occurrence (Osborn, 2004). It helps, to better understand elephant needs, ecology and habits. And with observing dynamics of HR it is possible to determine development of elephant influencing factors.

The extent of HR is most probably function of the extent of area where elephant can move freely and undisturbed by humans and after than by water availability (Osborn, 2004; Douglas-Hamilton, *et al.*, 2005; Roux, 2006). Hoare (1998) stated decline in elephant home range linked to agricultural expansion. An individual female elephant home range has been compressed by 58% due to human settlement expansion over a decade (Hoare, 1998).

Home range extent is mainly influenced by landscape heterogeneity. Patchy distribution of different habitats leads to lower HR size, especially in females (Grainger, *et al.*, 2005). Forest elephants form small herds around four individuals, if swamp forest is present, aggregations of 20 to 40 individuals can be observed. There is enough food supply all year round, so elephants are not forced to travel a lot more searching food and HR area vary from 150 to 200 $km^2$ (Merz, 1984).

HR size differs also according to growing and rainy season. It is caused by fruiting, new growth at the beginning of wet season and water availability (Mpanduji, *et al.*, 2007). Range decline exponentially with an increase in water source patch richness density. This indicates that elephants in areas of high water point richness density have smaller home ranges than those in areas with low water point richness density (Stokke, *et al.*, 2002; Shannon, *et al.*, 2006 a). In Tarangire National Park, elephants which lived near permanent water sources had smaller home ranges during dry season in compare with other elephants (159-606 $km^2$) (Galanti, *et al.*, 2000). Grainger (2005) support this state but dry season range of studied males was not affected by water distribution, but probably by musth related movements. Bull elephants can have greater HR, which probably reflects their long travelling searching for females in oestrus (Leggett, 2006).

However, in Cameroon, HR size increased after artificial flooding. Elephants there showed two distinct dispersal patterns, where in both of them elephants increased HR size. Home range areas increased from 3066 to 5895.75 $km^2$ and from 2484 $km^2$ to 3678.51 - 5338.71 $km^2$ (Foguekem, *et al.*, 2009).

Home range sizes of radio-collared elephants in Kenya varied from 102 to 5527 $km^2$. Several subpopulations were distinguished in this population. Elephants from different subpopulations had different movement patterns and home range sizes. The ranges of elephants from one subpopulation overlapped and members of one subpopulation were often observed close together (Thouless, 1996).

Home range size does not correlate with social rank during wet season, but during dry season low-ranking group home ranges were less concentrated into protected areas (Wittemyer, 2007).

### 1.6.1 Methods for home range determination

Data for determining home range are gathered by GPS telemetry in form of geo-referenced points. Gathered set of points represents area where collared elephant operate.

Until today, several methods how to estimate HR size are developed (Osborn, 2004). The most frequently used, but one of the most overestimating is Minimum convex polygon method (MCP) (De Boer, *et al.*, 2000; Leggett, 2006).

More accurate method is Kernel density estimator, which counts probability of occurrence (Osborn, 2004). With this method is even possible to count core area. Core area response to area of elephant´s mostly frequented places and the key habitats (50% probability of elephant presence) (Charif, *et al.*, 2005; Ntumi, *et al.*, 2005; Leggett, 2006). Table of home range areas counted over Africa are extracted in Tab. 3.

Douglas-Hamilton, *et al.* (2005) showed that home ranges estimated with MCP or density estimators are overestimating and old. He pointed that elephants does not use such estimated home range equally. More exact approach should be done by dividing study area into grid of squares and counting frequency of visiting these squares (Douglas-Hamilton, *et al.*, 2005). This approach is very useful especially when elephants use human settled areas and in arid regions (Leggett, 2006).

*Tab. 3: Home range sizes counted in different parts of Africa.* MCP-minimum convex polygon, kernel-kernel density estimation, F-female, M-male; * Study in particularly fenced area, ** Study in fenced reserve

| **HR area ($km^2$)** | **Core area ($km^2$)** | **Method** | **Location (country)** | **No. Individual** | **Rainfall (mm/year)** | **Reference** |
|---|---|---|---|---|---|---|
| 102-5527 | | MCP | Kenya | 20 F | | (Thouless, 1996) |
| 880 | | MCP | CAR, Congo | 1 | | (Blake, *et al*., 2001) |
| 159-660 | | MCP | Tanzania | 3 | 600-650 | (Galanti, *et al*., 2000) |
| 2100-3314 | | MCP | Tanzania | 2 | | (Galanti, *et al*., 2000) |
| 129 | | MCP | Mozambique | 1 | 690-1000 | (De Boer, *et al*., 2000) |
| 11651-24265 | | MCP | Mali | 3 | 150-450 | (Blake, *et al*., 2003) |
| 201-4057 | 20.8-698.6 | kernel | Tanzania | 9 | 800-1100 | (Hofer, *et al*., 2004) |
| 169-267 | 25.1-73.8 | kernel | Mozambique | 4 F | 690-1000 | (Ntumi, *et al*., 2005) |
| 453 | 66.1 | kernel | Mozambique | 1 M | 690-1000 | (Ntumi, *et al*., 2005) |
| 22.1-136.3 | 3.9-31.4 | kernel | Zimbabwe | 16 F | 680 | (Charif, *et al*., 2005) |
| 72-4451 | | MCP | SAR | 26 | | (Grainger, *et al*., 2005) |
| 871-5900 | | MCP | Namibia | 3 F | 50-350 | (Leggett, 2006) |
| 1564-12800 | | MCP | Namibia | 5 M | 50-350 | (Leggett, 2006) |
| 256-2224 | 6.2-117 | kernel | Namibia | 3 F | 50-350 | (Leggett, 2006) |
| 628-3251 | 27-141 | kernel | Namibia | 5 M | 50-350 | (Leggett, 2006) |
| 10.5-71.5 | 1.7-31.5 | kernel | SAR | 3 | 400-600 | (Shannon, *et al*., 2006 a) |
| 328-6905 | | MCP | Tanzania | 9 | 800-1100 | (Mpanduji, *et al.*, 2007) |
| 64-1190 | | MCP | Kenya | 5 F | 300-750 | (Graham, *et al*., 2009) |
| 665-6235 | | MCP | Kenya | 8 M | 300-750 | (Graham, *et al.*, 2009) |
| 3583-5621 | 503-898 | kernel | Cameroon | 3 F | 700 | (Foguekem, *et al*., 2009) |

# 2 Aims of the thesis

Studying elephant ecology in PNG is complex topic and objectives of my study were:

## 2.1 Evaluation of elephant distribution and seasonal movement dynamics in PNG

It will bring the answers to questions concerning the possible trans-boundary movements (Congo DR - Sudan) and to answer the question whether the national park boundaries (or hunting reserves boundaries) are sufficient to protect elephant population.

- *To figure out daily movements and movements during day parts*
- *To evaluate elephant spatial distribution*
- *To estimate elephant home range areas and its distribution*

## 2.2 Elephant habitat use and preferences determination

## 2.3 Herd composition and it seasonal fluctuations

## 2.4 Human-elephant conflict area identification

By detection of conflict areas we could establish a system for decision-making, based on the relation of environmental and socio-economic data. This would help us to evaluate the status of land where elephants disperse from the park and what is the potential for conflict there, and if can these better be resolved.

- *To detect possible conflict areas between humans (villages, fields, mines) and elephants*
- *To assess impact of human activities on elephant distribution and habitat utilisation*

# 3 Study area

Garamba National Park lies on north east border of DR Congo between latitudes 3 and 5°N and longitudes 28 and 30°S. It was founded in 1938 and it is part of UNESCO world heritage. Area of the park is 4900 $km^2$ and it is surrounded to the west by the hunting reserve Azande (2,892$km^2$), to the south by hunting reserve Gangala na Bodio (2,652$km^2$) and to the east by hunting reserve Mondo-Missa (1,983$km^2$).

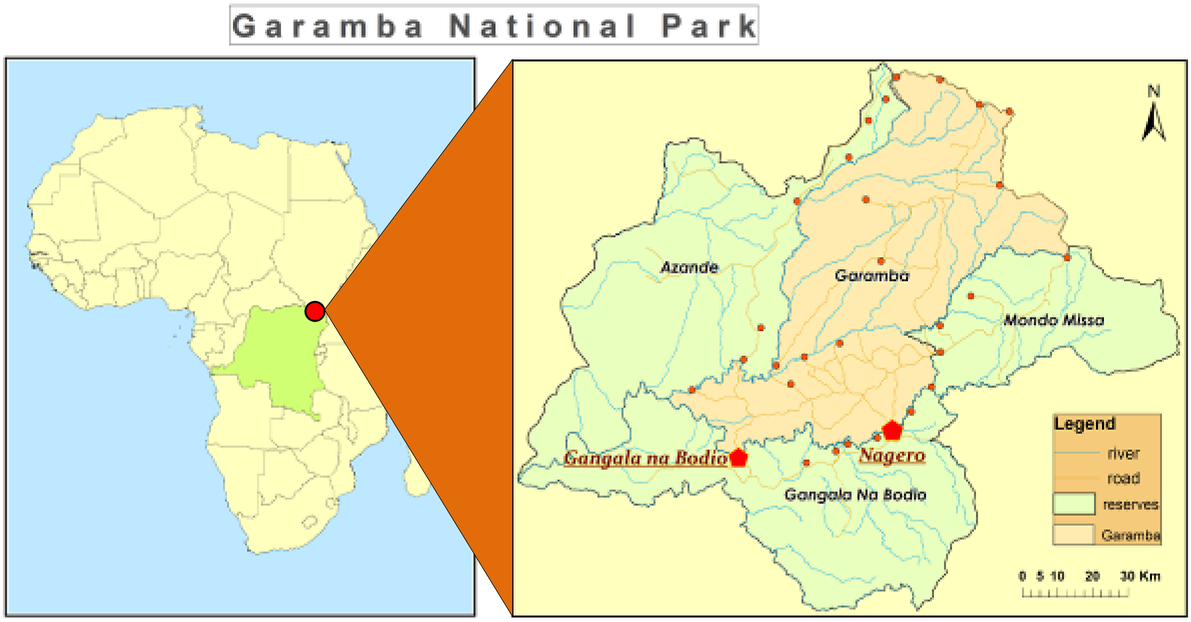


*Fig. 5: Position of Garamba NP in Africa and its area.*

Ecosystem of PNG is important mainly because of presence of great mammal species. The most important species is northern white rhino (*Ceratotherium simum cottoni*) which presence is not confirmed today and population of endemic giraffe species (*Giraffa camelopardalis congoensis*). Also elephants (*Loxodonta africana*) which form one of the most numerous population in Congo, and thousands of buffaloes (*Syncerus caffer caffer*) with populations of predators – lions and hyenas are greatly valuable.

PNG ecosystem falls into Sudan-Guinean vegetation type. Habitats vary from open and tree/bush long grass savannah in the park with small riverine forests on rivers to dense tree/bush savannah and woodland with gallery riverine forests in surrounding reserves. Mean annual rainfall is over 1,300 mm and it falls mainly in wet season from April to November (Hillman Smith, *et al*., 1995 a).

The park is under management of organisation African Parks Network today. The conservation effort is complicated by long term presence of Ugandan LRA rebels. Only small part of park centre between rivers Dungu and Garamba is safely accessible. Due to presence of rebels, roads were not maintained and so every movement is difficult and slow.

Land-use in reserves is mainly shifting agriculture with traditional use of bush meat, and there are areas of not allowed gold mining.

# 4 Material and Methods

## 4.1 Field data collection

Field work ran over period from 8th February 2010 to 25th May 2010 in form of missions. Missions were planified for 10 days staying in field. Because of reduced possibility of moving by roads, first and last day of mission were choosen for transport to field. The resting days we moved by foot and camping in the park. Missions had to be regulated according to changing conditions in field (Tab. 4).

The elephant research team composed of researcher (Pavel Hejčl), guard secretary (Matokaloma), and three or four skilled guards. Usualy we have been divided-three men working, two men resting and cooking in camp.

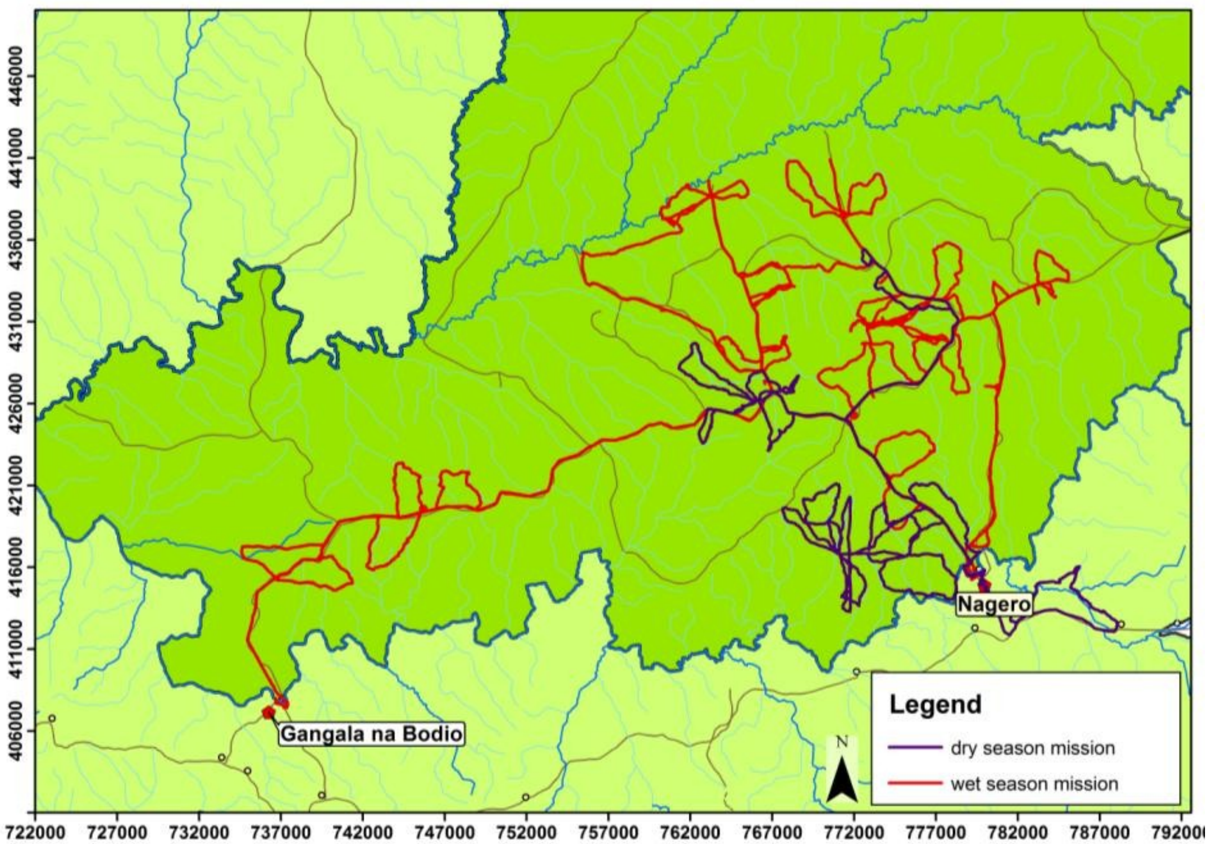


*Fig.6: Map of south part of PNG with tracks of missions.*

*Tab. 4: Schedule of field missions.*

| No. Mission | Date | Days | Distance (km) | Period |
|---|---|---|---|---|
| 1) | 8.2.-17.2. | 10 | 97.60 | dry season |
| 2) | 23.2.-4.3. | 10 | 87.00 | dry season |
| 3) | 12.3.-21.3. | 10 | 70.70 | wet season-beginning |
| 4) | 29.3.-2.4. | 5 | 45.70 | wet season-beginning |
| 5) | 6.4.-15.4. | 10 | 84.70 | wet season-beginning |
| 6) | 21.4.-30.4. | 9 | 69.73 | wet season-beginning |
| 7) | 5.5.-7.5. | 3 | 11.50 | wet season-beginning |
| 8) | 20.5.-25.5. | 6 | 57.60 | wet season-beginning |
| Total | | 63 | 524.53 | |

Field work design was planned as transect work at DISTANCE programme all over the PNG area (see annexe 3). Because of insecurity and insufficient infrastructure study was restricted only into the south part of the park, between rivers Dungu and Garamba.

During field work only two transects were walked thru. Rest of transect work was restricted. Thence, the field work proceeded in form of irregular random walkings in the proximity around each camp (Fig. 5). Average daily track was 11.4 km

First mission ran ten days from 8.2.2010 to 17.2.2010. First day we moved to field and last day back to the station. The rest of the days we worked in field. Second mission was in period 23.2.-4.3.2010 and we had to return from field after 6 days because one of my guards was ill. Rest of the days 1.3.-4.3.2010, we ride to field from Nagero station and return there each day. 3$^{rd}$ mission took ten days 12.3.-21.3.2010, we moved from field to Gangala na Bodio, second park station, for last two days. At the end of March we did not have food for missions, so 29.3.-2.4.2010 we went and return to field from Nagero station each day. After the food supply came, mission from 6.4.till 15.4.2010 was planned. But because we get insufficient amount of food for ten days, we came back 8$^{th}$ day and resting two days we finished go and return method. Next, 6$^{th}$ mission was for nine days (21.4.-30.4.2010). We moved from first camp to another because of poacher presence. During May we did only three days of go and return mission from 5.5.to 7.5.2010 and at the end of May last mission (20.5.-25.5.2010) took place. This was shorter because of inauguration of park campsite. The period of working in field covered up dry and beginning of wet season (Tab. 4 and 5).

*Tab. 5: Season changing during year.*

| Month | 1.12.-31.3. | 1.4.-31.7. | 1.8.-30.11. |
|---|---|---|---|
| Period | dry season | wet season-beginning | wet season- top (wet-end) |

### 4.1.1 Indirect data collection

During foot patrols on missions any signs of elephant presence were taken. Indirect signs like traces, dung piles, damaged trees, termitaria and depressed grass, were noted. For each data record we took GPS coordonates and noted type of observation, estimated number of individuals in herd, age of event and habitat type (Data sheet in annexe 4). Data on observation of elephant carcasses or human (poacher) presence signs were also gathered.

### 4.1.2 Direct observations

If elephants were observed directly, the same data as for indirect observation were noted. Additional information of age and sex composition of herd was possible to wrote down. Age categories and herd classification are drawn below.

Individual elephant age classification:

- *Young* - till age 15
  - *Calf* - 0-5 years
  - *Juvenile* - 5-15 years - bigger than a calf; not sexually mature; tusk absent or stubby; for older individuals where possible to identify sex will be noted.
- *Adult* - 15 and more years
  - *Adult male* - A huge markedly hourglass-shaped face with gaunt sunken temples; markedly rounded forehead; overall huge body size.
  - *Adult female* - Fully grown with developed mammary glands; flattened front skull with an angular point on the forehead.

Herd classification according to Stokke, *et al*. (2002):

- *Solitary male*
- *Bull group* – comprising adult males only; independent from family units.
- *Family group* – comprising a matriarch and other adult females with their offspring; not attended by adult male(s).
- *Mixed group* – Family unit attended by adult male(s).

When elephants did not know about us, activity observation was done (Tab. 6). One focal animal was observed until it was visible. For each activity, time and habitat in which took place and observing distance, was noted (Data sheet in annexe 5). Noted activities were eating, standing, moving, comfort and social behavior and antipredator behavior.

Anti-poaching department of PNG note direct animal observations as well as human presence observations during field patrols. These data are available in archive of PNG since 2008. Elephant observations and human activity observations were extracted and used as additional data in elephant distribution evaluation and human-elephant conflict appraisal.

### 4.1.3 Telemetry data

In May 2009 five elephants (2 bulls, 3 cows) were collared with GPS/VHF collars. The collars and system were provided by Africa Wildlife Tracking. GPS fixes were sent three times a day (morning, afternoon, night) and stocked on the internet. Data were downloaded into PNG database. One collar failed function after eleven months (bull Kimia: 31.5.2009 – 20.4.2010). But, four resting collars functioned and sent fixes regularly whole planned period 31.5.2009 – 10.12.2010.

### 4.1.4 VHF tracking

Collared elephants were frequently moving across south part of the park. When mission was planned, current collared elephant positions were taken into account. If the latest fix of any collared elephant was close presently targeted camp, we moved towards it. With VHF receiver exact position of elephant was located and direct observation was done.

*Tab. 6: Types of activity observation and its description.*

| Code 1 | Name 1 | Code 2 | Name 2 | Explication |
|---|---|---|---|---|
| **STA** | **Standing (Sur pie)** | STA1 | normal position | |
| **LIE** | **Lying (Se coucher)** | LIE1 | normal position (sternal) | |
| | | LIE 2 | sleeping | |
| **MOV** | **Moving (Deplacement)** | MOV1 | walk | |
| | | MOV2 | trot | |
| | | MOV3 | gallop | |
| **EAT** | **Eating (Manger)** | **EAT1** | **eating from the ground** | manger a niveau du sol |
| | | **EAT2** | **browsing below head level** | Bruter en bas le niveau de la tête |
| | | **EAT3** | **browsing in head level or up** | Bruter a niveau de la tête ou plus haut |
| | | **EAT4** | **branch breaking** | Casser une branch |
| | | **EAT5** | **browsing while moving** | Bruter au même temps de deplacement |
| | | **EAT6** | **soil** | sol/terre |
| **DRI** | **Drinking (Boire)** | | | |
| **COM** | **Comfort behaviour** | COM1 | scratching | *by horn-tips, legs, objects* |
| | **(Comportement de comfort)** | COM2 | grooming | *licking, biting* |
| | | COM3 | protection from insect | *by tail, legs, head shaking, twittering the skin* |
| | | COM4 | protection from oxpacker | *by tail, legs, head shaking, twittering the skin* |
| **SOC** | **Social behaviour** | SOC1 | communication | social licking, vocal (bleating,alarm bark), rubbing forehead/nasal brush, sniffing, nasonas., ano-gen. |
| | **(Comportement social)** | SOC2 | agonistic behaviour | dominance/threat displays, glance threat, chasing, head-low posture, fighting |
| | | SOC3 | sexual behaviour | lip-curl (urine-testing), head-resting, mounting, being mounted |
| | | SOC4 | parent/offspring behaviour | nursing, sucking, refusing suckling, sucking attempt, |
| | | SOC5 | play | object plays, moving plays, running/jumping, chasing, play-fighting, sexual plays |
| **ANT** | **Antipredator behaviour** | ANT1 | human presence | |
| **INV** | **Invisible** | | | |

### 4.1.5 Aerial monitoring

During May 2010, aerial monitoring was possible to make. Two flights as far as the northern border of PNG lies were led, for to get information about elephant presence there. Other shorter flights were passed thru during processing of vegetation map (Tab. 7). Flights were led over the places where transition zones between habitats occur and when habitats set by satellite image evaluation were not probable.

Any elephant observation during aerial patrols was noted as well. And this was used for elephant habitat preferences and spatial distribution evaluation.

*Tab. 7: Schedule of flights for detection of vegetation map reference points and for elephant distribution data collection.*

| Date | Hours total | Distance (km) |
|---|---|---|
| 20.6.2010 | 2:09 | 440 |
| 21.6.2010 | 1:35 | 308 |
| 28.6.2010 | 1:17 | 149 |
| 9.7.2010 | 0:49 | 120 |
| 10.7.2010 | 1:26 | 156 |
| 11.7.2010 | 0:33 | 97 |
| Total | 7:49 | 1270 |

## 4.2 Data analysis

### 4.2.1 Daily movements

Data from collars were used to evaluate movement patterns. The day was divided into three day parts: morning (5 h till13 h), afternoon (13 h till 21 h) and night (21 h till 5 h), according to time of fixes sending. Distance between each two successful continuous fixes was counted in ArcMap 9.3 (ESRI, 2008). For counting movement per day, walked distance from morning to morning was counted. As movement in day part was taken the distance between each two successful fixes. When one fix was missing, distance for such day or day part was set as Not Available (NA). Computation then skipped to next successful fix.

Statistics were than counted with one way ANOVA: difference between individuals, sexes, seasons (dependent variable distance per day); and difference between day parts (dependent variable distance per day part). With multi way ANOVA were studied differences between season:sex and season:individual interaction (dependent variable distance per day); and for dependent variable distance per day part differences between season:day part, day part:sex, day part:individual and day part:individual in particular seasons. When differences were significant, Tukey HSD test was processed. Statistics was processed in cran R software (R Development Core Team, 2009).

### 4.2.2 Elephant distribution and seasonal movements dynamics

For interpreting distribution maps I used data from field work, aerial observations and archive data. Archive data comes from years 2008-2010, but they are not of sufficient quantity to be divided into separate years. Resulting maps are divided into two seasons dry and wet and were processed in ArcMap 9.3 (ESRI, 2008).

### 4.2.3 Home range

For home range area estimation, data from collars were used. Telemetry data used were from period of 31.5.2009 to 20.4.2010 for male elephant named Kimia (failure of collar) and period 31.5.2009 to 10.12.2010 for rest of collared elephants (one male, three females).

Fixed kernel density estimation model method with 50% and 95% probability of elephant presence was used. Home ranges were counted in cran R software (R Development Core Team, 2009) with additional libraries adehabitat (Calenge, 2006), maptools (Lewin-Koh, *et al*., 2010). For exporting HR polygons, library shapefiles was loaded. Acquired number of fixes for each animal is sufficient also for to count HR for short period such as season or month. Seasonal home ranges were then counted.

Areas of individual home ranges and their overlapping were counted in ArcMap 9.3. This was used also for interpreting maps of HRs.

### 4.2.4 Habitat use and preferences

For habitat preference I have three types of data. First basic knowledge about habitat utilising gives me field work data (from field work, aerial survey and archive). These comprise information about distribution in given habitat despite activity performed. Habitat utilization was evaluated with Pearson's Chi-squared test.

Second type of data for habitat preference was gained from direct activity observation. For each activity observed is available habitat information. Differences in time spent with each activity were counted and tested with Kruskal-Wallis Anova. Frequency of activity re-initiation/interruption per hour was tested with Kruskal-Wallis Anova as well.

Third and the most voluminous type of data for habitat preference evaluation are data from collars. However, only information provided by collars is GPS position sent in given time. Standing alone, this information is pointless. By this reason vegetation map was processed. GPS fixes sent by collars were intersected with vegetation map in ArcMap (Hawth´s Analysis Tool-Intersect Point Tool) (Beyer, 2004). Each GPS location matches to one pixel (eg. one habitat) on vegetation map. The most visited habitats from vegetation map correspond to the most preferred habitats. Statistics were counted with Pearson's Chi-squared test (contingency tables).

#### *4.2.4.1 Modelling of vegetation map*

Vegetation map was modelled to analyse elephant habitat preferences as much exact as possible and for to get idea about vegetation dynamics in the park.

All staff of monitoring department of PNG uses for vegetation evaluation same habitat characteristics, including main species composition and percentage of tree cover. Habitat types and parameters for its identification are derived from Amube, *et al*. (1995) (Annexe 6). Habitat information data from all monitoring teams were exported to obtain sufficient volume of data for reference points.

North part of the park and most of area of reserve´s are not accessible on the ground, because of broken infrastructure and insecurity. Due to this we flew 20.6.2010 and 21.6.2010 over the north part of park. For better knowledge of reserve´s vegetation and/or when in some places, especially in forests and borderline areas of neighbouring habitats, it was not clear which habitat type to assign, ultra light plane flights to these areas passed over. Exact data for such areas were collected.

For modelling of vegetation map I have used programme MultiSpecW32 (Biehl, 2001). As baseline multispectral data were used appropriate LANDSTAT 4-5 Thematic Mapper satellite images with 30*30 meters per pixel resolution from 7.2.2003 (scenes available at http://glovis.usgs.gov/).

All field observations (field data, archive data, aerial data) contain GPS coordinates and habitat description. These were extracted and used as baseline habitat information for reference points from field data and aerial observations.

Inaccessible areas and places which were set during map processing as uncertain/not probable habitat were surveyed by plane. This was helpful to rose probability of resulting vegetation map.

#### *4.2.4.2 Vegetation map outcome*

For satellite image classification Maximum likelihood classifier method was used. Combination of channels 12345678 and classes used: threshold (background, no data), rivers and water ponds, riverine grass and swamps, papyrus swamp, grassless soil, tall grass savannah, tree bush savannah (dense), woodland, riverine forest, open forest, tree bush savannah (sparse), burnt tall grass savannah. Class background is present because all pixels from multispectral image cannot be sorted to groups. It is mainly formed by clouds and also by transition zones between given habitats.

The resulting map (Fig.7) had overall class performance 71%. Average likelihood probability is 40%.

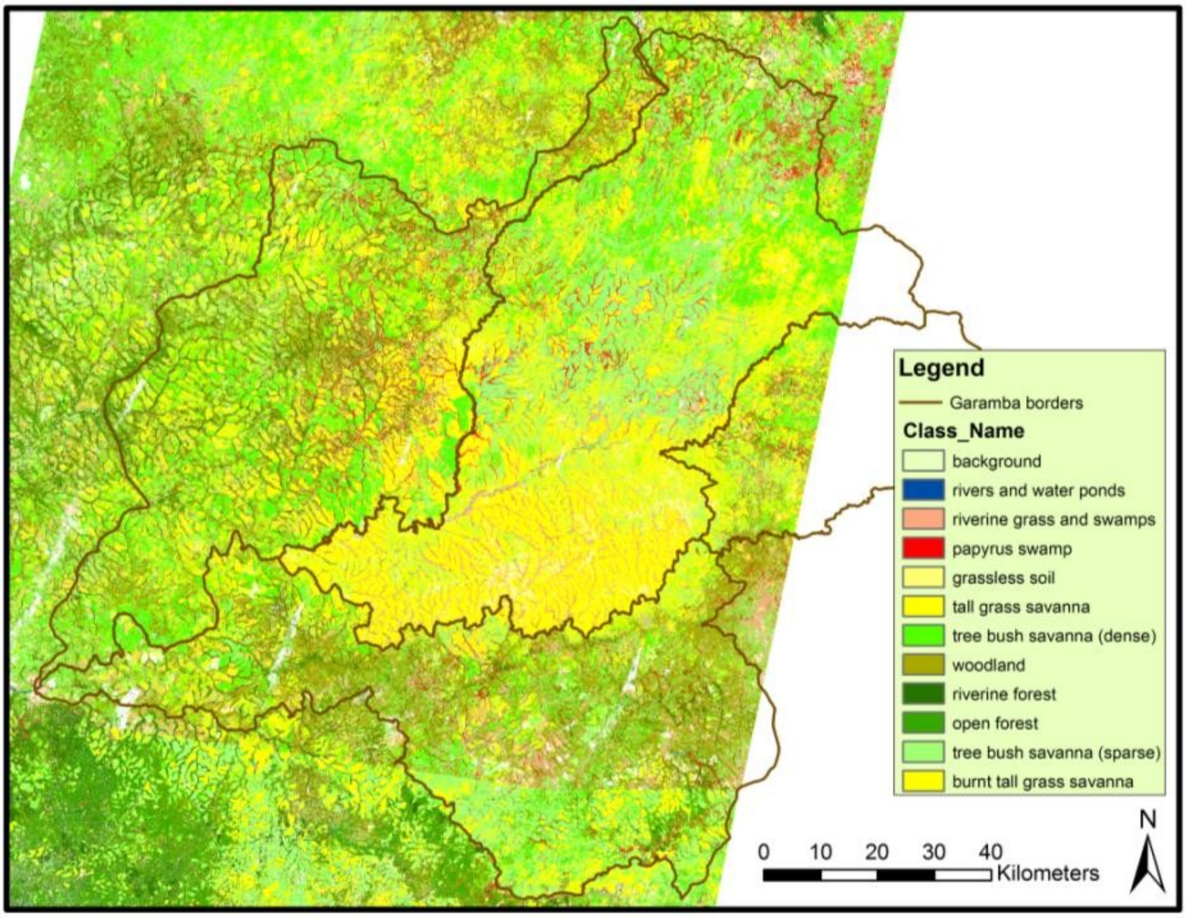


*Fig. 7: Resulting map of habitat distribution*. White fields in map image are background pixels caused by clouds. For eastern area of hunting reserve Mondo Missa vegetation map was not processed, because any of collared elephant position has been recorded there.

### 4.2.5 Herd composition

Numbers of individuals in herd were extracted from direct elephant observation from field work, aerial survey and archive. Two-way ANOVA was used for statistical analyse.

### 4.2.6 Human-elephant conflict area identification

During field patrols of park anti-poaching and monitoring departures and aerial surveys, all types of human presence (poaching, gold mining, villages and fields) in park area are noted. Telemetry data and all field elephant observations data were used for to determine elephant distribution range. These two sets of information were imported and visualized in ArcMap 9.3 (ESRI, 2008). Areas where elephants are influenced by and coexist with humans were designated. Especially areas of important poaching pressure were highlighted. Such areas identification could be useful in understanding to elephant movement patterns and identifying human-elephant conflict areas.

# 5 Results

## 5.1 Elephant seasonal movement dynamics

Records of telemetry data was highly successful, and four collars functioned correctly whole observation period. Detailed numbers of successful/unsuccessful GPS fixes sent by collars over whole study period are shown in Table 8. Field work plans were changed and due to field data collected were not of such volume.

*Tab. 8: Number of successful and unsuccessful fixes sent by collars.* 0D = any data sent, 1D = collar was connected, but sent no position. Successful fixes were used in HR and habitat preferences analysis.

| individual | sex | successful | | unsuccessful | | | Total |
|---|---|---|---|---|---|---|---|
| | | count | % | 0D | 1D | % | |
| **MAMA MONENE** | F | 1602 | 95.6 | 45 | 29 | 4.4 | 1676 |
| **MOKE** | F | 1490 | 89.0 | 88 | 96 | 11.0 | 1674 |
| **BONDEKO** | F | 1366 | 81.5 | 50 | 260 | 18.5 | 1676 |
| **BOMOI** | M | 1562 | 94.3 | 51 | 44 | 5.7 | 1657 |
| **KIMIA** | M | 838 | 86.0 | 62 | 74 | 14.0 | 974 |
| **Total** | | 6858 | 89.6 | 296 | 503 | 10.4 | 7657 |

### 5.1.1 Daily movements

Average movement distance travelled per day is 6375 m (± 1808 m S.E.). The shortes and the longest travelled distance in one day was 692 m and 28221 m, respectively. Mean movement distance travelled per day differ each season (df = 2, F = 58.62, $p < 0.05$). The shortest average travelled distance was in top wet season 5302 m (± 106 m S.E.) and the longest in the wet-beginning season 7440 m (± 173 m S.E.). The dry season movement per day was 6617 m (± 171 m S.E.)(Fig. 8).

Average movements per day did not differ between sexes (df = 1, F = 204182, $p > 0.05$), even there was no significant difference between individual animals (df = 4, F = 0.81, $p > 0.05$).

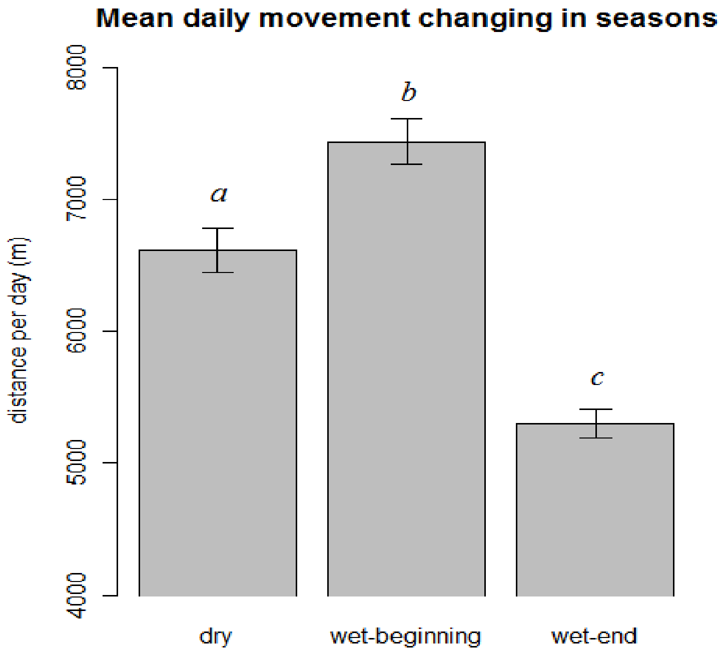


*Fig. 8: Graph of daily movement distances changing with seasons.* Vertical bars indicate standard error of the mean. Different letters indicate significant difference.

### 5.1.2 Movements during day parts

Elephants show differences in movements between particular day parts. The longest movements take place at night 2521 m (± 41 m S.E.) and continue in the morning 2177 m (± 42 m S.E.). Afternoon movement distance is the shortest one 1886 m (± 38 m S.E.) ($df = 2$, $F = 61.192$, $p < 0.05$). Females and males showed the same trend in movement changes during day parts and the distances does not differ ($df = 2$, $F = 2.792$, $p > 0.05$). But individuals show different diurnal movement patterns ($df = 8$, $F = 8.4134$, $p < 0.05$)
(Tab. 9).

*Tab. 9: Average distances of diurnal movements for individual animals*. Plus-minus sign interval indicate standard error of the mean. Distance numbers are in meters (m).

| Name / Daypart | BOMOI ♂ | BONDEKO ♀ | KIMIA ♂ | MAMAMONENE ♀ | MOKE ♀ |
|---|---|---|---|---|---|
| morning | 2228±100 | 2159±94 | 2256±110 | 2379±85 | 1882±75 |
| afternoon | 1816±72 | 2098±103 | 2039±106 | 1555±73 | 2057±77 |
| night | 2631±87 | 2862±116 | 2012±96 | 2422±69 | 2505±81 |

Travelled distances in particular dayparts differ with changing season (df = 4, F = 3.6869, p < 0.01) (Fig. 9). Between sexes, in particular seasons there is no significant difference (df = 2, F = 2.2079, p > 0.05). When looking on individuals, diurnal movements change and the differences are significant (df = 8, F = 2.9401, p < 0.05) (Annexe 7).

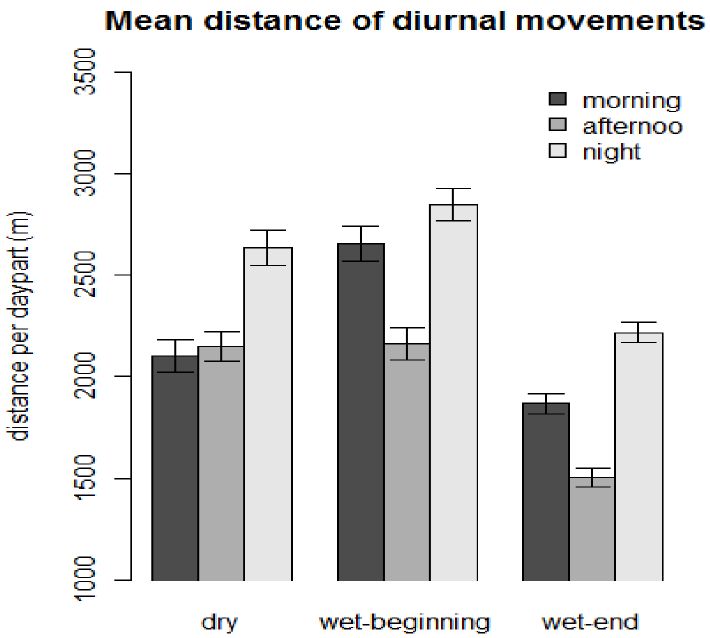


*Fig. 9: Graph of seasonal changies in diurnal movement distances.* Vertical bars indicate standard error of the mean.

### 5.1.3 Elephant spatial distribution

Elephant distribution maps designed with field, archive and aerial data are shown Fig. 10, 11. For identification of changes in spatial distribution see distribution map from 2007 (Annexe 1). Distribution data for top wet season originate only from archive and they are included in distribution map for wet season (Fig. 12). Field work and aerial survey did not run during period of top wet season (Tab. 4).

These data can be competently used for south part of park between rivers Dungu and Garamba. In remaining area of northern part of park and in reserves, the data are not of sufficient volume because missions are not frequent in these areas. My field work was not allowed to pass over these areas. It is obvious from field observations that whole southern part of the park is frequently used and visited by elephants.

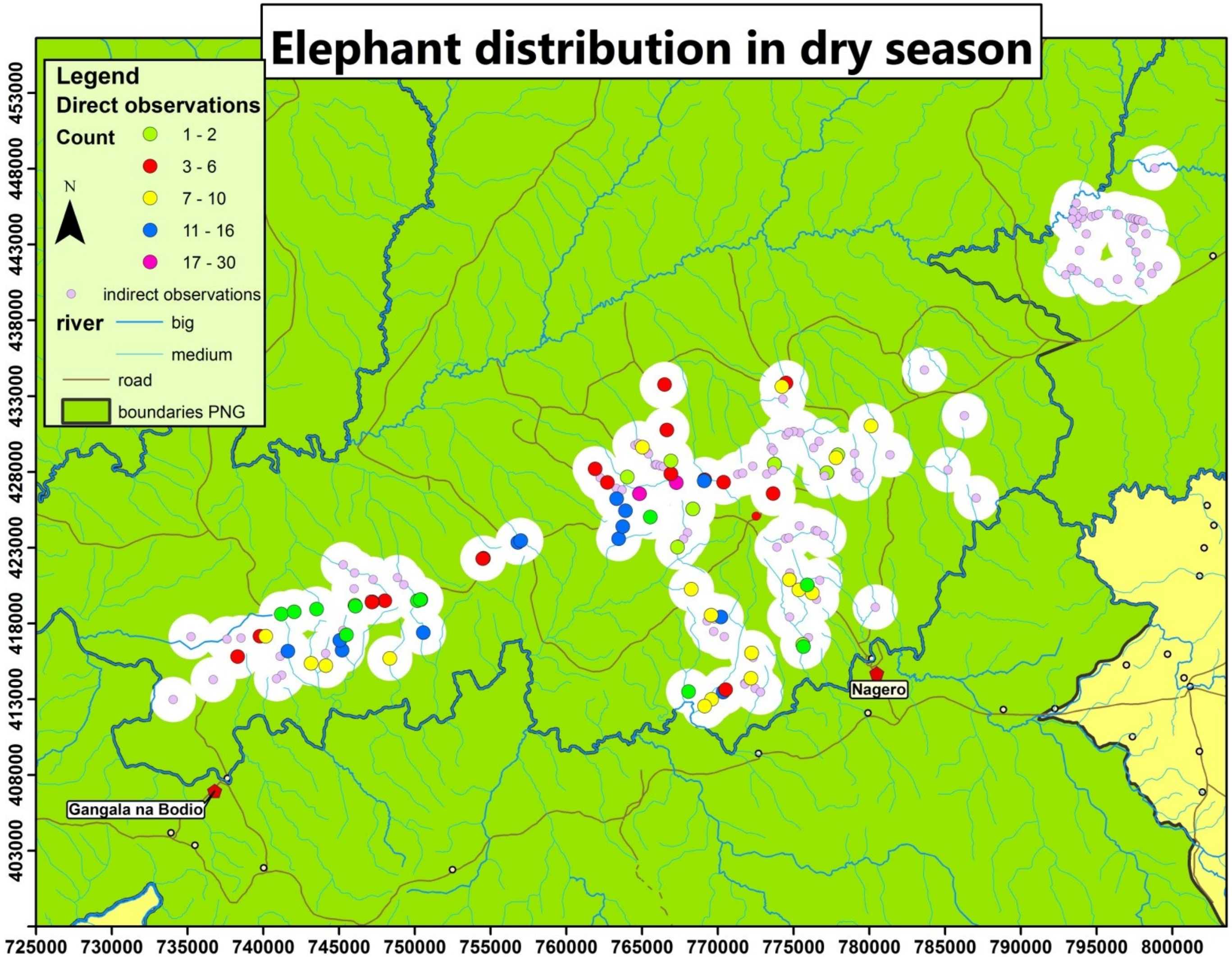


*Fig.10: Elephant distribution map for dry season*. Data gained from archive 2008-2010, field work and aerial survey 2010. White coloured spots are areas 1.5 km around observed elephants or elephant indirect observations; Areas of most probable elephant distribution.

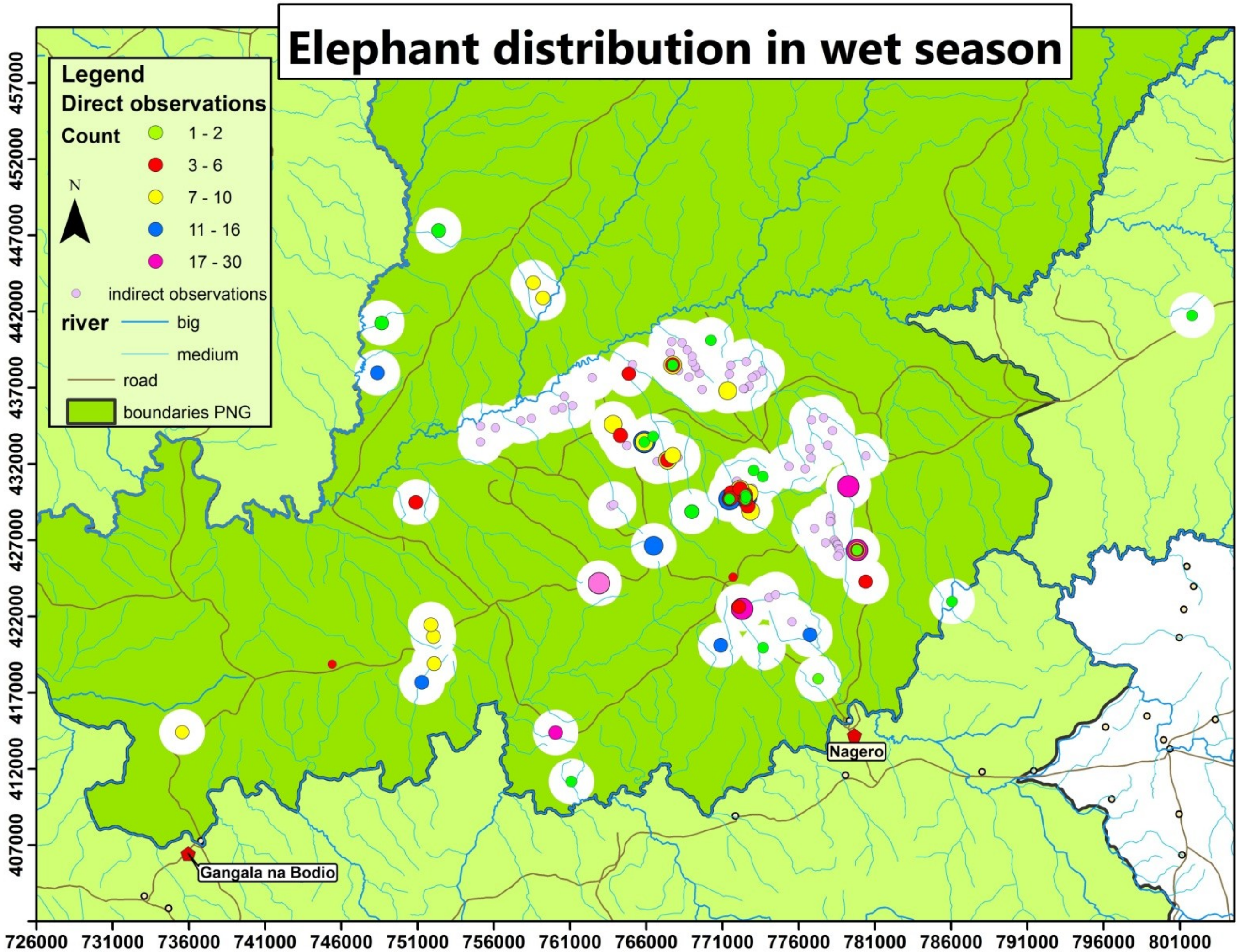


*Fig.11: Elephant distribution map for wet season.* Data are gained from archive 2008-2010, field work and aerial survey 2010. White coloured spots are buffer areas 1.5 km around observed elephants or elephant indirect observations (areas of most probable elephant distribution).

### 5.1.4 Home range area

Elephant distribution acquired by telemetry data collection is more complex. These data cover up all park and reserves area, despite inaccessible territories and security issue.

Overall home range area vary from 1002 $km^2$ to 3143 $km^2$ (mean 1987 ± S.E. 383 $km^2$) (Tab.10). Between home range areas for seasons, the difference is not significant (tested with Kruskal-Wallis $\chi^2$ (df = 2) = 5.6, $p > 0.05$), but top of wet season HRs are obviously smaller (Fig. 12). Differences between males and females are not significant and both sexes show same HR changes in seasons. Statistical results are influenced by low number of samples (5 elephants).

During top wet season 2009 two female herds had smaller home range area than other observed elephants (Bondeko 690 $km^2$, Moke 712 $km^2$). Next year 2010 at the end of wet season, the HR size increased (Tab. 10). It was affected by new born calf in their herd (pers. observation).

Kimia was collared as solitary male, but any repeated direct observation was done. He had the smallest HR of all collared elephants. During end of wet season Kimia ranged only over area 226.5 $km^2$ (Tab. 10).

Mean HR core area was estimated to 501 $km^2$ ± 116 $km^2$ (S.E.). Male core areas were both extreme values. The one of Kimia was the smallest 161 $km^2$ and the biggest one for Bomoi 804 $km^2$.

*Tab. 10: Extents of HRs for individual animals and seasons.* Core area = 50% kernel density estimation HR for all data collection period; 95% kernel density estimation HR for: all data = all data collection period, dry = dry season, wet.beg = beginning of wet season, wet.end = top wet season.

| **individual** / **area (km$^2$)** | **KIMIA ♂** | **BOMOI ♂** | **BONDEKO ♀** | **MOKE ♀** | **MAMA MONENE ♀** |
|---|---|---|---|---|---|
| **all data** | 1002 | 3143 | 1874 | 1840 | 2077 |
| **core area** | 161 | 804 | 489 | 473 | 576 |
| **dry** | 1234 | 2097 | 1846 | 1482 | 2362 |
| **wet.beg** | 1015 | 3117 | 2511 | 1644 | 1460 |
| **wet.end 2009** | 226 | 1740 | 690 | 712 | 1328 |
| **wet.end 2010** | NA | 1288 | 1028 | 1834 | 1139 |

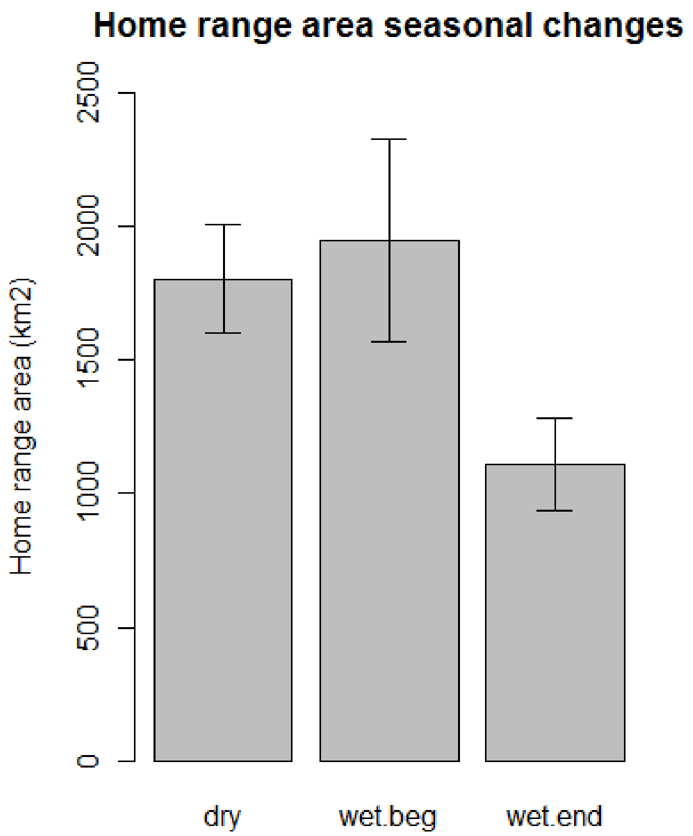


*Fig. 12: Average home range size in particular seasons*. Vertical bars indicate standard error of the mean.

All collared elephant home ranges overlaped each other (Fig. 13). Only top wet season HRs show differences in utilizing PNG area and some collared elephant pairs did not overlapped each other. Extent of overlaping areas are stored in Tab. 11. Core areas overlaped for some individual pairs. Bomoi with Mama Monene use together 310 km$^2$ of their core areas, Bondeko with Moke 256 km$^2$ Kimia with Moke 118 km$^2$, and Kimia and Bondeko commonly use 108 km$^2$, of their core areas.

*Tab. 11: Extent of overlaping HR areas* (in km$^2$ and percentages of individual HR area). ´Percent´ table indicate, how many percent of area of individual from row is affected by area of individual from column. During top wet season some elephants HRs did not overlaped. NA = Not Applicable.

| Area (km$^2$) | BOMOI | BONDEKO | KIMIA | MAMAMONENE | MOKE |
|---|---|---|---|---|---|
| BOMOI | NA | 766 | 654 | 1976 | 677 |
| BONDEKO | 766 | NA | 933 | 500 | 1343 |
| KIMIA | 654 | 933 | NA | 446 | 799 |
| MAMAMONENE | 1976 | 500 | 446 | NA | 348 |
| MOKE | 677 | 1343 | 799 | 348 | NA |

| Percent (%) | BOMOI | BONDEKO | KIMIA | MAMAMONENE | MOKE |
|---|---|---|---|---|---|
| BOMOI | 100 | 24 | 21 | 63 | 21 |
| BONDEKO | 41 | 100 | 50 | 26 | 72 |
| KIMIA | 65 | 92 | 100 | 44 | 80 |
| MAMAMONENE | 95 | 24 | 21 | 100 | 17 |
| MOKE | 36 | 73 | 43 | 19 | 100 |

| Season<br>ID overlapping HR | Dry | Wet beginning | Wet end 2009 | Wet end 2010 |
|---|---|---|---|---|
| MOKE – MAMA MONENE | 570.90 | 398.46 | NA | 78.39 |
| BONDEKO-MAMA MONENE | 548.49 | 736.13 | NA | 63.82 |
| BONDEKO-MOKE | 994.29 | 1455.70 | 464.78 | 851.11 |
| BOMOI-MAMA MONENE | 1482.61 | 1391.55 | 804.13 | 626.04 |
| BOMOI-MOKE | 118.17 | 745.32 | NA | NA |
| BOMOI-BONDEKO | 169.66 | 1137.45 | NA | NA |
| KIMIA-MAMA MONENE | 783.33 | 444.67 | NA | NA |
| KIMIA-MOKE | 909.88 | 842.04 | 157.59 | NA |
| KIMIA-BONDEKO | 867.87 | 945.00 | 206.82 | NA |
| KIMIA-BOMOI | 282.29 | 712.68 | NA | NA |

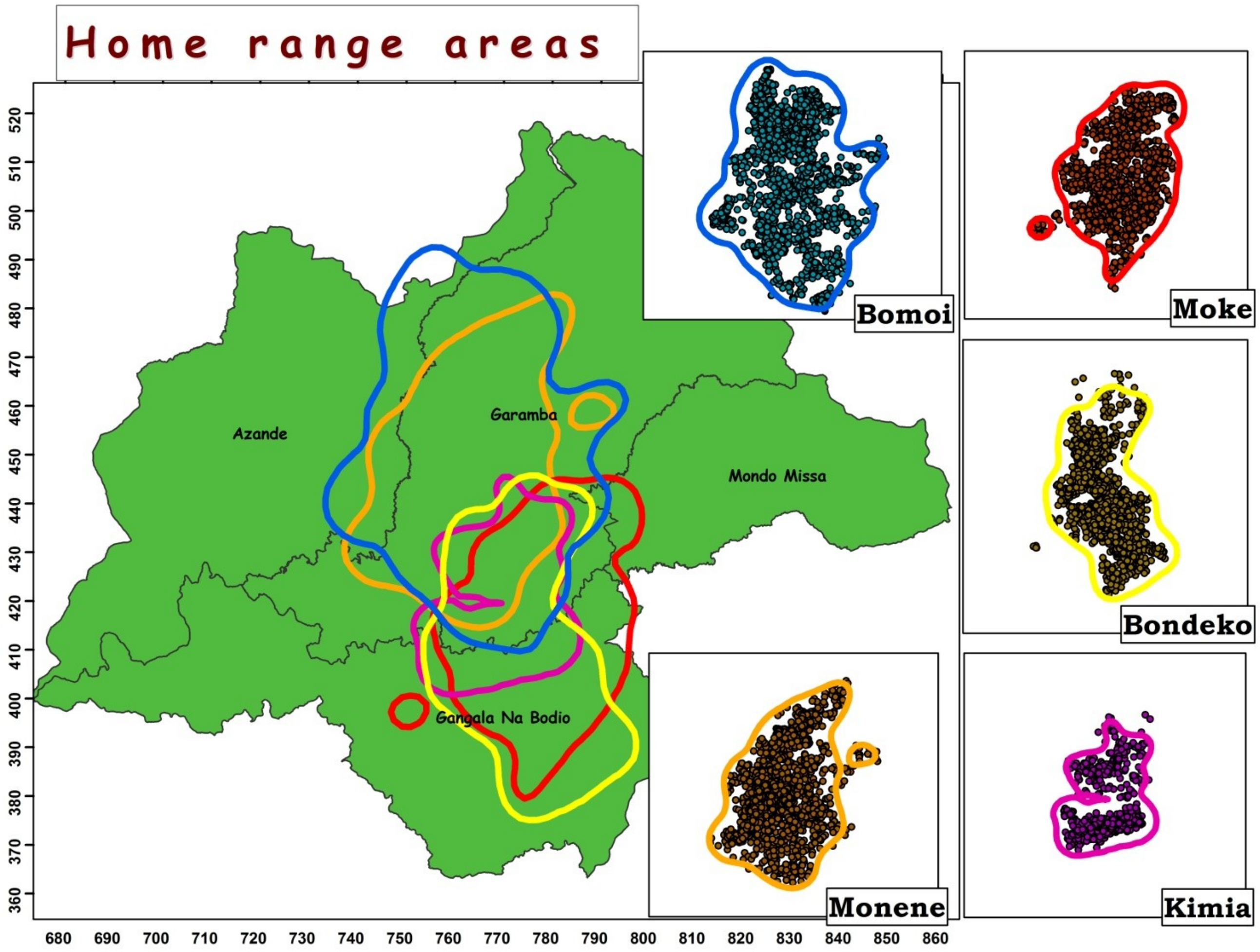


*Fig. 13: Home range areas of 5 collared elephants*. HR was counted for period 31.5.2009 to 10.12.2010 (period for Kimia 31.5.2009-20.4.2010). Sent positions distributions for single elephants are visualized in smaller frames. Colour filled spots in frames of each elephant design core areas (50 % kernel probability). Spatial distribution is shown on map of PNG. HR colours in map correspond to colours in smaller frames. Individuals: Monene (Mama Monene), Bondeko, Moke were cows; Bomoi and Kimia bulls.

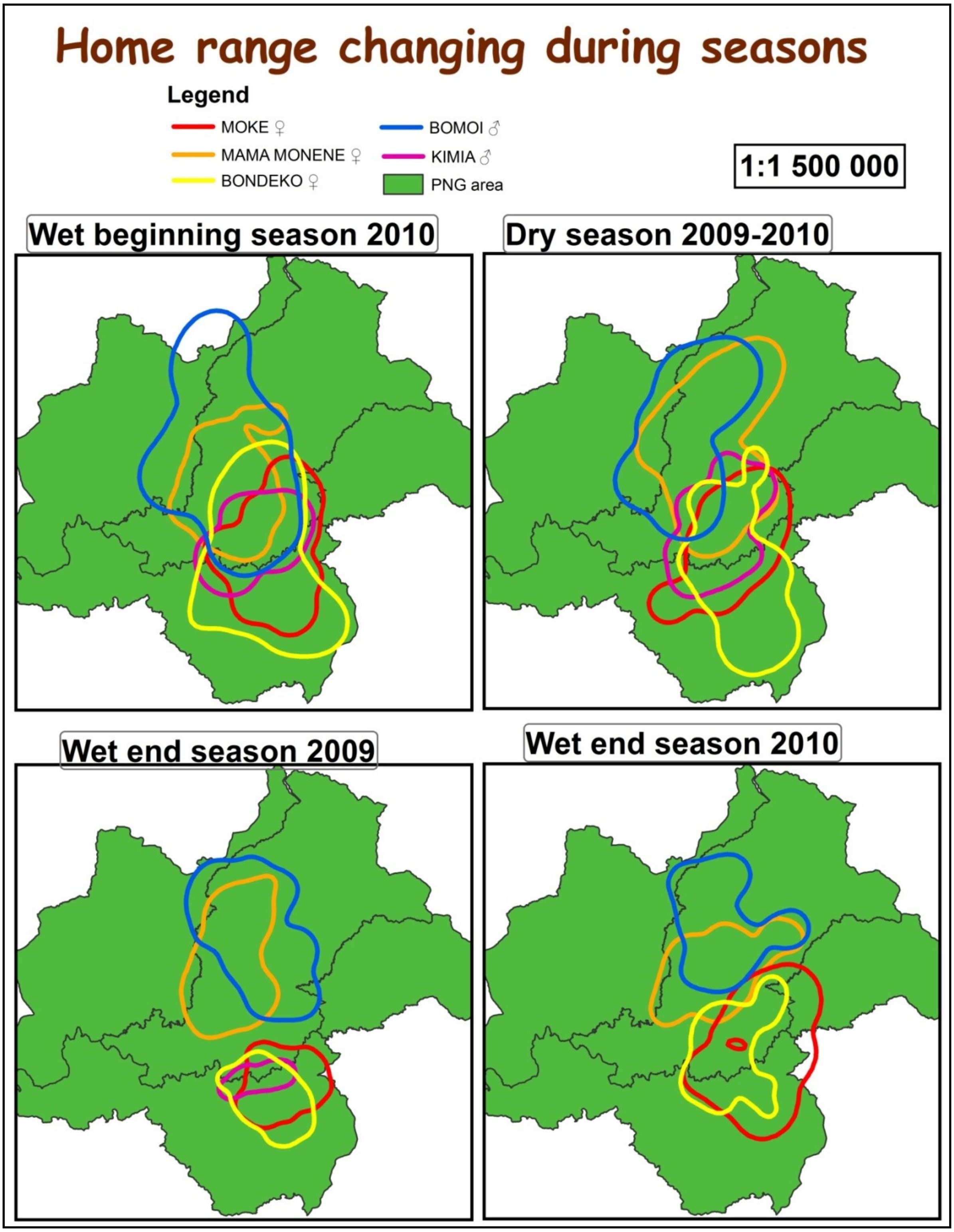


*Fig. 14: Home range spatial distribution changes between seasons.*

## 5.2 Habitat preferences

Direct and indirect elephant signs observed data which were noted during field work, aerial survey and gained from archive took place in 7 different habitats (H, HA, HV, P, R, RIV, SA; abbreviations description are noted in Tab. 13; detailed habitat description in annexe 6). Number of elephant observations in given habitat differed ($\chi^2$ (df = 6) = 1048.60, $p < 0.05$). The most often, elephants were observed in savannah (H) in 68% and in swampy river (R) in 21.8% of all observations.

Ratios in utilising particular habitats differ with seasons ($\chi^2$ (df = 12) = 43.31, $p < 0.05$). For top wet season there is lower amount of data. But it is visible that "wet habitats" (R, RIV, P) are more used in dry season, whereas savannah habitat utilisation increases with advancing wet season (Tab. 12).

*Tab. 12: Percentages of habitat use during seasons*. "Number" row indicate number of observations in given period. Wet end season results are strongly affected by low number of observations.

| Habitat | Habitat description | Dry (%) | Wet beginning (%) | Wet end (%) |
|---|---|---|---|---|
| **H** | tall grass savannah | 52.3 | 73 | 87.5 |
| **HA** | tall grass savannah with spotted trees | 4.7 | 0.4 | 0 |
| **HV** | valley grass savannah | 3.7 | 5 | 0 |
| **P** | papyrus swamps | 5.6 | 0.4 | 0 |
| **R** | riverine grass and swamps | 29.9 | 19.6 | 6.2 |
| **RIV** | river | 2.8 | 1.4 | 0 |
| **SA** | tree bush savannah | 0.9 | 0.4 | 6.2 |
| **Total (%)** | | 100 | 100 | 100 |
| **Number** | | 107 | 281 | 16 |

During field work we were able to observe nine elephants, 5 individuals were cows and 4 bulls. Mean time of observation was 1 hour 11 minutes, where the shortest observation time was 18 minutes and the longest observation lasted 2 hours 30 minutes. At all observations elephants were found in savannah habitat, swampy river, river with papyrus or in transition zone between these habitats.

Elephants spent the most of the time by feeding. Feeding activity proceed mainly at ground level on grass or on riverine grass. Once female elephant was observed browsing palm leaves. When elephants fed in papyrus swamp, they chose mainly tops of papyrus plants.

Feeding activity took proportionately 40.6 % of observed time. During separate feeding "bouts", elephants were walking to another place (14.7 %) for feeding, or just standing 7.9 % of time. Dusting and water splashing summarized in comfort behaviour took 2.4 % of time (Fig. 15). Between feeding, comfort and anti-predator activities there was significant difference ($H (4, N = 45) = 27.48$, $p < 0.05$).

The difference was also between switching (recommencing) of particular activities ($H (4, N = 45) = 12.40$, $p < 0.05$). Moving and standing were the most frequented activities, they were two main activities interrupting feeding bouts or switching each other. On the other hand comfort behaviour was the less frequent activity at all. Feeding was also activity of low frequency, but also of the most of the time spent with it in long periods. Anti-predator and comfort behaviour correspond with time spent with doing it (short time spent with-low frequencies of occurrence (Fig.16).

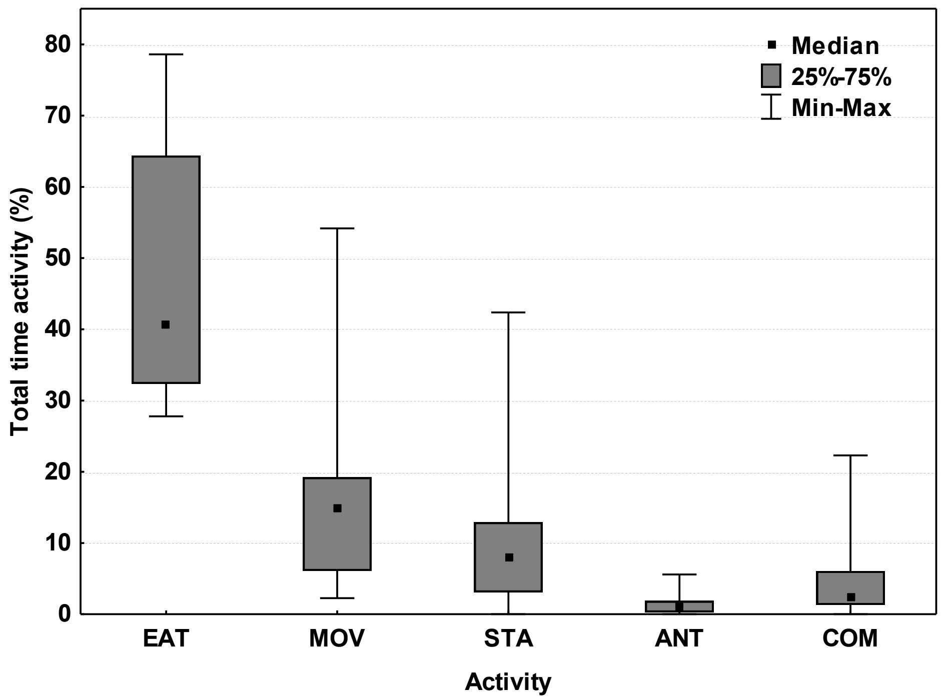


*Fig.15: Total time spent with given activity.* Abbreviations: EAT – feeding, MOV – moving, STA – standing, ANT – anti-predator behaviour, COM – comfort behaviour

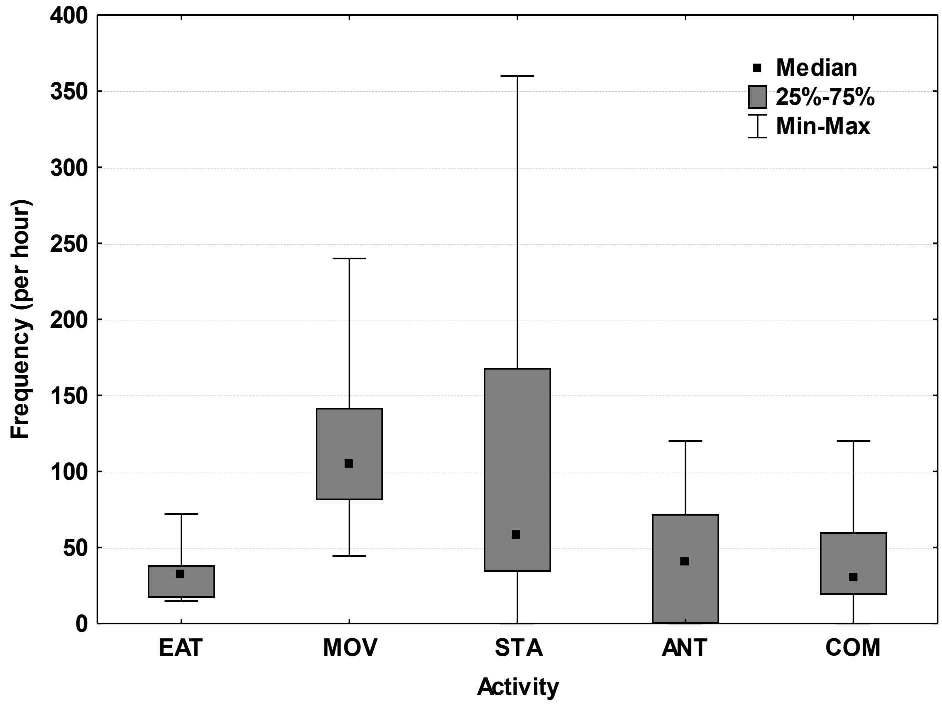


*Fig. 16: Activity re-initiation/interruption frequency per hour.* Abbreviations: EAT – feeding, MOV – moving, STA – standing, ANT – anti-predator behaviour, COM – comfort behaviour.

Thanks to vegetation map, I was able to evaluate habitat preference also with collar data. Because field work took place only in south part of the park, where forest and woodland formations are not represented. And because of finite possibilities of satellite image resolution, used habitat classification is not the same extent as in case of field observations.

During vegetation map classification process it is not possible to assign all the pixels to one of classes and so some pixels remained unclassified (back). On these unclassified pixels is situated 5.53 % of all sent position. On classified map pixels, the most frequented habitats are tall grass savannah 38 %, tree bush savannah – sparse 15 %, and dense 11%, riverine grass and swamp 12.5 % and woodlands 10.5 %.

There is slight difference between sexes in utilization rates of particular habitat. Males use in bigger portion savannah and sparse tree bush savannah. In the other side females use more dense tree bush savannah and woodlands (Annexe 8).

Different habitats are used in different rations during year ($\chi^2$ (df = 20) = 106.49, $p < 0.05$). With more rains and advancing wet season utilization of tall grass savannah, tree bush savannah and woodland and forest ecosystems very slightly rises, and decrease importance of riverine vegetation and swamp and papyrus ecosystems (Tab 13).

Habitat utilization between particular day parts differs significantly ($\chi^2$ (df = 20) = 50.68, $p < 0.05$). Tall grass savannah utilization rate increases at morning (day part 2). There is also tendency to visit closed ecosystems, as forest, riverine forest and woodlands, more frequently during night than day. However, these differences are not big (Annexe 9).

*Tab. 13: Habitat utilization ratios for particular seasons*. Abbreviations: F – forest, FR – riverine forest, H – open tall grass savannah, S – bare soil (correspond to open tall grass savannah, which was burnt when satellite image was taken), P – papyrus swamp complex, R – riverine grass and swamps, RIV – river/water, SAde – dense tree bush savannah, SAsp – sparse tree bush savannah, ZB – woodland, unclass – unclassified pixels.

| season | F | FR | H | S | P | R | RIV | SAde | SAsp | ZB | unclass |
|---|---|---|---|---|---|---|---|---|---|---|---|
| dry | 0.6 | 0.5 | 37.6 | 2 | 2.8 | 14.6 | 0.5 | 10.8 | 15.5 | 9.7 | 5.4 |
| wet-beginning | 1 | 0.4 | 38 | 2.7 | 2.5 | 15.3 | 0.5 | 10.9 | 11.5 | 10.9 | 6.3 |
| wet-end | 1.2 | 0.3 | 40.5 | 1.4 | 2.3 | 9.1 | 0.3 | 11.2 | 17.5 | 11.2 | 5 |

## 5.3 Herd composition

In distribution maps (Fig. 10, 11) number of individuals in observed herds is designed (differently coloured and sized points). Herd aggregations with more than 30 individuals were observed more frequently, during wet season. Average numbers of young and adult individuals in herds are changing during seasons (Tab. 14). Expected higher number of individuals in herd during wet season are good visible in Fig. 17.

Three of collared elephants were observed directly in groups (only females). Bondeko comes from herd of 11 individuals, where one juvenile and two calves are present. Adults are probably all females. Mama Monene is dominant female, and origin from small herd of two cows, one little calf and one juvenile. Moke has herd of three adult cows, two juveniles and one grown calf. All the observations were made in wet season. Bondeko and Mama Monene herds were observed 9$^{th}$ April, less than half kilometre close to each other. Herd of Moke was observed 7$^{th}$ May when walking towards aggregation of around 100 elephants.

When there were adult bulls and cows mixed in herd, it was not possible to distinguish their sex properly. Besides, direct elephant observations were not frequent. That is the reason, why small amount of data about sex composition for analysing were collected and so I did not analysed it.

*Tab.14: Average number of adult and young individuals in herd.*

| Season | dry season | | wet season | |
|---|---|---|---|---|
| **Age** | **mean** | **S.E.** | **mean** | **S.E.** |
| Adult | 4.82 | 0.43 | 9.07 | 2.52 |
| Young | 1.52 | 0.21 | 7.25 | 2.56 |

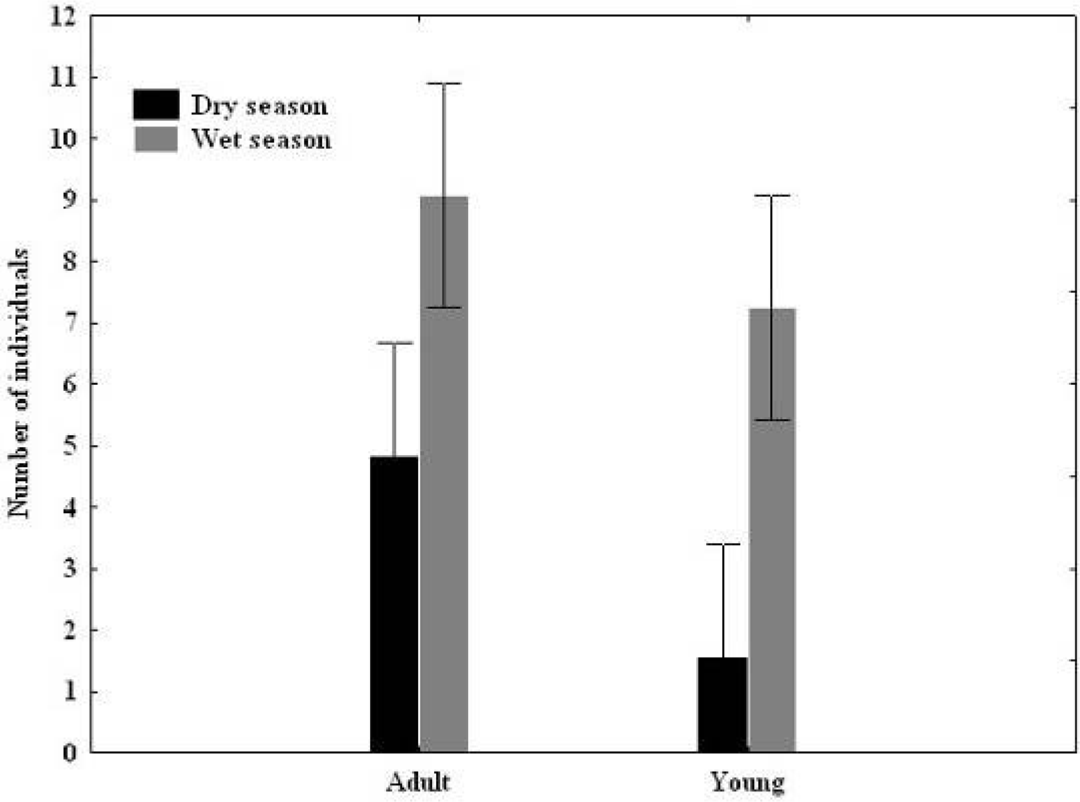


*Fig.17: Number of individuals in herd changing in seasons*. There is difference between age categories (df = 1, F = 546.24, $p < 0.05$) and difference between number of individuals and season (df = 1, F = 45.04, $p < 0.05$). Vertical bars indicate standard error of the mean (SE).

## 5.4 Human-elephant conflict area identification

Evaluation of possible conflict areas of human activities and elephants were divided into two categories, according to action (influence) on elephants. First map (Fig. 18) shows potential conflict areas in villages and their close neighbourhood. In these areas elephant dispersal is disturbed or influenced by agriculture presence, firewood exploitation and traffic.

More severe human activities affecting elephants are poaching, presence of armys, and gold mining (disturbing ecosystem and resources). Comparing data of elephant observations and anti-poaching department data I visualized map of elephant-poachers and other human activity interactions (Fig.19). For comparison, in Annexe 10 see map of distribution of human pressure affecting elephant population in 1994 (Hillman Smith, *et al.*, 1995 a).


*Fig. 18: Human (village and fields) - elephant conflict areas*. Yellow and orange circles around villages indicate area of possible contact/conflict areas of elephants with human activities. Red line indicates area of all elephant observations.

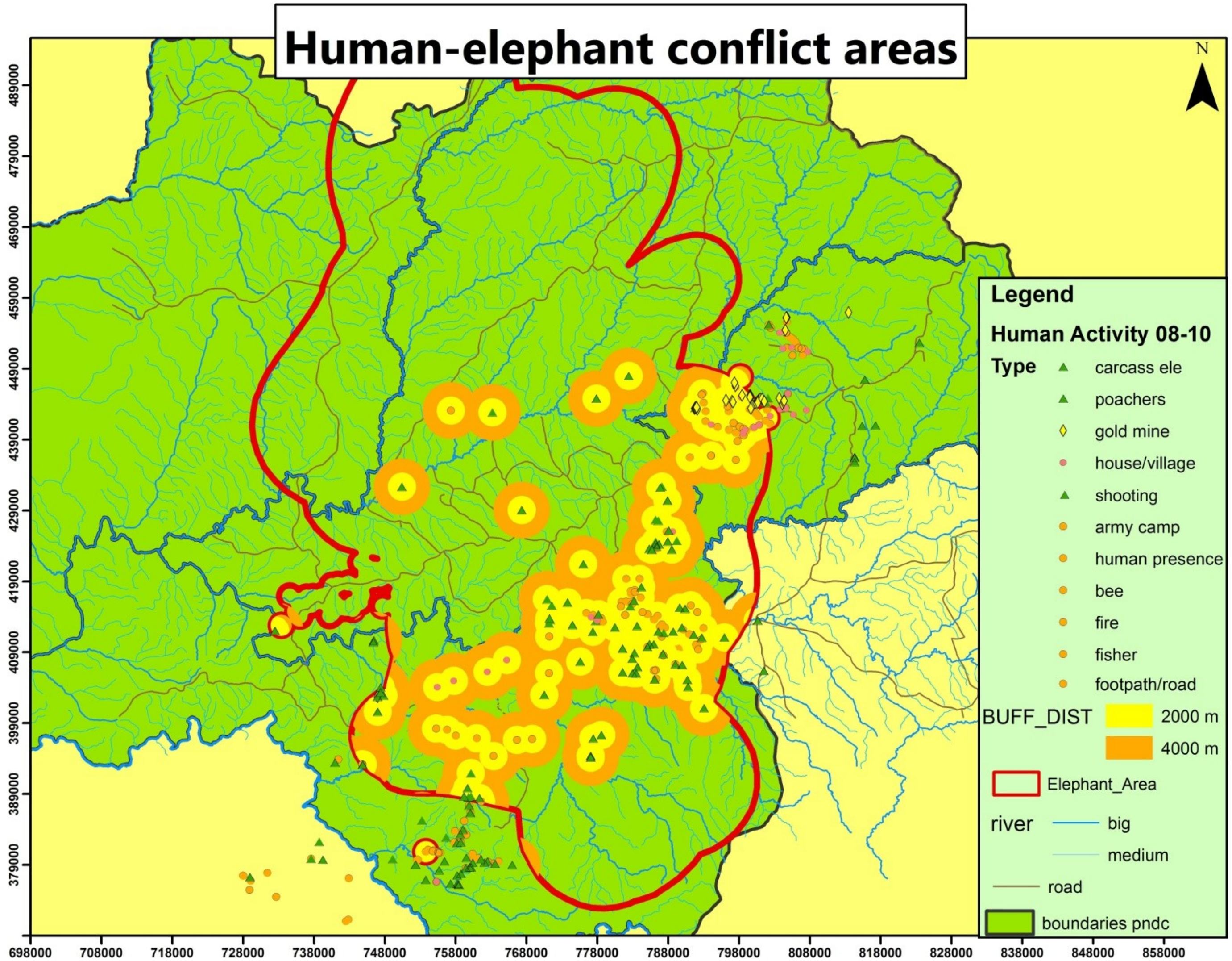


*Fig. 19: Human (mining, exploitation, poaching) elephant conflict areas.* Yellow and orange circles indicate zones around locations with active poaching or other human activities. In these areas severe conflicts can occur most probably (elephant and human-hunter presence overlap).

# 6 Discussion

## 6.1 Elephant movements and habitat preferences

Elephant distribution in south part of the park seems to be continuous over whole study area. More exact view gives us collar data, because distribution of field work was highly influenced by current situation. Western corner of south part of the park was not utilised by collared elephants and any field work ran over this area. Bigger herds and aggregations were observed in centre of south part of the park, northwards from Nagero station. This could be given by fact that poachers are not present, and in the past were not present in this area in such abundance as in other parts of the park (Hillman Smith, *et al*., 1995 a; Hillman Smith, *et al*., 2005; Reid, 2007).

For exact evaluation of elephant distribution over whole PNG area, collar data were used. Elephants range over the park area and reach also into all hunting areas. All collared elephant home ranges are overlapping in previously discussed area north from Nagero station (centre of south part of the park). When looking on map of all year home ranges, elephants can be divided in north ranging and south ranging. The division into such distribution pattern can be caused by dominance (social rank of group), different strategy in interaction with humans, or PNG population can be divided into more subpopulations (De Boer, *et al.*, 2000; Foley, 2002; Roca, *et al*., 2005; Wittemyer, 2007). This answer is not sure. However, from my research is obvious, that habitat utilization by those two differently ranging elephant groups was not distinct. Thence, the different habitat selection does not lead elephants to range differently. Elephants ranging north (Bomoi, Mama Monene) almost do not enter southern hunting reserve Gangala na Bodio. They use part of northwest hunting reserve Azande. Male Bomoi even cross borders of protected area and enters South Sudan. On the other side, elephants ranging south do not trench far north from river Garamba, and use almost all Gangala na Bodio hunting reserve.

Average HR area of elephants in PNG, correspond to HR areas of savannah elephants from such diverse regions as dessert in Namibia, miombo woodland in Tanzania or floodplain in Cameroun (Hofer, *et al*., 2004; Leggett, 2006; Foguekem, *et al*., 2009). Size of home range areas in particular season did not differ. Different size of home ranges between seasons are mainly influenced by water abundance, but PNG net of permanent rivers is very dense (Stokke, *et al*., 2002; Shannon, *et al*., 2006 a). It shows that elephant distribution in PNG is not limited by water availability. However, over sufficient permanent water sources, HRs are not as small in size as in other places with abundant water available (Galanti, *et al*., 2000; Stokke, *et al*., 2002; Shannon, *et al*., 2006 a). Except top wet season HRs which are visibly smaller. The most preferred habitat for top wet season is savannah, which is present anywhere in the PNG and elephants do not have to move long distances to support their needs. The similar reduce in HR size showed for example Mpanduji, *et al*. (2007) in Tanzania.

HR area sizes are not distinct between sexes. Even spatial distribution did not differ with different sex. Without possibility of observing collared elephants activity, it is not possible to say if bulls are led more by reproductive behaviour or by ecological factors as cows (Grainger, *et al*., 2005; Leggett, 2006). In habitat utilization slight differences were observed. Males tended to use in bigger portion savannah and sparse tree bush savannah and females utilized more frequently dense tree bush savannah and woodlands. This can be given by females more selective feeding behaviour or tendency to stay in safer vegetation (Barnes, 1982; Stokke, 1999; Shannon, *et al*., 2006 b).

Elephants perform grazing in around 70 % of total feeding time, during wet season. They mainly feed in vegetation with trees or bush (Beekman, *et al*., 1989; De Boer, *et al*., 2000; Foley, 2002; Osborn, 2005). In Mozambique, elephants used to prefer open grasslands, but they switched to more closed ecosystems due to poaching (De Boer, *et al.*, 2000). In PNG, open tall grass savannah is the most abundant ecosystem, and it is the most utilised by elephants, despite abundant poaching.

Importance of savannah declines with dry season. According to dry season switch to browse, higher preference of woodlands and forest is overall trend (Beekman, *et al*., 1989; Kabigumila, 1993; Nicholas, *et al*., 1995; Ntumi, *et al*., 2005). But our studied elephants slightly declined in utilization of those habitats in dry season. Nicholas, *et al*. (1995) showed high importance of woodlands, tree bush savannah and forests in dry season. Except sparse and moderate tree bush savannah, with higher utilization in wet season, all these habitats showed decreasing importance in wet season.

Without observations of elephants in woodlands and forests, we do not know whether elephants there are grazing or browsing and why the utilization pattern is opposite. The difference between recent study and study of Nicholas, *et al*. (1995) can be given by the fact that he studied elephant distribution and habitat use in hunting reserves around the park, where open savannah perform only small portion of available habitats. Or, elephants switched their feeding pattern, thanks lower poaching pressure in the park area since 1995. This is most probable because movement pattern has been changed (Hillman Smith, *et al*., 1995 a).

Correspondence with other elephants is visible in increasing preference of water related habitats during dry season (Foley, 2002; Hofer, *et al*., 2004).

Elephants move the shortest distances in top wet season. Probably, because growing grass in savannah provide sufficient quantity and quality forage and it is utilized more than during dry season. Higher grass selection during wet season is overall trend in several studies (Kabigumila, 1993; De Boer, *et al*., 2000). Ntumi, *et al*. (2005) however points out utilization of higher variety of habitats in wet season.

The food is also highly available during beginning of wet season, but elephants move the longest distances. This should be probably due to moving to places of maturing fruits (mango) and additionally crops (cassava) (Anonymous, 1993; Hillman Smith, *et al*., 1995 a). At these times great aggregations are formed and necessarily elephants have to walk distances to reach them.

During dry season, grass in the park is burnt or dry. Elephants at these times prefer wet habitats (riverine and swampy grasses and papyrus) which provide still green pasture and water. River net in PNG is very dense. In addition, in hunting areas surrounding park, vegetation is mainly formed with close habitats (tree-bush savannah, woodland, forest) and new leaves grow during dry season (Hillman Smith, *et al*., 1995 a). Thence, food and water available is not deficient even in dry season. That is the reason why dry season movements are not reduced and elephants are not clumped as in other regions (Leggett, *et al*., 2003; Charif, *et al.*, 2005; Shannon, *et al*., 2006 a; Hema, *et al*., 2010).

The sufficient food available thru whole year can be also visible from table of habitat utilization (Tab. 14). Rations in this table differ between seasons however the differences are not big. Thence, elephants are not as restricted in movements by food quantity and especially water availability as in other drier regions (Blake, *et al.*, 2001; Grainger, *et al*., 2005; Leggett, 2006). Important role affecting movements play forage quality and fruit and crop maturation, human pressures and social interactions.

Movement differences during day parts correspond to results of other studies. Afternoon activity is reduced due to hot temperatures and movements on distance take place at night (Wyatt, *et al*., 1974; Galanti, *et al*., 2000; Douglas-Hamilton, *et al*., 2005; Shannon, *et al*., 2008; Leggett, 2009 b; Graham, *et al*., 2009). The temperature seems to be significantly influencing factor, because morning movements in dry season are even shorter than afternoon hours (Blake, *et al*., 2001). In wet season morning conditions are milder because grass is wet by dew and after rains.

Direct activity observation was done in short periods from 8.03 h till 13.41 h. Feeding behaviour was then presented in 40 % of total observed time. This very low portion of feeding can be given by observation timing during afternoon reduced activity (Wyatt, *et al*., 1974; Shannon, *et al*., 2008; Leggett, 2009 b). Observed feeding rate correspond to elephant observation made by Moss, 1990 (Fig 2). Her observations were also made only in savannah and riverine habitats.

Mean group size in PNG differs seasonally. In wet season herds are bigger and dry season group size decrease. Group numbers from animal counting made in past years showed the same trend (Hillman, *et al*., 1983; Amube, 2007). Resulting numbers are even higher than in previous years, and possibly could show on growing elephant population (Moss, 1990; Moss, 2001).

## 6.2 Human Elephant conflict

Most important zone for possible human-elephant conflict lies around villages on the border of hunting reserve Gangala na Bodio and the park. Elephants traverse from open savannah to the more densely wooded hunting reserve, in this area. However, the villages are not much populated and elephants seem to be very slightly disturbed by humans there. Sometimes elephants benefit from extensive agriculture by crop raiding and mango fruit browsing (Nicholas, *et al*., 1995). Elephant distribution is only visibly limited by eastern border of Gangala na Bodio. Because more dense human population occurs around town Faradje and other villages lying on the border of Gangala na Bodio.

Mining and with it connected more dense human presence however seems to significantly influence elephants. The most visible area of this pattern is in the south west of the hunting area Gangala na Bodio. Except gold mining, heavy poaching take place there. Other place where mining determine elephant dispersal boundary lies in the Mondo Missa hunting Area.

Nowadays poaching seems to be lower than in past times (Hillman Smith, *et al*., 1995 a; Nicholas, *et al*., 1995). Elephants are freely ranging in the north of the park and even cross the border to South Soudan. In Azande hunting area, which was abandoned by humans as a consequence to rebel army presence, elephants are allowed to disperse far to the west from the park.

Around villages, lying at the border of the park and Gangala na Bodio hunting area, poacher observations are very frequent. Poaching activities are not only concerned to elephants (also fishing, honey mining). Even though elephants are frequently killed there, they are still utilising this area.

# 7 Conclusions

Elephant disperse in almost whole park area and hunting reserves. They even trench to Southern Sudan. But several areas, especially parts of hunting reserves furthest from the park, are visited less frequently or avoided. These are the areas of heavier exploitation by humans. This fact is very good visible in mining areas (for ex. south-western part of Gangala na Bodio hunting reserve). Dense human population also prevent elephant dispersal. On the other hand, poaching seems to have lower impact on elephant movement. But, the poaching was not so heavy after LRA presence in the park than before.

Generally, the most frequented habitat is tall grass savannah, which is also the most frequented habitat type in the park. Another very important is riverine grass and swamp vegetation, which provide still green vegetation and also water. Seasonal differences in use of these habitats were observed. Increasing importance of grass and decreasing utilization of riverine grass and swamp vegetation in wet season is comparable and similar trend with savannah elephants from other places. But in seasonal utilization pattern of habitats with bush and tree cover is different. Males and females showed slight difference in habitat utilization. Males tended to use in bigger portion savannah and sparse tree bush savannah and females utilized more frequently dense tree bush savannah and woodlands. This can be given by females more selective feeding behaviour or tendency to stay in safer vegetation.

From this study arise, that factors affecting elephant dispersal are vegetation (food) availability, elephant social interactions, human presence and poaching. Seasonal habitat production and it changes presents the most influencing factor, but it does not limit elephant dispersal, and social interactions.

Elephant range in PNG has expanded over past years. According to different spacing of home ranges, elephants there can be divided in two or more subpopulations which use different parts of PNG area. They can be distinct genetically or had different strategy in coexistence with humans. Possibly, this pattern could be led by social interactions, or as well by food competition. For explanation of this pattern, future research should be executed. South part of the park is still very frequently utilized by elephants, and it is important area where social interactions are performed.

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# 9 List of Figures and Tables

# 10 List of the Abbreviations

PNG – Garamba National Park and surrounding hunting reserves
LRA – Lord Resistance Army
CAR – Central African Republic
SAR – Republic of South Africa
GPS – Global positioning system
VHF – Very high frequency
NP - National Park

HR – Home range
MCP – Minimum convex polygon method
NA – Not available, Not aplicable

F – Female (elephant cow)
M – Male (elephant bull)

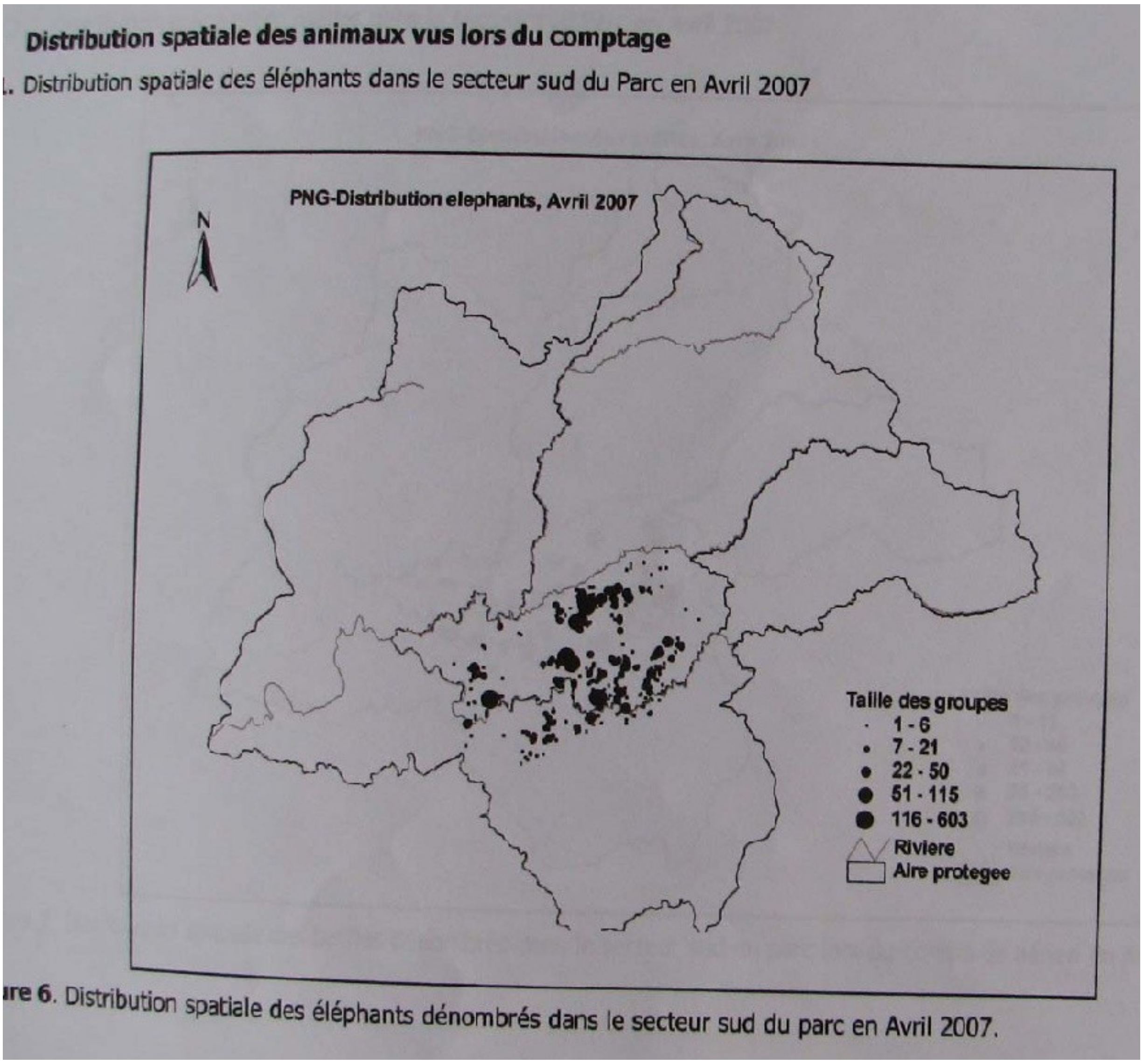
H – Open tall grass savannah
S – Bare soil (correspond to open tall grass savannah which was burnt when satellite image was taken)
P – Papyrus swamp complex
R – Riverine grass and swamps
RIV – River/water
SAde – Dense tree bush savannah
SAsp – Sparse tree bush savannah
ZB – Woodland
F – Forest
FR – Riverine forest
unclass – Unclassified pixels.

EAT – Feeding
MOV – Moving
STA – Standing
ANT – Anti-predator behaviour
COM – Comfort behaviour

W - Whole plant
Fr - Fruit
L - Leaves

## 11 Annexe

*Annexe 1: Spatial distribution of elephants noted during aerial census in April 2007* (Amube, 2007).



*Annexe 2: Table of utilized plants during 1994 elephant study* (Nicholas, *et al*., 1995).

**Species utilised by elephants in the domaine de chasse of Garamba National Park, dry and wet seasons 1994**

**DRY SEASON**

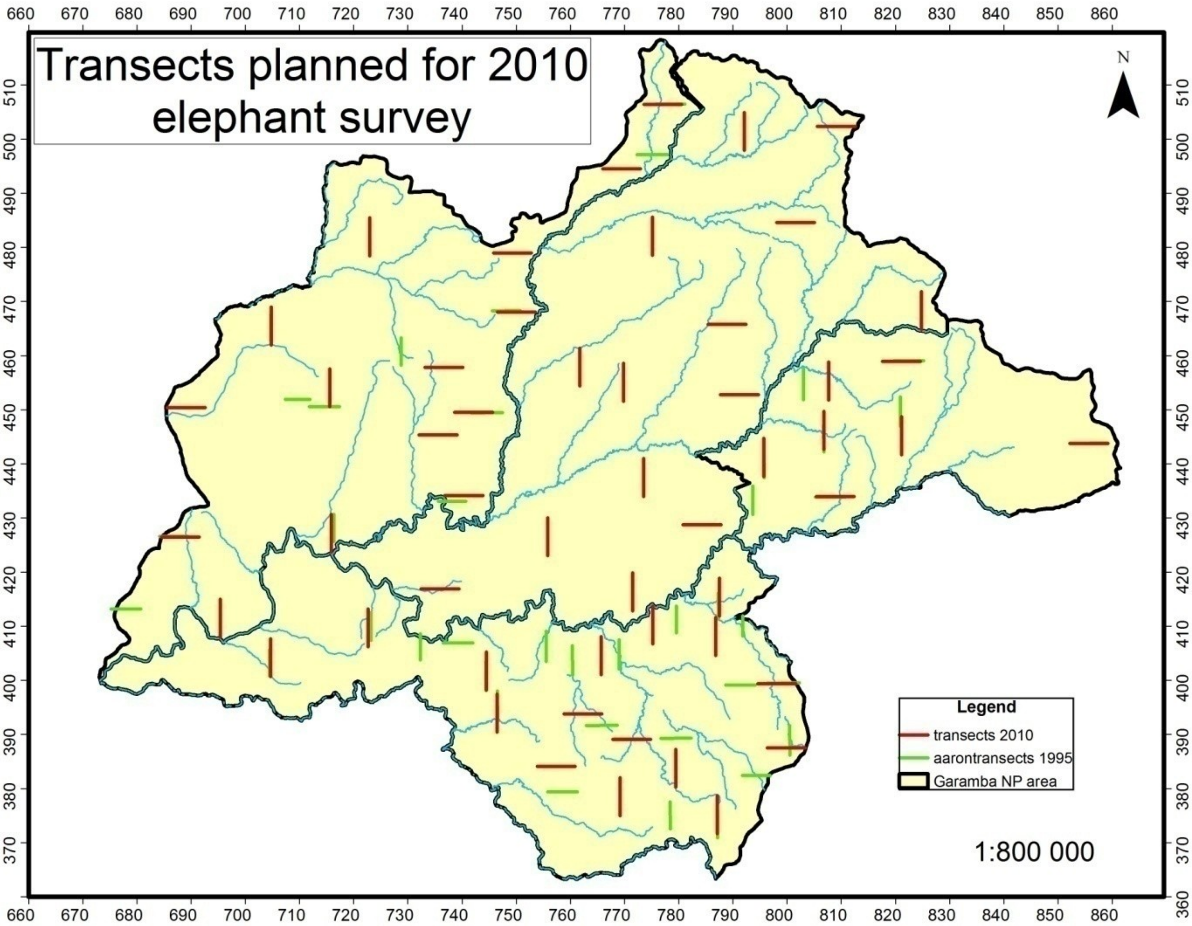
| | SPECIES | Pheno Code | Number Records | % | Relative Utilisation |
|---|---|---|---|---|---|
| 1 | Grewia mollis | 5 | 671 | 20.5 | 13722 |
| 2 | Annona senegalensis | 4-5 | 368 | 11.2 | 4121 |
| 3 | Combretum collinum | 4 | 342 | 10.4 | 3557 |
| 4 | Dombeya quinqueseta | 5 | 211 | 6.4 | 1350 |
| 5 | Albizia glaberina | 4 | 209 | 6.4 | 1338 |
| 6 | Bridelia scleuroneura | 4 | 209 | 6.4 | 1338 |
| 7 | Piliostigma thoningii | 4 | 182 | 5.5 | 1001 |
| 8 | Hymenocardia acida | 4 | 168 | 5.1 | 857 |
| 9 | Terminalia mollis | 1-3 | 139 | 4.2 | 584 |
| 10 | Lonchocarpus laxiflorus | 4 | 102 | 3.1 | 316 |
| 11 | Stereospermum kunthianu | 3-4 | 97 | 3.0 | 291 |
| 12 | Parinari curatellifolia | 4 | 75 | 2.3 | 173 |
| 13 | Nauclea latifolia | 4-6 | 71 | 2.2 | 156 |
| 14 | Vitex doniana | 4-5 | 64 | 2.0 | 128 |
| 15 | Acacia seyal | 4 | 57 | 1.7 | 97 |
| 16 | Vitex madiensis | 4-5 | 47 | 1.4 | 66 |
| 17 | Crossopteryx febrifuga | 6-7 | 37 | 1.1 | 41 |
| 18 | Rauwolfia vomitoria | 4 | 22 | 0.7 | 15 |
| 19 | Acacia sieberina | 1-3 | 21 | 0.6 | 13 |
| 20 | Ficus ovata | 4-6 | 19 | 0.6 | 11 |
| 21 | Bridelia micrantha | 4 | 16 | 0.5 | 8 |
| 22 | Combretum binderanium | 4 | 16 | 0.5 | 8 |
| 23 | Caloncoba crepingana | 6 | 13 | 0.4 | 5 |
| 24 | Ficus vallis-schoudae | 6 | 11 | 0.3 | 3 |
| 25 | Phyllanthus discoideus | 4 | 11 | 0.3 | 3 |
| 26 | Trema orientalis | 5 | 9 | 0.3 | 3 |
| 27 | Urena lobata | 6 | 8 | 0.2 | 2 |
| 28 | Zysyphus senegalensis | 4 | 7 | 0.2 | 1 |
| 29 | Cassia siamea | 4 | 7 | 0.2 | 1 |
| 30 | Maytenus senegalensis | 4 | 7 | 0.2 | 1 |
| 31 | Allophylus senegalensis | 4 | 7 | 0.2 | 1 |
| 32 | Manguifera indica | 6 | 5 | 0.2 | 1 |
| 33 | Kigelia africana | 5-6 | 5 | 0.2 | 1 |

SPECIES PHENOLOGY
1= leafless
2= dry leaves
3= leaves growth
4= in leaves
5= leaves and flowers
6= leaves and fruits
7= leaves, flowers and fruits.

**WET SEASON**

| | SPECIES | Pheno Code | Number Records | % | Relative Utilisation |
|---|---|---|---|---|---|
| 1 | Grewia mollis | 6 | 158 | 22.2 | 3508 |
| 2 | Annona senegalensis | 4 | 93 | 13.1 | 1218 |
| 3 | Combretum collinum | 5-6 | 70 | 9.8 | 686 |
| 4 | Piliostigma thonningii | 6-7 | 58 | 8.2 | 476 |
| 5 | Dombeya quinqueseta | 4-5 | 58 | 8.2 | 476 |
| 6 | Bridelia scleuroneura | 5-7 | 33 | 4.6 | 152 |
| 7 | Albizia glaberina | 4 | 27 | 3.8 | 103 |
| 8 | Lonchocarpus laxiflorus | 4 | 27 | 3.8 | 103 |
| 9 | Hymenocardia acida | 4-6 | 26 | 3.7 | 96 |
| 10 | Stereospermum kunthianu | 4 | 23 | 3.2 | 74 |
| 11 | Parinari curatellifolia | 4 | 18 | 2.5 | 45 |
| 12 | Terminalia mollis | 6 | 15 | 2.1 | 32 |
| 13 | Phyllanthus discoideus | 4 | 11 | 1.5 | 17 |
| 14 | Nauclea latifolia | 6 | 11 | 1.5 | 17 |
| 15 | Allophylus senegalensis | 6 | 10 | 1.4 | 14 |
| 16 | Vitex doniana | 6 | 10 | 1.4 | 14 |
| 17 | Combretum binderianum | 5-6 | 8 | 1.1 | 9 |
| 18 | ficus congoensis | 4 | 5 | 0.7 | 4 |
| 19 | Bridelia micrantha | 4 | 5 | 0.7 | 4 |

*Annexe 3: Distribution of transects planned for this study* (green lines). Red lines indicate transects surveyed by Nicholas, *et al*. (1995) (added for possible comparison of both studies).



*Annexe 4: Data sheet table used during field work.*

**REPUBLIQUE DEMOCRATIQUE DU CONGO**
**INSTITUT CONGOLAIS POUR LA CONSERVATION DE LA NATURE**
**AFRICAN PARKS NETWORK**
**PARC NATIONAL DE LA GARAMBA**
**FICHE DE LA SUIVI DES ELEPHANTS**

| | | | | | |
|---|---|---|---|---|---|
| NOM DU SITE | | Date début | | Pat ID | |
| STATION | | Date fin | | Distance totale | |
| Secteur patrouillé | | Nbre pers. | | Heures totales | |
| | | Nbre de jours | | Type de GPS | |

| No | DATE | HEURE | WPT | COORDONEES GPS | | RESULTATS SUR TERRAIN | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | X | Y | Observations (indice/espece) | Type d'observation | A-M | A-F | J | C | Total | Durée/Detail | Type d'habitat | Autres informations |
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*Annexe 5: Data sheet table used to note activities during direct elephant observation.*

| No | WPT | Direction | Distance | Time | Activity | Plant species | Part eaten | Type d'habitat | Note |
|---|---|---|---|---|---|---|---|---|---|
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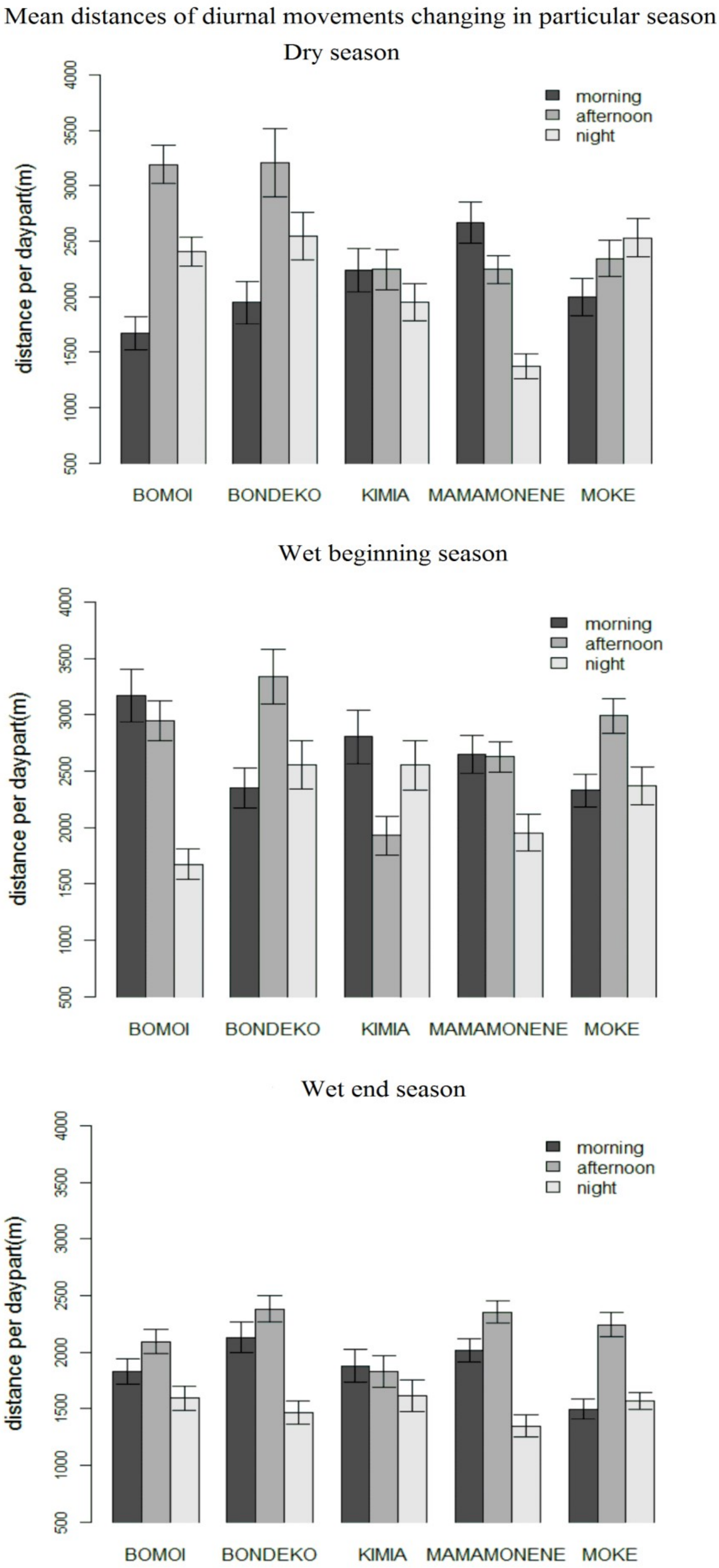
*Annexe 6: Habitat types and its classification* (Amube, *et al*., 1995). Bush (Un arbuste) is ligneous plant 0.5 to 3 meters tall, with DBH to 6 cm. Tree (Un arbre) is woody plant taller than 3 m and with DBH more than 6 cm. Vegetation type description according to Pratt & Gwynne, 1977.

| Abreviature | | Habitat type | l'habitat | description |
|---|---|---|---|---|
| **F** | | Forest | forêt | |
| **FR** | | Riverine/gallery forest | Gallérie forestière | Closed stand, 7-40m ground cover: herbs and shrubs |
| **ZB** | | Tall decidous woodland | Zone boisée de grands arbres decidus | Trees up to 20m, canopycover >20%, ground cover:grasses & herbs |
| | **ZB1** | Dense woodland | Dense | |
| | **ZB2** | Medium woodland | Moyenne | |
| | **ZB3** | Sparse woodland | Faible | |
| **BR** | | Riverine woodland | Zone boisée riveraine | Closed stand, 7-40m ground cover: herbs and shrubs, sparse |
| **BS** | | Source woodland | Zone boisée près des sources | Closed stand, 7-40m ground cover: herbs and shrubs, sparse, relict clumps at sources |
| **CR** | | Rocky hills | Collines rocheuses | |
| **SA** | | Tree - bush savanna | Savanes arbustives | Assemblage of shrubs and trees, usually <10m, with some emergents |
| | **SA1** | Dense tree/bush savanna | Dense | |
| | **SA2** | Medium tree/bush savanna | Moyenne | |
| | **SA3** | Sparse tree/bush savanna | Faible | |
| **SAR** | | Tree savanna | Savanes arborées | Grassland savanna with trees 5-20% cover |
| **H** | | Tall grass savanna | Savanes herbeuses | Grassland with scattered trees <5% cover |
| | **HP** | Tops of inter riverine ridges | Plateaux inter-riverains | |
| | **HC** | Edges | Lisières (cotes) des crêtes | |
| **T** | | Short termitaria grassland | Termitières avec des herbes courtes | |
| **R** | | Swamp and riverine complex | Complexe herbes-Cyperacés | colonisées par une végétation hydrophile tolérante |
| **P** | | Papyrus swamp | Marais à Papyrus et autres Cyperacés | |
| **N** | | Isolated pool or swamp | Mare inondée ou "Ndiwili" | |
| **AP** | | Trees planted | Arbres plantés | |
| **C** | | Cultivated area | Zones agricoles | |
| | **CO** | Clrared, not yet cultivated | Defriché mais non encore planté | |
| | **CV** | Growing crops | Culture | |
| | **CJ** | Fallow | Jachère | |
| | **CB** | Burned field | Champs brulés | |
| **FS** | | Secondary forest | forêt secondaire | Closed stand, 7-40m ground cover: herbs and shrubs |

*Annexe 7: Seasonal differences in diurnal movements for each individual.*



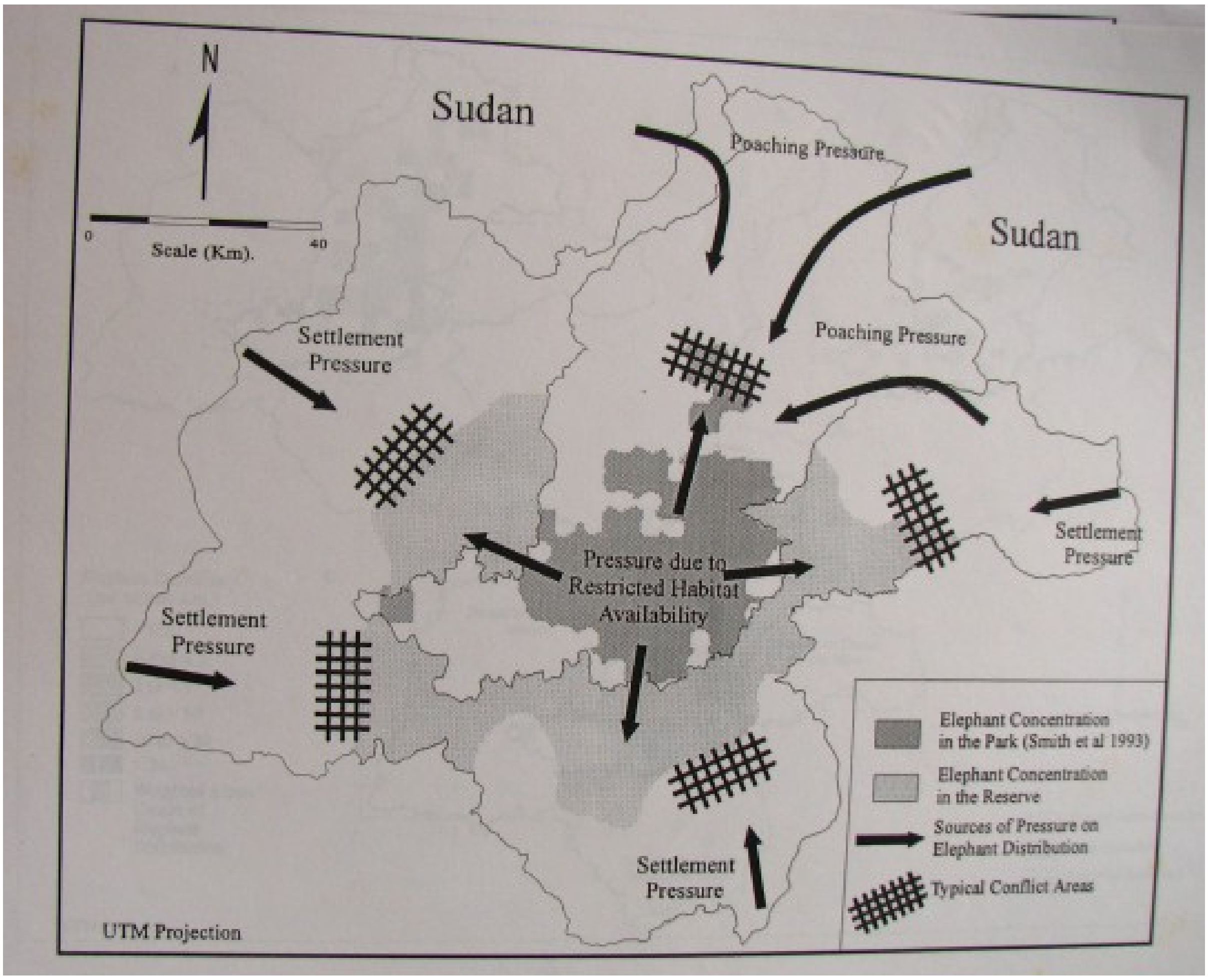
*Annexe 8: Frequency of utilization of particular habitats separately for males and females* ($\chi_2$(df=10)= 86.9599, $p < 0.001$).

| sex | back | F | FR | H | P | R | RIV | S | SA de | SA sp | ZB | Total | Count |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **F** | 6.3 | 1.3 | 0.4 | 37.5 | 1.8 | 13 | 0.3 | 2.2 | 12 | 14 | 11.2 | 100 | 4455 |
| **M** | 4.1 | 0.3 | 0.5 | 41.8 | 3.7 | 11.5 | 0.5 | 1.5 | 9.3 | 17 | 9.8 | 100 | 2400 |

*Annexe 9: Frequency of utilization of particular habitats in relation to day time* ($\chi_2$(df=20)= 50.6843, $p < 0.001$).

| daytime | back | F | FR | H | P | R | RIV | S | SA de | SA sp | ZB | Total | Count |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1** | 5.8 | 1.2 | 0.8 | 36.5 | 2.5 | 12.4 | 0.5 | 2 | 11.5 | 15.1 | 11.7 | 100 | 2168 |
| **2** | 5 | 0.7 | 0.2 | 42.7 | 2.3 | 12.4 | 0.2 | 1.6 | 9.5 | 15.7 | 9.7 | 100 | 2382 |
| **3** | 5.9 | 1 | 0.3 | 37.4 | 2.6 | 12.7 | 0.5 | 2.4 | 12 | 14.4 | 10.8 | 100 | 2305 |

*Annexe 10: Distribution of elements affecting elephants in 1994* (Hillman Smith, *et al*., 1995).



*Annexe 11: Vegetation of the PNG*

The mostly abundant vegetation cover in the park area. Tree cluster in centre of image is visible river source.

The mostly abundant vegetation cover in hunting reserves area. (Photo from Gangala na Bodio hunting reserve)

Transition zone between park area (grass cover in top of image) and Gangala na Bodio hunting reserve (tree cove in lower part of the image).