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## MOVEMENTS AND CONSERVATION OF THE MIGRATORY WHITE-EARED KOB (KOBUS KOB LEUCOTIS) IN SOUTH SUDAN

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**MOVEMENTS AND CONSERVATION OF THE MIGRATORY  
WHITE-EARED KOB *KOBUS KOB LEUCOTIS* IN SOUTH SUDAN**

A Dissertation Presented

By

MALIK DOKA MORJAN

Submitted to the Graduate School of the  
University of Massachusetts Amherst in partial fulfillment  
of the requirements for the degree of

DOCTOR OF PHILOSOPHY

September 2014

Environmental Conservation

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**MOVEMENTS AND CONSERVATION OF THE MIGRATORY WHITE-  
EARED KOB (*KOBUS KOB LEUCOTIS*) IN SOUTH SUDAN**

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## **DEDICATION**

This work is dedicated for the survival of wildlife in South Sudan; and a tribute to those who sacrifice their welfare and lives during difficult times for such a cause in our country.

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# ABSTRACT

MOVEMENTS AND CONSERVATION OF THE MIGRATORY WHITE-EARED

KOB

(*KOBUS KOB LEUCOTIS*) IN SOUTH SUDAN

SEPTEMBER 2014

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The annual movements of white-eared kob (*Kobus kob leucotis*), tiang (*Damaliscus korrigum tiang*), in eastern South Sudan was investigated to provide appropriate information for developing effective conservation actions for the migratory kob. Although kob is the focus of the study tiang has been included as the two migrations are ecologically linked and overlap at least in the wet season.

During the 20 years of the civil war which ravaged South Sudan, the kob and tiang populations were thought to be severely hunted for food by both the combatants and local people to the extent that their populations may have drastically fallen to levels that put the migrations in danger. However, recent aerial transect surveys suggest that the white-eared kob population may still exceed 800,000, and while tiang may have been reduced from almost 500,000 to 160,000. Despite these findings, post-war resettlement of about a million people, along with much needed economic development projects, could seriously jeopardize the population of these species.

Effects of the above mentioned factors on the migrations were studied through aerial surveys and via GPS-collar tracking and documentation of the migration patterns during 2009-2010. Possible barriers to the migrations have been identified and mapped. Satellite-based forage biomass estimates was used in assessing migrations occurrence throughout the seasons. Effects of environmental variables on kob movements and distributions were investigated with binary logistic and regression models. The subsistence use of kob by the local communities living in/around the Boma National Park, which is kob's dry season range, was assessed.

Findings of the study include: the 900 km kob movements is the longest antelope migration in Africa; facing challenges of potential landuse forms that threaten their corridors and combined with the human livelihood needs in the area could jeopardize the future of kob migration in South Sudan.

Conclusions and recommendations from findings of this study will contribute directly and help in developing conservation and management plans for the landscape and the kob migrations.

## PREFACE

White-eared kob (*Kobus kob leucotis*) and tiang (*Damaliscus korrigum tiang*) in eastern South Sudan take part in one of the three largest ungulate migrations in the world, the others being mostly wildebeest (*Connochaetes taurinus*) in the Serengeti-Masai Mara ecosystem, in East Africa; and caribou (*Rangifer tarandus*) in Alaska, USA. While white-eared kob apparently migrated in a cyclic pattern in the plains below the Boma Plateau, between the River Nile in South Sudan and Duma Wetlands in Gambella, Ethiopia, tiang probably moved between the Nile River and the vast plains in the Jonglei area (Fig. 1). Fryxell (1985, 1987a,b) studied the population dynamics of white-eared kob and followed them through most of their migration through aerial reconnaissance flights; he estimated a population of 800,000-1,000,000. Partial tiang migration routes were described from three aerial reconnaissance flights (as in Mefit-Babtie 1983, Howell *et al.* 1988), and though a rough estimate of 500,000 animals was made, their ecology remained unstudied. It also has been speculated that during part of their migration, the populations of kob and tiang overlap in an area farther to the south than was ever surveyed. In addition, Mongalla gazelles (*Gazella thomsonii albonotata*), a geographically separated subspecies of Thomson's gazelle, had long been known to occur in large numbers east of the Nile in southeastern Sudan (perhaps 66,000; Mefit-Babtie 1983, Howell *et al.* 1988), but migration movements were only speculated upon and ecological studies have yet to be undertaken.

During the 20 years of the South Sudan liberation war, the kob, tiang, and gazelle populations were thought to be vulnerable to severe hunting for food by both the combatants and local people, so much so that their populations may have drastically fallen to levels that put the migrations in danger. In addition, human settlements inside the Boma National Park might have impeded the course of kob migration, and canal construction efforts in the 1970s/1980s (Howell *et al.* 1988) may have interrupted tiang migrations.

Out of these concerns, efforts were exerted by concerned individuals and institutions during war times to ascertain the continued presence of these valuable species. A limited aerial reconnaissance survey was carried out in May 1999, as were ground transects in 2001 and 2002, all in Boma National Park; results suggested that the white-eared kob still existed but that their population of 800,000-1,000,000 may have been reduced substantially. However, recent (January 2007) aerial transect surveys indicated that the white-eared kob population may still exceed 800,000, and while tiang may have been reduced from 500,000 to 160,000; Mongalla gazelles, which have never been counted before, may number 250,000 (Fay *et al.* 2007 unpublished data). Despite these findings, post-war resettlement of nearly 1,000,000 people, along with much needed economic development projects in the same region, could seriously jeopardize the continued existence of these species.

The migratory kobs have provided the indigenous peoples with food through seasonal hunting and other traditional uses throughout their lives for centuries. This has been documented in previous studies carried out in the area and by the colonial

administrators' reports and books, as well as pre-colonial European explorers writings (e.g., Lewis 1972, Fryxell 1985, Deng *et al.* 2001).

In 1978 the Boma National Park was established for the protection of kob migrations; later, the Badingilu National Park was also established. But these parks have never been developed, probably due to 1) the political instability and protracted civil wars, and perhaps to 2) the uneven development programs policies that existed in the former one Sudan. It is worth mentioning that the jurisdiction of establishment and development of national parks has always been vested with the office of the President in the capital city of Sudan, Khartoum. Much of these parks' area falls within the Block 5 Central of the oil concession map drawn by the government of the Sudan in the 1970s. The areas around both Boma and Badingilu Parks lack any form of economic development, crop cultivation is still primitive and insufficient, and thus the indigenous people living therein depend importantly on hunting and gathering of wild food plants for their livelihoods.

In the light of the potential changes in the landscape of southeastern South Sudan, and thus of kob, tiang and gazelle numbers and distribution, this study has been designed to document the continued existence of kob abundance through aerial surveys, their migration patterns, and their subsistence use by local people. In addition I sought to identify and map possible barriers (e.g., human settlements, existing and potential development activities) detrimental to migratory wildlife populations, to use satellite-based forage biomass estimates to assess migration variability, and to develop models to help predict disturbance effects on the migration. These activities will provide key information needed for developing long-term conservation plans for the system.



This study was meant to generate comprehensive information on kob migrations and the surrounding environment. It was built upon 3 years (2009-2011) of my own research, data accumulation assisted by the Ministry of Tourism and Wildlife Conservation staff, and done jointly with the Wildlife Conservation Society and the National Geographic Society, to provide appropriate information for developing effective conservation actions for the migratory kob. The observations and strategies used to gather data and information relied on non-invasive techniques to assess the population status, condition of habitats and landscape required by migrations of large herds of antelope species, the human interactions and perceptions towards wildlife, as well as identification of existing and potential problems and conservation opportunities.

This is second major wildlife ecology study to be undertaken in South Sudan after Fryxell (1985), and the first of its kind to be undertaken by a native South Sudanese. It is also the first study that deployed GPS satellite collars on animals in South Sudan.

In Chapter 1 I present a literature review in the format of a “Mammalian Species Account” that describes the history, biology and conservation status of white-eared kob in the larger context of its family the *Kobus kob* to give an understanding of the study species, its origin and present conservation status. Due to the lack of wildlife research in South Sudan in general, and on the white-eared kob in particular, the review is done on all *Kobus* family species to derive understanding for the conservation needs of kob from the similarities they share.

In Chapter 2 I discuss the density distribution and abundance of kob where, during the 25 years of armed conflict which caused devastation on both humans and wildlife in South Sudan, it was thought that the population of white-eared kob has been

severely hunted to the extent that their continued existence was questionable. This chapter discusses the aerial survey that was conducted to mimic the surveys of the 1980s, when kob numbered around 1,000,000, with the aims to ascertain the continued existence of the white-eared kob in the Boma National Park ecosystem and assess if their abundances were still at level that supported migrations. A summary of results is presented for this survey which revealed to world that kob migration is still healthy and might be the second largest ungulate migration in the world. Factors affecting kob populations and densities also are discussed, and recommendations for conservation programs are put forward.

In Chapter 3 I present the annual movement patterns of kob and tiang together due to the ecological significance of these two migrations and their associations in the wet season. I give a full account of the extent of the migration and the routes at present as compared to previously described or presumed. In addition, I determine the two questions left open by previous studies: how far they south do they go, and if and where they meet with the migratory tiang. I conclude the chapter with recommendations on management and conservation actions urgently need for saving these unknown migrations.

Chapter 4 describes distribution patterns and seasonal home ranges of the white-eared kob through analyzing location data collected by the GPS collars fitted on kob. Seasonal distribution, as well as distribution patterns, is described and core areas across the ecosystem are identified and described; in addition, locations of spatial seasonal overlaps of kob with other species were described and quantified. Characteristics of the large landscape where kob migrations occur are assessed and recommendations for conservation and management are suggested.

In Chapter 5 I test whether the Normalize Difference Vegetation Index (NDVI) can be used to predict kobs locations and movements in this vast ecosystem (46,000 km. sq.) where they migrate annually. With the application of some modeling techniques I have determined that the NDVI is a good technique for prediction of kob location in any season of the year and that the NDVI techniques could be a useful tool for the management of kob migration.

In Chapter 6 I use the species distribution models based on observed presence-absence technique to predict the distribution of kobs. I used data from aerial surveys, stratified with data from various environmental factors interacting with the migratory kob, developed raster layers for each and combined them in a single file, then ran logistic regression and developed models that predict kob location at any time given certain variables in the surrounding ecosystem.

Chapter 7 presents an assessment of households living in/around the Boma National and their interactions and impact on the kob migrations. This includes the types and status of households, and their social and cultural settings. The socio-economic activities, including agriculture, livestock rearing, fishing, hunting and gathering are assessed, and the positive and negative impacts they exert on the migration of kob are assessed. Finally conservation and management actions are put forward to develop comprehensive action plans for the coexistence of kob, Boma Park, and the people who live there.

Chapter 8 summarizes the important findings of all chapters and synthesizes them into common conclusions to derive recommendations and actions plans. The most important conclusions are: 1) the kob migration is a spectacular migration phenomena

that is little known to the world. 2) Since Badingilu and Boma National Parks cover most of the kob seasonal ranges, they need serious government intervention for protection and development. However, much kob seasonal range falls outside these potentially protected areas and thus there is urgent need for creation of more reserves to address this problem before it is too late. 3) Kob populations are still healthy and migratory, but are disturbed by lots of illegal human activities in their ecosystem. Potential development projects that would run across their ecosystem pose danger to their conservation status if not well addressed. Human populations sharing the same ecosystem with kob live in dire poverty which is reflecting negatively on the kob movements; hence there is a need to address their socio-economic status. Kob migration can generate economic benefit to South Sudan through tourism just as the wildebeest do in East Africa if the government seriously invests on it.

### **Literature cited**

- Deng, L. (Overall Team Coordinator). (2001). *The Impact of Conflict on the Boma National Park: The Status of Food Security, Wildlife and Livestock*. SA/CB – STAR (USAID/ USDA/ PASA, Nairobi.
- Fryxell, J. M (1985). *Resource limitations and population ecology of white eared kob*. Ph.D. Thesis, University of British Columbia, Canada.
- Howell, P.P., M. Lock, and S. Cobb, eds. (1988). *The Jonglei Canal: Impact and Opportunity*. Cambridge University Press, UK.
- Lewis, B.A. (1972) *The Murle: Red Chiefs and Black Commoners*. In: Evans-Pritchard *et.al.* ed. Oxford University Press, UK.
- Mefit-Babtie, S. (1983). *Development studies in the Jonglei canal area: Final report*. Vol.

5. Wildlife Studies, Mefit-Babtie SRL, Glasgow, Rome and Khartoum, and Executive Organ of the National Council for Development of the Jonglei Canal Area, Khartoum, Sudan, Ministry of Finance and Economic Planning, Government of the Democratic Republic of the Sudan.

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**CHAPTER 1**  
**MAMMALIAN SPECIES ACCOUNT: KOBUS KOB**  
**(ERXLEBEN, 1777)**

**Abstract**

Extensive literature review was done and presented in the format of a “Mammalian Species Account” that describes the history, biology and conservation status of white-eared kob in the larger context of its family the Kobus kob to give an understanding of the study species, its origin and present conservation status. Due to the lack of wildlife research in South Sudan in general, and on the white-eared kob in particular, the review is done on all Kobus family species to derive understanding for the conservation needs of kob from the similarities they share.

**Context and content**

**Classification**

Kingdom: Animalia

Phylum: Chordata

Class: Mammalia

Order: Artiodactyla

Family: Bovidae

Sub-family: Reduncinae

Genus: *Kobus*

Species: *kob*

## **Subspecies**

Three subspecies have been described:

1. White-eared kob (*K. k. leucotis*)
2. Uganda kob (*K. k. thomasi*)
3. Buffon's kob (*K. k. kob*).

*K. k. kob* and *K. k. thomasi* are regarded as two separate subspecies due to the joint evolutionary history of their mtDNA sequences Lorenzen *et al.* (2007); Birungi (1999), however, proposed that the Puku (*Kobus vardonii*) might be a subspecies of kob rather than a distinct species. However, the African Antelope Specialist Group classifies *K.k. leucotis* and *K.k. thomasi* as subspecies of *Kobus kob* (IUCN 2011).

## **Description**

Total length: 90-100 (m), 80-90 (f)

Tail length: (m) 25 - 40 cm, (f) 18 - 30 cm

Shoulder height: (m) 92, (f) 78 cm

Horn: 40-69 cm

Weight: (f) 40-60 kg, (m) 60-120 kg

Gestation: 8 months

## **Diagnosis**

### **Distinguishing characters**

*Kobus kob* is a medium-sized antelope, females similar to males but smaller in size and without horns (Dorst and Dandelot 1970). Females and young males are a brown-brown colour. They have white throat patch, eye ring, inner ear and belly, and have black fronted legs (Estes 1992). Males turn darker with age and *K. k. leucotis* become

dark seal-brown, and almost black, with white rings around the eyes and ears that are completely white (Estes 1992; Dorst and Dandelot 1970). Males have large ridged horns that curve backward, forward and tip up forming an “S” shape (Dorst and Dandelot 1970). *K. k. leucotis* are gregarious live in large herds of several hundreds to thousands.

### **Distribution**

*K. k. leucotis* populations are distributed in South Sudan and Western Ethiopia. In South Sudan they occur in the plains of Jonglei and Eastern Equatoria, in the mid-eastern areas of the country always to the east of the River Nile. *K. k. thomasi* is confined to the wooded savannah from southern Bahr El-Ghazal in southwest South Sudan to Mount Elgon (Fryxell and Hilman 1988; Wanzie 1991). The *K. k. kob* is the most common antelope in the west and central Africa (Wanzie 1991), its distribution extends from Senegal, Gambia to Cameroon in West Africa; to Chad and Central African Republic in Central Africa (Mayaka *et al.* 2004; Wanzie 1991). *K. k. kob* distribution within its range is limited by vegetation, mountain ranges, deserts, river systems and human increase (Wanzie 1991).

### **Population size**

*K. k. leucotis* population size has been estimated at over 800,000 (Fryxell 1987a; Fay *et al.* 2007). Watson *et al.* (1977) had estimated 1.25 million. However, Mfit and Babbie (1983) estimated 2,000-11,700 in the Jonglei region. The general population trend is decreasing (IUCN 2011). The population size of *K. k. kob* was estimated at around 95,000 (East 1999), with a declining trend due to overhunting (Fischer and Linsenmair 2002 & 1999; Sinsin *et al.* 2002; Wanzie 1991). Sinsin *et al.* (2002) estimated the drop in *K. k. kob* in Benin at 56%. *K. k. thomasi* populations were estimated at 100,000 (East

1999).

### **Density**

During the dry season *K. k. leucotis* density in a single group around meadows and watercourses reaches between 500-1000 kob/km<sup>2</sup> (Frexyl 1987a). *K. k. thomasi* density was recorded at 136-182kob/km<sup>2</sup>, the highest among none-migrating ungulates (Balmford 1992). *K. k. kob* can reach high densities when well protected in areas of favorable habitat, ranging from 15-40 animals/km<sup>2</sup> (IUCN 2011; Amubode and Akossim 1989; Muhlenberg & Roth 1985); lowest densities recorded are less than 1/km<sup>2</sup> (Fischer and Linsenmair 2002, 2000 & 1999; Sinsin *et al.* 2002; Fischer 1998). Mayaka *et al.* (2004) reported a density of 1-12 kob/km<sup>2</sup> in Benoue National Park, Cameroon.

### **Fossil record**

Fossil data show an ancestral species of *Kobus kob* in Africa corresponding to the Plio-Pleistocene Shungura formation (Ethiopia) fossil deposit (Birungi and Arctander 2000). Accordingly during this period the range of *Kobus kob* was limited to the White Nile drainage system and Western Rift in Eastern Africa. However, this hypothesis needs to be tested further for the presence of solely A-lineage haplotypes with samples of the *K. k. leucotis*, presently in the White Nile drainage in South Sudan.

### **Form and function**

Adult male *K. k. leucotis* weigh 58 kg and female weigh 42 kg; therefore, the daily energy requirements for male, non-lactating female and lactating females were estimated at 10,466 KJ, 8216 KJ and 20,573 KJ respectively (Fryxell 1987c). Conservatively, the amount of daily food intake needed by *K. k. leucotis* to meet their



energy requirements was estimated at 1.18, 1.51 and 2.96 kg for male, non-lactating female and lactating females respectively (Fryxell 1987c). These figures exclude the additional energy expended in foraging, intra-specific aggression and reproductive behavior (Fryxell 1987c). Because kob habitats undergo seasonal changes in food availability, *K. k. leucotis* exhibit seasonal changes in body conditions due to loss of fat reserve during food stress in the dry season (Fryxell 1987c). Age-specific mortality in *K. k. leucotis* is higher in youngsters and adults but little in young and middle-aged adults (Fryxell 1987c). *K. k. leucotis* age distributions show pronounce bulge in the five-seven age group, this is probably due to increased recruitment of young or increased mortality of adults and youngsters (Fryxell 1987c).

## **Ecology**

### **Habitat**

Kob habitats cover savannah country and flood plains but never far away from water (Dorst and Dandelot 1970; Muhlenberg and Roth 1984); therefore water availability constrains kob's habitat use during the dry season (Fryxell 1987). During the dry season, 75% of *K. k. leucotis* populations were found within 10 km of water courses and only less than 5% of the populations roam farther than 20 km from water (Fryxell 1987). In the dry season range, kob concentrated at high densities in open meadows that produced green re-growth throughout the dry season, when surrounding grassland were unproductive (Fryxell 1987). *K. k. thomasi* inhabit areas of moist savannah and forest (Deutsch and Ofezu 1994; Deutsch 1991). *K. k. kob* lives mostly in dry woodland with low grass and lowland rainforest with tall grass and also in upland forest with grassland and mangrove forest (Wanzie 1991; Amubode and Akossim 1989). Nutrient quality e.g.

the extractable fats and the extent of cover from woody vegetation are among the characteristics of kob habitats (Amubode and Akossim 1989).

### **Home range**

Female *Kobus kob* occupy larger overlapping home ranges than males (Balmford 1992; Fischer and Linsenmair 2001). This might be due to territorial defense behavior in males and as anti predator and avoidance of poaching mechanisms by females (Fischer and Linsenmair 2001). Both sexes travel more or less the same distances in their daily movement rhythm (Fischer and Linsenmair 2001).

### **Sex ratio**

The sex ratio in *K. k. leucotis* is skewed towards females at 2:1 due to pressures of both natural and hunting mortality where local hunters prefer to kill males more than females (Fryxell 1987c), while *K.k. thomasi* has a structure of 1:3 male to females (Modha and Eltringham 1975).

### **Ontogeny and Reproduction**

*K. k. leucotis* exhibit a synchronous breeding resulting in calf production during the late wet season, opposite to the expectation that calf production would occur in the early wet season when food is most abundant (Fryxell 1987b). One explanation was that it is an anti-predator escape adaptation because the grassland in the northern range of their ecosystem has fewer predators; a second explanation was that female kob require substantial period to replenish fat reserves before giving birth (Fryxell 1987b). Lactation continues throughout the dry season which is characterized with food scarcity; consequently lactating females experience greater depletion of body fat reserves and become vulnerable to nutritional stresses (Fryxell 1987b). Because of a post-partition

interval of 4-months female kob gives birth to only one offspring in a year (Fryxell 1987b). In a kob population the proportion of lactating females decreases gradually in the dry season, reaching 25% in May, and the proportion of pregnant females' increases rapidly during the dry season, reaching 80% in April (Fryxell 1987b). Kob females are capable of conception as young as two years old and approximately 80% of female population conceived every year (Fryxell 1987b). This is evident as no multiple fetuses are observed in lactating female kob (Fryxell 1987b).

*K. k. kob* mate throughout the year but mostly February and March (Fischer and Linsenmair 2002 & 2000). *K. k. thomasi* mate through out the year with peaks during the rainy season (Balmford 1990 cited in Deutsch 1991), but with seasonal variations recorded in Queen Elizabeth National Park populations (Deutsch and Ofezu 1994). The estrous cycle of *K. k. thomasi* recurs one or more times every 6-13 days, and gestation period of kob has been observed to be 8 months (Morrison 1971). Increased body size is main factor determining male breeding success in *K. k. thomasi* as female tend to chose heavy mates, but it is not understood what female gain from the choice they make (Balmford *et al.* 1992).

### **Lek breeding and aggression behavior**

Lek breeding behavior has been confirmed in both *K. k. thomasi* and *K. k. leucotis* (Jackson and Skinner 1998; Deutsch 1994 & 1992; Balmford 1992; Balmford and Turyaho 1992; Fryxell 1987a; Leuthold 1966), while territoriality is confirmed in *K. k. kob*, which starts at age of 3 years. The size of a territory ranges from 0.63-1.27 km<sup>2</sup>. The territorial behavior exhibited by *K. k. kob* is a less aggressive behavior due to less

competitions resulting from lower population densities (Fischer and Linsenmair 2002 & 1999; Wazie 1988a; Muhlenberg & Roth 1985).

In lek breeding animals territorial males aggressively defend spaces where females visit for successful mating interactions. Therefore, the reproductive success of individual males should depend to a considerable degree on their ability to acquire and hold mating territories through body strength and aggressive interactions with other males (Balmford *et al.* 1992; Fryxell 1987a); and popular lek territories are usually defended by large males (Balmford *et al.* 1992). However, females in estrus primarily visit leks for breeding opportunities rather than resources in the area (Jackson and Skinner 1998). Sometimes estrus female enter larger herds in an attempt to reduce harassments outside leks (Jackson and Skinner 1998). Lek-breeding in *K. k. leucotis* takes place in the feeding areas during the dry season along the Akobo/Oboth river system in the northern range of their migration movements (Fryxell 1987a). Deutsch (1994) confirmed that, in a lekking antelope, the distribution of resources substantially explains the distribution of females, but not that of adult males. However, it was observed that leks of 100-250m, occupied by 20-65 male kob, were located in open areas adjacent to the feeding areas (Fryxell 1987a). Lekking behavior gives an advantage of reduced predation risk to mating *K.k. thomasi* males and females than elsewhere (Balmford and Turyaho 1992; Clutton-Brock *et al.* 1993). Lekking females *K. k. thomasi* prefer high visibility lek sites to reduce lion predation chances (Deutsch and Weeks 1992). In lekking *K. k. leucotis* territorial aggression occurred between males over leks and was positively related to the number of females that were present. Male kob strenuously fought for central territories that were favored by mating females and

territorial males often incurred injuries or death in the course of fights. Fryxell (1987b) suggested that wounding during territorial disputes was a leading proximate cause of male mortality during the breeding season (Fryxell 1987b). Kob aggressions disrupt mating activities and determine territorial position on lek (Fryxell 1987b). Males with females are more likely to be engaged in fights than unattended males and as a result females are scattered from single territory and redistributed to other territories (Fryxell 1987b). This type of disruptive behavior was reported only in the lekking *K. k. leucotis* (Fryxell 1987b). The aggression behavior declines over the breeding season and ad has been attributed to changes in potential mating, the dominance relations between male should have been established or because of changes in energy reserves of the males over time.

### **Disease and parasites**

*Kobus kob* is a reservoir to some *Trypanosoma* and nematode parasites. *Trypanosoma brucei gambiense*, *T. vivax* and *T. congolense* were detected in *K. k. kob* through serological tests conducted on animal populations in the Pendjari Biosphere Reserve in Benin (Guedegbe 1992). Other parasites include *Paramphistomum cervi* the common nematode parasite of ruminant has been found also in the *K. k. kob* isolated from the reticulum, abomasums and rumen of (Kaembe 1987b).

### **Mortality**

Mortality of adults and calves increases during the dry season due to insufficient food intake to meet their energy requirements. More specifically food availability determines kob adult mortality more than that of calves (Fryxell 1987c). Kob calves are protected against food limitation stresses because their mothers provide them with milk

throughout the dry season (Fryxell1987c). Mortality in kob population is also determined by the length of time kob individuals have to rely on body fat reserves during the time of nutritional deficit (Fryxell 1987c), where they become vulnerable to other mortality factors.

Kob suffer human-caused mortality through overhunting (Fischer and Linsenmair 2006 & 2002; Njiforti 1996; Hilman and Fryxell 1988; Wanzie 1991 &1988b). They also are preyed upon by the large carnivores, especially wild dogs, lions and spotted hyena (Bodendorfer *et al.* 2006; Breuer 2005 a & b; Hayward and Kerley 2005; Fischer and Linsenmair 2006 & 2002; Njiforti 1996; Balmford and Turyaho 1992; Ruggiero 1991; Wanzie 1988b; Modha and Eltringham 1975).

### **Kobus kob immobilization**

*K. k. kob* is less tolerant to immobilizing drug than *K. k. thomasi* (Wanzie 1986), but ImmoBlon is found to be tolerated well by kob (Okaeme *et al.* 1988). Male *K. k. kob* are less susceptible to immobilization than female probably due to the daily activities such as mating and territorial defense, which leave them with stiff muscles (Wanzie 1986). However, kob immobilization is effected by the rate of drug absorption and the region of shot, where the shoulder is the best shot area for efficient drug absorption due to extensive blood vessels in the area (Okaeme *et al.*1988; Wanzie 1986). Under proper drug combination and dosage kob collapses within 7-9 minutes (Wanzie 1986). Okaeme *et al.* (1988) recorded a minimum of 2.5 minutes. Most recover with revivon in 1-2 minutes, but signs of uncoordination persisted for 3-8 hours (Okaeme *et al.*1988). Overdose of Succinylcholine Chloride on *K. k. kob* was found to be fatal and irreversible (Okaeme 1987a).

## **Seasonal migrations**

*K. k. leucotis* make seasonal migrations in the plains of the Boma ecosystem in southeastern Southern Sudan. They move from southern savannah used during the wet season to northern flood plains used during the dry season; the two ranges are 150 to 200 km apart (Fryxell and Sinclair 1988). However, seasonal migrations by *K. k. leucotis* are linked to shifting distribution of critical resources (Fryxell and Sinclair 1988). During the dry season kob were mostly concentrated along major water courses in the north, particularly along Oboth River system. Kob migration into the northern areas of the park during the dry season because water courses there provided access to both green grass and water when these resources were scarce elsewhere in the ecosystem (Fryxell and Sinclair 1988). During the wet season kob migrate southward to avoid surface flooding that occur during the rains (Fryxell and Sinclair 1988), but the extent of their southern ranges not as clearly defined as the northern ranges. According to Fryxell and Sinclair (1988) it is less clear why *K. k. leucotis* move away from the northern plains during the wet season. They further explained that kob movement south is much farther than would be necessary to simply avoid flooding. One explanation was that the wet season ranges have low-rainfall, thus high nutrition quality and high digestibility due to less soil leaching (Fryxell and Sinclair 1988).

## **Social behavior**

Socially, *K. k. kob* group as follows: solitary males 17% and females 3%; bachelor male groups 13%; female herd 8%; nursery herds of young and mixed herds 20%, with maximum herd sizes of 80-150 animals (Wanzie 1988a). Changes in group size are influenced by such factors as visibility, food availability, reproductive status, and

anti-predator behavior (Fischer and Linsenmair 2000). Kob become more sociable in floodplains with good visibility during dry season (Wanzie 1988a). Water availability forces kob to tolerate associations with other ungulate species during water scarcity in dry seasons (Wanzie 1988a). None-breeding young kob gather in bachelor herds which provide cover and security for its members (Wanzie 1988a, Fryxell and Sinclair1988).

Most (82.1%) daily activity of kob is spent feeding and ruminating with other activities in between; feeding is the dominant activity in early hours and late evening in the day (Agbelusi 1991).

### **Conservation status**

According to IUCN (2013) the status of *Kobus kob* is recorded as: Least Concern ver 3.1, 2008.

### **Genetics**

Mitochondrial DNA studies revealed that *K. k. thomasi* has two distinct and genetically divergent clades: one clade comprised kob from Murchison Falls and the kobs from Queen Elizabeth, with Tooro Game Reserve kob having haplotypes from both Murchison Falls and Queen Elizabeth (Birungi and Arctander 2000; Muwanika *et al.* 2005). Accordingly, the Queen Elizabeth lineage is much more closely related to the *K. k. kob* and the puku than to the Murchison Falls lineage of kob. The depth of divergence between these lineages suggests a separation of several millions years ago. Although the presence of these lineages has no bearing on recent population size declines, the presence of distinct lineages separated by short geographical distances implies that local extinction could lead to complete loss of whole lineages.



Marchison kob was intermediate among *K. k. thomasi* and *K. k. leucotis* populations, but genetic differences were lowest between Marchison kob and *K. k. leucotis* (Lorenzen *et al.* 2007). Marchison kob resembled *K. k. leucotis* and therefore, consistently grouped with the populations from Sudan and Ethiopia. However, Marchison kob and *K. k. leucotis* differed in both phenotype and life-history. *K. k. leucotis* is migratory which move seasonally across 1500 km<sup>2</sup>. Their movements historically go to Uganda but now they no longer cover such distances due to disturbances of the civil war. On the other hand, the Marchison kob is sedentary and it is thought that they do not undergo long distance movements due to the ready availability of resources. *K. k. thomasi* breed perennially in leks while *K. k. leucotis* breed seasonally in leks while migrating. QENP populations showed low levels of genetic variability among all populations, probably due to small founder population or has been caused by a bottleneck. QENP and QES were genetically distinct. Population differentiation is very high between *K. k. leucotis* due to considerable gene flow. Results also suggest that there is ongoing migration between *K. k. leucotis* and *K. k. thomasi*, including Marchison kob, as evidenced by recurrent gene flow.

Kingswood *et al.* (2002) found that *K. kob* species are separate from *K. ellipsiprymnus*, *K. defassa* and *K. megaceros*; and that they have to be managed as separate populations. They recommended that future genetic research on genus *Kobus* species should be directed towards natural populations in Africa for a better management and conservation.

## **Literature cited**

- Agbelusi, A. (1989). Feeding-habits of the Senegal Kob (*Kobus kob kob*, Erxeleben 1777) under Ranching conditions and in the wild. *Applied Animal Behaviour*, **23**: 179-185.
- Agbelusi, A. (1991). Variations in activities of Senegal Kob (*Kobus kob kob*, Erxeleben 1777) during daylight period in an enclosure at Kainji Lake Research Institute range farm, New Busa, Nigeria. *Afr. J. Ecol.* **29**: 353-355.
- Amubode, F.O. and Akossim, C.A. (1989) Kob number and habitat characteristics of riparian vegetation in Nigeria wooded savanna. *Afr. J. Ecol.* **27**: 291-296.
- Balmford, A. (1992). Social dispersion and lekking in *K. k. thomasi*. *Behavior*, **120**: 177-191.
- Balmford, A. and Turyaho, M. (1992). Predation risk and lek-breeding in *K. k. thomasi*. *Anim. Behav.*, **44**: 117-127.
- Balmford, A., Albon, S. and Blakeman, S. (1992). Correlates of male mating success and female choice in a lek-breeding antelope. *Behav. Ecol.*, **3**(2): 112-123.
- Birungi, J. and P. Arctander. (1997). Large sequence divergence of mitochondrial DNA genotypes of the control region within populations of the African antelope, kob (*Kobus kob*). *Molecular Ecology* **9**: 962-1083.
- Birungi, J. and Arctander, B. (2000). Large sequence of mitochondrial DNA genotypes of the control region within populations of the African antelope, kob (*Kobus kob*). *Molecular Ecology*, **9**: 1997-2008.
- Breuer, T. (2005a). Diet choice of large carnivores in northern Cameroon. *Afr. J. Ecol.*, **43**: 97-106.

- Breuer, T. (2005b). Diet choice of large carnivores in northern Cameroon. *Afr. J. Ecol.*, **43**:181-190.
- Bodendorfer, T., Hoppe-Dominic, B., Fischer, F. and Linsenmair, K. E. (2006). Prey of leopard (*Panthera pardus*) and the lion (*Panthera leo leo*) in the Comoee and Marahoue National Parks, Côte D'Ivoire, West Africa. *Mammalia*: 231-246.
- Clutton-Brock, T.H., Deutsch, J.C. and Nefdt, R.J.C. (1993). The evolution of ungulates leks. *Anim. Behav.*, **46**: 1121-1138.
- Deutsch, J.C. (1992). *Reproductive strategy in a Lek breeding antelope, the Uganda kob*. Ph.D. dissertation, King's College, Cambridge University, UK.
- Deutsch, J.C. (1994). Lekking by default: female habitat preferences and male strategies in *K. k. thomasi*. *Journal of Animal Ecology*, **63**: 101-115.
- Deutsch, J.C. and Ofezu, A.A. (1994). Uganda kob reproductive seasonality – Optimal calving seasons or condition-dependent estrus. *Afr.J. Ecol.*, **32**(4): 283-295.
- Deutsch, J.C. and Weeks, P. (1992). *K. k. thomasi* prefer high-visibility leks and territories. *Behav. Ecol.*, **3**: 223-233.
- East, R., ed. (1999). African antelope database 1998. Vol. 21. IUCN, Morges, Switzerland.
- Fay, M., Elkan, P., Marjan, M. and Grossman, F. (2007). Aerial Surveys of Wildlife, Livestock, and Human Activity in and around Existing and Proposed Protected Areas of Southern Sudan, Dry Season 2007. Phase I. Juba, Southern Sudan, Sudan. Un-published report.
- Estes, R. (1992). *The Behavior Guide to African Mammals: Including hoofed mammals, carnivores and primates*. University of California Press, USA.

- Fischer, F. (2000). Changes in group size in *Kobus kob kob* (Bovidae) in the Comoé National Park, Ivory Coast (West Africa). *Zeitschrift für Säugetierkunde*, **65**(4): 232-242.
- Fischer, F. and Linsenmair, K. E. (1999). The territorial system of the kob antelope (*Kobus kob kob*) in the Comoé National Park, Côte d'Ivoire . *Afr. J. Ecol.*, **37**: 386-399.
- Fischer, F. and Linsenmair, K. E. (2001). Spatial and temporal habitat use of kob antelopes (*Kobus kob kob*, Erxleben 1777) in the Comoé National Park, Ivory Coast, as revealed by radio tracking. *Afr. J. Ecol.*, **39**: 249-256.
- Fischer, F. and Linsenmair, K. E. (2002). Demography of a West African kob (*Kobus kob kob*) population. *Afr. J. Ecol.*, **40**: 130-137.
- Fischer, F. and Linsenmair, K. E. (2006). Changing social organization and structure in an ungulate population subject to poaching and predation - the kob antelope (*Kobus kob kob*) in the Comoé National Park, Côte d'Ivoire . *Afr. J. Ecol.*, **45**: 285-292.
- Fryxell, J. M (1985). *Resource limitations and population ecology of white eared kob*. Ph.D. Thesis, University of British Columbia, Canada.
- Fryxell, JM. (1987a). Lek breeding and territorial aggression in *K. k. leucotis*. *Ethology*, **75**(3): 211-220.
- Fryxell, J. M. (1987b). Seasonal reproduction of *K. k. leucotis* in Boma National Park, Sudan. *Afr. J. Ecol.* **25**(2):117-124
- Fryxell, J. M. (1987c). Food limitation and demography of a migratory antelope, the *K. k. leucotis*. *Oecologia* **72**(1): 83-91

- Fryxell, J. M. (1991). Forage quality and aggregation by large herbivores. *The American Naturalist*, **138**:478-498.
- Fryxell, J.M., J. Greever, and A.R.E. Sinclair. (1988). Why are migratory ungulates so abundant? *The American Naturalist*, **131**: 781-798
- Fryxell, J.M. and A. Sinclair. (1988). Seasonal migration by *K. k. leucotis* in relation to resources. *Afr. J. Ecol.* **26**(1):17-31.
- Guedegbe, B., Verhulst, N., Van Meirvenne, N., Pandey, V.S. and Doko, A. (1992). Indications serologiques de l'existence d'un reservoir sauvage du Trypanosoma brucei gambiense dans la reserve de la Biosphere de la Pendjari en Republique du Benin. *Ann. Soc. belge méd. trop.*, (72): 113-120.
- Hayward, M.W. and Kerley, G.I.H. (2005). Prey preferences of the lion (*Panthera leo*). *J. Zool., Lond.*, **267**: 309-322.
- Hilman, J.C. and Fryxell, J.M. (1988). Sudan: from Antelope Global Survey and Regional Action Plan II. East and Northeast Africa. IUCN/SSC, 1988: Sudan Open Archive. Downloaded Thursday 26 April 2007 15:22 GMT. <http://www.sudanarchive.net>
- IUCN SSC Antelope Specialist Group 2008. *Kobus kob ssp. leucotis*. In: IUCN 2013. IUCN Red List of Threatened Species. Version 2013.2. <[www.iucnredlist.org](http://www.iucnredlist.org)>. Downloaded on **20 May 2014**.
- Kingswood, S.C., Kumamoto, A.T., Charter, S.J., Houck, M.L. and Benirschke, K. (2002). Chromosomes of the antelope genus *Kobus* (Artiodactyla, Bovidae): karyotypic divergence by centric fusion rearrangements. *Cytogenet Cell Genet.* **91**:128-133.

- Leuthold, W. (1966). Variations in territorial behavior of *K. k. thomasi* - *Adenota kob thomasi* (Neumann, 1896). *Behavior*, **27**: 215-257.
- Lorenzen, E.D., Neergaard, R. De., Arctander, P. and Siegismund, H. (2007). Phylogeography, hybridization and Pleistocene refugia of kob antelope (*Kobus kob*). *Molecular ecology*, **16**(15): 3241-3252.
- Mayaka, T.B., Stigter, J.D., Heitkong, I.M.A. and Prins, H.H.T. (2004). A population dynamics model for the management of Buffon's kob (*Kobus kob kob*) in the Benoue National Park Complex, Cameroon. *Ecological Modeling*, **176**: 135-153.
- Modha, K.L. and Eltringham, S.K. (1975). Population ecology of the *K. k. thomasi* (*Adenota kob thomasi* (Neumann)) in relation to the territorial system in the Rewenzori National Park, Uganda. EBSCO Publishing, 2005.
- Morrison, J.A. (1971). Morphology of corpora lutea in the *K. k. thomasi* antelope, *Adenota kob thomasi*. *J. Reprod. Fert.*, **26**: 297-305.
- Muhlenberg, M. and Roth, H.H. (1984). Comparative investigations into the ecology of the kob antelope *Kobus kob kob* (Erxleben 1777) in the Cômoe National Park, Ivory Coast. *S. Afr. J. Wildl. Res.*, 1985, **15**(1): 25-31.
- Muwanika, V.B., Nyakaana, S. and Siegismund, H. R. (2005). Genetic consequences of war and social strife in sub-Saharan Africa: the case of Uganda's large mammals. *African Zoology* **40**(1): 107-113.
- Njiforti, H.L. (1996). Preferences and present demand for bushmeat in north Cameroon: some implications for wildlife conservation. *Environmental conservation*, **23**(2): 149-155.

- Okaeme, A.N. (1987a). Succinylcholine Chloride overdose in western kob (*Kobus kob*). *Afr.J. Ecol.*, **25**(4): 295-296.
- Okaeme, A.N. (1987b). First record of *Paramphistomum cervi* in western kob (*Kobus kob*) at the Kainji Lake National Park, Nigeria. *Afr.J. Ecol.*, **25**: 297.
- Okaeme, A.N., Agbelusi, E.A., Mshelbwala, J., Wari, M., Ngulge, A. and Haliru, M. (1988). Effects of Immobilon and Revivon in the immobilization of western kob (*Kobus kob*). *Afr.J. Ecol.*, **26**(4): 63-67.
- Ruggiero, R.O. (1991). Prey selection of the lion (*Panthera leo* L.) in the Manovo-Gounda St. Floris National Park, Central African Republic. *Mammalia*, **55**(1):23-34.
- Sinsin, B., Tehou, A.C., Daouda, I. and Saidou, A. (2002). Abundance and species richness of larger mammals in Pendjari National Park in Benin. *Mammalia*, **66**(3): 369-380.
- Wanzie, C.S. (1986). Buffon's Kob (*Kobus kob kob* Erxleben) immobilization in Waza National Park, Cameroon. *Mammalia* **50**(2):253–262.
- Wanzie, C.S. (1988a). Sociability of Buffon's kob (*Kobus kob kob* Erxleben) in Waza National Park, Cameroon. *Mammalia* **52**(1): 21-33.
- Wanzie, C.S. (1988b). Mortality factors of *Kobus kob kob* (Erxleben) in Waza National Park, Cameroon. *Mammalia* **50**(3):351–356.
- Wanzie, C.S. (1991). The present distribution and status of *Kobus kob kob* in West and Central Africa. *Mammalia* **5**(1): 79-84.
- Watson, R.M., Tippet, C.I., Rizk, F., Becket, J.J. and Jolly, F. (1977). Sudan national livestock census and resource inventory. Volume 31. Results of an aerial census

of resources in Sudan from August 1975 to January 1977. Sudan Veterinary Research Administration, Ministry of Agriculture, Food and Natural Resources, Khartoum, Sudan.



## CHAPTER 2

### POPULATION SIZE AND DISTRIBUTION OF THE WHITE-EARED KOB (KOBUS KOB LEUCOTIS) IN SOUTH SUDAN

#### Abstract

Density distribution and abundance of kob were assessed and determined through aerial surveys following absence of conservation activities in the study area for nearly 25 years, where, the population of white-eared kob has been severely hunted for food to the extent that their continued existence was questionable. The aim of this study was to ascertain the continued existence of the white-eared kob in the Boma National Park ecosystem and assess if their abundances were still at level that supported migrations. A summary of results is presented for this survey which revealed to world that kob migration is still healthy and might be the second largest ungulate migration in the world. Factors affecting kob populations and densities also are discussed, and recommendations for conservation programs are put forward.

#### Introduction

White-eared kob are gregarious antelope that occur in large groups of hundreds to tens of thousands animals moving together. Kob migrations involve long distance movements across a vast ecosystem that spans Jonglei and Eastern Equatoria States in southeastern South Sudan (Fryxell 1985). Considering the dynamics of political, social, and economic changes in South Sudan, conservation of such an aggregated migratory species should be a conservation priority.

Conservation of mass migrations requires descriptive data and information to evaluate their status (Harris *et al.* 2009); it also requires the understanding of basic parameters of migration (locations, numbers, routes, distance moved), ecological drivers, habitat needs, and threats (Harris *et al.* 2009). Previous studies on ungulate populations have shown that effective conservation and management necessitates reliable information on density to help managers to making informed decisions (e.g. Rija and Hassan 2011, Young *et al.* 2010, Harris *et al.* 2009, Shorrocks *et al.* 2008, Pettorelli *et al.* 2007, Ogutu *et al.* 2006, Stoner *et al.* 2006, Pajor *et al.* 1995).

Active management of kob dates back to the 1970s when the Boma ecosystem in southeast South Sudan was declared as a Game Reserve, then later elevated to National Park conservation status eight years later. The first aerial counts of ungulates in the ecosystem were conducted in 1980-1983 through studies of Fryxell (1985) and Mefit and Babbie (1985). The former was directly studying white-eared kob population dynamics while the latter conducted impact assessment studies on the Jonglie Canal Project which was meant to shorten the course of the Nile River while draining the Sudd swamps. The current study followed a two decades long civil war in South Sudan, which actually started in areas within the migration ecosystem, as part of efforts started in 1990s by concerned individuals and institutions to restore wildlife conservation activities. Accordingly, two ground surveys employing foot and road transects were conducted in 2001 and 2002 (Deng *et al.* 2001, Marjan *et al.* 2001) following a 1999 aerial reconnaissance flight of the Boma National Park. The aim of that work was to confirm continued presence of wildlife species and estimate density at a small scale, as it was practically difficult to start with extensive aerial surveys amidst civil war. Following the

encouraging ground surveys, a full aerial survey was called for by concerned individuals; this survey was based on methods described by Norton-Griffith (1978), deemed the most suitable method for counting and determining kob density due to vastness of the study area and the gregariousness and migratory nature of the kob. Hence, this study was designed to mimic the 1982 surveys (Fryxell 1985) with a specific aim to estimate the density of the migratory white-eared kob and thus reveal whether the population size has changed over 25 years of armed conflict, and to identify any management implications.

### **Study area**

Kob migrations occur in eastern South Sudan in a savannah grassland area that extends across Jonglei and Eastern Equatoria States (Fig. 2.1), where there is the Boma National Park (BNP) in the northeast and Badingilu National Park (BdNP) in the southwest. BNP was established in 1978, and BdNP was established in 1982 out of amalgamation of two small reserves together with the areas in between them.

The mean annual precipitation ranges from 400-1,400 mm and falls between April-October (the wet season). The mean monthly temperature is 36°C during the dry season and 28°C during the wet season whose relative humidity is highest. Topography of the area is mostly flat with scattered isolated hills in addition to the Boma escarpment in the east. Most of the plains are dominated by “black cotton” clay soil, and on the slopes and the foot of the hills the soils are laterite and sandy (Willimott 1956). Most of the region is in a watershed that ultimately empties into the Nile River via the Sobat River (Fryxell 1985). The ecosystem contains the Guom swamps in the northern end of BNP, and is drained by the Kangen/Kong-Kong River system, the Oboth/Neubari Rivers to the

north, and the Veveno and Lotila Rivers to the south running through Badingilu National Park.

Major vegetation of the ecosystem is characterized as the East Sudanian savannah grassland, the Saharan flooded grassland, and the Northern Acacia-Commiphora bushland and thickets; there is also Victorian basin forest-savannah found on the Boma escarpment in the east. The eastern part of the ecosystem in BNP is covered with woodland dominated by *Combretum* species, while the middle-western flood plains are covered with open tall grassland dominated by *Hyperhenia rufa*, *Sporobolus spp.*, and *Pennisetum spp.* and *Echinoloa spp.* In between these two zones lies an intermediate zone of wooded grassland. The grasslands around the Guom swamps in the north include areas of *Hydrophila spinora*. Around the isolated hills occurs dense thicket dominated by *Ziziphus spina-christi*, *Acacia seyal*, *A. drepanalobium*, *A. fistula*, and *A. zanzibarica* (Willimott 1956).

## **Materials and Methods**

### **Kob abundance**

The survey followed procedures described in Norton-Griffith (1978) and was conducted over a period of 11 days (10-21 February) in the dry season of 2007. It ended up covering an overall survey area of 220,217 km<sup>2</sup> in much of Jonglei and Eastern Equatoria States (Fig 2.2). A total of 91 aerial transects were flown in an east-west orientation with transect spacing of 10 km. The census team consisted of four persons on board a Cessna 172 aircraft (one pilot, one front seat observer and two rear seat observers). The pilot flew the aircraft at the height of 300 feet above ground, kept track of the altimeter reading, and announced the start and end of each transect. The rear seat

observers identified and counted all animals that were seen between two rods fixed on the wing struts such that they each counted animals in a 150-m strip, and relayed observation to the front seat observer for recording. The front seat observer recorded animal counts and other environmental attributes seen across all transects. The survey width of 150 m on both sides of the aircraft resulted in a strip width of 300 m and, given the spacing of transects (10 km), represented 3% coverage of the study area. Kob were counted and noted whether they were in/out of transects as they occurred. Larger and clumped groups were photographed for later counting. Other attributes recorded included vegetation community, water locations, vegetation burnings, livestock, and human activities and settlements.

The total kob population was estimated by multiplying kob density by the total survey area.

Kob population density and size were estimated as follows:

$$D = \frac{n}{(2al)}$$

Where  $D$  = animal density,  $n$  = number of animals,  $L$  is length of transect; and  $a$  = half the strip width.

The strip width is practically not constant throughout the flights. Therefore, this is corrected through recording the perpendicular distances to the observed animals, and used to estimate average value for  $a$ . Then population density will be:

$$D = \frac{n}{2l} \left( \frac{l}{n} \sum \frac{l}{r_i} \right)$$

Where  $n$  and  $L$  are as before,  $r_i$  is the observed distance to each sighted animal  $i$ .

The width of the strip is calculated as:

$$w = Wx \frac{h}{H}$$

Where  $w$  = strip width on the ground,  $W$  = required strip width,  $H$  = flying height chosen,  $h$  =transect height.

Sample variance is calculated as (Howell 2008):

$$S_x^2 = \frac{\sum(x - \bar{x})^2}{N-1}$$

$$S_x^2 = \frac{\sum x^2 - \frac{(\sum x)^2}{N}}{N-1}$$

The sample standard deviation:

$$S_x = \sqrt{\frac{\sum(x - \bar{x})^2}{N-1}}$$

$$= \sqrt{\frac{\sum x^2 - \frac{(\sum x)^2}{N}}{N-1}}$$

### **Kob distribution**

A 70 x 70 grid cell array or fishnet (with each grid cell 10 km x10 km to conform to the aerial survey transect width) was created on GIS 9.3 and this net was converted to a polygon feature. With the use of Hawth's Analysis Tools Extension of ArcGIS (Beyer 2004) polygon centroids were created and data assigned so that we had data in the center of each grid cell of the net. Kob observation data were selected and output exported and saved as a shape file. The net was added to the kob centroid with the use of Spatial join tool. The geometry for the lat/long was calculated, then the kob + fishnet + centroid were joined and saved as Excel file. The polygon FID was summed up by rows and aggregates. With the use of Excel 2007 as pivot table, the number of animals seen in each cell was summed, then the Excel file was uploaded to the Map and joined with the sum numbers, the centroid rows and the fishnet. The consolidated aggregate of x,y was

added; and the output was exported as kob.centroid, and the fishnet 10x10-kob was joined with kob-centroid and exported saved as kob-density.shp. Flight track data (Fig 2.2) and kob GPS locations and numbers were entered into ArcGIS 9.3. Data were analyzed using spatial analyst tools and Hawth's tools. Total survey area and kob density/km<sup>2</sup> were calculated.

## **Results**

The total kob population size was estimated to be 792,782 ± 254.745. Group size of kob seen per survey point ranged from 1 kob to large clump of up to 5000. Kob distribution from 10 x 10 km Fishnet grid cells ranged from 1kob/cell in barren grounds to 16,659 in areas of high water and green vegetation (Fig 2.3). Kob distribution covered large areas from Guom swamps at the northern end of Boma National Park, throughout the plains of Jonglei up to north of Fam El-Zaraf where the Nile meets Sobat River at the borders of Jonglei and Upper Nile States.

## **Discussion**

The kob population estimate in this study is only 5-6% less than that of Fryxell (1985) twenty years ago (792,782 vs. 840,000), despite the impact of the two decades of armed conflict in the area. It was expected that the proliferation of firearms in the area would have had drastic effects on kob populations through unregulated, intensive, and indiscriminate hunting for food, especially since the local communities herd cattle and only grow a few crops, but rely entirely on wild meat for their livelihood. Contrary to this prediction, kob population estimates did not change noticeably. This might be explained by several factors: 1) kob are efficient breeders; i.e., exhibit high fecundity (Fryxell 1987b); 2) the densities of predators in the migration ecosystem are not high

enough to suppress kob population;3) there is high juvenile survival as female kob give birth while in the wet season ranges where there is plenty of food, enough cover from predators, and isolation from human disturbances; and 4) the intensity of the civil war has led to the displacement of human populations in kob range,thereby reducing poaching effects and leaving empty vast land for kob; 5) due to the long civil war there have been no major development projects in the area that might cause habitat alterations that disrupt kob migrations.

In other studies where trends of ungulates densities were compared over decades, most study species shown declines by 50% to over 90%, mostly due to intensive poaching, restriction of movements and poor quality forage, effects on/loss of habitats by agriculture and livestock, rainfall fluctuations and increasing human settlements; this would include the wildebeest in Masai Mara National Reserve in Kenya(Bhola *et al.* 2012; Ogutu *et al.* 2011; Ottichilo *et al.* 2001; Serneels and Lambin 2001), the grazers of Ngorongoro Crater in Tanzania (Estes *et al.* 2006), the wildebeest and zebra in Trangire, Tanzania (Voeten *et al.* 2009), wildebeest in Serengeti-Mara (Homewood *et al.* 2001), the large ungulates in western Tanzanian woodlands (Stoner *et al.* 2006), and the Buffon's kob in Camoê National Park in Ivory Coast(Fischer and Linsenmair 2001).

The observed kob numbers ranged from solitary individuals wandering alone to tens of thousands moving together. The survey was carried out during the dry season when kob emerge out of the tall grass ecosystem of their wet season range and spread out in smaller groups, thus improving visibility and counting. However, at the same time, kob were seen racing towards the dry season range amidst the unregulated burning of vegetation by the local inhabitants of the area. The survey team was using only one



aircraft and transects were spaced at 10 km apart. Thus we suspect that some large kob groups in the total population were missed during counting. We also believe that the survey was not free from errors such as observer effects (Pettorelli *et al.* 2007, Giotto *et al.* 1995) because throughout the survey the right rear seat observer did not change, but the left rear observation seat had several different observers. Any errors due to observer differences might have led to underestimation of the overall kob numbers. Also, larger groups of several hundreds or thousands of animals are difficult to count accurately (Williamson *et al.* 1988), even when photographed, and this might also have resulted in an inaccurate total numbers.

The abundance of kob varied from low/no animal in areas of dry barren grounds and areas with human settlements to highest in areas with plenty of water and green forage far from human disturbances. During the survey kob were observed concentrated or crossing through habitats with plenty of water and vegetation such as rivers, streams and swamps. This is in line with Fryxell's (1987c) finding that kob are always associated with water, and during the dry season about 80% of kob are seen within 10 km of water. Several other studies have also found that water is the primary factor motivating antelope movements and dispersal (e.g. Young *et al.* 2010, Voeten *et al.* 2009, Scholte *et al.* 2007, Williamson *et al.* 1988).

During the aerial survey kob were observed moving northeastwards, crossing the line transects and heading to the dry season ranges in the Guom swamps north of the Boma National Park. A few groups moved northwest crossing the partially excavated Jonglei Canal at the northwest end of the kob migration ecosystem. They were likely heading to the Sudd swamps with some vanguards observed resting in the expansive green

vegetation of the Sudd with abundance of water. The distances they cover to get to the Sudd (300-400 km) are more or less similar to those covered by the main migration that moves to the east (Chapter 3). However, it is not clear why these groups chose to move westward through densely populated human settlements with dangers of poaching. One explanation is that kob migrations historically covered wider areas across the Jonglei region between the Sudd swamps in the extreme west and the Guom and other swamps in the eastern end of the ecosystem before human settlements increased much in the region limiting their routes. In fact, the local communities near the Sudd have names for the white-eared kob in their languages; also, kob are well embodied in their local culturally traditions and folklore, a sign of interaction with kob for long time. The second possible explanation is that these groups found better nutritional qualities of forage with plenty of water in Sudd swamps. Williamson *et al.* (1988) reported similar observations with wildebeest in the Central Kalahari Game Reserve, South Africa.

### **Conclusions and Management Implications**

This study revealed that kob density varies over wide areas, even over greater areas than the 200,000 km<sup>2</sup> we surveyed, especially during the dry season. Although most of these areas currently are naturally protected through inaccessibility and lack of development projects, threats from increasing human settlements and developmental projects such as extractive industries are imminent. This should be of concern because of poaching (Ogutu *et al.* 2011, Scholte *et al.* 2007) and other negative effects on habitats usually associated with major development projects. Thus, the migratory kob also face the two principal and general threats to large antelope migrations reported by Harris *et al.* (2009); that is, overharvesting/unsustainable hunting and habitat loss, both of which

cause population declines. For the kob migration phenomenon to continue to exist, their population sizes have to be large and their numbers should be allowed to grow and be maintained. Conservation of kob necessitates urgent actions from both conservationists and land managers. This should include productive management of the existing protected areas at the extremes of the migration ranges and the corridors linking them, frequent surveys to establish effective monitoring of kob population trends, development of efficient anti-poaching program for the control and management of poaching by local communities (Waltert *et al.* 2009, Ogutu *et al.* 2011), and inclusion of the conservation interests of the kob migration in future land use plans that might affect the migration ecosystem by development of an urgently needed national action plan (Owen-Smith *et al.* 2012, Ogutu *et al.* 2011, Rija and Hassan 2011, Young *et al.* 2010, Giotto *et al.* 2009, Scholte *et al.* 2007, Pettorelli *et al.* 2007, Milner-Gulland *et al.* 2001).

### **Literature cited**

Beyer, H. L. (2004). Hawth's Analysis Tools for ArcGIS. Available at

<http://www.spatial ecology.com/htools>.

Bhola, N., Ogutu, J. O., Piepho, H-P., Said, M. Y., Ried, R. S., Hobbs, N. T. and Olf, H.

(2012). Comparative changes in density and demography of large herbivores in the Masai Mara Reserves and its surrounding human-dominated pastoral ranches in Kenya. *Biodiversity Conservation*, 21: 1509-1530.

Deng, L. (Overall Team Coordinator). (2001). The Impact of Conflict on the Boma

National Park: The Status of Food Security, Wildlife and Livestock. SA/CB – STAR (USAID/ USDA/PASA, Nairobi).

- Estes, R. D., Atwood, J. L. and Estes, A. B. (2006). Downward trends in Ngorongoro crater ungulate populations 1986-2005: Conservation concerns and the need for ecological research. *Biological Conservation*, 131: 106-120.
- Fischer, F. and Linsenmair, K. E. (2001). Decreases in ungulated population densities: examples from the Camoë National Park, Ivory Coast. *Biological Conservation*, 101: 131-135.
- Fryxell, J. M. (1985). Resource limitation and population ecology of the white-eared kob. PhD Thesis. University of British Columbia, Canada.
- Fryxell, J. M. (1987b). Seasonal reproduction of white-eared kob in Boma National Park, Sudan. *African Journal of Ecology* 25: 117-124
- Fryxell, J. M. (1987c). Food limitation and the demography of a migratory antelope, the white-eared kob. *Oecologia*, 72: 83-91.
- Giotto, N., Obsieh, D. Joachim, J. and Jean-François, G. (2009). The population size and distribution of the vulnerable beira antelope *Dorcatragus megalotis* in Djibouti. *Oryx*, 43: 552-555.
- Harris, G., Thirgood, S. Hopecraft, J. G. C., Cromsigt, J. P. G. M. and Berger, J. (2009). Global declines in aggregated migrations of terrestrial mammals. *Endang Species Res*, 7: 55-76.
- Homewood, K., Lambin, E. F., Coast, E., Kariuki, A., Kikula, I., Kivelia, I., Said, M. Sernnel, S. and Thompson, M. (2001). Long-term changes in Serengeti-Mara wildebeest and land cover: pastoralism, population, or policies? *PNAS*, 98(22): 12544-12549.

- Marjan, M. D., Ojok, L. I., Nicholas, B. B. AND Solomon, I. S. (2002). The Impact of Conflict on the Boma National Park: The Status of Wildlife, V. II - Dry Season Wildlife Counting. Unpublished report, SACB, USAID, USDA/ PASA, Nairobi. Boma National Park - Dry Season Survey.
- Mefit-Babtie, S. (1983). Development studies in the Jonglei canal area: Final report. Vol.5. Wildlife Studies, Mefit-Babtie SRL, Glasgow, Rome and Khartoum, and Executive Organ of the National Council for Development of the Jonglei Canal Area, Khartoum, Sudan, Ministry of Finance and Economic Planning, Government of the Democratic Republic of the Sudan.
- Milner-Gulland, E. J., Kholodova, M. V., Bekenov, A. Bukreeva, O. M., Grachev, Iu. A., Amgalan, L. and Lushchekina, A. A. (2001). Dramatic declines in saiga antelope populations. *Oryx*, 35: 340-345.
- Norton-Griffiths, M. (1978). Counting Animals. 2nd ed: African Wildlife Foundation, Nairobi, Kenya.
- Ogutu, J. O., Owen-Smith, N., Piepho, H. P. and Said, M. Y. (2011). Continuing wildlife population declines and range contraction in the Mara region of Kenya during the 1977-2009. *Journal of Zoology*, 285:99-109.
- Ogutu, J. O., Bholá, N., Piepho, H. P. and Reid, R. (2006). Efficiency of strip and line-transect surveys of African Savanna mammals. *Journal of Zoology*, 269: 149-170.
- Ottichilo, W. K., de Leeuw, J. and Prins, H. H. T. (2001). Population trends of resident wildebeest [*Conochaetes taurinus hecki* (Neumann)] and factors influencing them in the Masai Mara ecosystem, Kenya. *Biological Conservation*, 97: 271-282.

- Owen-Smith, N., Chirima, G. J., Macandza, V. and Le Roux, E. (2012). Shrinking sable antelope numbers in Kruger National Park: what is suppressing population recovery? *Animal Conservation*, 15:195-204.
- Pajor, T. M., Bowden, D. C. and Gill, R. B. (1995). Aerial counting experiments to estimate Pronghorn density and herd structure. *Journal of Wildlife Management*, 59: 117-128.
- Petorelli, N., Côté, S. D., Gingras, A., Potvin, F. and Huot, J. (2007). Aerial survey vs hunting statistics to monitor deer density: the example of Anticosti Island, Quebec, Canada. *Wildlife Biology*, 13: 321-327.
- Rija, A. A. and Hassan, S. N. (2011). Population density estimates of some species of wild ungulates in Simanjiro Plains, northern Tanzania. *African Journal of Ecology*, 49: 370-372.
- Serneels, S. and Lambin, E. F. (2001). Impact of land-use changes on the wildebeest population in northern Serengeti-Mara ecosystem. *Journal of Biogeography*, 28: 391-407.
- Scholte, P., Adam, S. and Serge, B. K. (2007). Population trends of antelopes in Waza National Park (Cameroon) from 1960-2001: the interacting effects of rainfall, flooding and human interventions. *African Journal of Ecology*, 45: 431-439.
- Shorrocks, B., Cristescu, B. and Magane, S. (2008). Estimating density of Kirk's dik-dik (*Madaqua kirkii* Gunther), impala (*Aepyceros melampus* Lichtenstein) and common zebra (*Equus burchelli* Gray) at Mpala, Laikipia District, Kenya. *African Journal of Ecology*, 46: 612-619.

- Stoner, C., Caro, T., Mduma, S., Mlingwa, C., Sabuni, G., Borner, M. and Schelten, C. (2006). Changes in large herbivore populations across large areas of Tanzania. *African Journal of Ecology*, 45: 202-215.
- Voeten, M. M., Claudius, A. D. M, de Vijver, V., Olf, H. and van Langevelde, F. (2009). Possible causes of decreasing migratory ungulate populations in an East African savannah after restrictions in their seasonal movements. *African Journal of Ecology*, 48: 169-179.
- Waltert, M., Meyer, B., and Kiffner, C. (2009). Habitat availability, hunting or poaching: what affects distribution and density of large mammals in western Tanzanian woodlands? *African Journal of Ecology*, 47: 737-746.
- Williamson, D., Williamson, J. and Ngwamotsoko, K. J. (1988). Wildebeet migration in the Kalahari. *African Journal of Ecology*, 26: 269-280.
- Willimot, S. G. (1956). Soils and Vegetation of Boma Plateau and Eastern District of Equatoria. *Sudan Notes and Records*, 32: 9-20.
- Young, J. K., Murray, K. M., Strindberg, S., Buuveibaatar, B. and Berger, J. (2010). Population estimates of endangered Mongolian saiga *Saiga tatarica mongolica*: implications for effective monitoring and population recovery. *Oryx*, 44: 285-292.

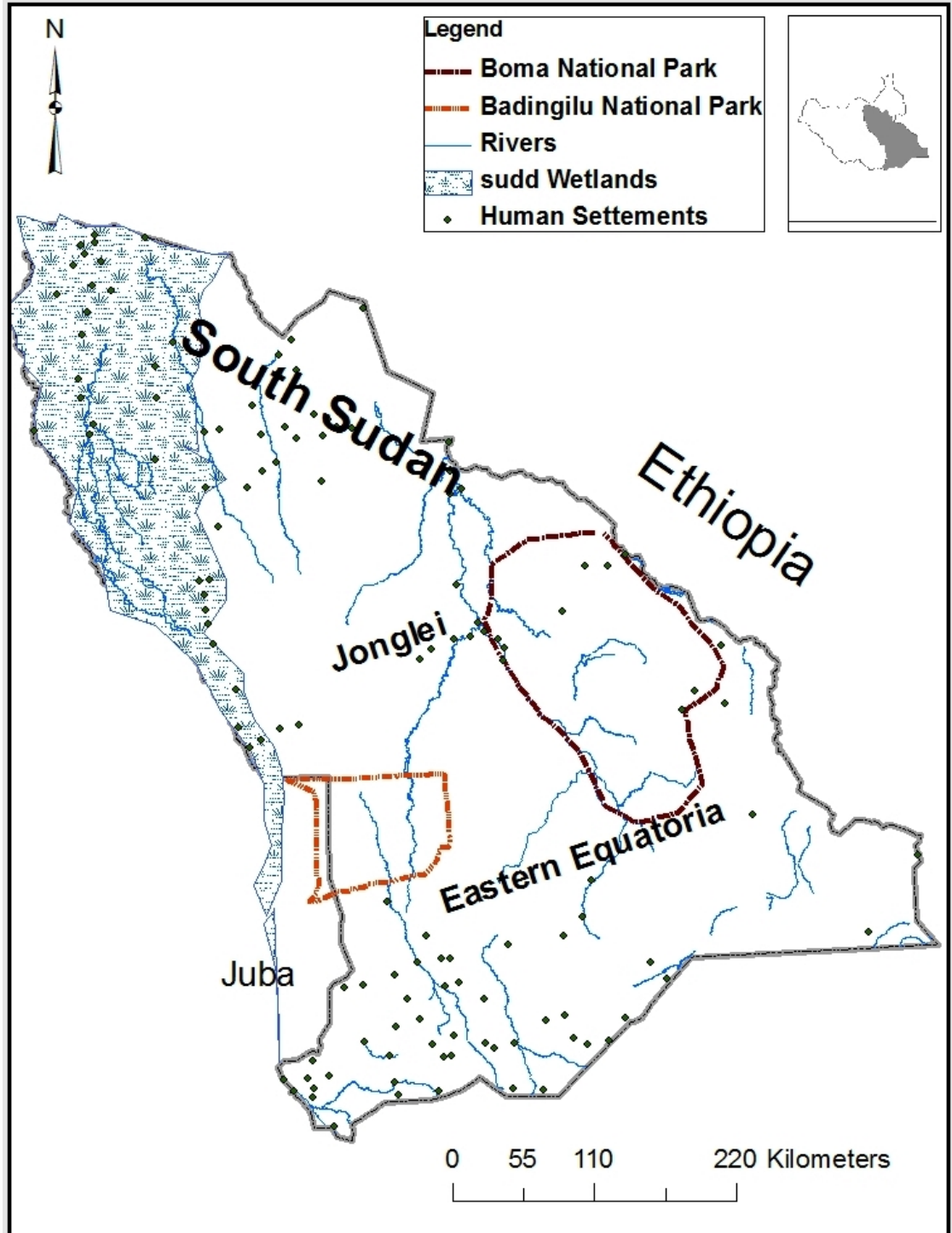


Figure 2.1. Koba study area in eastern South Sudan.



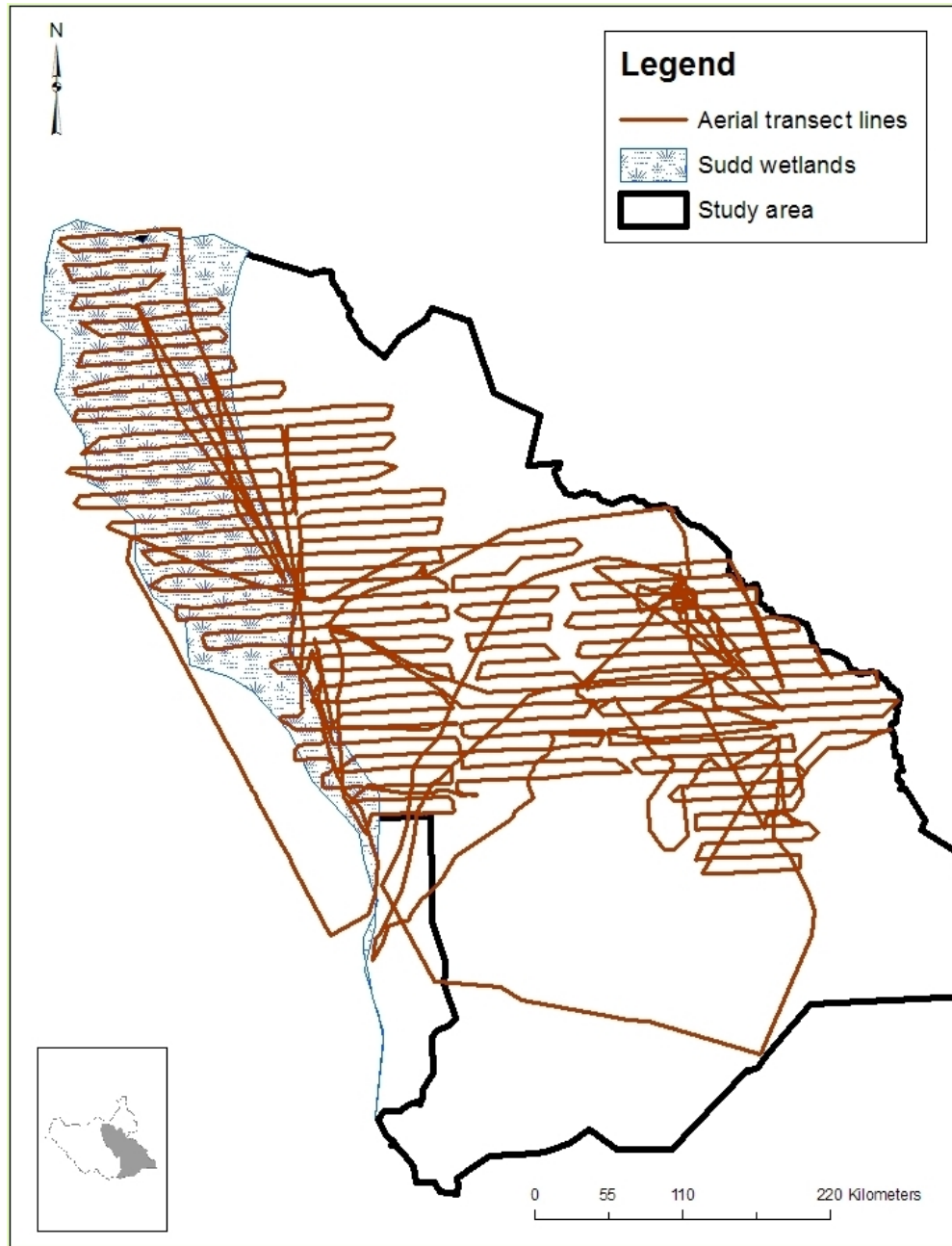


Figure 2.2. Location of aerial transects flown during 10-21 February, 2007 in South Sudan.

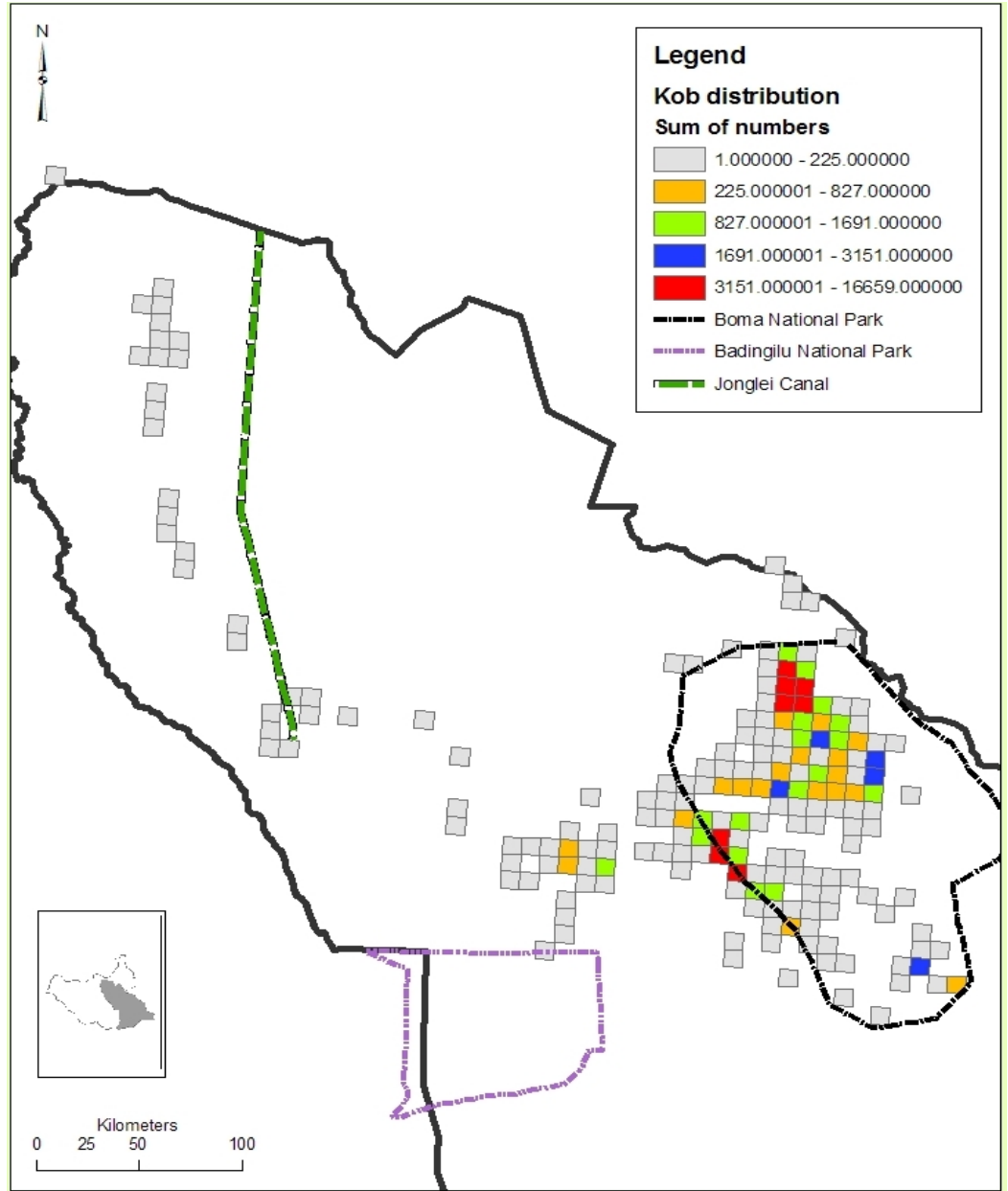


Figure 2.3. Distribution of kob numbers observed per grid cell distribution across the study area in South Sudan.

# CHAPTER 3

## CO-MINGLED MIGRATIONS OF WHITE-EARED KOB AND TIANG IN SOUTH SUDAN

### Abstract

Earlier studies indicated that kob and tiang undergo seasonal movements influenced by shift in resources and that they might overlap sometimes during the course of their movements. Like other migratory ungulates these two species face the challenges of poaching and natural and anthropogenic factors affecting their habitats. By the use of GPS telemetry this chapter aims to track and document the migrations of these species, their seasonal ranges, routes and important corridors as well as confirming areas of actual seasonal overlaps. The two questions left open by previous studies: how far south do kob go, and if and where they meet with the migratory tiang have been determined. The chapter is concluded with recommendations on management and conservation actions urgently need for saving these widely unknown migrations.

### Introduction

Long distance movements are characteristic of large herbivores in African savannah ecosystems that exhibit pronounced seasonal changes in grassland productivity due to periodic variations in rainfall (Fryxell 1985), and are primarily influenced by search for forage and water resources (Coughenour 2008, Gates *et al.* 2005). In South Sudan, the overlapping migrations of the white-eared kob (*Kobus kob leucotis*) and tiang (*Damaliscus korigum lunatus*) form one of largest animal movements on earth, but remain only partially known. Kob populations were estimated to be over 800,000 (Fryxell

1987a, Fay *et al.* 2007), while tiang numbers range between 500,000 (Mefit-Babtie 1983) and 120,000 (Fay *et al.* 2007). While kob movements were thought to be cyclic in the plains of Boma National Park, tiang movements seemed to occur on north-south directions in the plains of Jonglei landscape which reach up to the Sudd Swamps in the Jonglei State, with concentrations east of the partially dug Jonglei Canal. Observations by Mfit-Babtie (1986) and Fryxell (1985) indicated that groups from the two migratory species might meet during the wet season in an area bounded between the Boma and Badingilu National Parks, on the eastern bank of the River Nile, east of Juba, South Sudan. Whether this was coincidental or an ecological phenomenon that occurs seasonally needed to be confirmed and further understood.

Over the last century, ecosystems with large herbivores have been increasingly threatened by land conversion, land use intensification, resource extraction, and artificial barriers disrupting the movements of these species (Coughenour 2008, Gates *et al.* 2005). Such disruptions, in addition to other threatening factors to the migratory behavior of ungulates such as overhunting and habitat destruction, have caused worldwide concerns for the future of ungulate migrations (Harris *et al.* 2009, Hebblewhite *et al.* 2006). Accordingly, the migrations of kob, tiang, and other antelope in southeastern South Sudan are thought to be facing dangers of 1) overhunting due to wide spread of firearms as result of the 22 years of armed struggle for independence of South Sudan, 2) the potential and expanding post-conflict development of resource extractive industries in and around the migration corridors and landscapes, and 3) anthropogenic disturbances associated with expanding human settlements as many people return home from displacement during war time.

Since antelope migration is appreciated as a phenomenon of abundance, it is important to protect the species when still at high population levels (Wilcove and Wikelski 2008). The significance of this study is that it reveals the extent of antelope migrations in South Sudan, illustrates how kob and tiang migrations relate to each other, and identifies potential impacts on the migrations. The objectives of this study were: 1) to determine whether kob and tiang are still migratory; 2) to identify kob and tiang migrations pathways on the landscape, and compare how the current migration patterns relate to historical ones; 3) to determine the wet season (southern) ranges of the two migrations; and 4) to determine whether the white-eared kob and tiang overlap seasonally in some areas within the migration ranges.

### **Study area**

Kob migration occurs in eastern South Sudan in savannah grassland areas that extend between Jonglei, Central and Eastern Equatoria States (Fig 2.1). This vast area encompasses Boma National Park, Badingilu National Park and Zeraf Island Game Reserve in the Sudd swamps of the River Nile. These protected areas are separated by hundreds of kilometers expanding over vast landscapes of similar environmental features. Kob population dynamics was studied in the Boma National Park by Fryxell (1985) and tiang were surveyed in the plains of Jonglei by Mfit and Babbie (1986).

Boma National Park was established in 1978 and Badingilu National Park was established in 1982. The two parks are about 300 km apart therefore have similar environmental features (e.g., climate and vegetation). The mean annual rainfall in the area ranges from 400-1,400 mm at the nearest meteorological station at Juba International Airport (Fig 3.2). The mean monthly temperature is 36C<sup>o</sup> during the dry season

(December – March) and 28C<sup>o</sup> during the wet season (March – November). Relative humidity is highest during the wet season.

Topography of the area is mostly flat with scattered isolated hills in addition to the Boma escarpment. Most of the plains are dominated by “black cotton” clay soil. On the slopes and the foot of the hills the soils are laterite and sandy (Willimott 1956). The ecosystem is a bed for major swamps like the Guom swamps in the northern end of Boma National Park. In the north in Boma National Park it is also drained by a number of rivers such as the Kangen/KongKong River system, the Oboth/Neubari Rivers and the Kuron River, while the Veveno and Lotila Rivers drain south through Badingilu National Park. The entire region is in a watershed that ultimately empties into the Nile River via the Sobat River (Fryxell 1985).

Vegetation of the migration ecosystem (Fig 3.1) comprises the East Sudanian savannah grassland, Saharan flooded grassland and the Northern Acacia-Commiphora bush land and thickets, while the Victorian basin forest-savannah is found on the Boma escarpment in the east. The eastern part of the ecosystem in Boma National Park is covered with woodland dominated by *Combretum* species, while the middle-western flat flood plains are covered with open grassland dominated by *Hyperhenia rufa*, *Sporobolus* spp., *Pennisetum* spp., and *Echinoloa* spp. In between these two zones lies an intermediate zone of wooded grassland. The grasslands around the Guom swamps in the north include areas of *Hydrophila spinora*. Around the isolated hills occurs dense thicket dominated by *Ziziphus spin christi*, *Acacia seyal*, *A. drepanalobium*, *A. fistula*, and *A. zanzibarica* (Willimott1956).

The white-eared kob is a medium-sized antelope, with females similar to males

but smaller in size and without horns (Dorst and Dandelot 1970). Females and young males are chestnut-red. Males turn darker with age and become dark seal-brown, and almost black, with white rings around the eyes and ears that are completely white (Dorst and Dandelot 1970). Males have large horns which curve backward, forward and tip up forming an “S” shape (Dorst and Dandelot 1970). White-eared kob are gregarious and live in large herds of several hundreds to thousands. White-eared kob have been considered as a conspecific to the Uganda kob (*Kobus kob thomasi*), one of the lekking species in Africa. White-eared kob populations are distributed in southeastern South Sudan and western Ethiopia. In Southern Sudan they occur in the corner of the country always to the east of the River Nile. Kob population was estimated to be over 800,000 (Fryxell 1987a, Fay *et al.* 2007). The population is rated at lower risk Near threatened by the IUCN’s Red List.

The tiang is a sub-species of hartebeest, a large antelope weighing 90-140 kg. It has a long head and shoulders higher than the rump, making the body slope to the back (Dorst and Dandelot 1970). It is reddish brown to purplish red color, with distinct dark patches in the face, upper parts of the fore leg and thighs. Its horns are thick, ridged, and lyrate, rising vertically and curving evenly backwards. Females differ from males with lighter color, and shorter and less ridged horns (Dorst and Dandelot 1970). Tiang prefer habitats of open savannah, woodland and dry country. They are grazers and survive on dry grasses left by other species. They can survive for long periods without water (Dorst and Dandelot 1970). They are highly gregarious and groups can number up to 12,000 individuals (Dorst and Dandelot 1970); they also take part in one of largest antelope migrations in the world (Fay *et al.* 2007; Mfit-Babtei 1983; Dorst and Dandelot 1970).

Tiang are categorized in the IUCN Red List as Lower Risk/near threatened, with population trends rated as declining (Antelope Specialist Group 1996). Major threats for the species are harvesting (hunting/gathering) for food, human disturbance in the form of ongoing civil wars.

### **Materials and Methods**

In August 2009, we captured 2 adult female white-eared kob and 2 adult female tiang using a dart gun (with suitable doses of M-99 drug [American Cyanamid, West Patterson, NJ]) from a helicopter fitted them with GPS collars [North Star Science and Technology, King George, VA] following the procedures described by Fuller *et al.* (2005) and Ito *et al.* (2005). The GPS units were monitored for a period of 20 months. The collar units obtained locations varied from 1-5 times/day and were transmitted only via a satellite receiver station and Argos uplinks.

Captured animals were sexed, aged (estimation based on tooth eruption and wear), measured (head length circumference, neck circumference, chest circumference, body length, tail length, hind foot length, ear length), and had hair samples taken from between the shoulder and tips of tails for potential genetic analysis. After the operations all captured animals were injected with reversal drug (naltrexone [Vivitrol]; Alkermes, Inc., Waltham, MA), released and monitored before the team left the area. All operations conducted successfully with no mortality recorded at the release time.

The data obtained from the GPS collars were loaded onto ArcGIS 9.3 and projected into UTM WGS 1984 for spatial analysis. Digitized maps of the study site used in the analysis maps were obtained from the FAO, UN/OCHA South Sudan Program. Data were analyzed to determine movement patterns and migration routes across the



habitats throughout the study area (cf. Buho *et al.* 2011, Bolstad 2005, Boone *et al.* 2006, Dodd *et al.* 2007, Igota *et al.* 2004, Ito *et al.* 2005&2006, Museiga and Kazadi 2004, Person *et al.* 2007).

## **Results**

### **Kob annual movement patterns**

Analysis of the GPS data showed that the white-eared kob is a long distance migratory antelope. Their migration covers large areas across grassland ecosystem that expands between Boma and Badingilu National Parks in the Jonglei and Eastern Equatoria States (Fig. 3.3). Habitats across the kob migration ranges are situated in altitudes of around 2,000-6,000 feet above sea level.

Kob migration occurs between two distinct seasons; that is, a short dry season (December-March) and a long wet season (April-November) with dry spell period occurring occasionally, every year. Kob spend the wet season in the western end of their migration ranges; that is, in and around the northern areas of Badingilu National Park, while at the onset of the dry season in December they start moving northeast. They enter Boma National Park in January and continue north to the Guom swamps and beyond into the Gambella swamps in Ethiopia by January (Fig 3.4). This movement stretches about 300 km one way and the total migration covers about 900 km between the two ranges. The total area covered by the migration is about 46,500 km<sup>2</sup>.

The migration cycle of kob between the dry and wet season ranges is about 6 months. They take about 30 days to reach the dry season ranges where they spend December to March, and then at the early rainfall in April they start moving southwest to

the wet season ranges where they reside from June to October. They then start the journey again in November and the cycle repeats.

### **Tiang annual movement patterns**

Tiang, like kob, also take part in long distance migration throughout the year between the plains of Jonglei up north and Badingilu National Park southwards in the Central and Eastern Equatoria States (Fig 3.5). They spend the long wet season (May-October) in Badingilu and its surrounding areas. In November, late in the rainy season, and at the onset of the dry season (December – March) they start movements northwards across the Jonglei Plains and head to the edges of the Sudd wetlands at the River Nile where there is plenty of green vegetation and water. Tiang movements cover distances of about 350 km one way and the total area covered by the entire yearly migrations reach up to above 33,000 km<sup>2</sup>. The length of distances covered by tiang depends on the patterns of the rains.

### **Migration routes**

Kob appear to use at least six routes to get in and out of Boma National Park during the course of their migrations between the two seasonal ranges. These routes are scattered within an area of 155km wide along the western boundary of the Boma National Park (Fig 3.4). These routes are associated with availability of water bodies and seasonal rivers draining the migration ecosystem; these rivers are either feeding into or draining out of the Kengen River which forms the western boundary of the Boma National Park.

Tiang, on the other hand, do not enter a specific protected area in their dry season ranges up north. They to follow long routes east of Juba-Bor-Malakal road and their

movement corridors extends between 30-170 km east of this main road and east of the partially dug Jonglei Canal because of the human settlements along the road.

### **Seasonal overlaps between kob and tiang migration**

The ranges of migratory kob and tiang populations overlap during the long wet season approximately from May to November every year. The overlap area lies at about 40 km west of Boma National Park and extends into the northern and eastern areas of the Badingilu National Park (Fig 3.6 and 3.7). This overlap area covers about 7,921 km<sup>2</sup> which represents 17% of the overall kob migration area and about 28% of the kobs' wet season home range. It also represents 24% and 28% of tiangs total migration area and wet season range, respectively. This area is of a prime conservation importance for these two species and their migration phenomena.

## **Discussion**

### **Seasonal movements**

Migratory ungulates have regular seasonal and round trip movements to and from spatially disjoint seasonal ranges (Olson *et al.* 2010). Kob and tiang migrations involve long distance movements between two distinct ranges with core areas: 1) the wet season range around Badingilu National Park, and 2) the dry season range, which for kob is northeast in the Boma National Park where they spend 3-4 months, and for tiang is up north in the plains of Jonglei where there is no protected area. They spend the rest of the time on the move crossing intermediate areas between the two ranges.

Results of this study confirmed that kob migrations make regular long distance movements between the two ranges every year that appeared to be timed or influenced by the rainy season. This is in agreement with Fryxell (1987c) and Fryxell and Sinclair

(1988) who found out that seasonal migration by kob are linked to shifting distribution of critical resources. They explained that during the dry season kob were mostly concentrated along major watercourses in the north, particularly along the Oboth River system. Kob migrate into the northern areas of the Boma National Park during the dry season because water courses there provided access to both green grass and water when these resources were scarce elsewhere in the ecosystem (Fryxell and Sinclair 1988); therefore water availability constrains kob's habitat use during the dry season (Fryxell 1987c). Tiang also move towards the Sudd swamps in search for water and green forage. Similar findings on wildebeest and zebra migrations in Serengeti-Mara ecosystem have been reported by (Bolger 2008, Imbahale *et al.* 2008, Boone *et al.* 2006, Kahurananga and Silkiluwasha 1997, and by Williamson *et al.* 1988 for wildebeest migrations in the Kalahari.

The kob migration patterns we found differed somewhat from those described by Fryxell (1985). We found western-eastern movements between mainly Badingilu National Park in the southwest and Boma National Park in the northeast of the migration ecosystem, while the earlier description was a circular movement around Boma National Park with occasional kob observations further west of the Boma National Park's boundaries. Fryxell and Sinclair (1988) indicated that the distance between the southern savannah used during the wet season and the northern flood plains used during the dry season is 150 to 200 km apart, but we found that kob cover distances up to 300-400 km between the two ranges and that they also cross the international borders in to the Gambella swamps in western Ethiopia. Bohu *et al.* (2011) found similar results on the migrations of the Tibetan antelopes in terms of the distance they cover (300 km) between

the core (winter) ground and the calving grounds, only that they spend a relatively short time at the destination (calving) grounds than the kob do in their dry season ranges. The shifts in the kob movements and distribution might have been due to: 1) changes in the ecosystem during the long period of 25 years separating the two studies; 2) difference in the methods where the first study used observations and surveys while this study used GPS telemetry; and 3) effect of the disturbances of the 22 years of civil war that affected the region.

Kob use habitats covering savannah country and flood plains but are never far away from water (Muhlenberg and Roth 1984, Dorst and Dandelot 1970). The overall migration range is largely savannah grassland on black cotton soil, which is sticky during rainy season and quickly turns dry with cracking soils except for the Guom swamps in the northern end of the range during the dry season. Under such harsh conditions kob move to utilize water and green vegetation of the swampy habitats in the northern ranges till the onset of the rainy season. Fryxell and Sinclair (1988) indicated that during the wet season kob migrate southward to avoid surface flooding that occur during the rains, but they added that the extent of the southern ranges was not as clearly defined as the northern ranges. However, this study has revealed that the southern range of the kob migrations ends in Badingilu National Park at the eastern bank of the River Nile and that kob do not cross the Nile itself.

By end of April 80% of female kob are pregnant (Fryxell 1987b), which implies that kob mating season takes place while they are in the dry season ranges through the lekking system (Fryxell 1987a); calving takes place during the late wet season where food is abundant for lactating mothers and young calves (Fryxell 1987b). This means

that mating and reproduction could be among the driving forces for the kob migration phenomenon.

Bush fire has become a common practice by natives in the rural South Sudan and very much pronounced in the kob migration ranges. Such uncontrolled grass burning under the dry season conditions with strong winds across the migration ecosystem affect the overall kob movements, perhaps causing depletion of late season forage across the migration corridors. By the time the advance kob groups approach Boma National Park most of the area would have been burnt completely, depleting them of essential food supply and eliminating stopover locations on the long trip towards the final destination at Guom swamps.

Bolger et al. (2008) stated that there are three human activities that contribute to the decline of ungulate migrations, including overhunting, anthropogenic barriers and habitat loss. Looking at the kob migration ecosystem, such factors appear to also affect kob in one way or the other. At present there are no physical barriers such rail or major roads that hinder the migration routes or stopovers. However, there are potential problems from planned development projects such as roads, oil concessions and town expansion plans. Potential effects of development plans on the kob migrations should be investigated in advance and mitigations should be put forward.

Oil concessions (Fig 3.8) including the ungulate migrations routes were awarded long ago, and some actual seismic work was done in the area in the early 1980s. The recent political events that followed the split of South Sudan from Sudan have led to the idea that South Sudan would construct pipelines to transport its crude oil for export through ports facilities in the East African countries. It is important that planning of such

development projects should seriously take care of the conservation interests of the kob migration corridors since the migration ecosystem is thought to be entirely located on oil reserves concessions.

### **Migration routes**

The current migratory routes have minimal contact with roads and foot paths throughout the area, as there are no urbanization and major human settlements in the region. With the exception of seasonal cattle camps, kob migration routes tend to avoid human settlements in the study area.

Potential problems threatening kob and tiang migration corridors are oil concessions and other potential post conflict development projects in the area. However, out of the ten first priority road networks unveiled recently by the government of South Sudan, three of them (Juba-Bor-Malakal; Bor-Pibor-Pochalla-Akobo and Raad-Boma-Kapoeta) cross through the antelope migration corridors (Fig 3.9). The current oil concessions in the area were given out by the government in the mid-1970s and were renewed recently, covering large portion of the migration corridors (Fig 2.8). While oil is much needed for the economy of the emerging country, lessons should be drawn from previous studies; e.g., Person *et al.* (2007) cautioned land managers negative impacts of oil and gas development on the movements of Teshskpuk caribou in Alaska, and from studies which indicated that major development structures such as railroads and highways create hindrances to antelope migrations (Buho *et al.* 2011, Beck *et al.* 2006, Ito *et al.* 2005). Holdo *et al.* (2011) simulated effects of a proposed road through the Serengeti ecosystem and predicted that it would lead to reduction in the population size of wildebeest even without habitat fragmentation. It is therefore important that future

development projects in the area take into consideration the conservation interests of the migratory species and their routes. Conservationists and land managers should start looking at this matter as early as possible at all levels.

Where multiple migration routes exist, some are used by a larger proportion of the population than others (Sawyer *et al.* 2009), and in such cases management and conservation efforts should be focused initially on routes that are used by larger proportion of the migratory population to reduce risks of the potential impacts (Sawyer *et al.* 2009). This would be a good strategy to follow in the conservation of kob and tiang migratory routes, given the current economic situation of South Sudan as a new country with an undeveloped economy. It is important for conservationists and managers to identify areas like Kengen River, where kob tend to spend some time in the course of their movements, and include them in management plans as migration stopovers locations where animals accumulate energy reserves necessary for completion of their journey (Sawyer 2011).

### **Seasonal overlaps between the migratory species**

This study has revealed for the first time that the migratory kob and tiang meet and spend the rainy season in one area. This seasonal overlap area covers a small but probably an important portion of the migration wet season ranges (Fig 3.6 and 3.7). The overlap area lies in the northern areas of Badingilu National Park but largely in areas outside the park's boundary; thus, it is only partially protected. It is drained by the Veveno River and other tributaries which form reliable source of water for the numerous kob and tiang. The area should be rich with food plants as it lies within the Saharan flooded grassland and the East Sudanian savannah grassland eco-regions. Thus, there



should be enough grass species for the migratory species to feed on throughout the wet season. It is also apparently free from road networks and human footpaths, and also is free from human settlements; thus, migratory animals find some safe refuge from human disturbances throughout the long wet season where their movements are limited. Clearly there is a need for some detailed studies to be carried there to confirm the area's ecological significance.

An apparent source of potential danger is the fact the overlap areas are entirely covered by oil concessions, especially the Block 5 Central (Fig. 3.8). However, since these concessions were given out to French oil companies, no serious exploration has carried out to date, probably due to the long protracted civil war. But as the situation may not remain the same forever, and given the political changes that are taking place following the split of South Sudan from the former Sudan, it is of prime importance to urge that action be taken to conserve this area for the survival of the migratory species.

### **Conclusions and conservation implications**

White-eared kob and tiang take part in long distance migrations over large areas moving between two distinct dry and wet season ranges. These migrations currently form the second largest antelope migration on earth. The kobs' dry season range is also a destination for migrating herders and thousands of livestock. Despite the large population size of kob, their migration routes are being squeezed in a relatively smaller areas bounded by human settlements along its northern edges. Both kob and tiang tend to avoid human settlements and roads while migrating due to anthropogenic disturbances and hunting pressure. The areas of the seasonal overlap of the two migrations are important intermediate areas which should be protected. The two migrations also move

through areas that are only temporarily protected due to human inaccessibility; these areas need protection through creation of reserves.

Although the migration ecosystem has remained untapped by developers during the decades of civil wars, post-conflict economic development plans in the area particularly the extractive industries as well as increase in human settlements are set to pose threats to the migrations corridors if not well addressed. Therefore policy and management implications are large and a newly passed wildlife conservation policy document should be enacted by the Parliament and implemented as soon as possible.

### **Literature cited**

Beck, J. L., Peek, J. M. and Strand, E. (2006). Estimates of elk summer range nutritional carrying capacity constraints by probabilities of habitat selection. *J. Wildl. Management*, **70**(1): 283-294.

Beyer, H. L. (2004). Hawth's Analysis Tools for ArcGIS. Available at

<http://www.spatial ecology.com/htools>.

Bolger, D. T., William, D., Newmark, Morrison, T. A. and Doak, D. F. (2008). The need for integrative approaches to understand and conserve migratory ungulates.

*Ecology Letters*, **11**: 63-77.

Bolstad, P. (2005). *GIS Fundamentals: A First Text on Geographic Information Systems*. 2<sup>nd</sup> Ed. Eider Press, White Bear Lake, Minnesota.

Boone, R.B., Thirgood, S.I. and Hopcraft, J.G.C. (2006). Serengeti Wildebeest Migratory Patterns Modeled from rainfall and New Vegetation Growth. *Ecology*, **87**(8): 1987-1994.

- Bro-Jorgenson, J., Brown, M. E. and Petorelli, N. (2008). Using the satellite-derived normalized difference vegetation index (NDVI) to explain ranging patterns in a lek-breeding antelope: the importance of scale. *Oecologia*, **158**: 177-182.
- Buho, H., Jiang, Z., Liu, C., Yoshida, T., Halik Mahamut, D., Kaneko, M., Asakawa, M., Motokawa, M., Kaji, K., Wuc, X., Otaishi, N. Ganzorig, S. and Masuda, R. (2011). Preliminary study on the migration patterns of the Tibetan antelope (*Panthlops hodgsonii*) based on satellite tracking. *Advances in Space Research*, **48**: 43-48.
- Coughenour, M.B. (2008). Causes and consequences of herbivore movement in landscapes and ecosystems. In: K. A. Galvin *et al.* (eds.), *Fragmentation in Semi-Arid and Arid Landscapes: Consequences for Human and Natural Systems*, 45-91.
- Dodd, N.L., Gagnon, J.W., Boe, S. and Schweinsburg, R.E. (2007). Assessment of elk highway permeability by using global positioning system telemetry. *Journal of Wildlife Management*, **71**(4):1107-1117.
- Dorst, J. and Dandelot, P. (1970). *A field guide to the Larger Mammals of Africa*. London: Collins.
- Fay, M., Elkan, P., Marjan, M. and Grossman, F. (2007). Aerial Surveys of Wildlife, Livestock, and Human Activity in and around Existing and Proposed Protected Areas of Southern Sudan, Dry Season 2007. Phase I. Juba, Southern Sudan, Sudan.
- Fryxell, J. M. (1985). *Resource limitation and population ecology of the White-eared kob*. A PhD Thesis. University of British Columbia, Canada.

- Fryxell, JM. (1987a). Lek breeding and territorial aggression in White-eared kob.  
*Ethology*, **75**(3): 211-220.
- Fryxell, J. M. (1987b). Seasonal reproduction of White-eared kob in Boma National Park, Sudan. *Afr. J. Ecol.* **25**(2): 117-124
- Fryxell, J. M. (1987c). Food limitation and the demography of a migratory antelope, the White-eared kob. *Oecologia*, **72**: 83-91.
- Fryxell, J.M. and A. Sinclair. (1988). Seasonal migration by White-eared kob in relation to resources. *Afr. J. Ecol.* **26**(1): 17-31.
- Fuller, M.R., Millspaugh, J.J., Church, K.E. and Kenward, R.E. (2005). Wildlife radio telemetry. In Braun, C.E. Edition: Techniques for Wildlife Investigations and Management. 6<sup>th</sup> Ed. *The Wildlife Society*, 377-417.
- Gates, C.C., Stelfox, B., Muhly, T., Chowns, T. and Hudson, R.J. (2009). The ecology of bison movements and distribution beyond Yellowstone National Park. A critical review with implications for winter use and transboundary populations management. Faculty of Environmental Design, University of Calgary, Calgary, Alberta
- Harris, G., Thirgood, S., Hopcrafts, J.G.C., Cromsig, J.P.G.M. and Berger, J. (2009). Global decline in aggregated migrations of large terrestrial mammals. *Endang. Species Res.*, **7**: 55–76
- Hebblewhite, M., Merrill, E.H., Morgantini, L.E., White, C.A., Allen, J.R., Bruns, E., Thurston, L. and Hurd, T.E. (2006). Is the migratory behavior of Montane elk herds in Peril? The case of Alberta's Ya Ha Tinda elk herd. *Wildlife Society Bulletin***34**(5):1280-1294

- Holdo, R. M., Fryxell, J. M., Sinclair, R. E., Dobson, A. and Holt, R. D. (2011). Predicted impacts of barriers to migration on the Serengeti wildebeest population. *PLoS ONE*, **6**(1): e16370. Doi: 10.1371/journal.pone.0016370.
- Igota, H., Sakuragi, M., Un, H., Kaki, K., Kaneko, M., Akamatsu, R. and Maekawa, K. (2004). Seasonal migration patterns of female sika deer in eastern Hokkaido, Japan. *Biological Research*, (**19**): 169-178.
- Imbahale, S. S., Githaiga, J. M., Chira, R. M. and Said, M. Y. (2008). Resource utilization by large migratory herbivores of the Athi-Kapiti ecosystem. *Afr. J. Ecol.*, **46**(1): 43-51.
- Ito, Y.T., Miura, I.N., Lhagvasuren, B., Enkhbileg, D., Takatsuki, S., Tsunekawa, A. and Jiang, Z. (2006). Satellite tracking of Mongolian gazelles (*Procapra gutturosa*) and habitat shifts in their seasonal ranges. *J. of zool.*, **269**(3): 291-298.
- Ito, Y.T., Miura, N., Lhagvasuren, B., Enkhbileg, D., Takatsuki, A. and Jiang, Z. (2005). Preliminary Evidence of a Barrier Effect of a Railroad on the Migration of Mongolian Gazelles. *Cons. Biol.* **19**(3): 945-948.  
[http://www.jennessent.com/arcview/weighted\\_mean.htm](http://www.jennessent.com/arcview/weighted_mean.htm).
- Kahurananga, J. and Silkiluwasha, F. (1997). The migration of zebra and wildebeest between Trangire National Park and Simanjiro plains, Northern Tanzania, in 1972 and recent trends. *Afr. J. Ecol.*, **35**: 179-185.
- Lian, X., Zhang, T., Cao, Y., Su, J. and Thirgood, S. (2001). Road proximity and traffic flow perceived as potential predation risks: evidence from the Tibetan Antelope in the Kekexeli National Nature Reserve, China. *Wildlife Research*, **38**: 141-146.

- Olson, K. A., Fuller, T. K., Mueller, T., Murray, M. G., Nicolson, C., Odonkhuu, D., Bolortsetseg, S. and Schaller, G. B. (2010). Annual movements of Mongolian gazelles: Nomads in the Eastern Seteppe. *Journal of Arid Environments*, 74: 1435-1442.
- Mefit-Babtie, S. (1983). *Development studies in the Jonglei canal area: Final report*. Vol.5. Wildlife Studies, Mefit-Babtie SRL, Glasgow, Rome and Khartoum, and Executive Organ of the National Council for Development of the Jonglei Canal Area, Khartoum, Sudan, Ministry of Finance and Economic Planning, Government of the Democratic Republic of the Sudan.
- Muhlenberg, M. and Roth, H.H. (1984). Comparative investigations into the ecology of the kob antelope *Kobus kob kob* (Erxleben 1777) in the Cômoe National Park, Ivory Coast. *S. Afr. J. Wildl. Res.*, 1985, **15**(1): 25-31.
- Musiega, D.E., Kazadi, S-N. (2004). Simulating the East African wildebeest migration patterns using the GIS and remote sensing. *Afr. J. Ecol.*, **42**: 355-362.
- Pepin, D., Morellet, N. and Goulard, M. (2009). Seasonal and daily walking activity patterns of free-ranging adult red deer (*Cervus elaphus*) at the individual level. *Eur. J. Wildl. Res*, 55: 479-486.
- Person, B. T., Prichard, A., Carrol, M. G., Yokel, D. A., Suydam, R. S. and George, J.C. (2007). Distribution and movements of the Teshekpuk Caribuo herd 1990-2005: Prior to oil and gas development. *Arctic*, **60**(3): 238-250.
- Sawyer, H., Kauffman, M. J., Nielson, R. and Horne, J. S. (2009). Identifying and prioritizing ungulate migration routes for landscape-level conservation. *Ecological Applications*, **19**(8): 2016-2025.

- Thirgood, S., Mosser, A., Tham, S., Hopcraft, G., Mwangomo, E., Mlengeya, T., Kilewo, M., Fryxell, J., Sinclair, A.R.E. and Borner, M. (2004). Can parks protect migratory ungulates? The case of the Serengeti wildebeest. *Animal Conservation*, **7**: 113 – 120.
- Wilcove DS, Wikelski M. (2008). Going, going, gone: Is animal migration disappearing? *PLoS Biol*, **6**(7): e188. doi:10.1371/journal.pbio.0060188
- Williamson, D., Williamson, J. and Ngwamotsoko, K. J. (1988). Wildebeest migration in the Kalahari. *Afr. J. Ecol.*, **26**: 269-280.

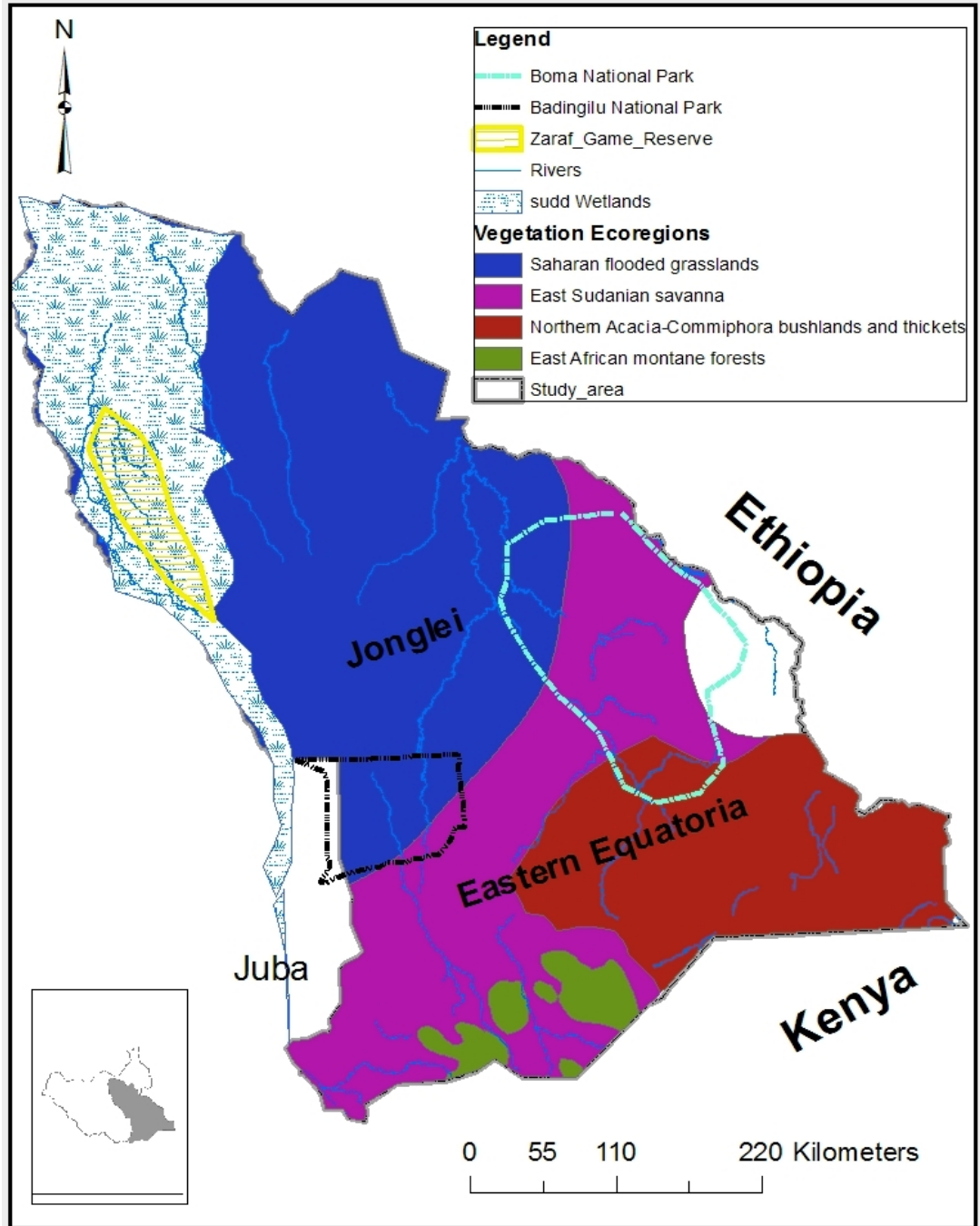


Figure 3.1. Study area showing distribution of major vegetation communities, protected areas and the antelope migrations ranges.



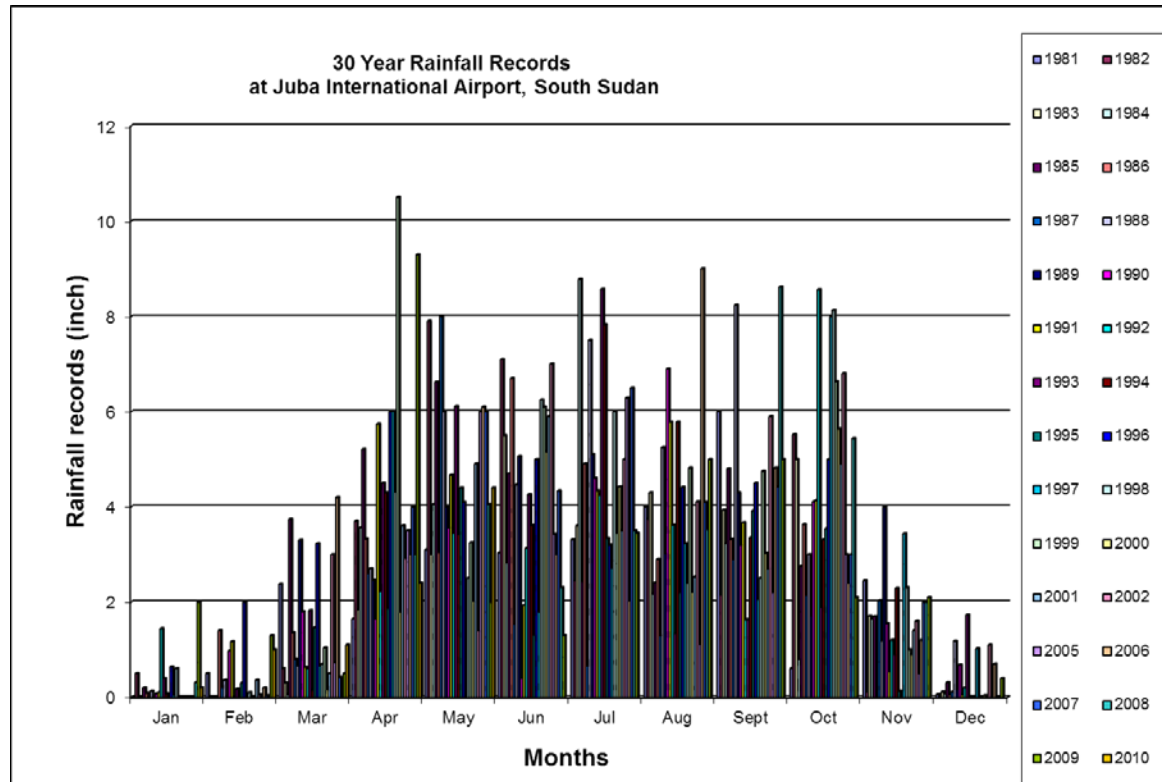


Figure 3.2. 30-year rainfall records at Juba International Airport, 40 Km south of Badingilu National Park

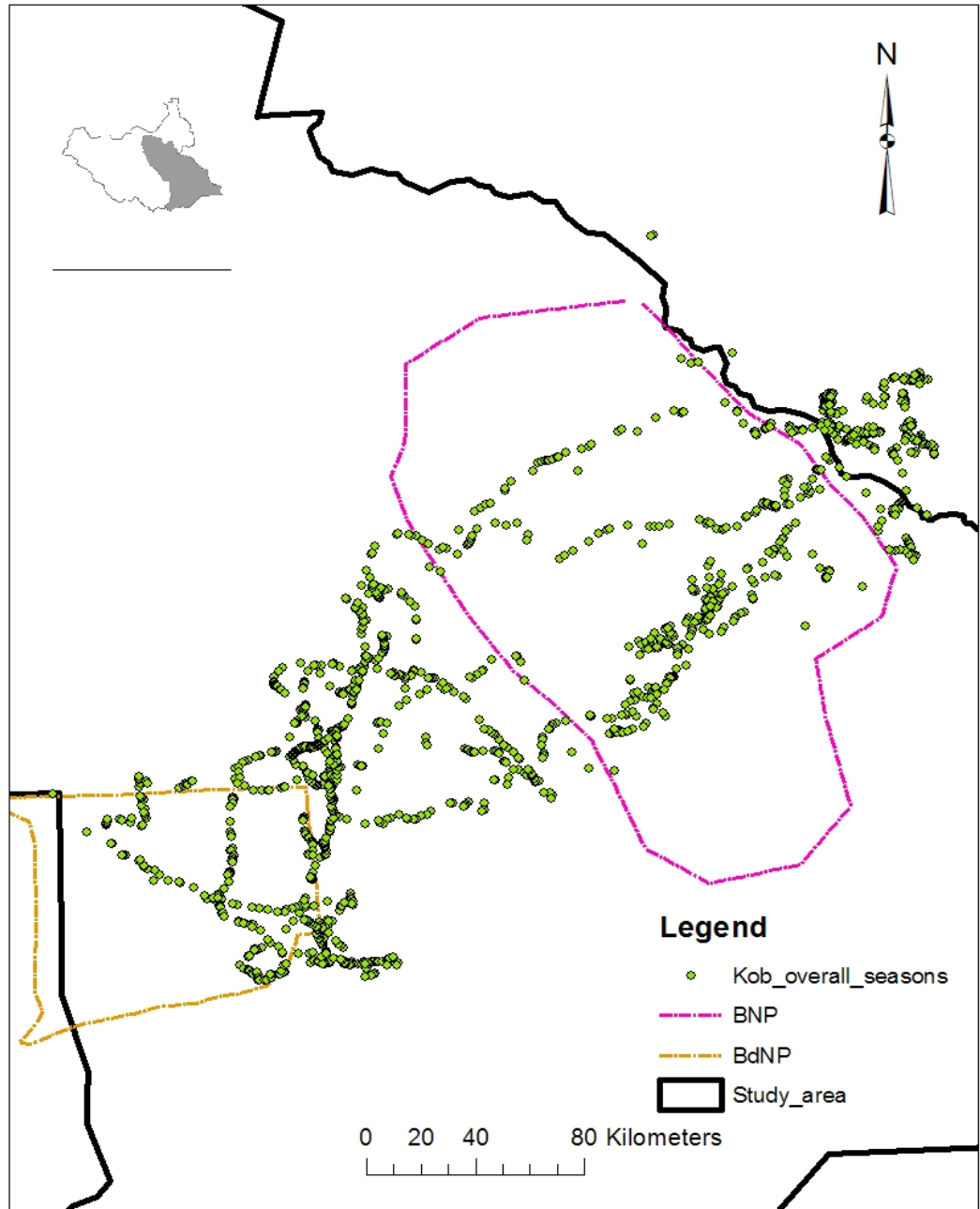


Figure 3.3. Kob movements across Jongle-Eastern Equatoria ecosystem.

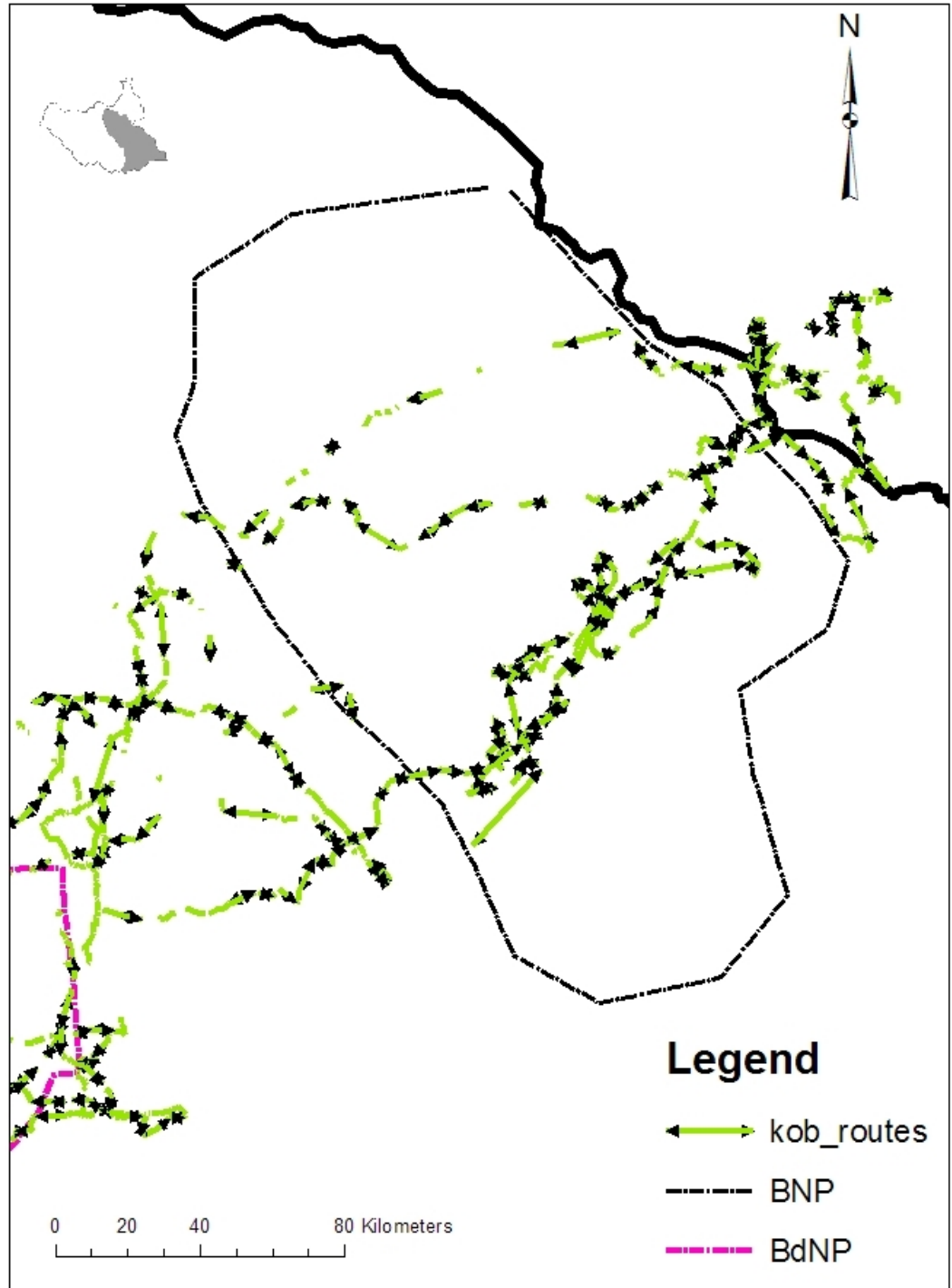


Figure 3.4. Kob migration routes.

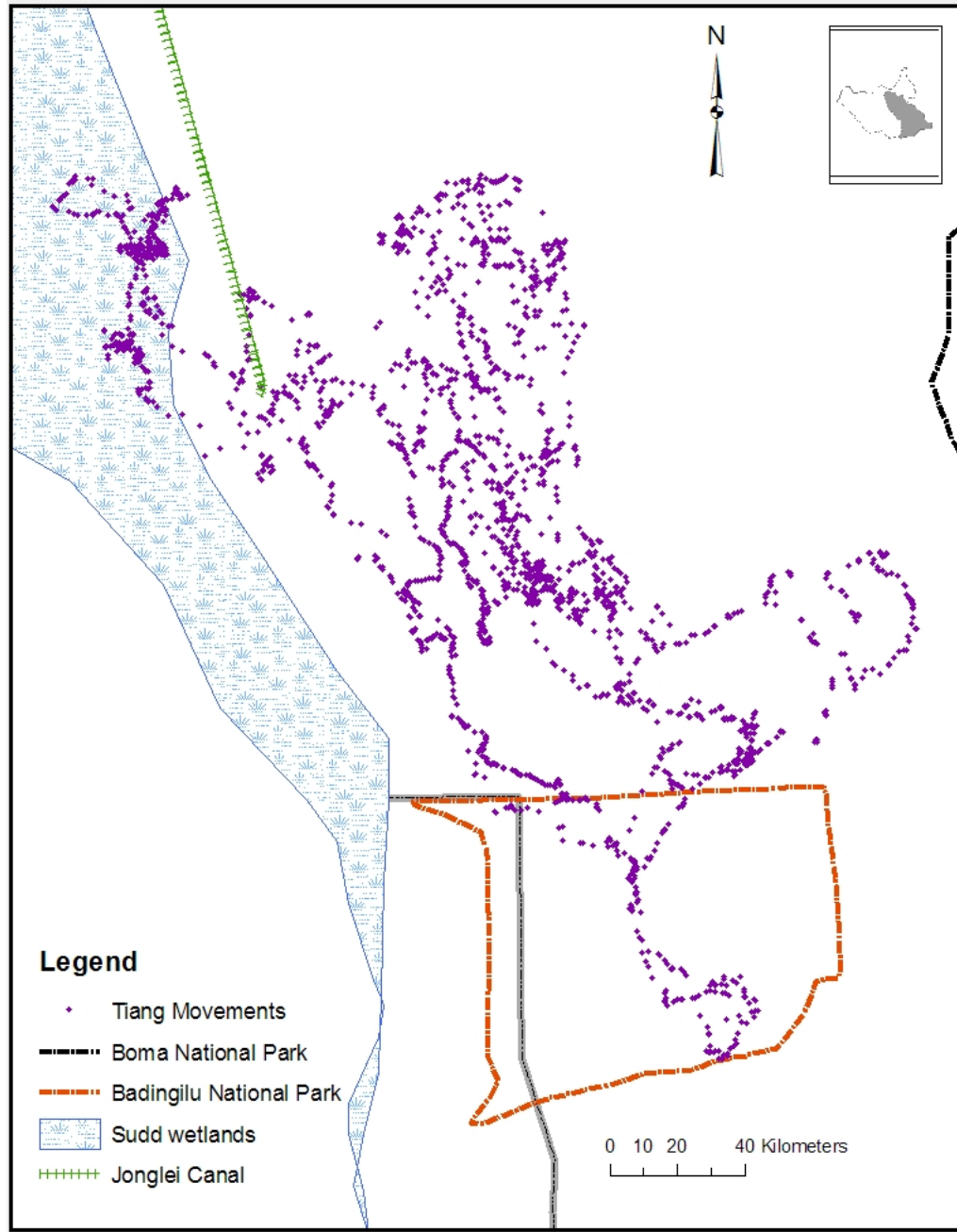


Figure 3.5. Movements of tiang across Jongle-Eastern Equatoria ecosystem.

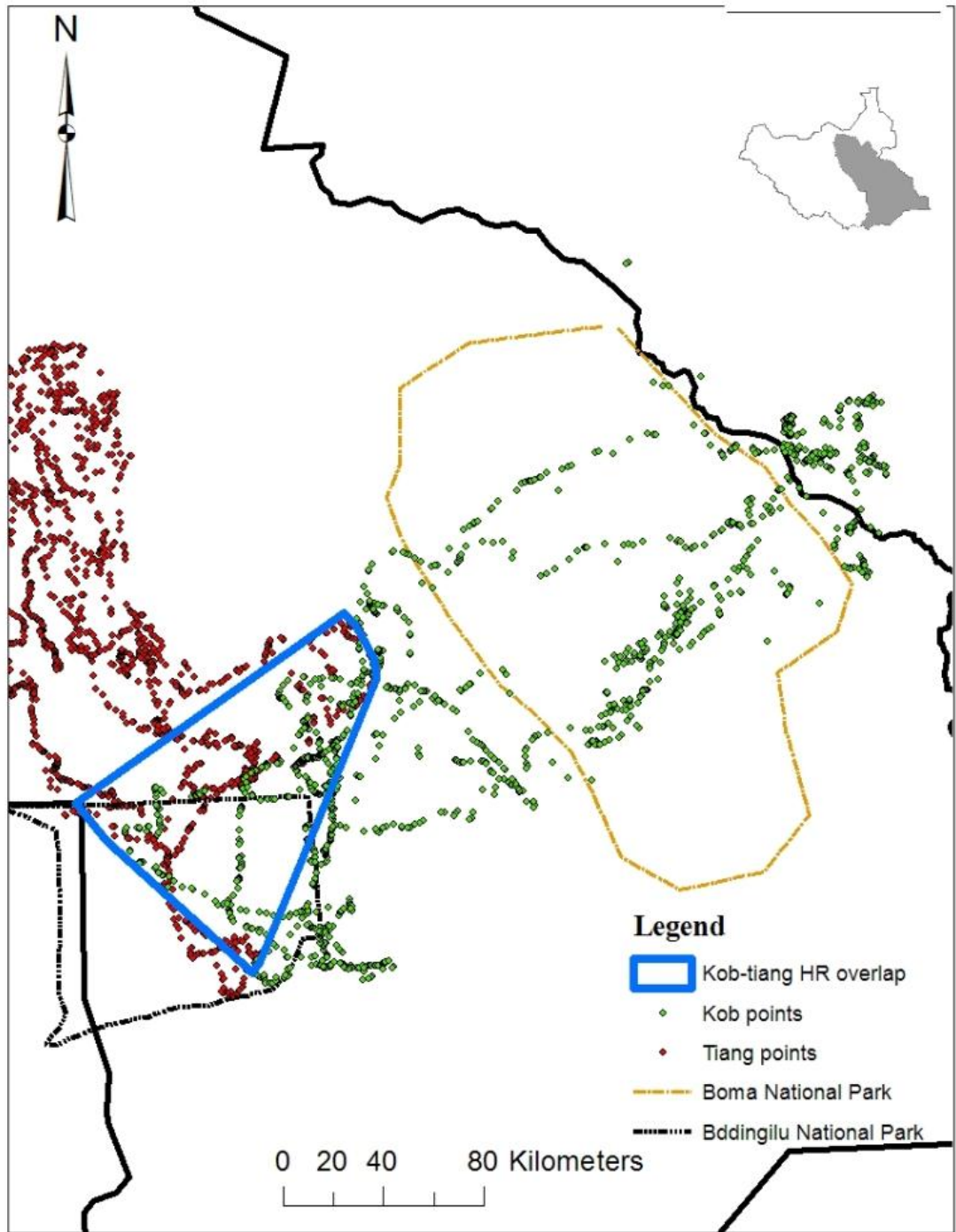


Figure 3.6. Kob-Tiang wet season overlap range.

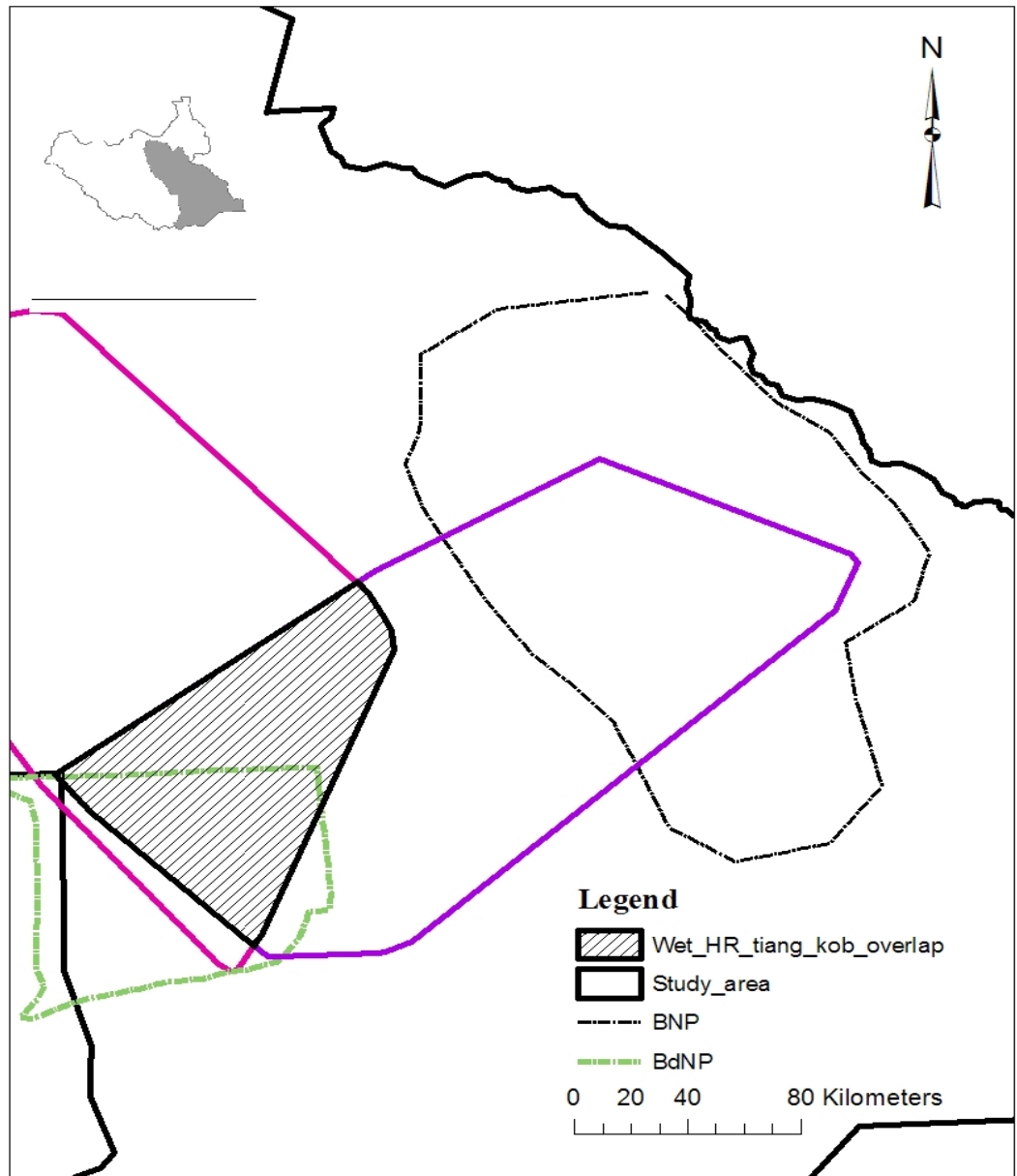


Figure 3.7. Areas where kob overlaps with tiang during the wet season every year.

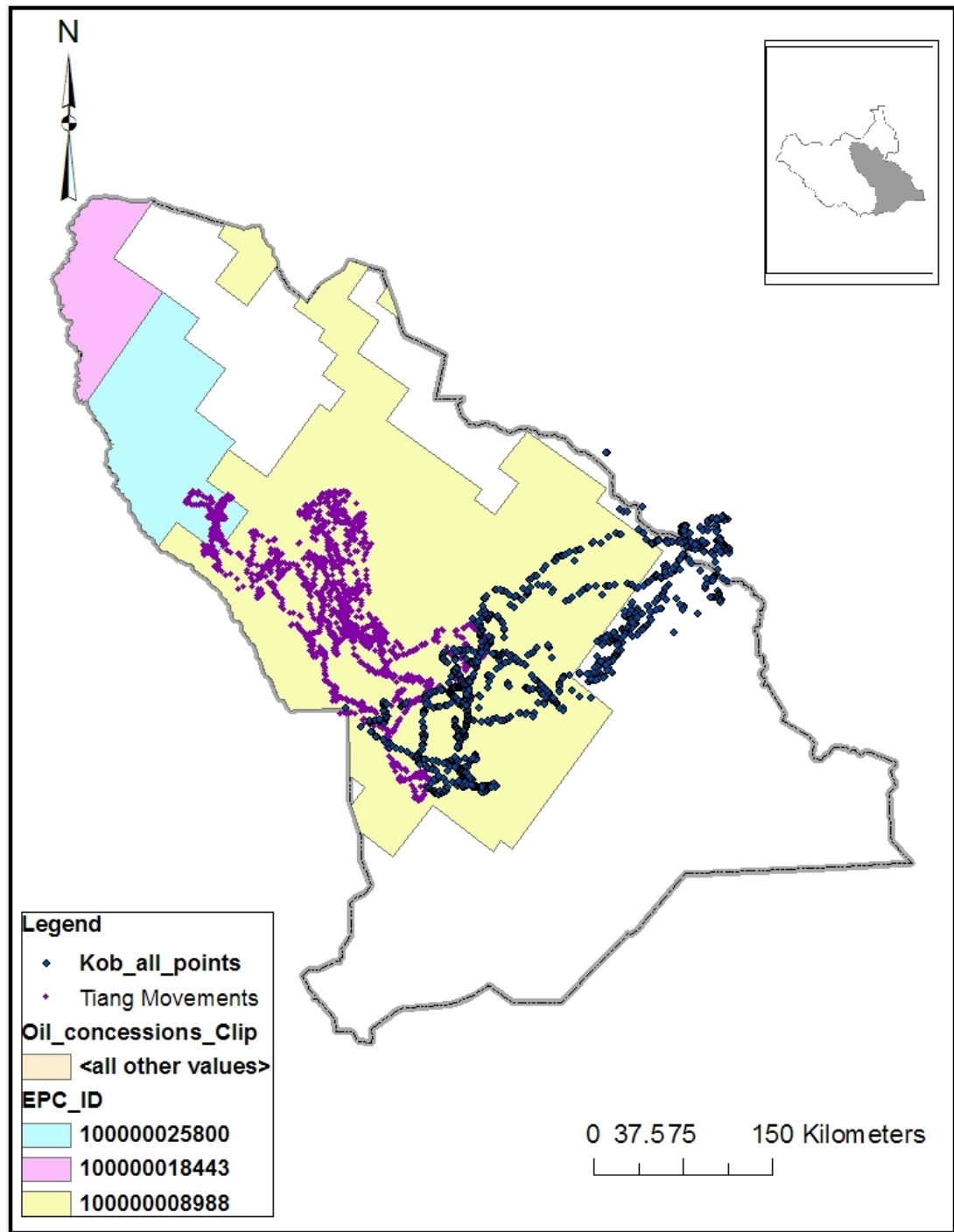


Figure 3.8. Oil Concession areas with the study covering migration routes and ranges of White-eared kob.

**CHAPTER 4**  
**SEASONAL DISTRIBUTION AND RANGES OF**  
**MIGRATORY WHITE-EARED KOB (KOBUS KOB**  
**LEUCOTIS)**

**Abstract**

Kob distribution patterns and seasonal home ranges are described through analyzing location data collected by the GPS collars fitted on kob. Seasonal distribution, as well as distribution patterns, and core areas across the ecosystem are identified and described; in addition, locations of spatial seasonal overlaps of kob with the migratory tiang and other species were described and quantified. Kob overall range covers an area of 46,41km<sup>2</sup>; the wet season range is 28,225 km<sup>2</sup>, while the dry season range was 27,531 km<sup>2</sup>. The daily and monthly distance moved by kob was also determined. Characteristics of the large landscape where kob migrations occur are assessed and recommendations for conservation and management are suggested forward.

**Introduction**

A home range is defined as a particular area that an animal confines itself to over a period of time (Horne *et al.* 2006). The size, shape, structure and location of a home range is affected by predator-prey relationships, competition, locations of important resources, social pressures and mating systems (Horne *et al.* 2006). Information on seasonal variation in various aspects of species' home range is important for understanding its biology and for establishing conservation strategies (Xu *et al.* 2009), and effective management policies should be supported by understanding of movement



patterns (Thomas *et al.*2008). Estimating home range size also can provide vital insight into important ecological processes (Horne & Garton 2006) affecting the species.

Migratory white-eared kob respond to the seasonal shifts in resources with seasonal movements and varying distribution patterns (Fryxell 1985). Besides shifts in resources, other factors such as social structure (e.g., lekking and aggressive behaviors), as well as reproductive success, also affect kob distribution patterns, especially in the core areas. Thus, migratory kob tend to have seasonal home ranges across the migration ecosystem. Although there are formal Protected Areas at the extreme ends of the kob migration range (Chapter 3), knowledge of kobseasonal home ranges and daily movement patterns is still limited.

Home range estimation and understanding is important for our understanding of factors that cause animal movements, behavior, and space use (Horne *et al.* 2006). There is no way to precisely estimate home range size, but ecologists usually estimate it from a sample of locations where an animal has occurred (Horne *et al.*2006). The goal of this study is to describe and quantify core seasonal range areas using location data collected from kob collared with GPS telemetry over two season cycles. This approach is used specifically to: 1) describe kob seasonal distribution across the migration ecosystem; 2) describe and quantify distribution patterns and core areas; 3) identify locations of spatial and seasonal overlaps. This study treats kob migration as occurring by one entire population unit, thus concentrating on space use and core areas during the shifting seasonal environment. This study will contribute knowledge to improving existing Protected Areas and the creation of new ones within same ecosystem for the conservation and management of the kob migration. However, usage of specific areas by individual

kob within the seasonal range needs long-term study. The specific objectives of this study were: 1) to confirm the spatial locations of the wet season home ranges of kob migrations; 2) to estimate the seasonal range sizes of the migratory kob; 3) to estimate the daily and monthly movement rates of the migratory kob, and 4) to assess the protection status of kob movements between their seasonal ranges.

### **Study area**

Kob migrations occur in southeast Sudan in savannah grassland area that expands between Jonglei and Eastern/Central Equatoria States (Fig. 3.1 in Chapter 3). They spend the wet season partially in Badingilu National Park in the southwest of the range and the dry season in the Boma National Park in the northeast of the migration range. Some smaller groups make occasional northward movements to the Sudd swamps.

The kob migrations cover an area of >100,000 km<sup>2</sup> extending from the Boma escarpment in the east to the River Nile at western end of Badingilu National Park. Boma National Park was established in 1978; Badingilu National Park was established in 1982 out of amalgamation of two small reserves together with the areas in between them. The mean annual rainfall in the area ranges from 400-1,400 mm as indicated by the nearest meteorological station at Juba International Airport. The mean monthly temperature is 36C<sup>o</sup> during the dry season (Dec – Mar) and 28C<sup>o</sup> during the wet season (Apr – Nov); relative humidity is highest during the wetseason.

Topography of the area is mostly flat with scattered isolated hills in in addition to the Boma escarpment. Most of the plains are dominated by “black cotton” clay soil. On the slopes and the foot of the hills the soils are laterite and sandy (Willimott 1956). The ecosystem is a bed for major swamps like the Guom swamps in the northern end of Boma

National Park. It is also drained with a number of rivers such as the Kangen/KongKong River system, Oboth/Neubari Rivers and the Kuron River up north in Boma National Park; while rivers veveno and lotila drain south through Badingilu National Park. The entire region is in a watershed that ultimately empties into the Nile River via the Sobat River (Fryxell 1985).

Vegetation of the migrations ecosystem comprises the East Sudanian savannah grassland, Saharan flooded grassland and the Northern Acacia-Commiphora bushland and thickets, while the Victorian basin forest-savannah is found on the Boma escarpment in the east. The eastern part of the ecosystem in Boma National Park is covered with woodland dominated by *Combretum* species, while the middle-western flat flood plains are covered with open grassland dominated by *Hyperhenia rufa*, *Sporobolus* spp., and *Pennisetum* spp., and *Echinoloa* spp. In between these two zones lies an intermediate zone of wooded grassland. The grasslands around the Guom swamps in the north include areas of *Hydrophila spinora*. Around the isolated hills occurs dense thicket dominated by *Ziziphus spina christi*, *Acacia seyal*, *A. drepanolobium*, *A. fistula*, and *A. zanzibarica* (Willimott 1956).

## **Materials and Methods**

### **Animal capture**

In August 2009, we captured 2 adult female white-eared kob and 2 adult female tiang using a dart gun (with suitable doses of M-99 drug [American Cyanamid, West Patterson, NJ]) from a helicopter fitted them with GPS collars [North Star S & T, LLC, 12265 Harford Road, Glen Arm, Maryland 21057] following the procedures described by Fuller *et al.* (2005) and Ito *et al.* (2005). The GPS units were monitored for a period of

20 months. The collar units obtained locations varied from 1-5 times/day and were transmitted only via a satellite receiver station and Argos uplinks.

Captured animals were sexed, aged (estimation based on tooth eruption and wear), measured (head length circumference, neck circumference, chest circumference, body length, tail length, hind foot length, ear length), and had hair samples taken from between the shoulder and tips of tails for potential genetic analysis. After the operations all captured animals were injected with reversal drug (naltrexone [Vivitrol]; Alkermes, Inc., Waltham, MA ), released and monitored before the team left the area. All operations conducted successfully with no mortality recorded at the release time.

### **Animal movements**

The data obtained from the GPS collars were loaded onto ArcGIS 9.3 projected into UTM WGS 1984 for spatial analysis. Other data used in the analysis were obtained from digitized maps of the FAO, UN/OCHA South Sudan Program, and analyzed to estimate movement patterns, range size, migration routes and distances moved across the habitats throughout the study area (Buho *et al.* 2011, Bolstad 2005, Boone *et al.* 2006, Dodd *et al.* 2007, Igota *et al.* 2004, Ito *et al.* 2005 & 2006, Museiga and Kazadi 2004 and Person *et al.* 2007).

### **Seasonal Ranges**

Home ranges are estimated based on 100% MCP and 95% fixed kernel estimation using animal movement software (Thomas *et al.* 2008, Xu *et al.* 2009, Sager-Fradkin *et al.* 2008). In this study, Hawth's Analysis Tools (Beyer 2004), an extension to ARC GIS 9.3, was used to estimate the seasonal home ranges of kob across the yearly wet and dry seasons and saved as new layers on the Arc GIS project. The MCP was estimated from

2,481 GPS locations collected over an 18-month period. The habitats were divided into wet and dry season ranges based on the amount of rainfall received. Accordingly the period from December to March is classified as the dry season, while May to October is wet season. April is early wet season and November is late wet season. Using the Hawth's Analysis tools and the Spatial Analyst tools the seasonal home range areas were calculated for each season. Then from the seasonal home range values the seasonal overlap percentages between home ranges were calculated.

### **Daily and monthly distances moved during migrations cycle**

The daily and monthly distance movement rates calculated using the Weighted Mean of Points v. 1.2c Extension of Arc View 3.2 (Jenness 2004). This extension creates a new shape file of the weighted mean center point, and/or a graphic symbol representing the weighted mean or simply the values can be saved in tabular form. The weighted mean values then summarized per day and months using r script. The mean daily distances and the total monthly distances moved were then tested for differences between the dry and wet seasons' movements, by the use of t-tests. All statistical tests were performed by the software SPSS PASW v18.

### **Time spent along migration corridors**

To quantify the time spent in different protected areas and other migration corridors, the daily fixes were grouped by each area traversed by the collared migratory kob. The areas were grouped into protected and unprotected according to their legal statuses. These areas were 1) the Boma National Park lies up east of the study area, represents the dry season range for the migration; 2) the Badingilu National Park in the southwest of the study site, represents the wet season range; 3) the corridor linking Boma

and Badingilu parks; and 4) the Duma wetlands in Gambella, Ethiopia, east of Boma National Park. The proportion of each day spent in each area was calculated and averaged to percentages according to methods described by Thirgood *et al.* (2004).

## **Results**

### **Kob ranging patterns in relation to Protected Areas**

Collared kob spent most of the wet season (May, June, July, and October) in and around Badingilu National Park, while the months of August and September were spent in the corridor between Badingilu and Boma National Parks. They spent the peak of the dry season (January - April) in Boma National Park, while during May and December the reverse movements between the wet and dry season range areas occur.

Whilst in Boma National Park the kob occasionally cross the international borders from South Sudan into the Duma wetlands in the Gambella region west of Ethiopia. Their movements inside Ethiopia were recorded in distances ranged from 1- 45 km from the border inside the Gambella Region, Ethiopia. Kob seasonal distributions throughout the year are shown in Figure 4.3.

### **Daily and monthly distances moved by the migratory kob**

The overall distance moved by the kob during the tracking period was 3,112 km. The mean daily distances covered averaged  $6.73 \pm 1.43$  km during the dry season and  $6.88 \pm 1.43$  km during the rainy season (Fig. 4.1). The longest daily distance moved was 7.06 km in August while the shortest distance moved was 0.23 km in November.

The mean monthly distances covered by kob movement estimated to be  $163.78 \pm 90.53$  km, and the cumulative monthly distances moved varied from shortest 1.75 km to longest 314.3 km (Fig 4.2). There was no significant difference shown in the daily

movements between the dry and wet seasons  $p > 0.05$  ( $df = 211$ ,  $t = -218$ ), but the monthly movements in the two seasons were significantly different ( $p < 0.05$ ,  $df = 7$ ,  $t = -3.519$ ).

### **Seasonal range sizes of the kob migrations**

The distance between the cores wet and dry season ranges is approximately 200km (Fig 4.2). The size of kob overall MCP seasonal ranges is summarized in Table 4.1 and Figure 4.3. The seasonal home ranges for individual kob are shown in Table 4.2.

The overall range area covered by kob migration is 46,416 km<sup>2</sup> and the annual movements cover 895 km round trip. Seasonal ranges vary, whereby the size of the wet season range is 28,225km<sup>2</sup>, which is slightly larger than the dry season range of 27,531 km<sup>2</sup>. The kob wet and dry seasons' ranges overlap over an area covering 12,933 km<sup>2</sup>; this overlap represents 28% of the overall kob migration range, and about 46% and 47% of the kob's wet and dry seasons ranges, respectively.

### **Time spent by kob in/outside protected areas**

The migratory kob spent 65% of the year time inside two National Parks (Table 4.3). That is approximately 124 days in Boma National Park during the dry season and about 113 days in Badingilu National Park during the wet season. They spent about 66 days (18%) of the year in the corridors connecting the Boma and Badingilu Parks during the course of their migrations when seasons shift between dry and rainy seasons. The rest of the time, about 61 days (16.7%) is spent in the Duma swamps in Gambella, the western region of Ethiopia, which they enter crossing the South Sudan-Ethiopia borders just east of Boma National Park.

## **Discussion**

### **Ranging patterns inside and outside of protected areas**

This is the first attempt to use GPS telemetry to study the wildlife migrations in South Sudan. This study followed two female kob collared 200 km apart, but it appeared that they followed same path, and even met and mingled together within a short time. Despite the small sample it has provided good insights on the migrations and seasonal ranges of the kob in South Sudan that are helpful for the conservation of this species.

Results of this study confirmed that the migratory kob annually move between dry season ranges in the north of Badingilu National Park and the wet season ranges at the Guom swamps in the up north of Boma National Park. They traverse the vast areas separating the two parks as an important corridor. Although the two parks were gazetted for the protection of the migrations and other biodiversity therein, the actual situation there can fairly be described as partial protection due to practical difficulties on the ground since the end of the liberation war for the independence of South Sudan. The two parks are still true wilderness as there are no land conversions activities taking place there, but there is a need for more conservation and protection actions to be undertaken there to secure their boundaries and integrity as protected areas before its too late.

On the other hand, the corridors between Badingilu and Boma National Parks, which kob and certainly other wildlife species use, remains as "no man's land" at present because of the instability in that region which render the area inaccessible. This area is not formally gazetted for conservation and protection of wildlife, but is safer for the animals now due to its inaccessibility, particularly in the rainy season. But the situation will not remain the same for long, especially when South Sudan attains final peace and



stability. Prospects of development and resource extraction will affect this corridor unless some conservation measures taken early enough to conserve the migration corridors therein.

### **Daily movement rates and distances traveled**

Kob migrate between wet and dry season due to shifts in resources (Fryxell 1985), making long distance movements between these two distinct ranges. The shift from wet to dry conditions across the migration ecosystem happens dramatically and quickly. In a short time the whole area dries and kob race up to the northeast to their dry season ranges to secure forage and water in the swampy areas therein. However, on the return journey southwest towards the wet season range they move at a pace dictated by the rains. As most females leave dry season range pregnant, perhaps the pregnancy conditions would affect their movement rates, as well.

Once in the dry season range, kob appear to settle down; they spread out in smaller groups and are observed feeding and resting most of the time in the swamps where water and vegetation are in abundance. Thus they make minimal movements and spend less energy. In fact, with the availability of food in the dry season range, the main activity that kob engage in is lekking behavior, whereby females visit harems protected by strong males for mating. This is similar to Pepin *et al.* (2009) who found that the daily movement pattern of deer is reduced after rut.

In the wet season where the black cotton soils turn sticky and vegetation growth shoots to over 2 m, kob daily movements would increase while individuals search for palatable forage and improved visibility as they care for newborn young. This might

affect their daily activities and hence their daily movement rates which are higher than in the dry season, thus increasing the size of their wet season range.

Kob migration is associated with water. During the dry season, 75% of kob populations were found within 10 km from water courses and only less than 5% of the populations roam farther than 20 km from water (Fryxell 1987c). In the dry season range, kob concentrated at high densities in open meadows that produced green re-growth throughout the dry season, when surrounding grassland were unproductive (Fryxell 1987c). Thus, the proximity to water reduces kob daily movement activities in search for water and consequently the distances they cover for that purpose.

### **Seasonal range size**

An important goal of home range estimation is to gain an insight into the underlying distribution of space use of a particular animal or group of animals (Horne and Garton 2006). The kob migration range sizes in this study have been defined by the Minimum Convex Polygons (MCPs) of the migration's seasonal movements between the seasonal ranges. Due to limited number of collared individuals, the MCPs have been calculated at the population level rather than individual animal level. The determinant factors considered here are the rainfall, forage, and water availability which drives the seasonal movements of kob populations. However, the optimal home ranges at individual animal levels which employ determinants at fine scales will have to be considered in future studies at fine scales. At the population level kob seasonal migration ranges cover large areas - of tens of thousands of square kilometers. This is obviously due to the nature of the long distance movements they make between their seasonal ranges. At the seasonal level the dry season range is smaller than the wet season due to minimal

activities of kob therein. While in the dry season kob engage in mating activities through a lekking system, and at the end of the season most females returning to the wet season range were observed pregnant (Fryxell 1987a). Since female kob give birth while in the wet season ranges, activities of lactating mothers with young lead to increase in their home range size. This is similar to conclusions of van Beest *et al.* (2011) that reproductive status is one of factors cause variations in home sizes of female moose. Also, the overlap of kob with other migratory species in the wet season range might lead to competition. Kob might tend to escape from mature tall grass, like the case of other species (Willems *et al.* 2009, Bro-Jorgenson 2008), in search of more palatable forage as well as improved visibility as anti-predator behavior/mechanism. Such activities would lead to local movements that eventually affect the size of the wet home season range.

The dry and wet season ranges overlap at intermediate areas, which are considerably large. This is because during the early and late rainy seasons kob make forward and backward movements between the two ranges as related to the early and late rainfalls. These overlap areas are very important for the migration because they hold water and forage to sustain the kob movements between the two ranges.

### **Conclusions and conservation implications**

Although in this study I followed only a small sample size of two female kob, I know that kob move in large groups of up to 500-3000 animals at a time. The two kob were collared at distance of 200km apart (Badingilu and Boma), yet they met at some stage. Therefore, results from this study can be extrapolated and used for management of the overall population.

I found that kob migrations traverse vast a landscape with two national parks at its extreme ends, forming the dry and wet season ranges, separated by a large area where there is no other formally protected area by law, but it is protected in the sense that it is inaccessible to humans most periods of the year.

This study revealed that availability of water and forage in the vast swamps in the dry season range affect kobs' daily activities and the distances they walk.

The sticky soil conditions and thick grass cover increase kob mobility in search of better home grounds and visibility, therefore, increasing their daily movements and distances covered, as well.

At the beginning of the dry season, kob tend to move long distances to beat the harsh conditions and reach the swamps in the dry season range, thus increasing their daily and monthly distances moved. In contrast, at the advent of the rainy season they walk at slower pace heading back to the wet season range, therefore having shorter daily movements and monthly distances, as well.

Based on the accounts above there is a need for conservation action to safeguard the seasonal ranges and migration corridors identified. Such actions include the enactment and implementation of the recently passed South Sudan Wildlife Conservation and Protected Areas Policy. This new policy document has provisions that if well implemented will help in improving wildlife and habitats conservation actions needed for the conservation of the kob migrations.

Effective anti-poaching patrols should be implemented in Boma and Badingilu National Parks to protect the seasonal ranges and areas in between them. Urgent actions

also needed for creation of new reserves for the protection of the overlap areas where the dry and wet season ranges intersect.

Future details studies to generate knowledge about the ecological processes that affecting the habitats within the seasonal ranges of the kob migration are very important for the management and conservation of the kob migration.

Peace and stability is vital factor for the conservation and management of wildlife to achieve its objectives. Previous and armed conflict for whatever goals in South Sudan in the recent three decades always concentrated in the region where kob migrations occur. It is therefore important that political differences be resolved as soon as possible so that conservation of White-eared kob and wildlife in general take effect in South Sudan.

### **Literature cited**

Beyer, H. L. (2004). Hawth's Analysis Tools for ArcGIS. Available at

<http://www.spatial ecology.com/htools>.

Bolstad, P. (2005). *GIS Fundamentals: A First Text on Geographic Information Systems*.

2<sup>nd</sup> Ed. Eider Press, White Bear Lake, Minnesota.

Boone, R.B., Thirgood, S.I. and Hopcraft, J.G.C. (2006). Serengeti Wildebeest Migratory

Patterns Modeled from rainfall and New Vegetation Growth. *Ecology*, **87**(8):

1987-1994.

Bro-Jorgenson, J., Brown, M. E. and Petorelli, N. (2008). Using the satellite-derived

normalized difference vegetation index (NDVI) to explain ranging patterns in a

lek-breeding antelope: the importance of scale. *Oecologia*, **158**: 177-182.

- Buho, H., Jiang, Z., Liu, C., Yoshida, T., Halik Mahamut, D., Kaneko, M., Asakawa, M., Motokawa, M., Kaji, K., Wuc, X., Otaishi, N. Ganzorig, S. and Masuda, R. (2011). Preliminary study on the migration patterns of the Tibetan antelope (*Panthlops hodgsonii*) based on satellite tracking. *Advances in Space Research*, 48: 43-48.
- Dodd, N.L., Gagnon, J.W., Boe, S. and Schweinsburg, R.E. (2007). Assessment of elk highway permeability by using global positioning system telemetry. *Journal of Wildlife Management*, **71**(4):1107-1117.
- Dorst, J. and Dandelot, P. (1970). *A field guide to the Larger Mammals of Africa*. London: Collins.
- Fryxell, J. M. (1985). *Resource limitation and population ecology of the White-eared kob*. A PhD Thesis. University of British Columbia, Canada.
- Fryxell, JM. (1987a). Lek breeding and territorial aggression in White-eared kob. *Ethology*, **75**(3): 211-220.
- Fryxell, J. M. (1987c). Food limitation and the demography of a migratory antelope, the White-eared kob. *Oecologia*, 72: 83-91.
- Fuller, M.R., Millspaugh, J.J., Church, K.E. and Kenward, R.E. (2005). Wildlife radio telemetry. In Braun, C.E. Edition: Techniques for Wildlife Investigations and Management. 6<sup>th</sup> Ed. *The Wildlife Society*, 377-417.
- Honre, J. S. and Garton, E. O. (2006). Selecting the best home range model: An Information-Theoretic Approach. *Ecology*, **87**(5): 1146-1142.

- Igota, H., Sakuragi, M., Un, H., Kaki, K., Kaneko, M., Akamatsu, R. and Maekawa, K. (2004). Seasonal migration patterns of female sika deer in eastern Hokkaido, Japan. *Biological Research*, **(19)**: 169-178.
- Ito, Y.T., Miura, I.N., Lhagvasuren, B., Enkhbileg, D., Takatsuki, S., Tsunekawa, A. and Jiang, Z. (2006). Satellite tracking of Mongolian gazelles (*Procapra gutturosa*) and habitat shifts in their seasonal ranges. *J. of Zool.*, **269**(3): 291-298.
- Ito, Y.T., Miura, N., Lhagvasuren, B., Enkhbileg, D., Takatsuki, A. and Jiang, Z. (2005). Preliminary Evidence of a Barrier Effect of a Railroad on the Migration of Mongolian Gazelles. *Cons. Biol.* **19**(3): 945-948.
- Jenness, J. (2004). Weighted mean of points (weightmean.avx) extension for ArcView 3.x, v. 1.2c. Jenness Enterprises. Available at:  
[http://www.jennessent.com/arcview/weighted\\_mean.htm](http://www.jennessent.com/arcview/weighted_mean.htm).
- Lian, X., Zhang, T., Cao, Y., Su, J. and Thirgood, S. (2001). Road proximity and traffic flow perceived as potential predation risks: evidence from the Tibetan Antelope in the Kekexeli National Nature Reserve, China. *Wildlife Research*, **38**: 141-146.
- Musiega, D.E., Kazadi, S-N. (2004). Simulating the East African wildebeest migration patterns using the GIS and remote sensing. *Afr. J. Ecol.*, **42**: 355-362.
- Pepin, D., Morellet, N. and Goulard, M. (2009). Seasonal and daily walking activity patterns of free-ranging adult red deer (*Cervus elaphus*) at the individual level. *Eur. J. Wildl. Res.*, **55**: 479-486.
- Sager-Fradkin, K. A., Jenkins, K. J., Happe, P. J., Beecham, J.J., Gerald Wright, R. and Hoffman, R. (2008). Space and habitat use by black bears in the Elwha Valley prior to dam removal. *Norhtwest Science*, **82**: 164-178.

- Sawyer, H., Nielson, R. M., Lindzey, F. G., Keith, L., Powell, J. H. and Abraham, A. A. (2007). Habitat selection in rocky mountain elk in a non-forested environment. *J. Wild. Management*, **71**(3): 868-874.
- Thirgood, S., Mosser, A., Tham, S., Hopcraft, G., Mwangomo, E., Mlengeya, T., Kilewo, M., Fryxell, J., Sinclair, A.R.E. and Borner, M. (2004). Can parks protect migratory ungulates? The case of the Serengeti wildebeest. *Animal Conservation*, **7**: 113 – 120.
- Thomas, B., Holland, J.D. and Minot, E.O. (2008). Elephant (*Loxodonta Africana*) home ranges in Sabi Sand Reserve and Kruger national Park: A five year satellite tracking study. *Plos ONE*, 3(12): e3902. Doi:10.1371/journal.pone.0003902.
- van Beest, F. M., Rivrud, I. M., Loe, L. E., Milner, J. M. and Mysterud, A. (2011). What determines variation in home range size across spatiotemporal scales in a large browsing herbivore? *J. of Animal Ecol.*, **80**: 771-785.
- Willems, E. P., Barton, R. A. and Hill, R. A. (2009). Remotely sensed productivity, regional home range selection, and local range use by an omnivorous primate. *Behav. Ecol.*, **20**: 985-992.
- Xu, J-L, Zhang, X-H, Sun, Q-H, Zheng, G-M., Wang, Y. and Zhang, Z-W. (2009). Home range, daily movements and site fidelity of male Reeves's pheasants *Syrnaticus reevesii* in the Dabie Mountains, Central China. *Wildl. Biol.* **15**: 338-334. DOI: 102981/08-032.



Table 4.1. Summary of kob seasonal range sizes (km<sup>2</sup>) in South Sudan.

Details	100% MCP
Kob overall seasons range	46,416
Kob Wet season range	28,224
Kob dry season range	27,530
Kob dry-wet seasons ranges overlap	12,933

Table 4.2. Annual range sizes (100% MCP, 95% Kernel and 50% Kernel) for individual radiocollared kob.

Animal ID	No..of Locations	100%MCP	95% Kernel	50% Kernel
Kob0-315657	2,458	29,648.545	16,968	4,355
Kob 0-315648	23	23,648.499	20,191	9,748

Table 4.3. Summary of kobs' time spent between protected versus none-protected areas during the course of yearly migrations.

<b>Location</b>	<b>Protection level</b>	<b>No.of days Spent per year</b>	<b>% Per year</b>
Boma National Park	Partially protected	1254	34.25
Badingilu National Park	Partially Protected	113	30.96
Corridor between Boma Badingilu	Temporarily protected by natural factors & inaccessibility	66	18.08
Gambella swamps in Ethiopia	Not protected	61	16.71
<b>Total</b>		<b>365</b>	<b>100</b>

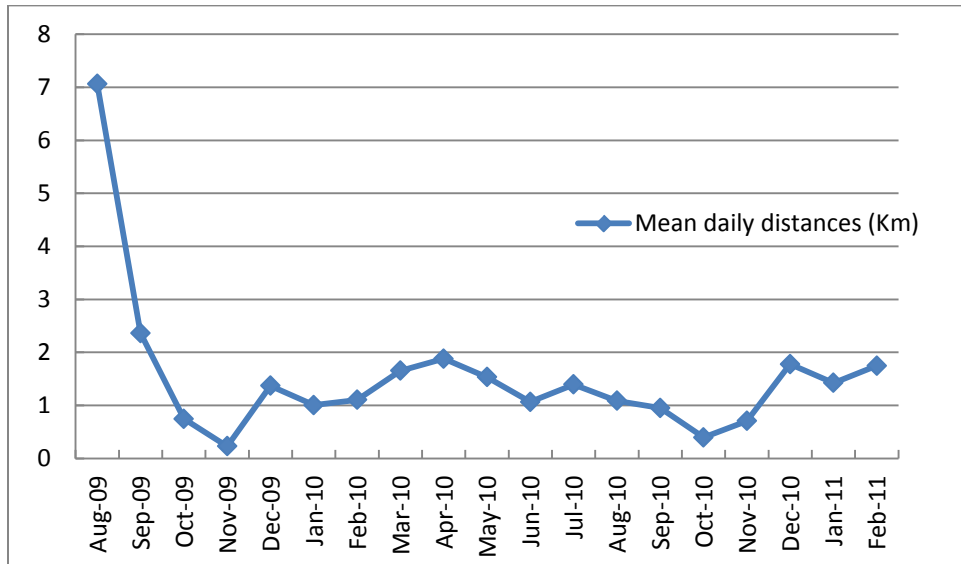


Figure 4.1. Mean daily distances moved by collared kob.

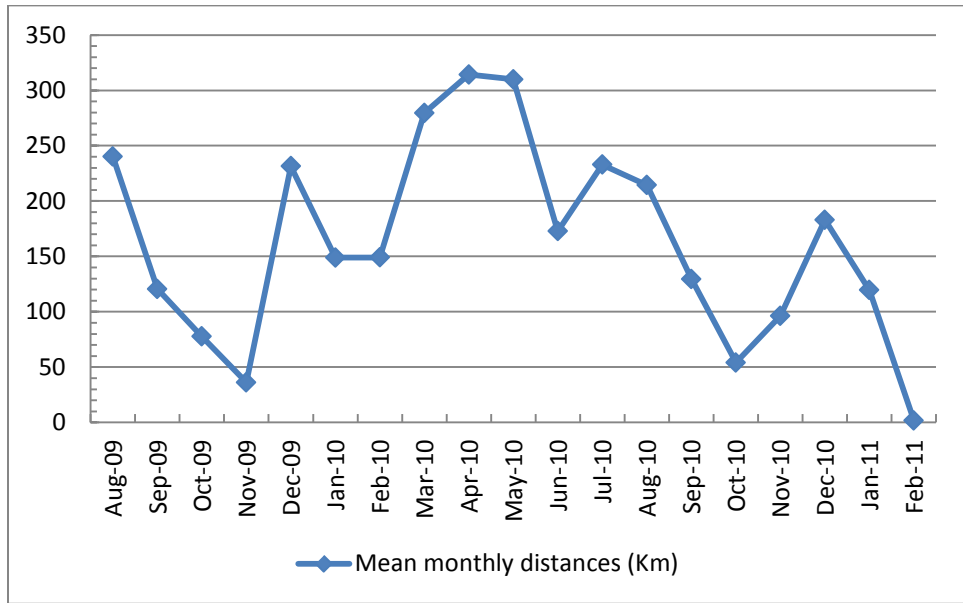


Figure 4.2. Total monthly distances moved by collared kob.

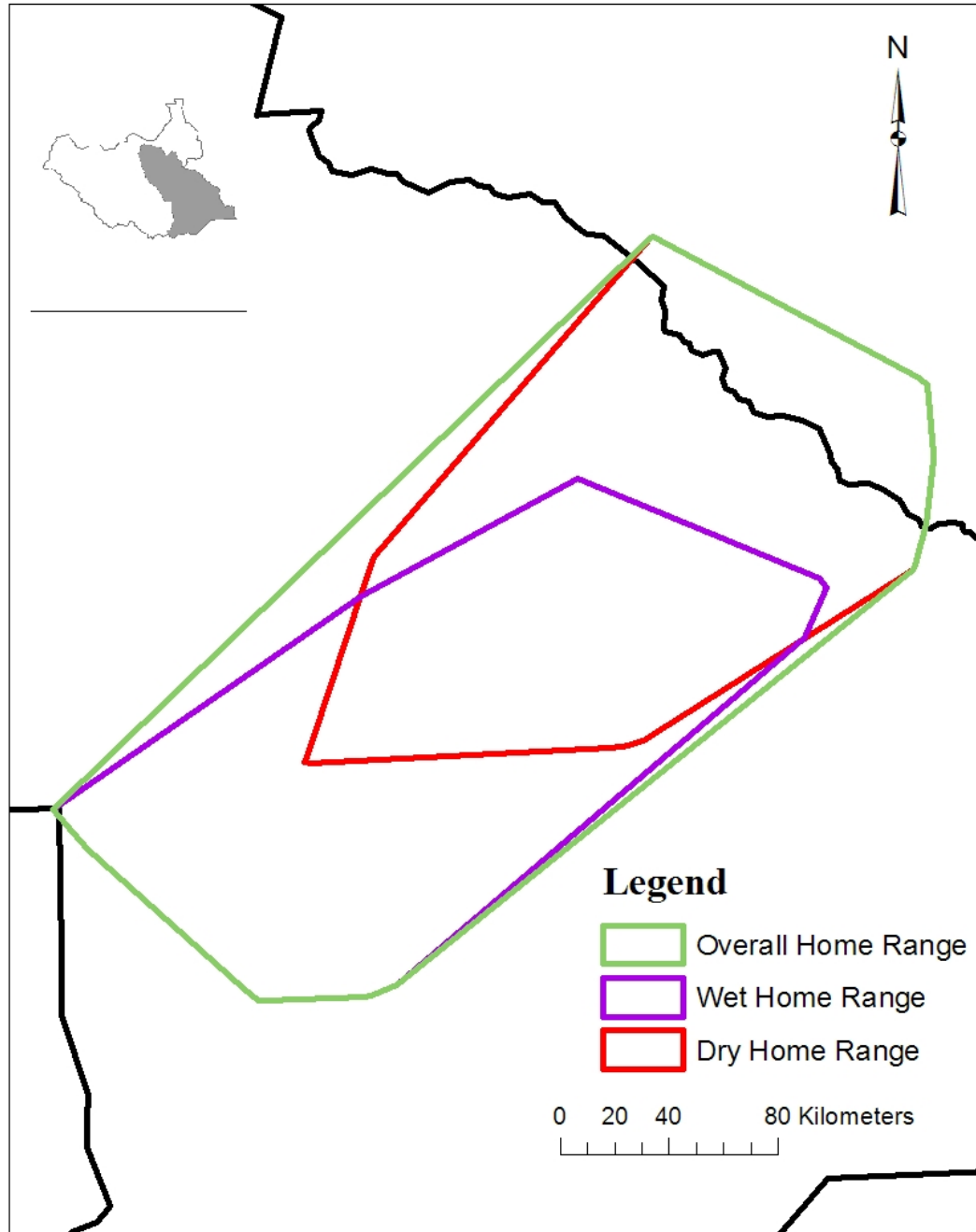


Figure 4.3. MCPs of the kob migrations ranges.

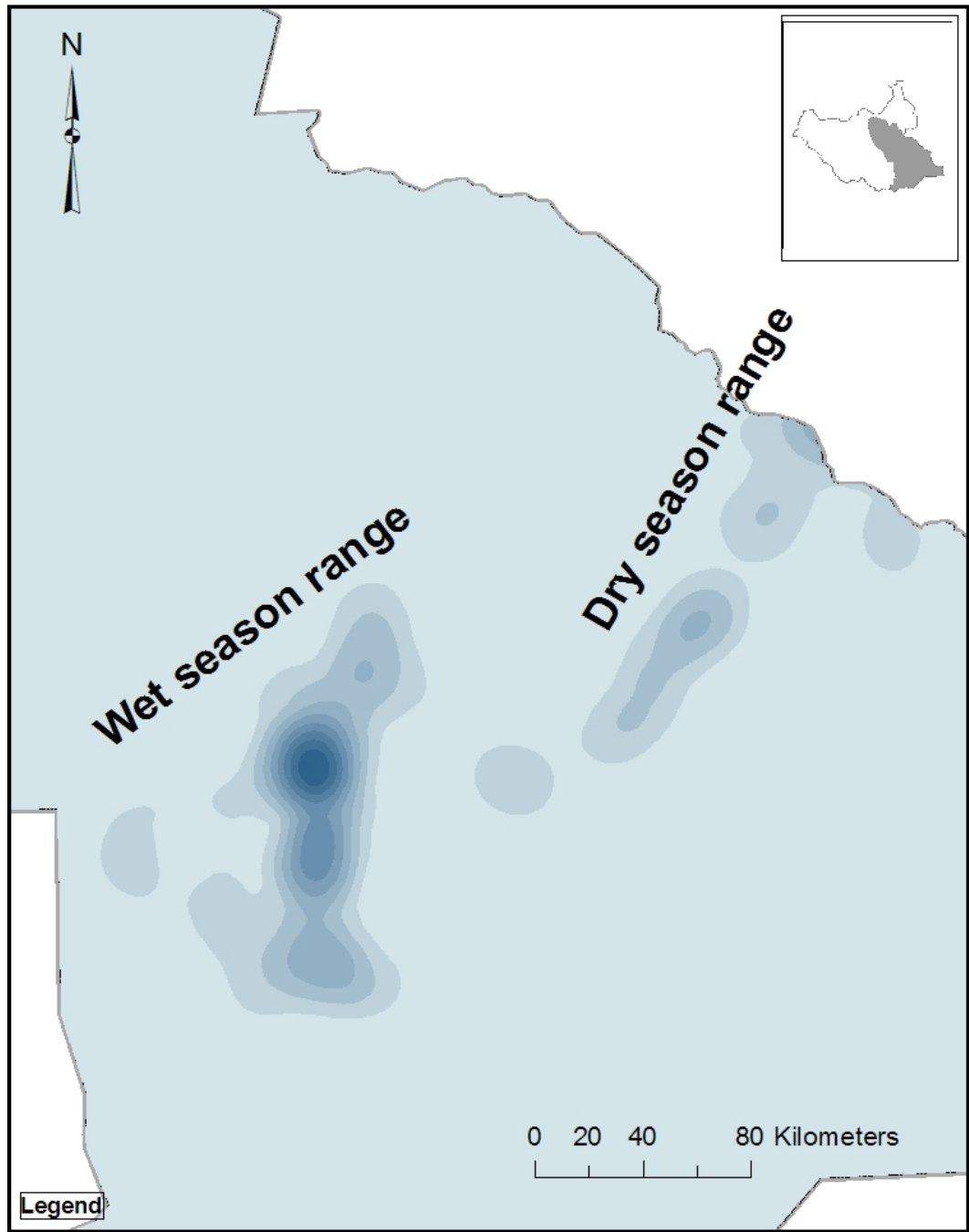


Figure 4.4. Core areas of kobs' seasonal ranges.

**CHAPTER 5**  
**PREDICTION OF WHITE-EARED KOB MOVEMENTS**  
**USING THE NORMALIZED VEGETATION DIFFERENCE**  
**INDEX (NDVI) ANALYSIS**

**Abstract**

In this Chapter I test whether the Normalize Difference Vegetation Index (NDVI) can be used to predict kob locations and movements in this vast ecosystem (46,000 km. sq.) where they migrate annually. NDVI in the study area showed lowest values (-0.0038) in March during the dry season, but increase gradually throughout the wet season with peak value of (0.7907) in September. The linear relationship between kob density and NDVI values was significant ( $p < 0.001$ ) throughout the seasons. With the application of some modeling techniques I have determined that the NDVI, which provides a temporally varying indices of habitat structure and greenness productivity, is a good technique for prediction of kob location in any season of the year and that the NDVI techniques could be a useful tool for the management of kob migration.

**Introduction**

The White-eared kob (*Kobus kob leucotis*) occurs in southeastern South Sudan and western Ethiopia. They live in large herds of several hundreds to thousands with a total population estimated to be over 800,000 (Fryxell 1987a, Fay *et al.* 2007), but the kob population in the last two decades has been in decline and is rated by IUCN Red List as a species of “Least Concern of near threatened status, with declining trends” (IUCN 2014). Long distance movements are characteristic of large herbivores in African



Savannah ecosystems, which exhibit pronounced seasonal changes in grassland productivity due to periodic variations in rainfall (Fryxell 1985), and white-eared kob (*Kobus kob leucotis*) migrate seasonally between wet and dry seasons every year. Kob move into the northern areas of Boma National Park during the dry season because water courses there provide access to both green grass and water when these resources are scarce elsewhere in the ecosystem (Fryxell and Sinclair 1988); therefore, water availability constrains kob habitat use during the dry season (Fryxell 1987c). Kobs also mate by means of a lek system in the dry season range and most females are pregnant when making return journey to the wet season range (Fryxell 1987b). Kobs give birth at the wet season range where food availability sustain lactating mothers and young babies before they start long distance movements to the dry season range (Fryxell 1987b). Thus, it seems clear that kob distribution and reproduction are linked to shifts in forage and water resources in their migration ecosystem. It also follows that the use of variations in NormalizedVegetation Difference Index (NDVI) values to identify variations in the primary productivity (e.g., Mueller *et al.* 2008) would be useful to predict kob distribution, and could be an important tool to use in management decisions. The use of NDVI technique has been useful in population distribution and wildlife management studies (e.g. Hamel *et al.* 2009, Bro-Jorgenson 2008, Meuller *et al.* 2008; Boone *et al.* 2006; Ito *et al.* 2006 & 2005, Kawamura *et al.* 2005 and Mueiga *et al.* 2004).

I predict that kob,like other ungulates (e.g. Mueller *et al.* 2008), will prefer an intermediate range of biomass productivity that are variable in space and time, presumably facing quality and quantity trade-offs where areas with low NDVI are limited by low ingestion rates and areas with high NDVI are limited by the low

digestibility of mature forage. I expect that the spatiotemporal variation of kob habitat areas will be high, but predictable, and that kob movements will reveal a predictable pattern of migration. This study focuses on landscape and ecosystem patterns, and thus a spatial resolution with a pixel size of 250 m X 250 m with NDVI data from the Moderate resolution imaging Spectro-radiometer (MODIS) was used. Such high resolution analysis should allow for effective tracking of these dynamics and delineating habitat selection across broad spatial scales. This approach would be especially useful to develop landscape level conservation and management plans, and this study aims at predicting kob locations from the NDVI values and detecting any relationship between NDVI values and kob abundance in the ecosystem.

### **Study area**

Kob migrations occur in southeast Sudan in savannah grassland area that expands across Jonglei and Eastern Equatoria States (Fig.5.1). They spend wet season partially in Badingilu National Park (BdNP) in the southwest of the range and the dry season in the Boma National Park (BNP) in the northeast of the migration range. Some smaller groups make occasional northward movements to the Sudd swamps. BNP was established in 1978; and BdNP was established in 1982 out of amalgamation of two small reserves together with the areas in between them.

The mean annual rainfall in the area ranges from 400-1,400 mm as monitored at the nearest meteorological station located at Juba International Airport. The mean monthly temperature is 36°C during the dry season and 28°C during the wet season; relative humidity is highest during the rainy season.

Topography of the area is mostly flat with scattered isolated hills in addition to the Boma escarpment. Most of the plains are dominated by “black cotton” clay soil. On the slopes and the foot hills, the soils are laterite and sandy (Willimott 1956). The ecosystem is a system of major swamps like the Guom swamps in the northern end of BNP. It is also drained by a number of rivers such as the Kangen/Kong-Kong River system, Oboth/Neubari Rivers and the Kuron River up north in BNP; while rivers veveno and lotila drain south through BDNP. The entire region is in a watershed that ultimately empties into the Nile River via the Sobat River (Fryxell 1985).

Vegetation in the ecosystem comprises of the East Sudania savannah grassland, the Saharan flooded grassland and the Northern Acacia-Commiphora bushland and thickets; while the Victorian basin forest-savannah found on the Boma escarpment in the east. The eastern part of the ecosystem in BNP is covered with woodland dominated by Combretum species, while the middle-western flood plains are covered with open grassland dominated by *Hyperhenia rufa*, *Sporobolus* spp., and *Pennisetum* spp. and *Echinoloa* spp. In between these two zones lies an intermediate zone of wooded grassland. The grasslands around the Guom swamps in the north include areas of *Hydrophila spinora*. Around the isolated hills occurs dense thicket dominated by *Ziziphus spina-christi*, *Acacia seyal*, *A. drepanolobium*, *A. fistula*, and *A. zanzibarica* (Willimott 1956).

## **Methods**

### **GPS tracking**

GPS tracking data were collected after darting, collaring (Northstar GPS), and monitoring of 2 kobs from August 2009 to March 2011. For the NDVI analyses, GPS

data were processed and grouped into two seasons: the peak dry season (1 Jan-31 Mar) and the peak wet season (1 Jul-30 Nov). The two-season data were used in the analyses to indicate kob density and locations across the seasons. During April-June the early rainy season rains were erratic, and during November-December, the late rainy season, rainfall were also not consistent.

### **NDVI analysis**

NDVI analysis technique used in this study is described in Mueller *et al.* (2008), Leyequien *et al.* (2007), Ito *et al.* (2006), Ito *et al.* (2005), Boone *et al.* (2006) and Leimgruber *et al.*(2001). The NDVI values were obtained from MODIS AQ13-L1 and downloaded from the USGS website. The NDVI of 16-day composites at the 250m x 250m resolution for dates corresponding to the kob tracking period, were processed using ArcGIS 9.3. The NDVI values were extracted and analyzed at all kob locations. The NDVI values for the study sites ranged between +1.0 to -1.0 which reflects the extent of vegetation biomass: where the positive values indicate green vegetation cover, and negative values indicate barren ground, rocks, etc.

Annual and seasonal home ranges were computed by the use of kernel density tool in ArcGIS 9.3. Kernel density estimation is currently one of the most robust and widely applied techniques in animal spatial ecology for quantifying animal range use (McFarland *et al.*2012; Willems *et al.*2009; Bro-Jorgenson *et al.* 2008). Several GPS locations (n= 2438) were used to create time-specific relative densities.

### **Statistical analysis**

Statistical analysis was conducted using the SPSS Pasw 18 software. The aim was to predict kob abundance from the associated NDVI values. A draw of 100 random points

was generated with the use of Hawth's Tools (Beyer 2004) an extension to the ArcGIS. Kob density with corresponding NDVI values for each of the 100 random points were extracted using the spatial analyst tools; and entered into excel file for bivariate statistical analysis. These files were also loaded on to SPSS PASW 18.

With kob density set as response variables and NDVI values as the predictor variable, tests of correlations (Pearson 1978), Generalized Linear Models (Quinn and Keough 2002) and Linear and non-linear regression models (McCullagh 1984, Howell 2008) were run to detect significance of relationships between NDVI values and kob densities across seasonal home ranges.

Pearson correlation and Factor analysis were also conducted to assess interactions. The default Wald Chi-sq. was selected for testing the model. The likelihood ratio chi-sq is used to test whether the model will reflect the observed patterns in the actual data. If the Likelihood ratio is significant, then the coefficients are significantly different from zero and the model is accepted.

The Generalized Linear Modelling (GLM) is a technique of modeling which allows other types of distributions besides the normal distribution (Quinn and Keough 2002):

$$g(\mu) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \dots + \dots + \beta_n X_n$$

$g(\mu)$  is the link function; and  $\beta_0, \beta_1, \dots, \beta_n$  are parameters to be estimated.

$X_1, X_2, \dots$  are the predictors or the independent variables. In this case here the model is a bi-variate then we have only  $X$

*Then,*

$$y = f(\beta_0, \dots, \beta_n, X_1, \dots, X_n)$$

When,

$g(\mu) = \mu$ , this models the the means of expected value of y (response variable), in standard linear models.

$g(\mu) = \log(\mu)$ , models log of the mean for non-negative data, used for log-linear models

$g(\mu) = \log[\mu/(1-\mu)]$ , used for binary data and logistic models.

Chi-sq. is calculated as follows:

$$\chi^2 = \sum(o - e)^2/n - 1,$$

where o is the observed, e is expected; and (n – 1) is the df

N = sample size

Non-linear regression was used to detect whether there are arbitrary relationships between kob densities and the NDVI values in both wet and dry seasons:

$$Y = a + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_1 X_2 + \beta_4 X_1^2 + \beta_5 X_2^2$$

$$Kob\ density_{dry} = a + b * NDVI_{Jan} + c * NDVI_{Jan}^2 + d *$$

$$NDVI_{ds} + e * NDVI_{Jan} * NDVI_{ds} + f * NDVI_{ds}^2$$

$$Kob\ density_{wet} = a + b * NDVI_{Jul} + c * NDVI_{Jul}^2 + d * NDVI_{ws} +$$

$$e * NDVI_{Jul} * NDVI_{ws} + f * NDVI_{ws}^2$$

Where, ds= dry season; ws = wet season; a,b,c,d,e&f= starting values

The Chi-sq. ( $\chi^2$ ) distribution:

Chi-sq. distribution is used for testing hypothesis about population variances. Shape and type of Chi-Sq distribution vary depending on the *df*, i.e. usually they are not symmetrical, *Hence*:

$$\chi^2 \text{ distribution} = (n - 1)s^2/a$$

Where,

$$\chi^2 = \sum(\chi - \bar{\chi})^2/(n - 1)$$

where (n - 1) is the *df*, N = sample size

If the observed value exceed the critical value of  $\chi^2$  the null hypo is rejected, the alternative hypo is accepted at the established level of significance (Quinn and Keough 2002).

Pearson Correlation: correlation coefficient (Pearson product-moment correlation coefficient (r) (Howell 2008) is calculated as follows:

$$r = \frac{cov_{xy}}{s_x s_y}$$

$$r = \frac{N\sum XY - \sum X \sum Y}{\sqrt{[N\sum X^2 - (\sum X)^2][N\sum Y^2 - (\sum Y)^2]}}$$

## **Results**

The annual movement cycle of the kob migration starts at the onset of the dry season in late November/ early December from areas in and around the Badingilu National Park and move northeast into the Boma National Park in search of water and green forage. By late December/ early January the advanced groups of kobs would already reach the Guom swamps at the north end of Boma National Park and some of them would have crossed the border into Gambella swamps in western Ethiopia. Kob distributions as related to NDVI are shown in Figures 5.2-5.7.

Kob overall density across the study area ranged between 0.0527-0.4742 animals/km.sq. Mean kob density in the dry season range areas was  $0.065 \pm 0.033$  ( $n = 100$ , range = 0.00053-0.15738), while in the wet season range was a little higher at  $0.125 \pm 0.103$  ( $n = 100$ , range= 0.0008-0.3608). NDVI values are low in the dry season (December-April) reaching smallest negative records (-0.0038) in March 2011, but increase gradually throughout the wet season (May-November) to reach the highest recorded values of 0.7907 in September (Table 5.1).

The linear relationship between kob density and NDVI values was significant ( $p < 0.001$ ) throughout the seasons (Table 5.2).

Linear regression showed significant relationship between wet season kob densities and corresponding NDVI values ( $p = 0.001$ ,  $df = 4$ ,  $F = 4.704$ ); while it was not significant for the dry season ( $p > 0.05$ ,  $df = 4$ ,  $f = 1.138$ ).

Pearson Correlation tests showed negative association between NDVI values and kob densities for most of the wet season (September and October 2009; July and August 2011), but was only negative in January 2010 for the dry season. This is expected because kobs avoid thick grass habitats for reasons of poor visibility and also ingestion rate is poor withold thicker vegetation. Pearson Correlation for each month shown in Table (5.5) and Table (5.6), indicate a no significant effect in the dry season, but only in the wet season, where in July 2010 there was significant relationship between NDVI values and kob density.

The Generalized linear model did not show any relationship patterns between kob densities and NDVI values for March in the dry season of 2011.



Factor analysis showed that there was no significant relationship between kob density and NDVI values in the dry season months throughout 2010 and 2011 (Tables 5.7, 5.8 & 5.9). It was observed that only the July 2010 NDVI values were highly significant in their influence on the kob density in wet season (Tables 5.10, 5.11 & 5.12). Hence, further analysis on January and July were conducted through Factor analysis and a non-linear regression for quadratic form.

The non-linear regression analysis run on kob density and corresponding NDVI for January 2010 (Tables 5.13 & 5.14), showed that the NDVI values of January 2010 reduce kob density by 47%; while the squared or  $(\text{NDVI Jan})^2$  increases the density by 2%. Seasonal NDVI values for the whole dry season reduces kob density by 3%; whereas squared seasonal NDVI increase the density by 2%, showing an upward curvature of the function. The combined interaction of January NDVI with the seasonal NDVI reduces kob density by 3% indicating that increases in both seasonal and January NDVI reduces kob density by 3%. On the other hand the July 2010 NDVI values reduce kob density by 419% in the peak wet season (Table 5.15 & 5.16). July NDVI values squared also reduce kob density by 3%, showing a downward curvature of the function. The seasonal NDVI for wet season increase kob density by 11% while seasonal NDVI values squared reduce kob density by 11%. While the interactions of July NDVI with the seasonal NDVI values combined increase kob density by over 79%.

### **Discussion**

White-eared kob migrate between wet season range in and around the eastern areas of the Badingilu National Park; and dry season range to northeast up in and around the Guom swamps in the Boma National Park. These movements are influenced by shifts

in forage and water resources(Fryxell and Sinclair 1988). Kob reproduction system can be considered one of the driving factors for the kob migration phenomenon as kob mating season takes place while they are in the dry season ranges through the lekking system (Fryxell 1987a), while calving takes place during the late wet season where food is abundant for lactating mothers and young (Fryxell 1987b). So kob reproduction is also connected with shifts in forage abundance.

This study shows that kob densities increase with the increase in NDVI values, which means that kob like to concentrate in areas of green vegetation and water especially during the dry season. The study area lies in the Eco-region of savannah flood grassland which dries up completely during dry season with the green vegetation and water concentrate only within areas of swamps, rivers and other water courses. Such areas are preferred by kob during the dry seasons and thus they make long distance movements to reach and utilize such areas during the dry season. Previous studies showed positive correlations between high NDVI values and animal occurrences and/or densities across their habitats (Meuller *et al.*2010, Butt 2010, Willems *et al.* 2009, Bro-Jorgenson 2008,Ito *et al.* 2006, Musiega and Sanga-Ngoie 2006, Ito *et al.* 2005, Musiega *et al.*2004 and Leimgurber *et al.* 2001). Kawamura*et al.* 2005) showed that MODIS NDVI is a better predictor of vegetation indices and very helpful to land managers in predicting when and where high quality grassland occurs and to predict where animal might graze.

The negative correlation in the wet season is a result of kob concentrations in few higher grounds with less vegetation cover. Kobs prefer such areas as an escape mechanism from flooded water; tall grass cover and sticky black cotton soil that spanning

the vast ecosystems of Jonglei and Eastern Equatoria States. Similar conclusion on topi was reported by Bro-Jorgenson *et al.* (2008). Fryxell (1985) noted that kobs' journey southwards is longer than simply avoidance of rains in the northern edge of their migration. In fact kob covers a one way distance of around 300 km between its two distant season ranges. The rainfall pattern in both ranges are similar, therefore, the movements between the two ranges have other driving factors than just rainfall. This is what the NDVI is now revealing from the negative associations between kob densities and the NDVI values in the wet season ranges.

In contrast to the above explanations, January 2010 has shown a negative correlation despite it is in the midst of the dry season time where kobs are expected to be concentrated around green vegetation areas in the swamps and rivers. January is a peak time of dispersal during the northbound movements of kob migrations. By that time the migratory kob would have reached their dry season ranges in Guom swamps at the northern end of the Boma National Park and some large groups of them would have crossed the Ethiopian border to utilize the green forage and plenty of water in the Duma wetlands in the Gambella region of Ethiopia. They spend some time till early-mid February unless disturbed by poachers and other illegal activities. Such dispersal affects their concentrations which reflect negatively on the mean density in the dry season ranges. This would explain as to why the density is affected even though NDVI values are high with in the dry season ranges.

This study concurs with previous studies in the conclusion that animal densities are positively related to NDVI values. Accordingly kob migrations move to areas of high NDVI values during the dry season where they utilize green biomass and water in such

areas as indicated by the high NDVI values. This means that during the dry season the migratory kob select their home ranges in areas with higher NDVI values than in the immediate surroundings. This finding agrees with previous studies (e.g. Meuller *et al.* 2010, Willems *et al.* 2009, Bro-Jorgenson 2008, Boone *et al.* 2006, Ito *et al.* 2006 and Steinbauer 2011) found that locust in green areas with higher NDVI were larger and fattier than those in areas with low NDVI values.

Kob also do avoid areas of high NDVI values in the wet season as they prefer higher ground with less vegetation as a mechanism to avoid tall savannah grasses. One explanation was that the wet season ranges have low-rainfall, thus high nutrition quality and high digestibility due to less soil leaching (Fryxell and Sinclair 1988). Bro-Jorgenson (2008) found out that topi tend to avoid high vegetation in search for improved visibilities against predators, while Meuller *et al.* (2010) found that Mongolian gazelle prefer areas of intermediate productivity. Therefore, as the case with other antelopes NDVI is a strong predictor of kob occurrence at any season in the year.

Meuller *et al.* (2010) analyzed vegetation quantity and quality for the prediction of Mongolian gazelles. This study utilized vegetation quantity only to determine whether NDVI could detect kob occurrences across the yearly seasons, however, future detailed study of kob food quality in relation to NDVI would add more insight to area utilization and kob management as well. Hamel *et al.* (2009) recommended that the use of NDVI data at a smaller resolution than the size of study area should favored as it provide better estimate of vegetation productivity.

From NDVI analysis the routes used by kob during the dry season journey (December) follow areas of high NDVI values, probably because of the need for food as

they race to the swamps in northern Boma National Park. Whereas the routes used during the wet season follow areas of low NDVI values because they tend to use higher grounds to avoid the sticky soils during the early rainfall.

### **Conclusions and management implications**

This study revealed that kob prefer areas of intermediate biomass productivity in both dry and wet season ranges and avoided areas of high biomass productivity in the wet season due to avoidance of mature forage characterized by low digestibility. The variations in NDVI values in the seasonal areas of kob use can be used to predict the spatiotemporal variation in kob habitat use, thus efficient in predicting their pattern of migration. Therefore, estimates of NDVI values at high resolution would be effective in tracking kob-habitat dynamics which managers and conservationists need to effectively manage the migration ecosystem and the landscape. Future studies at finer scales relating NDVI values to vegetation productivity attributes are recommended for the kob migration ecosystem.

### **Literature cited**

- Boone, R. B., Thirgood, S. J. and Hopcraft, J. G. C. (2006). Serengeti wildebeest migratory patterns modeled from rainfall and new vegetation growth. *Ecology*, **87**(8): 1987-1994.
- Bro-Jorgenson, J., Brown, M. E. and Petorelli, N. (2008). Using the satellite-derived normalized difference vegetation index (NDVI) to explain ranging patterns in a lek-breeding antelope: the importance of scale. *Oecologia*, **158**: 177-182.

- Butt, B. (2010). Pastoral resource access and utilization: Quantifying the spatial and temporal relationships between livestock mobility, density and biomass availability in southern Kenya. *Land Degrad. Develop.*, 21: 520–539.
- Fryxell, JM. (1987a). Lek breeding and territorial aggression in White-eared kob. *Ethology*, **75**(3): 211-220.
- Fryxell, J. M. (1987b). Seasonal reproduction of White-eared kob in Boma National Park, Sudan. *Afr. J. Ecol.* **25**(2): 117-124
- Fryxell, J. M. (1987c). Food limitation and the demography of a migratory antelope, the White-eared kob. *Oecologia*, 72: 83-91.
- Fryxell, J. M. (1985). *Resource limitation and population ecology of the White-eared kob*. A PhD Thesis. University of British Columbia, Canada.
- Fryxell, J.M. and A. Sinclair. (1988). Seasonal migration by White-eared kob in relation to resources. *Afr. J. Ecol.* **26**(1): 17-31.
- Hamel, S., Garel, M., Fest-Bianchet, M, Gaillard, J-M. and Cote, S. D. (2009). Spring Normalized Difference Vegetation Index (NDVI) predicts annual variation in timing of peak faecal crude protein in mountain ungulates. *J. App. Ecol.*, 46: 582-589.
- Howell, D.C. (2008). *Fundamental statistics for the behavioural sciences (Student edition)* Wadsworth Publishing, Inc. pp. 181-192
- Ito, T. Y., Muira, N., Lhagvasuren, B., Enkhbileg, D., Takatsuki, S., Tsunekawa, A. and Jiang, Z. (2006). Satellite tracking of Mongolian gazellez (*Procapra gutturosa*) and habitat shifts in their seasonal ranges. *J. Zool.* 269: 291-298.

- Ito, T. Y., Muira, N., Lhagvasuren, B., Enkhbileg, D., Takatsuki, S., Tsunekawa, A. and Jiang, Z. (2005). Preliminary evidence of a barrier effect of a railroad on the migration of Mongolian gazelles. *Cons. Biol.***19**(3):945-948.
- IUCN SSC Antelope Specialist Group 2008. *Kobus kob*. In: IUCN 2014. IUCN Red List of Threatened Species. Version 2013.1. <[www.iucnredlist.org](http://www.iucnredlist.org)>. Downloaded on 11May 2014.
- Kawamura, K., Akiyama, T., Yokota, H-O, Tsutsumi, M., Yasuda, T. and Watanabe, O. (2005). Comparing MODIS vegetation indices with AVHRR NDVI for monitoring forage quality and quantity in inner Mongolia grassland, China. *Grassland Science*, **51**(1): 33-40.
- Leimgruber, P., McShea, W. J., Brookes, C. J., Bolor-Erdene, L., Wemmer, C. and Larson, C. (2001). Spatial patterns in relative productivity and gazelle migration in eastern Steppes of Mongolia. *Biol. Cons.*, 102: 205-212.
- McCullagh, P. (1984). Generalized linear model. *European Journal of operation research*. 16(3): 285 – 292. Call Number: UB110164.
- McFarland, T. M., Van Riper, C. and Johnson, G. E. (2012). Evaluation of NDVI to assess avian abundance and richness along the upper San Pedro River. *J. Arid Evt.*, 77: 45-53.
- Musiega, D.E., Kazadi, S-N and Fukuyama, K. (2006). A framework for predicting and visualizing the East African wildebeest migration-route patterns in variable climatic conditions using geographic information system and remote sensing. *Ecol. Res.*, 21: 530-543.

- Musiega, D.E., Kazadi, S-N. (2004). Simulating the East African wildebeest migration patterns using the GIS and remote sensing. *Afr. J. Ecol.*, 42: 355-362.
- Mueller, T., Olson, K. A., Fuller, T. K., Schaller, G. B., Murray, M. G. and Leimgruber, P. (2008). In search of forage: Predicting dynamic habitats of Mongolian gazelles using satellite-based estimates of vegetation productivity. *J. App. Ecol.*, 45: 649-658.
- Steinbauer, M. J. (2011). Relating rainfall and vegetation greenness to the biology of spur-throated and Australian locusts. *Agric and Forest Ento.*, 13: 205-218.
- Wilmhurst et al (1999). Spatial distribution of Serengeti wildebeest in relation to resources. *Can J. Zool.*, 77: 1223-1232.
- Willems, E. P., Barton, R. A. and Hill, R. A. (2009). Remotely sensed productivity, regional home range selection and local range use by an omnivorous primate. *Behav. Ecol.*, 20: 985-992.
- Pearson, R. (1978). Statistical analysis: A decision-making approach. 2<sup>nd</sup> edn. Harper & Row, New York. Pp. 397, 445, 584.
- Quinn, G.P., and Keough, M.J. (2002). *Experimental design and data analysis for biologists*. Cambridge University Press, UK. pp.



Table 5.1. Comparison of mean NDVI values within and outside kob peak seasonal home ranges (n = 100).

Season	Month	Within Range		Outside Range	
		Mean	SEM	Mean	SEM
Peak wet	Sep 2009	0.56	0.01	0.32	0.071
	Sep 2010	0.60	0.01	0.36	0.073
Peak dry	Jan 2010	0.26	0.009	0.25	0.016
	Mar 2011	0.16	0.009	0.20	0.014

Table 5.2. The relationships between NDVI (250-m spatial resolution) and Kob densities from generalized linear modeling tests, (n=100).

Season	Year	NDVI			95% Wald CI		
		Wald Chi-2	df	p Value	Lower	Mean ± SE	Upper
Wet	2009	35,590.415	97	<0.001	0.125	0.126 ± 0.001	0.127
	2010	4,764.586	95	<0.001	0.124	0.127 ± 0.002	0.130
Dry	2010	8,230.371	98	<0.001	0.065	0.066 ± 0.0004	0.066
	2011	1,757.267	94	<0.001	0.064	0.065 ± 0.001	0.067

Table 5.3. The correlation coefficients between kob densities and NDVI values in the dry season range.

NDVI				
period	January	March	February	March
Month/year	2010	2010	2011	2011
Kob density in the dry season range	-0.008	0.129	0.148	0.146

Table 5.4. The correlation coefficients between kob densities and NDVI values in the wet season range.

NDVI				
period	October	July	August	September
Month/year	2009	2010	2010	2010
Kob density in the wet season range	-0.163	-0.293	0.133	0.052

Table5.5. Pearson Correlation Coefficients for dry season kob density  
Vs monthly NDVI Values.

		Kob density	Monthly NDVI Values for dry season			
			Jan 2010	Mar 2010	Jan 2011	Mar 2011
Kob density	Pearson Correlation	1	-0.02	0.13	0.15	0.15
	Sig. (2-tailed)		0.94	0.20	0.14	0.15
	Sum of Squares and Cross-products	1075.46	-22.84	211.36	441.84	449.71
	Covariance	10.86	-0.23	2.14	4.46	4.54
	N	100	100	100	10	10
Jan 2010	Pearson Correlation	-0.01	1	0.35	0.28	0.28
	Sig. (2-tailed)	0.94		0.00	0.00	0.00
	Sum of Squares and Cross-products	-22.84	7980.88	1546.35	2295.67	2392.23
	Covariance	-0.23	80.62	15.62	23.19	24.16
	N	100	100	100	100	100
Mar 2010	Pearson Correlation	0.13	0.35	1	0.26	0.35
	Sig. (2-tailed)	0.20	0.00		0.01	0.00
	Sum of Squares and Cross-products	211.36	1546.35	2487.86	1192.22	1639.33
	Covariance	2.14	15.62	25.13	12.04	16.56
	N	100	100	100	100	100
Jan 2011	Pearson Correlation	0.15	0.28	0.26	1	0.34
	Sig. (2-tailed)	0.14	0.00	0.01		0.00
	Sum of Squares and Cross-products	441.84	2295.67	1192.22	8233.54	2911.87
	Covariance	4.46	23.19	12.04	83.17	29.41
	N	100	100	100	100	100
Mar 2011	Pearson Correlation	0.15	0.28	0.35	0.34	1
	Sig. (2-tailed)	0.15	0.00	0.00	0.00	
	Sum of Squares and Cross-products	449.71	2392.23	1639.33	2911.87	8877.32
	Covariance	4.54	24.16	16.56	29.41	89.67
	N	100	100	100	100	100

Table. 5.6. Showing Pearson Correlation Coefficients for kob wet season density Vs the monthly NDVI values across wet months.

		Kob wet season density	NDVI Values			
			Oct 2009	Jul 2010	Aug 2010	Sep 2010
Kob density	Pearson Correlation	1	-0.16	-0.29**	0.13	0.05
	Sig. (2-tailed)		0.11	0.00	0.19	0.61
	Sum of Squares and Cross-products	10548.53	-1224.82	-3471.09	1473.38	523.92
	Covariance	106.55	-12.37	-35.06	14.883	5.29
	N	100	100	100	100	100
Oct 2009	Pearson Correlation	-0.16	1	0.23*	0.21*	0.02
	Sig. (2-tailed)	0.11		0.02	0.04	0.81
	Sum of Squares and Cross-products	-1224.82	5363.85	1956.96	1655.57	175.84
	Covariance	-12.37	54.18	19.77	16.72	1.78
	N	100	100	100	100	100
Jul 2010	Pearson Correlation	-0.29**	0.23*	1	0.47**	0.27**
	Sig. (2-tailed)	0.00	0.02		0	0.01
	Sum of Squares and Cross-products	-3471.09	1956.96	13304.94	5834.89	3057.18
	Covariance	-35.06	19.77	134.39	58.94	30.88
	N	100	100	100	100	100
Aug 2010	Pearson Correlation	0.13	0.21*	0.47**	1	0.54**
	Sig. (2-tailed)	0.19	0.04	0		0
	Sum of Squares and Cross-products	1473.38	1655.57	5834.89	11547.26	5689.88
	Covariance	14.88	16.72	58.94	116.64	57.47
	N	100	100	100	100	100
Sep 2010	Pearson Correlation	0.05	0.02	0.27**	0.54**	1
	Sig. (2-tailed)	0.61	0.81	0.01	0	
	Sum of Squares and Cross-products	523.92	175.84	3057.18	5689.88	9773.66
	Covariance	5.29	1.78	30.88	57.47	98.72
	N	100	100	100	100	100

Table 5.7. Factor analysis of the dry season NDVI influence on kob density.

		Correlation Matrix <sup>a</sup>				
		Dry season kob density	Dry season NDVI Values			
			Jan 2010	Mar 2010	Jan 2011	Mar 2011
Correlation	Kob density	1	-0.01	0.13	0.15	0.15
	Jan 2010	-0.01	1	0.35	0.28	0.28
	Mar 2010	0.13	0.35	1	0.26	0.35
	Jan 2011	0.15	0.28	0.26	1	0.34
	Mar 2011	0.15	0.28	0.35	0.34	1
Sig. (1-tailed)	Kob density		0.47	0.1	0.07	0.07
	Jan 2010	0.47		0	0.00	0.00
	Mar 2010	0.1	0		0.00	0
	Jan 2011	0.07	0.00	0.00		0
	Mar 2011	0.07	0.00	0	0	

a. Determinant = .595

Table 5.8. KMO and Bartlett's Test.

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.70
Bartlett's Test of	Approx. Chi-Square	50.18
Sphericity	df	10
	Sig.	0.00



Table 5.9. Showing Component Matrix for NDVI values and kob densities in dry season 2010/2011.

	Component	
	1	2
Kob density	0.29	0.90
Jan 2010	0.65	-0.44
Mar 2010	0.71	-0.08
Jan 2011	0.67	0.07
Mar 2011	0.72	0.04

Extraction Method: Principal Component

Analysis.

a. 2 components extracted.

Table 5.10. Factor analysis of effects of the monthly NDVI values on kob density in the wet season 2009-2010.

		Correlation Matrix <sup>a</sup>				
		Kob density	Dry season NDVI Values			
			Oct-09	Jul-10	Aug-10	Sep-10
Correlation	Kob density	1	-0.16	-0.29	0.13	0.05
	Oct-09	-0.16	1	0.23	0.21	0.02
	Jul-10	-0.29	0.23	1	0.47	0.27
	Aug-10	0.13	0.21	0.47	1	0.54
	Sep-10	0.052	0.02	0.27	0.54	1
Sig. (1-tailed)	Kob density		0.05	0	0.09	0.31
	Oct-09	0.05		0.01	0.02	0.41
	Jul-10	0.00	0.01		0	0
	Aug-10	0.09	0.02	0		0
	Sep-10	0.31	0.41	0	0	

a. Determinant = 0.409

Table 5.11. KMO and Bartlett's Test.

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.52
Bartlett's Test of	Approx. Chi-Square	86.22
Sphericity	<i>df</i>	10
	Sig.	0.00

Table 5.12.Component Matrixa

	Component	
	1	2
Kob density – wet	-0.15	0.83
Oct 2009	0.42	-0.47
Jul 2010	0.76	-0.32
Aug 2010	0.84	0.32
Sep 2010	0.69	0.42

Extraction Method: Principal Component Analysis.

a. 2 components extracted.

Table 5.13. Parameter estimates of the Non-linear regression analysis of the effects of January 2010 NDVI values on kob density in the peak dry season.

Parameter	Estimate	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
A	11.21	3.35	4.57	17.86
B	-0.47	0.24	-0.94	0
C	0.02	0.01	0.01	0.04
D	-0.03	0.34	-0.71	0.65
E	-0.03	0.02	-0.06	0
F	0.02	0.01	-0.01	0.05

Table 5.14. Showing coefficients of ANOVAa

Source	Sum of Squares	df	Mean Squares
Regression	4457.59	6	742.93
Residual	881.95	94	9.38
Uncorrected Total	5339.54	100	
Corrected Total	1075.46	99	

Dependent variable: Dry season density

a.  $R^2 = 1 - (\text{Residual Sum of Squares}) / (\text{Corrected Sum of Squares}) = 0.180$ .

Table 5.15. Parameter Estimates for the Non-linear regression analysis of the effects of the July 2010 NDVI values on the wet season kob density.

Parameter	Estimate	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
a	-111.34	48.6	-207.83	-14.86
b	-4.19	1.51	-7.19	-1.18
c	-0.03	0.01	-0.05	0.00
d	7.93	2.83	2.31	13.56
e	0.11	0.04	0.03	0.19
f	-0.11	0.04	-0.19	-0.03

Table 5.16. ANOVAa Coefficients – Nonlinear regression.

Source	Sum of Squares	df	Mean Squares
Regression	17753.7	6	2958.96
Residual	8489.83	94	90.32
Uncorrected Total	26243.6	100	
Corrected Total	10548.5	99	

Dependent variable: Den-wet\_season

a.  $R^2 = 1 - (\text{Residual Sum of Squares}) / (\text{Corrected Sum of Squares}) = 0.195$ .



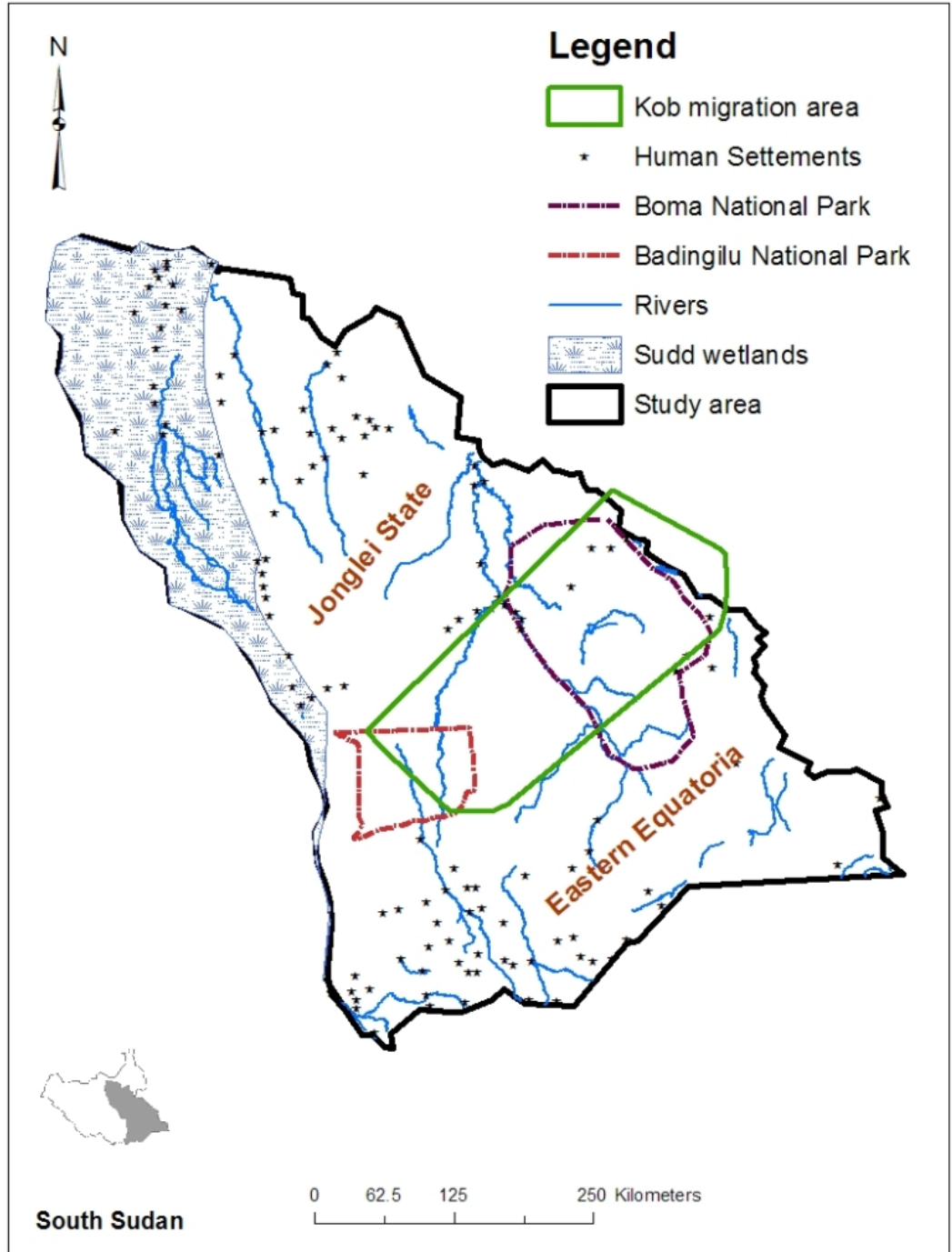


Figure 5.1. Koba study area in eastern South Sudan.

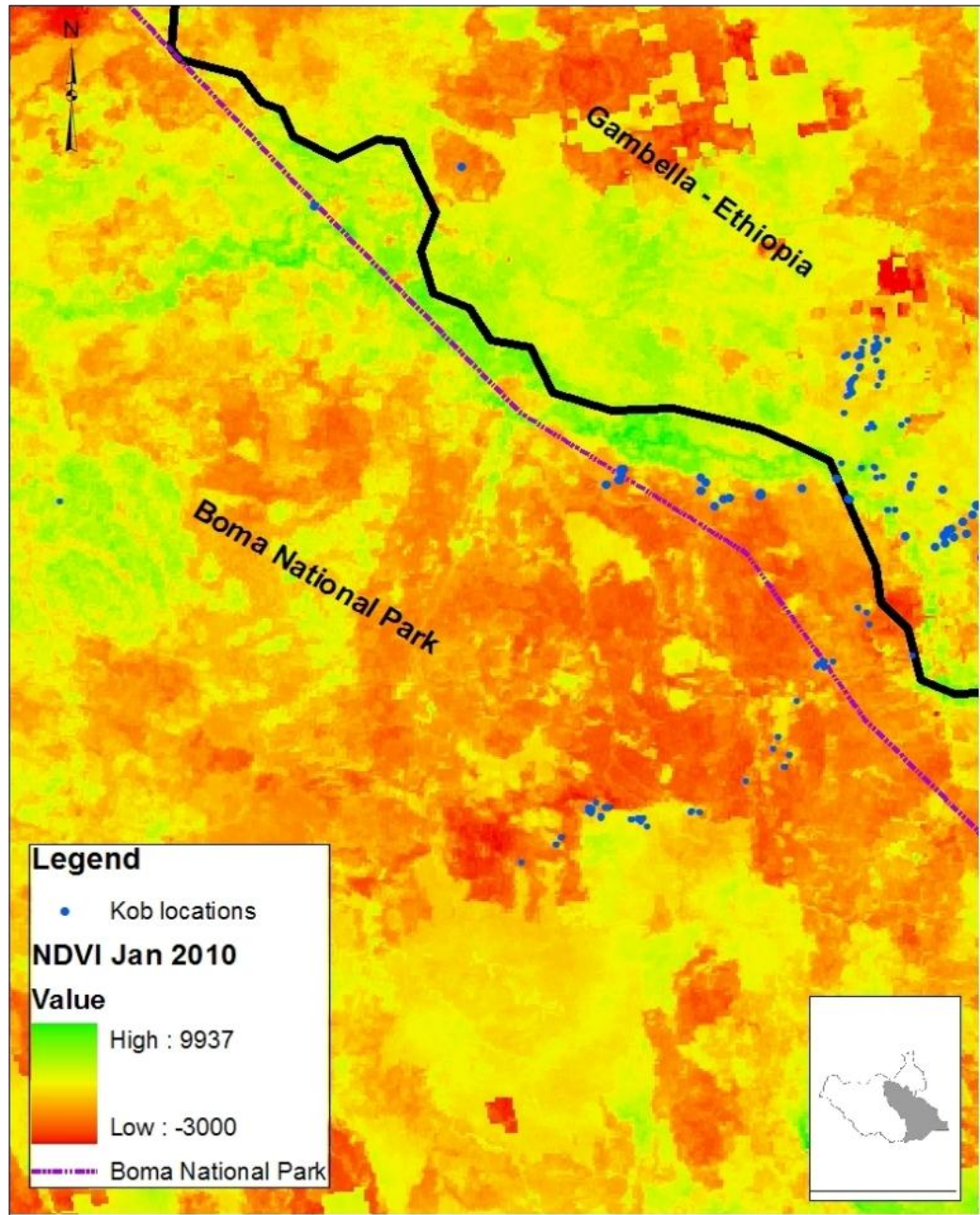


Figure 5.2. Dry season kob distributions and NDVI: By January 2010 some large groups of kobs would cross the international borders into Ethiopia to utilize forage and water resources available in the swamps therein.

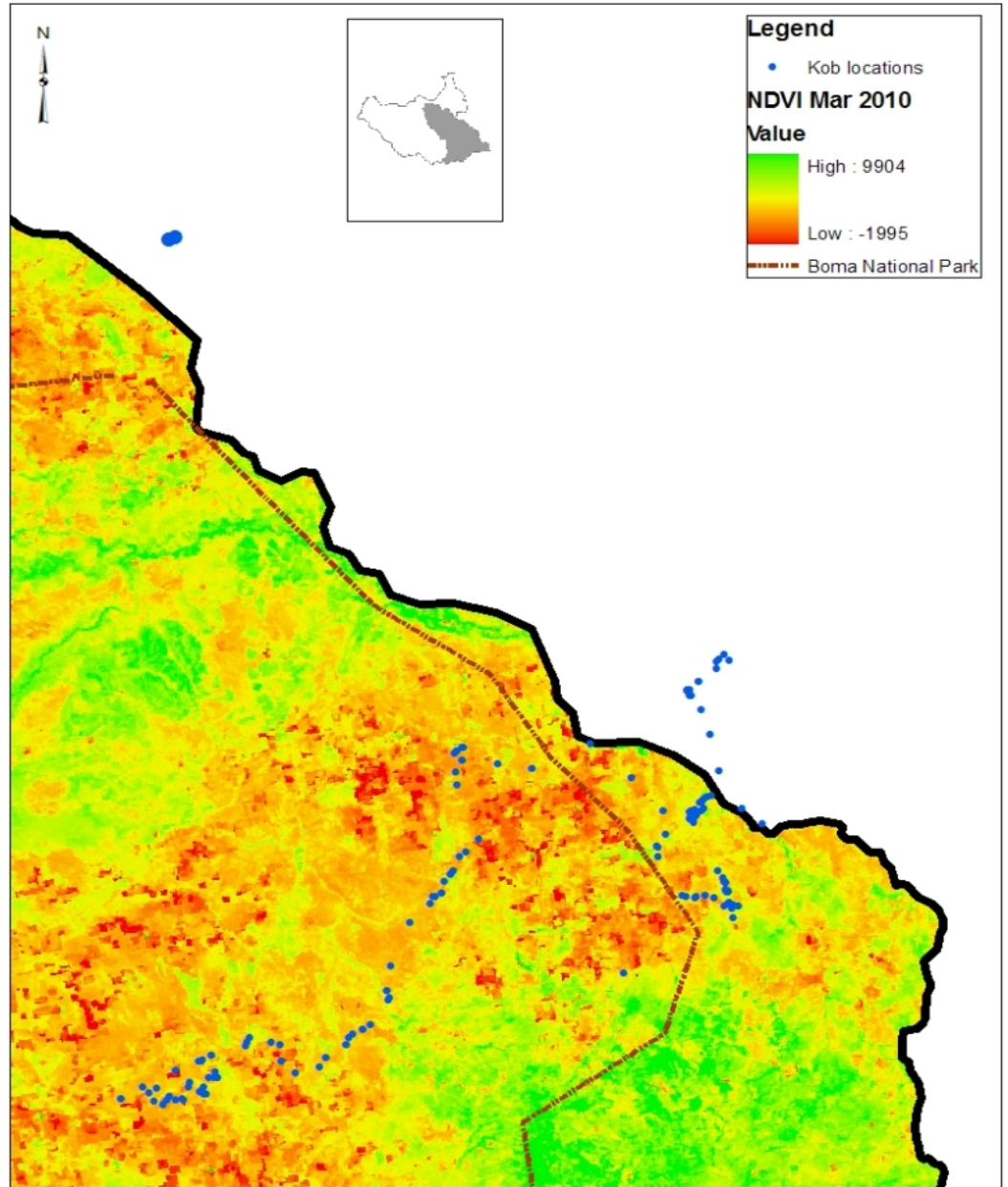


Figure 5.3. Dry season kob distributions and NDVI: March 2010.



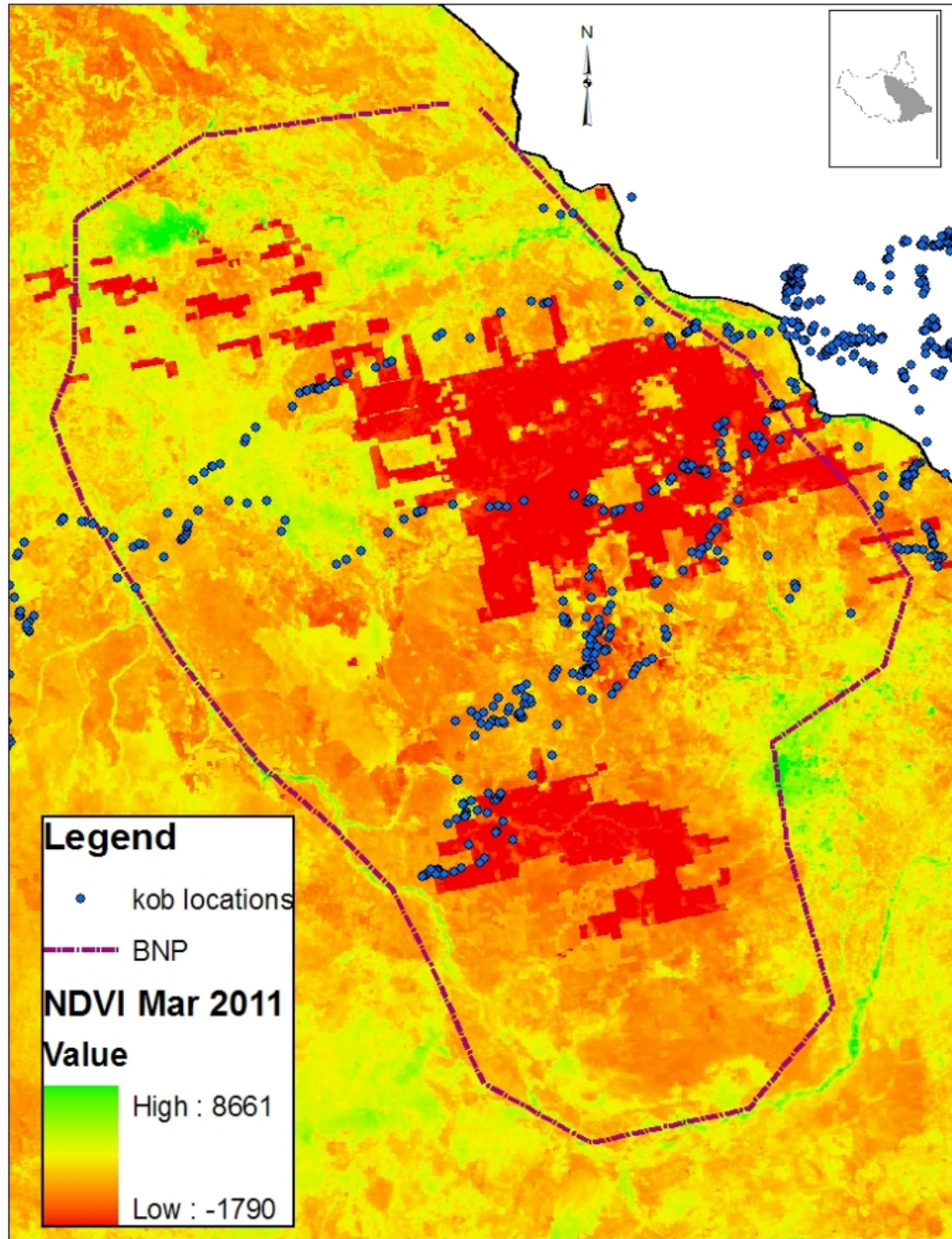


Figure 5.4. Dry season kob distributions and NDVI: March 2011.

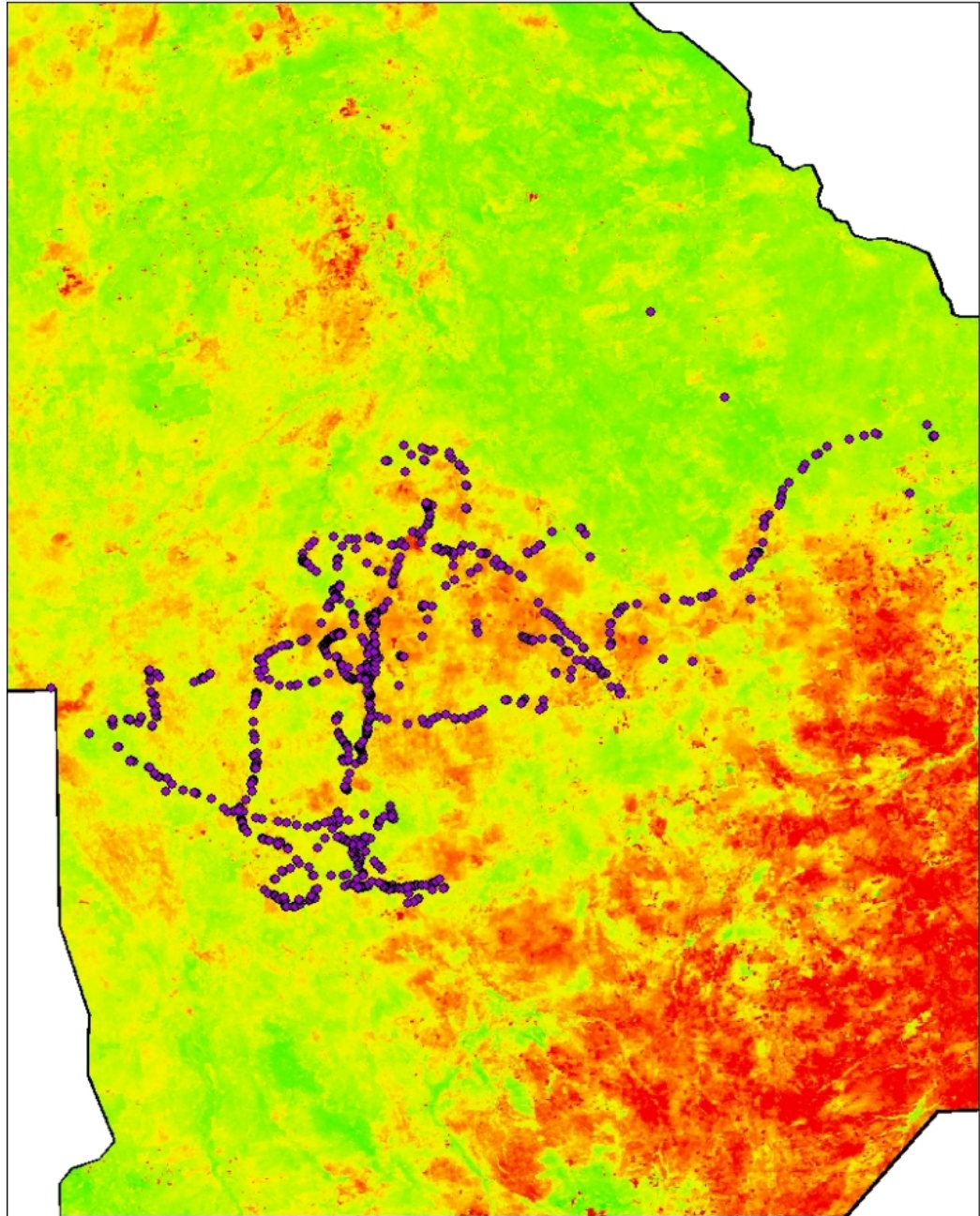


Figure 5.5 Wet season kob distributions and NDVI: August 2009.



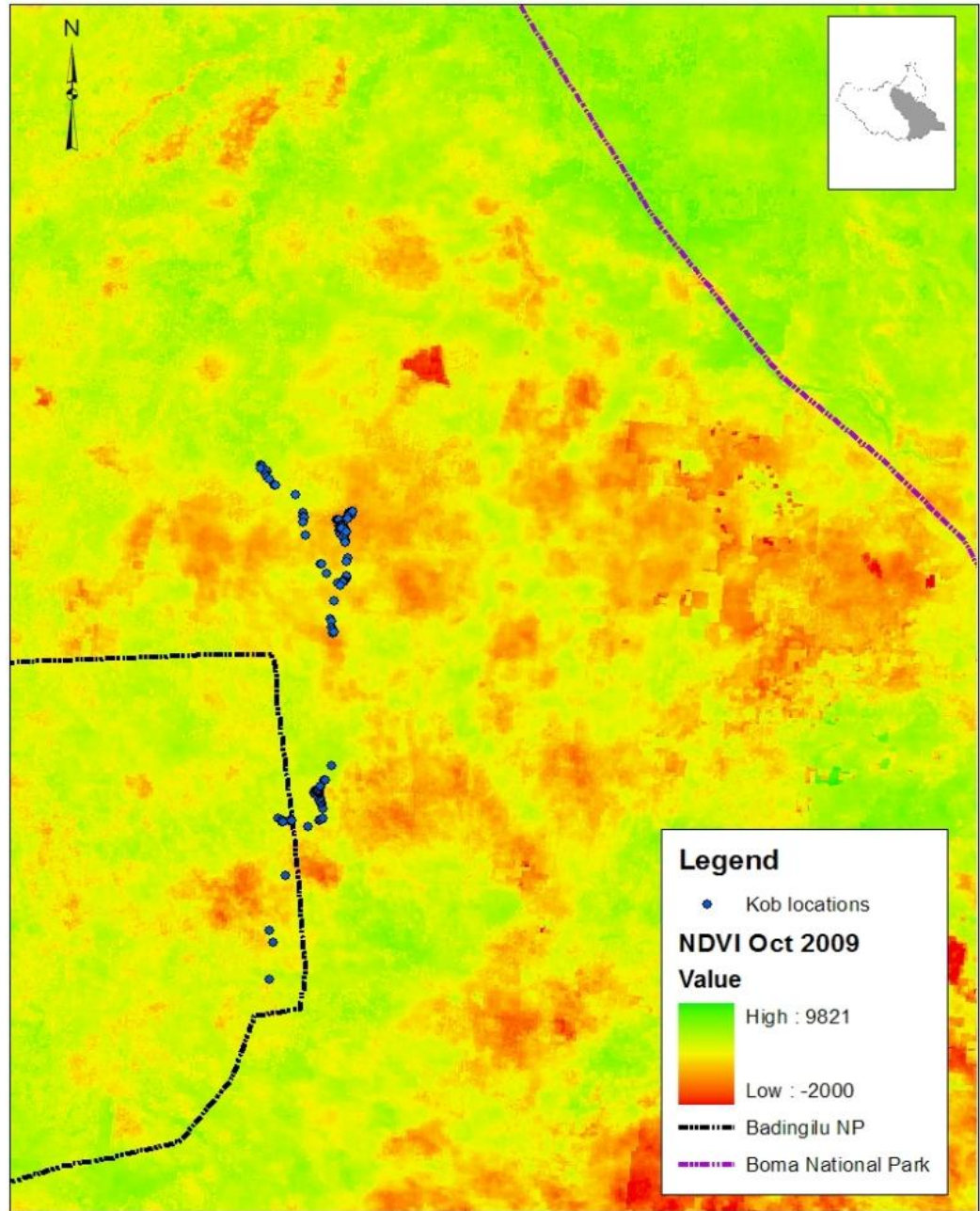


Figure 5.6. Wet season kob distributions and NDVI: October 2009.

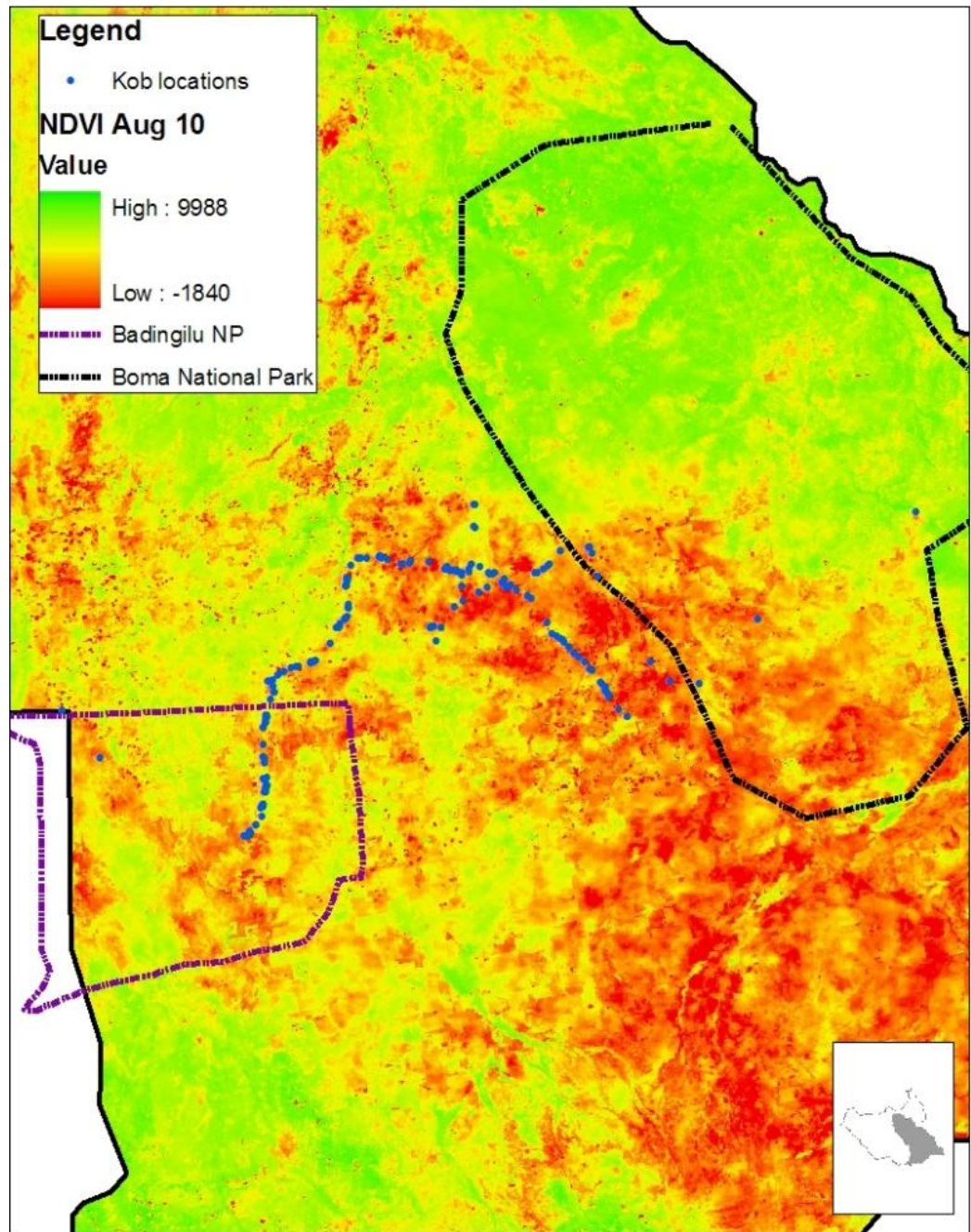


Figure 5.7. Wet season kob distributions and NDVI: August 2010.

# CHATER 6

## MODELING AND PREDICTING THE WHITE-EARED KOB DISTRIBUTION

### Abstract

I used the species distribution models based on observed presence-absence technique to predict the distribution of kobs. I used data from aerial surveys, stratified with data from various environmental factors interacting with the migratory kob, developed raster layers for each and combined them in a single file, then ran frequency analysis and logistic regression and developed models that predict kob location at any time given certain variables in the surrounding ecosystem. Kob did not coexist with tiang or reedbuck during the dry season. Mongalla gazelles, rivers and open habitat and Grassland habitats significantly affect kob presence. Whereas, tiang, reedbuck, human settlements were negative to kob. The models were tested for accuracy and were effective.

### Introduction

In response to seasonal changes in environmental factors, migratory species such as the white-eared kob (*Kobus kob leucotis*) tend to move and disperse over large landscapes (Fryxell and Sinclair 1988). Such highly seasonal distributions exhibited by migratory kob pose conservation and management challenges, especially under the uncertainty of the ever-changing ecological, political, and developmental dynamics in the migration ecosystem areas. Therefore, prediction of kob movements and distributions is vital for future conservation and management of kob migrations.



Predicting the distribution of species is a goal in ecology and, increasingly, a requirement for effective conservation and management, as well as in informed policy development (Jewell *et al.* 2007, Early *et al.* 2008, Jones 2011). Species distribution models based on observed presence-absence data are commonly used for ecological and conservation planning (Gibson *et al.* 2004, Gavashelishvili and Lukarevskiy 2008, Syartinilia 2008, Wang *et al.* 2009, Jones 2011, Santika 2011), however, specific applications include modeling and predicting species distribution and habitat suitability studies. Species distribution modeling requires species occurrence data and environmental spatial data layers, which are combined to create a predictive model describing the suitability of any site for the species (Graham *et al.* 2008). Species distribution models have proved valuable to wildlife and land managers because they allow them to obtain decision criteria within a relatively short time (Cassini 2011). The use and application of species distribution models lead to substantial savings of costs and surveys efforts (Hamer *et al.* 2008, Wang *et al.* 2009), as well as careful modeling can maximize the value of poorly collected data to conservation and management use (Jones 2011). Often, a simplified model that incorporates only two or three of the most important variables can be developed (Dörgeloh 2006), such models are usually more stable, easily generalized, have smaller standard errors, and are less dependent on observed data (Dörgeloh 2006).

Logistic regression (Quinn and Keough 2002, Garson 2012) is one of the most commonly used and comparatively reliable statistical techniques for predictive species distribution models based on the presence-absence data (Keating and Cherry 2004, Gibson *et al.* 2004, Dörgeloh 2006, Newton-Cross *et al.* 2007, Hamer *et al.* 2008,

Syartinilia 2008, Wang *et al.* 2009, Baasch *et al.* 2010, Santika 2011 and Pittigilio *et al.* 2012). Logistic regression provides better group separation and significantly better fit, as well as being more robust to deviations from normality, thus it is important in ecological studies as many ecological phenomena are inherently non-linear (Dörgeloh 2006, Newton-Cross *et al.* 2007, Johnson and Gillingham 2008). Baasch *et al.* (2010) pointed out that logistic regression produces more accurate and precise probability distribution when levels of availability and use of resources occur at larger scale. Some previous distribution modeling studies used other statistical techniques such as the Generalized Linear Modeling Technique (Syartinilia 2008, Santika 2011, Meisingset 2013).

Errors and bias in occurrence data, dependent and independent variables and model design might influence model performance (Graham *et al.* 2008, Johnson and Gillingham 2008). Such errors are caused by a variety of factors, including errors in data transfer from field sheets to electronic databases, rounding errors, failures to specify georeferencing (Graham *et al.* 2008) and thematic misclassification of vegetation, habitat or other resource map. All of these errors could have implications for model robustness (Johnson and Gillingham 2008) as they could either lead to under prediction or over prediction of model (Evangelista *et al.* 2008, Syartinilia 2008).

Models performance is determined by calculating the area under the receiver operating characteristic curve (AUC), such that a curve that maximizes sensitivity for low values of the false positive fraction is considered a good model (Russell *et al.* 2007, Evangelista *et al.* 2008, Graham *et al.* 2008). Graham *et al.* (2008) found no evidence that models developed using regression-based techniques have lower performance.

Distribution models, when appropriately chosen, are fairly robust to location errors and can be built even if occurrence data are imprecise (Graham *et al.* 2008).

In this study, white-eared kob distribution in eastern South Sudan was investigated with the use of logistic regression models and GIS based presence-absence data combined with biotic and abiotic factors in their surrounding environment to produce predictive models for their distribution and occurrence.

### **Objectives**

1. To develop logistic model that predicts kob distribution in relation to other migratory antelope species and habitat.
2. To assess the effects of disturbances (predation, hunting, other competing wildlife species) on kob distribution.

### **Hypothesis:**

$H_0$  = Kob distribution and movements is not affected by the presence and distributions of other migratory antelope species

$H_a$  = Kob distribution is affected by presence of the other migratory antelopes in the migration ecosystem

### **Study area**

We conducted aerial surveys in the plains of Boma National Park and Jonglei State in eastern South Sudan during January-February 2007.

The mean annual precipitation in the study area ranges from 400-1,400 mm falling between April-November. The mean monthly temperature is 36o C during the dry season and 28o C during the wet season; relative humidity is highest during the rainy season.

Topography of the area is mostly flat with scattered isolated hills in addition to the Boma escarpment. Most of the plains are dominated by “black cotton” clay soil. On the slopes and the foot of the hills the soils are laterite and sandy (Willimott 1956). The ecosystem is a bed for major swamps like the Guom swamps in the northern end of BNP. It is also drained with a number of rivers such as the Kangen/Kong-Kong River system, Oboth/Neubari Rivers and the Kuron River up north in BNP; while rivers Veveno and Lotila drain south through BDNP. The entire region is in a watershed that ultimately empties into the Nile River via the Sobat River (Fryxell 1985).

Vegetation of the migrations ecosystem as described by Willimott (1956) comprises the East Sudanian savannah grassland, the Saharan flooded grassland and the Northern Acacia-Commiphora bush land and thickets; while the Victorian basin forest-savannah found on the Boma escarpment in the east. The eastern part of the ecosystem in Boma National Park is covered with woodland dominated by *Combretum* species, while the middle-western flood plains are covered with open tall grassland dominated by *Hyperhenia rufa*, *Sporobolus spp.*, and *Pennisetum spp.* and *Echinoloa spp.* In between these two zones lies an intermediate zone of wooded grassland. The grasslands around the Guom swamps in the north include areas of *Hydrophila spinora*. Around the isolated hills occurs dense thicket dominated by *Ziziphus spina-christi*, *Acacia seyal*, *Acacia drepanolobium*, *Acacia fistula*, and *Acacia zanzibarica*.

## **Materials and Methods**

Data on White-eared kob and other migratory antelope species (tiang *Damaliscus lunatus*, Mongalla gazelle *Eudorcas albonotata* and reedbuck *Redunca redunca*), as well as environmental attributes of the study area, were collected from aerial survey conducted in January-February 2007.

### **Aerial survey**

The aerial survey followed procedures described by Norton-Griffith (1978) and was conducted over a period of 11 days 10-21 February 2007 covering an overall survey area of 220,217.30 km<sup>2</sup> expanding over the Jonglei and Eastern Equatoria States (Fig 1). A total of 91 aerial transects were flown in an east-west and west-east orientation with transect spacing of 10 km (Fig. 2). 5536 transect data points were recorded by GPS during the survey and data recorded into excel spreadsheet.

The census team consisted of four persons on board the Cessna 172 aircraft (one pilot, front seat observer and two rear seat observers). The Pilot flown the aircraft at the height of 300 feet above ground, kept the altimeter reading and announced the start and end of each transect. The rear seat observers identified and counted all animals that seen between two rods fixed on the wing struts at 150 m width and relayed to the front seat observer for recording. The front seat observer recorded animal counts and other environmental attributes seen across all transects. The rod width of 150 m on both sides of the aircraft gives a strip width of 300 m representing 3% observation of the study area. Kobs were counted and noted whether they were in/out of transects as they occurred. Larger and clumped groups were photographed. Other attributes recorded included

vegetation community, water locations, vegetation burnings, livestock and human activities and settlements.

### **Data analysis**

Flight track data (Fig 2.2, Chapter 2) and kobs GPS locations and numbers were entered into ArcGIS 9.3 Data was analyzed using spatial analyst tools and Hawth's tools. Total survey area and kob density/km<sup>2</sup> were calculated. The kob population was estimated by multiplying kob density by the total survey area.

Absence-presence columns for each of the four species were created on the data sheet. The data were then entered into ArcGIS 9.3 and converted into raster format. The environmental attributes including rivers and water points, grassland or woodland habitats, human settlements, roads, etc. were converted into raster format, as well. All files were projected to WGS 1984, Zone 32N. With the use of ArcGIS extension "Join", all the saved raster files were combined into one single file and the output exported and saved into a new file "kob\_joined". The joined file was then used for building a model for the kob distributions and interactions with the other species. The model has been built specifically to predict how the presence/absence of kob might be affected by the other antelope species, habitats, and anthropogenic disturbance resulting from the presence of human settlements in the ecosystem.

Buffers of 1 km, 5 km and 10 km were created around rivers, roads and human settlements by the use of Spatial Analyst extension of ArcGIS 9.3. Random points within the kob locations areas were generated by the use of Hawth's Tools. Distances to point of kob locations from rivers, roads and human settlements were extracted by the use of

Spatial Analyst tools. The extracted values were then entered into logistic regression as independent variables to model and predict their effects on kob distribution.

Vegetation is based on observations during the aerial surveys; vegetation cover was categorized into grassland and woodland. The grassland mix and cover density was categorized into 5 groups:

Grassland (1) 0% vegetation cover = bare ground

Grassland (2) between 0 - 40% vegetation cover = open habitat

Grassland (3) 40-70% vegetation cover = moderately open habitat; and

Grassland (4) >70% cover = dense habitat.

Woodland/wooded grassland = a mixture of grass, shrubs and tree stands

These quantity-based vegetation cover categories were used as predictor variables to model kob distribution and occurrence in these habitats.

### **Statistical analysis**

Statistical analysis given kob as the dependent variable was conducted using frequency tables and chi-square test to explore kob frequency distribution given presence-absence of the other three migratory antelope species. Binary logistic regression is used to develop models for predicting effects of the independent variables (antelope species and environmental attributes) on kob presence-absence. A logistic model was possible to run with Mongalla gazelle only, but was not with tiang and reedbuck because they never coexisted with kob during the dry season period where the survey was done. Finally, a regression test was run to develop models that predicted effects of habitat types (grassland and woodland) on kob distribution. Kob distribution in the grass habitats was tested and a logistic model developed to identify their effects.

Models developed in this study were evaluated for accuracy using the area under the ROC curve (AUC) technique (Russell *et al.* 2007, Early *et al.* 2008, Evangelista *et al.* 2008). The AUC is a measure of probability that a random positive point falls within the predicted range of occurrence and a random negative point falls outside. The strength of predictability ranges from weak to strong (0 to 1.0) (Evangelista *et al.* 2008). An AUC value of 0.5 represents complete random prediction, whereas a value of 1.0 shows perfect discriminatory ability (Evangelista *et al.* 2008). The AUC classification as cited by Russell *et al.* (2007) was used, where:

AUC between 0.5 – 0.7	=	reflects low accuracy
0.7 – 0.9	=	reflects moderate accuracy
> 0.9	=	reflects excellent accuracy

Generating ROC curves was possible only under the cut values of 1.0 and 0, but any other value tried did not work. With the cut value of 1.0 all models performed poorly, but the cut value of 0 worked well throughout.

## **Results**

As recorded from aerial surveys in the plains of Boma National Park and Jonglei in eastern South Sudan, kob and Mongalla gazelles were the most frequently documented species, while tiang and reedbuck were less frequently recorded (Table 6.1).

Kobs were not found in any transect where tiang or reedbuck occurred, meaning that these two antelope species did not coexist with kob during the dry season. Kob did co-occur with Mongalla gazelle, but only at only 9 transect points ( $p < 0.001$ ,  $X^2 = 665.403$ ,  $df = 1$ ).



From the results explained above, the null hypothesis that a kob movement was not affected by the presence of other migratory species was rejected.

The logistic model for kob indicates that the presence of Mongalla gazelles, distance to human settlements, and presence of Grassland (2) open habitat and Grassland (3) moderately dense habitat significantly affect kob presence (Table 6.2). The odds ratios indicate that when gazelle are absent, the chance that kob are present is only 0.011 (95% Wald CL = 0.006-0.022) that of when gazelle are present. Regression coefficients for tiang, gazelles and reedbuck shown in Table (6.2) are negative indicating that these species negatively affect kob presence. Also, Phi Coefficients of the logistic regression (Table 6.3) are less than 1 and  $p < 0.001$  means that the model is strong in predicting the effect of the presence of the other antelope species on the kob presence.

Open habitats of Grassland (2) and Grassland (3) were preferred by kob and thus significant for their distribution ( $p < 0.001$ ). Regression coefficients (Table 6.4) showed that Kob distribution was significantly influenced by overall grass habitats ( $p < 0.001$ ;  $t = -27.853$ ); whereas the wooded habitat was not significant ( $p > 0.05$ ;  $t = -1.396$ ).

Minimum distances or proximity to roads negatively affecting kob distribution ( $t = -71.565$ ,  $p < 0.001$ ), while proximity to river shown favorable to kob distributions ( $p < 0.001$ ) as shown in (Table 6.5).

The models were evaluated with the area under the ROC curves (Figure 6.6) constructed for the kob with the variables for the models. The habitat variables of grass and wood had the largest AUC (Table 6.6), therefore performed excellent and were significant ( $p < 0.001$ ) for kob prediction modeling. Classifications of open and dense grass habitat performed poorly ( $p > 0.05$ ), as did Mongalla gazelle (AUC = 0.5) and the

distance from human settlements (AUC = 0.59), reflecting low accuracy in kob distribution modeling.

## **Discussion**

### **Kob distribution in relation to other migratory antelope species**

Considering the proportion of sites where the four antelope species under this study were found, kob are the most prevalent as evidenced by their wider distribution in the ecosystem than the other three species. Kob may be able to cope well with the harsh environmental conditions and cover long distances during the dry season. The model indicates that kob is "negatively" affected by the other migratory antelopes species present in the kob migration ecosystem in that they rarely co-occur during the time of the survey. Where tiang or reedbuck was present, kob were absent, though, kob co-occurred with *Mongalla gazelles* in some areas. This is an indication of strong negative interspecific competition among these herbivore species. A similar conclusion to this was made by Hobbs *et al.* (1996) on elk and cattle in western USA, by Darmon *et al.* (2012) on mountain ungulates, and by Macandza *et al.* (2012) on tall grass grazers in African savanna.

These four antelope species do, however, have overlapping wet season ranges (Chapter 3); they seem similarly influenced by the habitats conditions that confine them to smaller adjacent but often overlapping areas during the rainy season. But at the onset of the dry season they start migrating to different dry season ranges in different directions. Kob principally move to the east to utilize Guom swamp north of Boma National Park (Chapter 3), while tiang and reedbuck move northwest ward through the plains of Jonglei towards the Sudd swamps. Some groups of kob, however, move

northwest through the plains of Jonglei, similar to the tiang, heading towards the Sudd swamps, and in fact were observed further north than tiang during the aerial surveys (Chapter 5).

Also, some large groups of tiang migrate to Boma National Park but do not reach the Guom swamps where many kob spend the dry season. Rather, they often remain in the southern areas of the Park where there is dry forage and limited water supply. It is not clear as to why this group of tiang confined itself to the southern areas of Boma national Park; perhaps they would be out-competed by the high density of kob in the Guom swamps where there seems to be plenty of forage and water, or maybe they have just restricted themselves to avoid competitive overlaps. Other factors that might be related to the habitat itself such as the quality of the forage in the area might not be preferable to tiang. Also the anthropogenic disturbances such as hunting pressure around the swamps might have affected their distribution behavior. Of all these possible factors, avoidance of competition is consistent with Macandza's *et al.* (2012) conclusion on sable antelope.

The Mongalla gazelle population divides into two during the dry season. Some groups follow kob to the Guom swamps in the east while others head towards the Sudd swamps in the northwest. Hence, they occurred with kobs in some areas within the ecosystem, as shown by the modeling I in this study. The fact that the odds ratio of Mongalla gazelle's occurrence with kob being below zero is an indication that the effects of gazelle on kob is negative, as mentioned earlier. The high Wald statistic value for Mongalla gazelle indicates that the gazelle occurrence is a very important variable for

predicting kob presence-absence distribution. This is supported by the low Phi coefficients described above.

### **Kob distribution patterns in relation to habitats**

It is clear that kob prefer grassland over wooded habitats. This is consistent with findings of Dörgeleh (2006) on tsessebe in Nylsvley Nature Reserve, South Africa. In the kob migration ecosystem woodland habitats occur mostly along some rivers and water courses; otherwise the ecosystem is primarily flooded grassland with wooded species such as *Acacia* and *Balanites* sparsely occurring in some areas. Kob distribution correlates well with grassland due to the kob's preference for open habitats to get to forage and replenish their body energy for the long journey towards the swamps in the dry season ranges. This conforms to the Månsson *et al.* (2012) conclusion that forage availability is an important factor influencing large herbivore distribution. Moreover, the use of open grassland habitats is an anti-predator mechanism (Chapter 4). Smith (2011) shown that resources and reduced predation risks in open habitats influence preference of herbivore species better than dense habitats. This is an indication that grassland is a suitable habitat for predicting kob presence-absence. Deviations from this fact are linked to biotic factors such as competition (Cassini 2011). Thus considering grassland as suitable habitat for kobs concurs with Cassini (2011) who stated that the greater the number of locations in which the species occurs for a given value of an environmental variable, the greater the environmental suitability for that species. Grassland habitat influence on Kob distribution in this study has been taken quantitatively in terms holistic grassland versus woodland categories; therefore, kob occurrence in relation to habitat quality (Cassini 2011) and scales of movements (Johnson *et al.* 2002) should be a focus

of future research. Kob aggregations may also influence their occurrence across habitat at one time or the other, similar to the Månsson *et al.* (2012) conclusion that densities at which herbivore congregate at certain scale could be an incentive for prediction of their occurrence. The influence of habitat on kob distribution model in this study can be useful in planning the conservation of the vast ranges of kob movement areas.

### **Distribution of kob in relation to human settlements**

The logistic model (Table 2) has shown that keeping distances from human settlements are significant for kob distributions. This is particularly important because human settlements represent sources of disturbances to kob populations, mainly in form of hunting during their migrations. Human settlements in the migration ecosystem are mostly small villages and temporary cattle camps. Human populations living in the kob migrations areas are more or less cattle keepers who keep their cattle for traditional values but depend on seasonal hunting (mostly kob) for livelihood. They also migrate with their cattle seasonally to major swamps in search of green forage and water, putting more pressure on kob distribution. The intensity of poaching has risen in the recent decades due to the wide spread of illegally acquired firearms and supply of ammunition, the result of decades-long civil war and insecurity. Thus, it appears that kob have developed the tendency to avoid human settlements. This is similar to other studies (e.g. Syartinilia 2008, Gavashelishvili and Lukarevskiy 2008) which stated that habitat models demonstrate positive association with certain elevation, ruggedness and vegetation types; but negative with proximity to roads and human density. Wang *et al.* (2008) pointed out that lands where there is less anthropogenic disturbance harbor more species. Also improved roads and access openings increase access to hunters (Syartinilia

2008). In contrast to the generality, Pittiglio *et al.* (2012) showed in a logistic model that elephants had a positive association with human settlements and minor roads because elephant tracks water and green vegetation even in proximity to human infrastructures, whereas antelopes tend to avoid humans, regardless of the availability of land resources.

### **Conclusion**

Interactions between environmental variables, species dispersal and active aggregation can play a role in determining species occurrence patterns (Santika 2011). Mongalla gazelle and grassland habitat were the most significant predictors of kob presence and distribution during the January-February dry season. Thus, models developed in this study can predict significant habitats for kob distribution, similar to Evangelista *et al.* (2008). The models developed in this study are the first attempt to develop species distribution models based on absence-presence data and a holistic vegetation map of South Sudan, as well as other attributes in the study area. Thus it is a significant contribution to the knowledge base for and conservation of migratory white-eared kob. Due to lack of research and data on wildlife and habitats in the kob migration ecosystem in South Sudan, these models will contribute significantly to the understanding of the kobs ecology and conservation, but could still be refined with future research studies, especially with regard to the influence of the components and quality of forage (Dörgeloh 2006) in the study area.

### **Management and Policy Implications**

The coefficients for gazelle, tiang and reedbuck are negative values revealing negative interactions and competitions between the migratory kobs and each of these species. Since all the four species are grazers and share overlapping seasonal ranges,

therefore, conservationists and managers should study and address effects of competitions among these antelope species and develop management plans for them.

The positive coefficients for the open grassland habitat indicate positive significance of these types of habitats for the kob migration. However, the coefficient for the overall grassland habitats in the study area was negative due the underlying effects of internal grass habitat components where some areas are open and others are dense and unfavorable for the kobs. This implies that conservation and management plans of the migration should be developed in such a way that to adopt suitable strategies for habitat suitability management that favors kob migration corridors and their seasonal ranges.

The distance from human settlements with small coefficient means that such distances are important for management and conservation of kob migration and wildlife in general. It is therefore, important that conservation managers monitor the distances between human settlements and wildlife areas in order to manage and control human disturbances and poaching. Since the model detects that these animals tend to keep themselves at far distances, thus wildlife conservationists and managers should take into consideration the importance of protecting migration corridors and manage nearest distances for human settlements and activities. Development projects envisioned in areas near to the migration ecosystem should take serious account of migration corridors and seasonal ranges.

Distances to roads with negative coefficients have negative significant effects on the movements of kobs because the migratory kobs tend to avoid roads due to the associated disturbances caused by activities of humans using such roads. Therefore,

conservation plans should take serious concerns to manage effects of roads crossing through wildlife areas and corridors.

The coefficient for the distances to rivers showed positive significance of kob's movements association with water bodies. Therefore the conservation of water courses along kob migration routes should be taken in to consideration in the management plans of the landscape harboring the kob migration.

### **Literature cited**

Baasch, D. M., Tyre, A. J., Millsbaugh, J. J., Hygnstrom, S. E. and Vercauteren, K. C.

(2010). An evaluation of three statistical methods used to model resource selection. *Ecol. Modelling*, 221: 565-574.

Cassini, M. H. (2011). Ecological principles of species distribution models: the habitat matching rule. *J. Biogeogr.*, 38: 2057-2065.

Darmon, G., Calenge, C., Loison, A., Jullien, J-M., Maillard, D. and Lopez, J-F. (2012).

Spatial distribution and habitat selection in coexisting species of mountain ungulates. *Ecography*, 35: 44-53.

Dörgeleh, W. G. (2006). Habitat suitability for tsessebe *Damaliscus lunatus lunatus* Afr.

*J. Ecol*, 44: 329-236.

Evangelista, P. H., Norman III, J., Berhanu, L., Kumar, S. and Alley, N. (2008).

Predicting habitat suitability for the endemic mountain nyala (*Tragelaphus buxtoni*) in Ethiopia. *Wildl. Res.*, 35: 409-416.

Fryxell, J.M. and A. Sinclair. (1988). Seasonal migration by white-eared kob in relation

to resources. *Afr. J. Ecol.*, 26: 17-31.



- Garson, G. D. (2012). *Logistic regression: Binary and multinomial*. Statistical Publishing Associates. North Carolina State University.
- Gavashelishvili, A. and Lukarevskiy, V. (2008). Modelling the habitat requirements of leopard *Panthera pardus* in west and central Asia. *J. Appl. Ecol.*, 45: 579-588.
- Gibson, L. A., Wilson, B. A., Cahill, D. M. and Hill, J. (2004). Modelling habitat suitability of the swamp Antechinus (*Antechinus minmus maritimus*) in the coastal heathlands of southern Victoria, Australia. *Biol. Conserv.*, 117: 143-150.
- Graham, C. H., Elith, J., Hijmans, R. J., Guisan, A., Peterson, A. T., Loiselle, B. A., and the Nceas Predicting Species Working Group. (2008). The influence of spatial errors in species occurrence data used in distribution models. *J. Appl. Ecol.*, 45: 239-247.
- Hamer, T. E., Varland, D. E., McDonald, T. L. and Meekins, D. (2008). Predictive model of habitat suitability for the Marbled Murrelet in Western Washington. *J. Wildl. Manage.*, 72: 983-993.
- Hobbs, N. T., Baker, D. L., Bear, G. D. and Bowden, D. C. (1996). Ungulates grazing in sagebrush grassland: Mechanisms of resource competition. *Ecol. Applications*, 6: 200-217.
- Jewell, K. J., Arcese, P. and Gergel, S. E. (2007). Robust prediction of species distribution: Spatial habitat model for a brood parasite. *Biol. Conserv.*, 140: 259-272.
- Johnson, C. J. and Gillingham, M. P. (2008). Sensitivity of species-distribution models to error, bias and model design: An application to resource selection functions for woodland caribou. *Ecol. Modelling*, 213: 143-155.

- Johnson, C.J., Parker, K. L., Heard, D. C. and Gillingham, M. P. (2002). Movement parameters of ungulates and scale-specific responses to the environments. *J. Anim. Ecol.*, 71: 225-235.
- Jones, J. P. G. (2011). Monitoring species abundance and distribution at the landscape scale. *J. App. Ecol.*, 48: 9-13.
- Keating, K. A. and Cherry, S. (2004). Use and interpretation of logistic regression in habitat selection studies. *J. Wildl. Manage.*, 68: 774-789.
- Macandza, V. A., Owen-Smith, N. and Cain, J. W. (2012). Dynamic spatial partitioning and coexistence among tall grass grazers in an African savanna. *Oikos*, 121: 891-898.
- Månsson, J., Bunnefeld, N., Andren, H. and Ericsson, G. (2012). Spatial and temporal prediction of moose winter distribution. *Oecologia*, 170: 411-419.
- Meisingset, E. L., Loe, L. E., Brekkum, O., Van Moorter, B. and Mysterud, A. (2013). Red deer habitat selection and movements in relation to roads. *J. Wildl. Manage.*, 77: 181-191.
- Newton-Cross, G., White, P. C. L. and Harris, S. (2007). Modeling the distribution of badgers *Meles meles*: Comparing predictions from field-based and remotely derived habitat data. *Mammal Rev.*, 37: 54-70.
- Pittigilio, C., Skidmore, A. K., van Gils, H. A. M. J. and Prins, H. H. T. (2012). Identifying transit corridors for elephant using a long time-series. *International J. Appl. Earth Observ. Geoinform.*, 14: 61-72.
- Quinn, G.P., and Keough, M.J. (2002). *Experimental design and data analysis for biologists*. Cambridge University Press, UK. 537 pp.

- Russell, R. E., Saab, V. A. and Dudley, J. G. (2007). Habitat suitability model for cavity-nesting birds in a postfire landscape. *J. Wildl. Manage.*, 71: 2600-2611.
- Santika, T. (2011). Assessing the effect of prevalence on the predictive performance of species distribution models using simulated data. *Global Ecol. Biogeogr.*, 20: 181-192.
- Singh, N. J. and Milner-Gulland, E. J. (2011). Conserving a moving target: planning protection for a migratory species as its distribution changes. *J. Appl. Ecol.*, 48: 35-46.
- Smith, I. P. J. (2011). Resources driving landscape-scale distribution patterns of grazers in an African savanna. *Ecography*, 34: 67-74.
- Syartinilia, S. T. (2008). GIS-based modeling of Javan Hawk-Eagle distribution using logistic and autologistic models. *Biol. Conserv.*, 141: 756-769.
- Wang, C., Liu, Y. and Axmacher, J. C. (2009). Habitat-GIS-based models for ground beetles (*Coleoptera carabidae*) distribution in agricultural landscape. *Proceedings of the 17<sup>th</sup> International Conference on Geoinformatics*, Fairfax, VA. Digital Object Identifier: 10.1109/GEOINFORMATICS.2009.5293477

Table 6.1. Overall frequency of occurrence of white-eared kob and other migratory antelopes at transect points during an aerial survey in eastern South Sudan, January-February 2007.

Species	N	Present	Absent
		%	%
White-eared kob	5536	28.8	71.2
Tiang	5536	5.6	94.4
Mongalla gazelle	5536	23.8	76.2
Reed buck	5536	5.3	94.7

Table 6.2. Coefficients of the logistic regression models of the white-eared kob presence-absence data collected from aerial survey of the kob migration ecosystem in South Sudan.

Variable	$\beta$	S.E.	Wald	df	p-Value
Mongalla gazelle	-4.47	0.336	177.008	1	<0.001
Tiang	-20.378	2290.207	0	1	NS
Reed buck	-20.374	2348.098	0	1	NS
Distance to human settlements	0.138	0.04	11.71	1	0.001
Grassland-2 open habitat	3.175	0.254	155.656	1	<0.001
Grassland-3 moderately dense habitat	3.717	0.381	95.003	1	<0.001

Table 6.3. Phi coefficients and their statistical significance for the logistic model of kob by other migratory antelopes (n = 5536).

Variable	Phi Coefficient	df	p-value
Mongalla gazelle*kob	-0.3467	1	<0.001
Reedbuck*kob	-0.1503	1	<0.001
Tiang*kob	-0.1543	1	<0.001

Table 6.4. Coefficients of regression models for the effects of grassland and woodland habitats on kob distribution.

Variables (habitat)	Unstandardized Coefficients		Standardized Coefficients			95% CL for B	
	$\beta$	S.E.	Beta	<i>t</i>	<i>P-value</i>	Lower Bound	Upper Bound
(Constant)	0.381	0.007	-	57.984	0.000	0.368	0.394
Grassland	-0.001	0.000	-0.353	-27.853	<0.001	-0.001	-0.001
Woodland	-0.001	0.001	-0.018	-1.396	0.163	-0.003	0.001

Table 6.5. Coefficients of regression model for the model for the effects of minimum distance to rivers and roads on the migration of White-eared kob.

Model	Unstandardized Coefficients		Standardized Coefficients		Sig.	95.0% C.I. for (B)	
	B	Std. Error	Beta	t		Lower Bound	Upper Bound
(Constant)	0.800	0.001		810.956	0.000	0.798	0.802
Distance to road	0.000	0.000	-.135	-71.565	<0.001	0.000	0.000
Distance to river	0.000	0.000	.049	25.954	<.001	0.000	0.000



Table 6.6. Area under the ROC for the kob logistic models performance.

Test Result Variable(s)	Area	Std. Error	Asymptotic Sig.b	Asymptotic 95% C. I.	
				Lower Bound	Upper Bound
Tiang	0.50	0.07	1.00	0.37	0.63
Mongalla gazelle	0.50	0.07	1.00	0.37	0.63
reedbuck	0.50	0.07	1.000	0.37	0.63
Grass	0.95	0.03	0.00	0.00	1.00
Wood	0.93	0.04	0.00	0.84	1.00
Distance to human settlements	0.60	0.07	0.16	0.46	0.73
Distance to road	0.57	0.07	0.32	0.43	0.70
Distance to river	0.55	0.07	0.48	0.41	0.68
grass_2	0.61	0.07	0.09	0.48	0.75
grass_3	0.56	0.07	0.37	0.42	0.70



Figure 6.1. Environmental attributes potentially influencing white-eared kob distribution in eastern South Sudan.

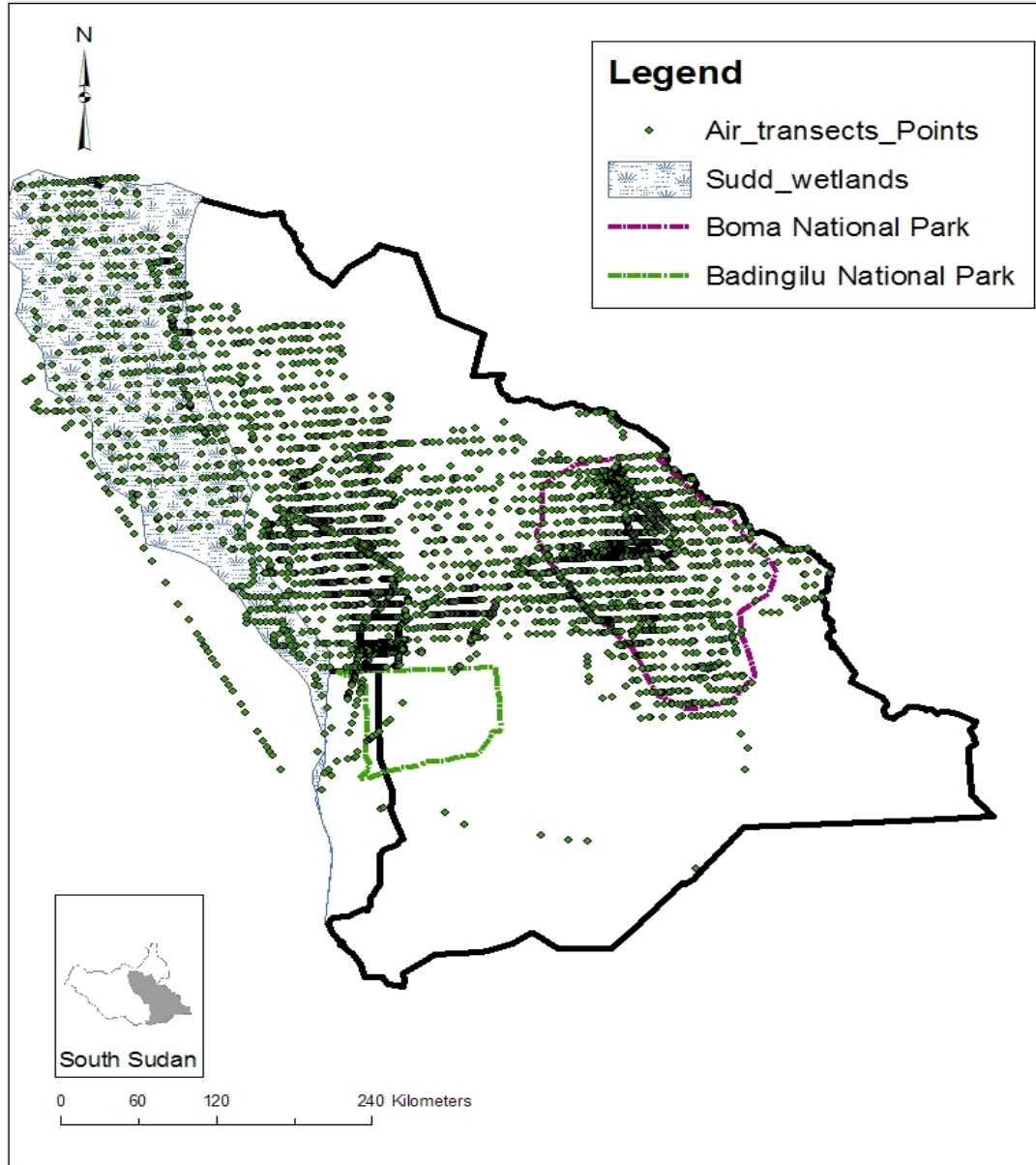


Figure 6.2. Showing the aerial survey transect points with observations on the distribution of kob and other species, with the environmental attributes collected during the survey.

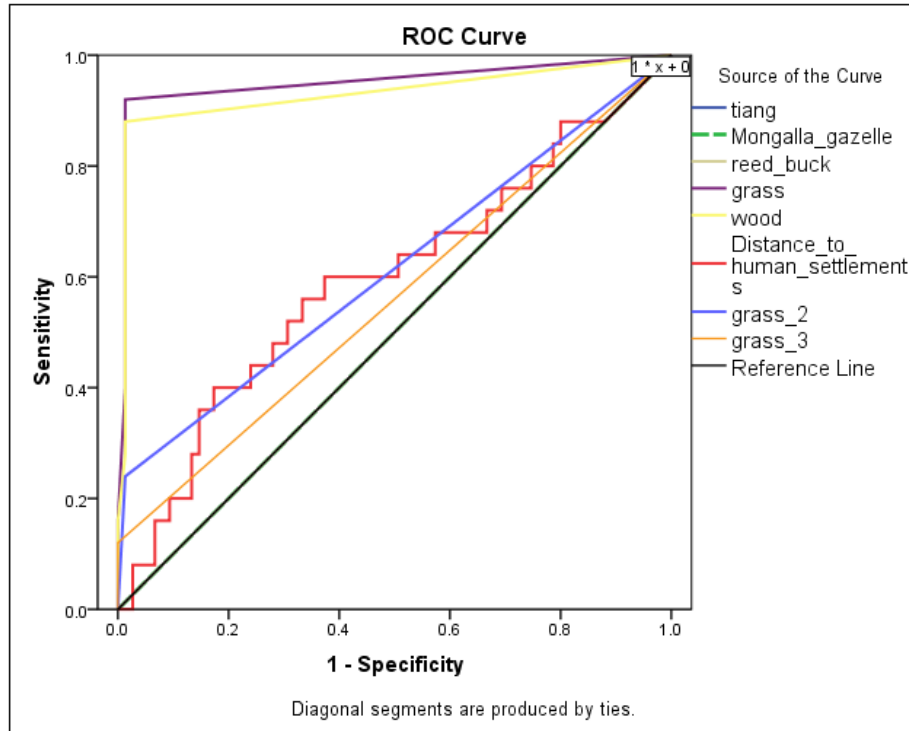


Figure 6.3. ROC Curves for the logistic models for the white-eared kob,

## CHAPTER 7

### HUMAN IMPACT ON THE WHITE-EARED KOB MIGRATIONS

#### **Abstract**

This chapter explores and presents an assessment of households living in/around the Boma National and their interactions and impact on the kob migrations. This includes the characteristics, types and status of households, and their social and cultural settings. The socio-economic activities, including agriculture, livestock rearing, fishing, hunting and gathering are assessed, and the positive and negative impacts they exert on the migration of kob are assessed. Finally conservation and management actions are put forward to develop comprehensive action plans for the coexistence of kob, Boma Park, and the people who live there.

#### **Introduction**

The migratory white-eared kob (*Kobus kob leucotis*) pass near villages and human settlements during the course of their seasonal movements whereby they come into closest contact with people and livestock during the dry season, especially in water and in grassy areas where they are hunted for food. The Kob migration ecosystem overlaps with areas that have seen some of the worst impacts of the South Sudan liberation war (1983-2005). War impacts such as movements of troops, massive human displacements, counter insurgencies, etc. expose kobs to negative activities, including indiscriminate killing, putting heavy pressure on the kob population and it was thought their population must have been severely reduced.

However, recent aerial surveys conducted in the kob migration ecosystem areas suggested that kob and other migratory antelope species thrived despite the fact that they have been severely hunted for food over the period of war (1983 – 2005).

The migratory kobs have provided the indigenous peoples living within their ecosystem with food through seasonal hunting and other traditional uses for centuries. This has been documented in previous studies carried out in the area, also documented by the British Colonial Administrators in their reports and books as well as in the pre-colonial European Explorers' writings. Some of these studies and reports include Deng *et al.* (2001), Fryxell (1985), Mefit-Babtie (1983), Lewis (1972). But in light of the current changes in the landscape and political ecology of South Sudan, the dependency of the indigenous communities on wildlife for their livelihood in and around Boma National Park has increased tremendously (Deng *et al.* 2001). Previous studies in other areas have warned of consequences of excessive illegal hunting, one example is Bennett (2002) who used the situation in the Asian as an example and warned that over hunting over long periods, except perhaps in remote forest areas, even small birds and small mammals may become extinct.

There have been a number of studies on community wildlife use and conservation carried out in other countries. These studies have agreed that providing benefits from wildlife to communities living around protected areas can safeguard the future of wildlife in such areas (Ezebilo 2010, Leon and Monteil 2008, Bouare 2006, Kaltenborn *et al.* 2005, Kiss 2004, Stem *et al.* 2003, Fortin and Gagnon 1999, Kahurananga and Silkiluwasha 1997).

The Boma National Park (Fig 7.1) was established in 1978, for the protection of the White-eared kob migration especially during the dry season movements. However, the Park has never been developed due to insecurity and instability that resulted from the protracted civil wars and counter insurgencies in the area. Necessary Park infrastructures such as road networks have not yet been constructed in the Boma National Park despite the fact that some millions of donor money have already been spent there. Park staffs are all of military background who have little or no training in wildlife management. The areas surrounding the park lacks economic development, crop cultivation is still a peasantry practice and food production has always been insufficient; and thus the indigenous people living in the area depend on poaching in the park especially during kob migration seasons; and gathering of wild food plants (non-timber forest products) for their livelihood. However, it is important to be noted that no subsistence hunting is allowed within the national park, and hence their continuing subsistence practices are considered to be “poaching” by the national park authorities. Kob skin has also been used traditionally for clothing and sleeping mats as well as other traditional uses in the area<sup>1</sup>.

People who live within the Boma Park’s boundaries have been there before even the establishment of the Park was proposed and they have never been relocated afterwards. Some of their villages inside the park boundary, such as Maruwa, have been elevated to Payam (District) level.

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<sup>1</sup>Similar to the case of kob in Boma, migratory species especially the wildebeest, form the bulk of herbivores hunted around Serengeti (Ndibalema and Songorwa 2007).

However, it is important to be explained that the South Sudan Protected Areas and Wildlife Conservation Laws prohibit settlements and uses of resources inside national parks. Therefore, the settlements within the boundaries of the Boma National park are illegal, once the area was designated a park they should have been relocated or else other options of Protected Areas categories be considered. Accordingly the continuing customary uses of natural resources although are not allowed inside the national park (in paper only) should be enforced, or else the designation of the park be reconsidered. And finally under the present governance arrangement for the national parks participation by resident peoples is not allowed! It is strictly government. This should be well considered in the current policy and laws development process such that peoples' participation is accommodated and harmonized with the principles of people and land ownership.

The current protected areas and wildlife conservation policy has provisions for the development of regulation of the relationships between communities, their rights and obligations with respect to wildlife and protected areas, but it is yet to be implemented. Because of the absence of community conservation and awareness programs, the relationship between communities and the Park administration so far has been restricted to policing.

Traditionally rural people in South Sudan used wildlife for food, but under the conditions of the armed civil strife, peoples' dependency on wildlife has increased to more than 60% of their livelihood in Boma (Deng *et. al.* 2001). Previous studies in other areas showed that hunting has cultural roots and thus is not just the killing of animals for food and other subsistence purposes. For example Kaltenborn *et al.* (2005) stated that hunting is driven by the need not only to increase food supply and cash income but also



to fulfill cultural and social needs. He further suggests that hunting by community members is deeply rooted in the community life, and even if social services in communities improved and individuals had improved access to food and cash, hunting would still exist (Leon and Moteil 2008, Kaltenborn *et al.* 2005) this is also true in South Sudan both for residents and for others. Before the latest civil war with the Sudan government, for example, merchants and senior government officials used to hunt and eat wildlife meat even though they have sufficient food at their homes. These practices were for prestige and business, and often used to go beyond limits of hunting permit those days.

In 2011 South Sudan gained independence from the Republic of Sudan and, as a result, began to benefit from hefty oil revenues while it still continued to face many economic and political challenges that are actually affecting wildlife conservation efforts. The government of South Sudan has enormous tasks to undertake including: 1) the establishment of peace and good governance, 2) provision of food security, 3) resettlement of an estimated 3-5 million returning refugees and internally displaced people to their original homes; and 3) extraction of resources such as oil to drive the otherwise non-existent economic development in the new country. Resettlement and land use are of the most interest with regard to the conservation of kob migration. Due to anticipated increase in human settlements near wildlife reserves and with imminent pressure on land use from potential privatization demands for land by investors and

indigenous people, as well as land grabbers<sup>2</sup>, it is probable that wildlife populations in the area will decline significantly (Lamprey and Reid 2004)

Historically, South Sudan's wildlife resources not only played a crucial role in the provision of food alternatives, particularly in rural areas, but were also once an important source of income for the then Regional Autonomous Government of Southern Sudan (1972 – 1983) through sport hunting. This was especially true during the 1970s where the wildlife authorities used to set up hunting blocks in many places across the Southern Sudan Region, some of which were near protected areas. Neither the ecological nor economic impacts of these sport hunting activities have been evaluated, and remain important areas for future research. Other economic use options such as ecotourism are yet to be tested. It seems likely that, if well conserved and managed, the kob migrations could potentially generate sufficient revenues to reinvigorate the rural economy and contribute to sustainable development in South Sudan in addition to today's oil revenues, which currently accounts for about 98% of the national income.

Recently the government of South Sudan enacted a new policy for wildlife conservation to fill the long existing gap in wildlife conservation policy. But the gap in data and information on human impacts on wildlife populations remains a challenge. This study will contribute to the knowledge on the human impact on the kob migration and

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<sup>2</sup> Studies conducted by the Norwegian Peoples' Aid (NPA) revealed cases of grabbers taking huge chunks of land illegally from individuals without following proper procedures.

help addresses the conservation and management needs of kob from the human dimension.

This research has been designed to investigate the needs of local people for food security (subsistence hunting, gathering or grazing livestock) through sustainable use and participation in the management of Boma National Park and its surroundings, to ensure the conservation of one of the greatest antelope migrations on earth. It is anticipated that this study would contribute to a new national park management plan and the introduction of the participatory concepts that would harmonize the needs of the people with those of wildlife migrations that share a common landscape or ecoregion. Results from this study would help in the development of recommendations for the government of South Sudan to design policies which would balance the, much needed, economic development and the wildlife conservation needs in the area.

### **Objectives**

1. To assess the characteristics of households in/around Boma National Park, including their status and their effects on the kob migrations.
2. Assess the socio-economic activities/status of the households in the study area.
3. Assess the current level of households' dependency on hunted meat as a primary source of protein.
4. Assess the effectiveness of South Sudan's conservation policy in the protection of kob migration.
5. To assess hunting mortality and its long term effect on the conservation of kob.

## **Study area**

This study was conducted in 16 villages occurring in and around the Boma National Park, 6 in Pibor and 10 in Pochalla counties administrative authorities. This area represents the dry season range for the kob migration and it is the area where kob come into the closest contact with human beings. They generally remain here from December to April before they head back to their wet season range in the south-west.

The Boma National Park (Fig 7.1 and Fig 7.2) was established in 1978 for the protection of the White-eared kob migration, especially in the dry season. Geographically the larger portion of the park falls in the Pibor and Pochalla Counties of Jonglei State, while a (smaller) southern part falls in the Kapoeta East County of the Eastern Equatoria State. Pibor County forms the largest portion of the park's area and it is the entry and exit points for kob migration into the park. It is inhabited by the Murle, Kachipo and Jie communities. Pochalla County covers the northern part of the park encompassing the Guom Swamps (wetlands) where kob spend the dry season. It is inhabited by the Anuak community who earn livelihood from the Guom Swamps. Human population size in both counties is shown in Table (7-1). Communities from these administrative areas live in and around the park. In fact, when the park was proposed and gazetted in the late 1970s many villages already existed within its boundaries and they are now slowly growing into towns. The Murle and Anuak communities interact directly with the migratory kob throughout the dry season. The Murle also migrate seasonally with their cattle to Guom swamps in search of water and green forage. To the south are the Jie; and Kachipo are in the east up on top of the Boma plateau, about 12 km east of

the Park boundary. These latter two groups make expeditions to intercept the kob migration in the park to make their livelihood through hunting.

The mean annual rainfall in the area ranges from 400-1,400 mm as indicated by the nearest meteorological station at Juba International Airport (Fig 2.2, chapter 2). The mean monthly temperature is 36° C during the dry season and 28° C during the wet season; relative humidity is highest during the rainy season.

Topography of the area is mostly flat with scattered isolated hills in addition to the Boma escarpment. Most of the plains are dominated by “black cotton” clay soil. On the slopes and at the foot of the hills the soils are laterite and sandy (Willimott 1956). The ecosystem is a bed for major swamps including the Guom swamps at the northern end of Boma National Park. It is also drained by a number of rivers including the Kangen/Kong Kong River system, Oboth/Neubari Rivers and the Kuron River in the north of Boma National Park. The rivers Veveno and Lotila drain south through the Badingilu National Park. The entire region is in a watershed that ultimately empties into the Nile River via the Sobat River (Fryxell 1985).

Vegetation of the migration ecosystem (Fig 7.1) comprises the East Sudanian savannah grassland, Saharan flooded grassland and the Northern *Acacia-Commiphora* bush land and thickets. The Victorian basin forest-savannah is found on the Boma escarpment in the east. The eastern part of the ecosystem in Boma National Park is covered with woodland dominated by *Combretum* species, while the middle-western flat flood plains are covered with open grassland dominated by *Hyperhenia rufa*, *Sporobolus spp.*, and *Pennisetum spp.*, and *Echinoloa spp.* In between these two zones lies an intermediate zone of wooded grassland. The grasslands around the Guom swamps in the

north include areas of *Hydrophila spinora*. Around the isolated hills occurs dense thicket dominated by *Ziziphus spin christi*, *Acacia seyal*, *A. drepanalobium*, *A. fistula*, and *A. zanzibarica* (Willimott 1956).

In 2007 the Ministry of Environment, Wildlife Conservation and Tourism in South Sudan signed a Memorandum of Understanding with the New York based Wildlife Conservation Society (WCS) to work in and help the development of Boma National Park. The US government has been providing funds for this partnership as part of its development assistance to the Government of South Sudan. The United Nations Development Program (UNDP), as part of its assistance to the government of South Sudan, has been disbursing funds from the Global Environment Facility (GEF) to WCS for development of three national parks in South Sudan including Boma. Earlier in 1980s the Frankfurt Zoological Society had started development project in Boma National but their program was halted by the civil war in 1982. Between 1999-2007 the New Sudan Wildlife Society (NSWS), the Catholic Relief Services led consortium with Winrock International and VSF Belgium; VSF Germany and the Sudan Relief and Rehabilitation Association implemented various conservation related projects in response to resolution of the Boma Wildlife Workshop 2001 organised by the NSWS. These projects were funded by USDA/USAID included a hospital, a primary school, water boreholes, micro-credit, wildlife training center and livestock health campaign. Merlin joined later to provide health service and managed to upgrade Boma primary health clinic to a rural hospital with wards and theatre serving the entire Pibor area till the time of Yau Yau rebellion.

During the National Population Census conducted in the Sudan in 2008/09 prior to South Sudan independence, the Jonglei State, where kob migrations have the most contact with humans, was determined to be the most populous state with 1,358,602 residents (Population Census Council 2009). Population Statistics for all of the counties surrounding Boma National Park are summarized in Table (7.1).

Boma National Park staff and ranger forces face challenges that seriously hamper their work. These challenges include:

- 1 Harassment by the local SPLA army soldiers in the area.
- 2 Lack of reinforcement with additional forces from the Ministry Headquarters especially during kob migration season.
- 3 Lack of patrol equipment
- 4 Lack of mobility means e.g. cars, motorcycles, and boats. The few cars supplied by the Ministry are usually reserved for the senior officers residing in Boma Town, while the patrol posts far in the Park have nothing.
- 5 Lack of mobile communication equipment.
- 6 Shortage of food, dry ration and other field provisions.
- 7 Lack of tents/mobile houses for shelter.
- 8 Lack of training and funds for community-based conservation program activities.

## **Theory**

In this study the households were separated in two geographic groups of Pibor and Pochalla Counties. Larger portion of the Boma Park's area is contained within Pibor and it's the gate where migratory kobs enter the Park in the dry season and leave through it also. Murle is the largest community inhabiting Pibor and most important in relation to conservation of kob due to their poaching and grazing activities. Pochala on the other hand, covers northeastern parts of the Parks and inhabited by the Anuaks. Who are agro-pastoralists practice some crop cultivations and fishing but also depend on kobs for food. These are the major groups of human populations that have major impacts on the migratory kob population in the dry season ranges. They are different tribes, different livelihood patterns, and one would expect that they have different behavior patterns with respect to their interactions with the Kob. And therefore management and conservation plans should tackle them in different fashions. For example a program that would suit Anuak well many not work with the Murle; and so forth with the Jie and Kachipo.

## **Methods**

### **Household Surveys**

With the assistance of four officers from the staff of the Ministry of Tourism and Wildlife Conservation we interviewed 200 households using a semi-structured questionnaire (Deng *et al.* 2001, Ite 1996) in August 2011. The study was carried out in villages within and around the Boma Park, 6 villages in Pibor County side in the west and 10 in Pochalla County side in the north (Table 7.4, Fig 7.2). Where it was needed, the interview team used interpreters from the respective communities to help in translation. Some of the interviewers and interpreters have actually participated in the surveys we



have conducted earlier in 2001 in Boma and other national parks. I trained the Field Assistants on the questionnaire and interview procedures and familiarized them with the IRB procedures. Steps on how to obtain consent, how to safeguard confidentiality and privacy was followed.

A household is defined as a group of people living in one place and share the same pot for livelihood. Due to the polygamous nature as well as the constant mobility of men in rural areas of South Sudan, household head can also be assigned to be the mother in a family. Accordingly a family with five wives will be considered five households and so forth. This is the system used by the World Food Program, for their relief program “Operation Lifeline Sudan” (1998-2005) during the civil war. It has also been adapted by other humanitarian organizations operating relief programs in South Sudan.

Households were selected randomly from each village. The first village household to be interviewed was selected at random. Every third (3rd) household on the right hand direction was then selected for the subsequent interviews.

During the interviews household types and sizes, occupation and education levels were discussed. Local dependency on the park’s resources was then assessed. Pair-wise and bean pile<sup>3</sup> ranking procedures was used to rank the periods of the year during which,

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<sup>3</sup>This method is used by WFP and relief NGOs operating in Sudan; due to high illiteracy in the rural areas there, when food security monitors go to the villages for assessment they put 100 beans on the ground and ask household head to divide this bean pile

communities depend on meat and other non-timber food sources obtained from the park; also the percentage of non-meat vegetable grains and meat consumption by the household. Household members were asked about wildlife trends and movements as they may have valuable historical information based on their observations. Land use within the park as well as peoples' attitudes towards the park were also discussed and documented. Accordingly livelihood activities such as farming, fishing, and possession of land, livestock, walking time and distances to hunting ground, hunting seasons, and hunting gear were assessed.

Efforts were made to identify people who hunt kob and to survey them to identify the methods, tools, seasons and the usual areas of hunting, as well as the number of animals they usually harvest per hunting expedition and throughout the year. Additional survey questions focused on their willingness to accept change in the status of the area and shift from hunting to other forms of livelihoods; and their perceptions for such changes have been asked and noted.

### **Analysis**

A total of 200 households were interviewed. However, 5 were removed from analysis, due to incomplete data leaving a sample of 195. These households chose not to cooperate with the survey due to lack of trust or fear of the local tension that was building up in the area. 118 (61%) respondents were male and 77 (39%) female. The gender

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according to the situation of food available in their households in accordance to what is available and what is needed.

distribution by county was as follows: Pibor 71% to 29% male/female, while in Pochalla the ratio was almost 50=50 (Table 7.2).

Data from the questionnaire were entered into SPSS PASW vr. 18 database and saved for analyses. Descriptive statistics (Frequency procedure) were used to summarize the properties of the dataset. Inferential tests one-way ANOVA test and Chi-square test were computed to analyze and interpret differences in responses among the respondents and villages surveyed. The 95% *CL* of significance was used in reporting the statistical analysis.

### **Limitations**

My long time work and association with with the people especially during the war time; and the fact that some of the interview questions are obviously sensitive, thus let to my judgement to depend on Field Assistants as much as possible to clear out chances of bias that my personality would create. For these reasons and because the area was politically charged, it is still highly likely that some people were not frank and open about sharing information and views in sensitive matters that came up during the interviews.

At the beginning of the surveys the household members of Pibor County were suspicious of the information needed in the questionnaires and intention behind it, because of the insecurity that was hitting the area. But after 1-2 days of discussions, they gained confidence in the team and therefore, the surveys were completed. So the first five questionnaires which explained above did not succeed in obtaining the targeted information and consequently were removed from the analysis. The initial 5 households were reluctant to answer a number of the survey questions due to their suspicions.

Originally, a participatory workshop was planned to be held later, after data analysis, to validate results. Unfortunately, this workshop could not be held due to the David Yau Yau rebellion and the subsequent disruption, death and destruction.

Practical difficulties resulted from insecurity due to the intertribal fights and rebellions which have resulted from cattle rustling, local politics and election politics within the Pibor County and the Jonglei State. This has rendered additional planned work impossible. In mid 2009 I thought it would be appropriate to conduct the questionnaire surveys right after the collaring operations when the GPS collars were deployed on the kob, so that socio-economic data collected from the household might be compared with corresponding environmental data collected with the GPS on kobs. Collaring was done in late August 2009 and the survey was to be conducted in 2010. But 2010 became the year of elections, the first to be held since 1980 and under a new type of political dispensation in the region. The election experience was not easy in Jonglei State where some candidates (including David Yau Yau of the Pibor County) rejected election results and waged rebellion against the government. This was not resolved until mid-2011, and we could begin conducting household survey only after that. The project team began surveying in August 2011 during the rainy season, in two areas (Pibor and Pochalla) which were accessible by air. After to the State by air the survey work was done by walking on foot between villages.

The other two areas (Lower and Upper Boma) were to be surveyed during the dry season of 2012, but unfortunately, in Christmas, a tribal conflict between Nuer Lou and Murle was sparked by cattle raiding and abduction of women and children. Nuer youth militia marched into Pibor Town, prompting a counter rebellion of Murle that has spread

throughout the Pibor County. The Murle rebel demands included breaking away from the Jonglei State to have an administrative state of their own. While waiting for the situation to be resolved, the Nuer rebellion against the government arose in December 2013 led by the sacked former Vice President of the Country. This conflict quickly engulfed the Jonglei State among others. In the wake of these events it is now impossible to complete the study in the way it was originally designed and the results presented below is based on the data collected to date.

## **Results**

### **Sex of the respondents**

Out of the 195 valid interviews, 61% were with males and 39% with females across the two study sites. Distribution of the respondents by county and village levels is shown in Table (7.2, 7.3 and 7.4).

### **Respondents' occupation**

Respondents' occupations (Figure 7.3) were distributed significantly different between the two counties ( $\chi^2 = 32.558$ ,  $df = 12$ ,  $p = 0.001$ ). People interviewed in the Pibor area of the Park spanned ten different professions while the Pochalla side showed thirteen professions. The majority in both areas was farmers, Teachers and soldiers were the next most frequent responses for Pibor. Housewives were the second most frequent occurrence in Pochalla.

### **Types of household**

From Fig (7.4) the majority of the respondents indicated that their households are of the extended family type which are made up of husband, wife, own children and other related children and adults. On the other hand the nuclear family type where husband,

wife and their own children occurs less frequently in both of the study areas. There was no significant difference between the two study sites in this regards ( $\chi^2 = 1.26$ ,  $df = 1$ ,  $p > 0.05$ ). However Fig (7.5) shows that customs and traditions were strong reasons for the phenomenon of the extended families in these communities ( $\chi^2 = 9.796$ ,  $df = 1$ ,  $p = 0.002$ ). However, a good number of respondents mentioned war effects also as a cause for the extended family.

### **Wealth status**

Households were asked, how does the community describe their households' wealth status? A large number of the respondents reported being poor<sup>4</sup> in Pochalla while in Pibor the response was about 50-50 (Fig 7.6 & 7.7). However, there was a significant difference in the reported household wealth status between the respondents in the two study sites according to the way they were being described locally by their communities ( $\chi^2 = 6.519$ ,  $df = 2$ ,  $p < 0.05$ ), but there was no significant difference in the way they described their own wealth status by themselves ( $\chi^2 = 3.807$ ,  $df = 2$ ,  $p > 0.05$ ).

### **Children attending School**

Respondents in both areas indicated that few boys (Fig 7.8) ( $\chi^2 = 17.555$ ,  $df = 11$ ,  $p = 0.092$ ) and even a fewer number of girls (Fig 7.9) ( $\chi^2 = 20232$ ,  $df = 13$ ,  $p = 0.09$ ) from households attend Schools. Reasons mentioned for children not attending school (Fig 7.10) were significant for both areas ( $\chi^2 = 15.185$ ,  $df = 7$ ,  $p < 0.05$ ). Such reasons in order of importance included domestic work, lack of schools, engagement in livestock management and at times children are not interested in going to School.

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<sup>4</sup> Poverty was defined by residents as not enough cattle wealth, few wives or children.

### **Displacement during the war period**

Most household members in Pochalla have been displaced from their home during the 22 years of wartime (Fig 7.11), while those from Pibor mostly remained at their places. Those who got displaced indicated that their household moved to the major towns in the country and others even crossed the borders to seek refugee status protection in the neighboring countries (Fig 7.12).

### **Sources of risks face by the households**

On the households response about the sources of risks that disturb or threaten the households in their daily lives at home (Fig 7.13) there was no significant difference in the responses from the two areas ( $\chi^2 = 5.700$ ,  $df = 5$ ,  $p > 0.05$ ). Major sources of risks in both areas were tribal fights and cattle rustling. A good number of respondents, especially in Pibor area, indicated that they have lost some members of their household in recent tribal fights as well as cattle rustling raids (Fig 7.14). However, severe droughts and diseases also affect households in the Pibor area, while risks from floods and human causes are more pronounced in Pochalla.

### **Involvement of household in food crop cultivation**

Households were asked: Were they involved in cultivation? Overall, 85% of households indicated that they were involved in agricultural production (Fig 7.15). However, there was significant difference between responses of the two study sites ( $\chi^2 = 4.921$ ,  $df = 1$ ,  $p < 0.05$ ). They also differed significantly in the types of crops they grow ( $\chi^2 = 4.908$ ,  $df = 1$ ,  $p < 0.05$ ) with 55.9% of households grow sorghum in Pochalla area and 44% grow maize cultivation in Pibor area (Fig 7.16). Respondents indicated they sell or exchange of crops cultivated by their households in order to obtain other food types

such as meat mostly happens in Pibor area (48%) (Fig 7.17), while respondents in Pochalla (30%, Fig 7.17) have less exchange of crops ( $\chi^2 = 9.271$ ,  $df = 1$ ,  $p < 0.01$ ).

Households were asked: How many months, on average, would the yearly agriculture produce sustain their household livelihood? Respondents indicated that what they cultivate can mostly support their households for a period of two to four months in Pibor and three to five months in Pochalla areas (Fig 7.18); and there was significant difference in their responses ( $\chi^2 = 41.709$ ,  $df = 9$ ,  $p < 0.001$ ). Households were asked what the main constraints to household farming were? The main constraints to household farming in the two areas included lack of tools which appeared to be most in Pibor and lack of seeds is the main problem in Pochalla (Fig 7.19). But the responses to this question were significantly different ( $\chi^2 = 24.608$ ,  $df = 6$ ,  $p < 0.001$ ).

### **Livestock management**

Households were asked: Were they involved in livestock management? More than 55% of the respondents from Pibor as opposed to about 20% of Pochalla respondents indicated that their household was involved in livestock management (Fig 7.20). Responses were significantly different between the two study areas ( $\chi^2 = 5.375$ ,  $df = 1$ ,  $p < 0.05$ ). They were asked what the main uses of livestock were for the households. The overall majority indicated that livestock is mostly used for traditional purposes (Fig 7.21) such as marriage and dowry in Pibor (Fig. 7.22). This response differed significantly from Pochalla ( $\chi^2 = 4.926$ ,  $df = 1$ ,  $p < 0.05$ ); where there is less rearing practiced. Households were also asked whether they sell livestock products to generate income. Their response indicated that income generation from livestock was not significantly practiced in both areas ( $\chi^2 = 1.440$ ,  $df = 1$ ,  $p = 0.05$ ). Households in both areas use



livestock products such as meat, milk, ghee, blood, hides and skin for home consumption in the same way ( $\chi^2 = 0.956$ ,  $df = 1$ ,  $p > 0.05$ ).

### **Fishing as a source of livelihood**

Level of fishing contribution to the household livelihood is shown in Table (7.6). It was not significant for the household in the study areas ( $\chi^2 = 10.000$ ,  $df = 5$ ,  $p > 0.05$ ) as very few respondents indicated that fish contribute around 40% of their subsistence, while many respondents stated that fish contributions to their livelihood were less than 40% of what they consume at home.

### **How often households consume meat per week**

Households were asked: Do they often eat meat? Overall, a majority of the respondents indicated that their household often consumes meat (Fig 7.23). Consumption of meat per week was not significantly different between communities ( $\chi^2 = 6.151$ ,  $df = 4$ ,  $p > 0.05$ ), it is less consumed in Pochalla but consumption can reach up to 5 times per week in Pibor areas (Table 7.5). More than 50% of the respondents ( $\chi^2 = 1.931$ ,  $df = 1$ ,  $p > 0.05$ ) indicated that they prefer to consume domestic meat than meat from poached wildlife (Fig 7.24). But those who prefer wild meat indicated that they mostly get them through buying and hunting by themselves in both study areas (Fig 7.25). Only a few respondents mentioned that they barter some items to obtain meat sometimes.

The level of contribution of hunted meat to the household food (Table 7.7) was significant ( $\chi^2 = 10.00$ ,  $df = 4$ ,  $p < 0.05$ ) in both study areas and reaches up to 50-80% in the Pochalla area. Households were asked, what hunting tools do they use for hunting? Household members who hunt used tools that varied between spears, firearms and traps (Fig 7.26). A large number of the respondents indicated that they use spears for hunting

kob, followed by those who use firearms in the second rank (it is to be noted that respondents may have under-reported their use of firearms). The types of firearms used for hunting was not different in both areas ( $\chi^2 = 1.735$ ,  $df = 2$ ,  $p > 0.05$ ), with a majority using the AK47 rifles (Fig 7.27), it is the assault gun used by the army (the Sudan People's Liberation Movement) and organized forces, as well as rebels in South Sudan. Methods of acquiring the firearms was not significant ( $\chi^2 = 4.306$ ,  $df = 2$ ,  $p > 0.05$ ) as most people acquired firearms from their military service, but In Pochalla good numbers of people buy the arms they use for hunting and a few others borrow from relatives (Fig 7.28).

### **Quantifying kob hunting mortality through household consumption**

The following context are important in quantify the level of hunting off-take by the indigenous communities resident in/around the Park for their households' consumptions through hunting during kob migration season in/around Boma National Park in the dry season every year:

About 23% among respondents in Pibor County indicated that they seasonally hunt kob for household consumption (Fig 25)

Also 34% of the respondents in Pochalla County stated that they do hunt kob

Male members of households are the ones who go for hunting at least once a year

However, according to the 5<sup>th</sup> Population Census of Sudan (Population Census Council 2009) sex structure the adult males were as follows:

The number of males  $\geq 17$  years in Pibor County = 36,690 persons

The number of males  $\geq 17$  years in Pochalla County = 15,330 persons

Extrapolating from the Census figures above, the minimum number of people in the two study areas who hunt kobs during the dry season will be as follows:

$$\text{In Pibor County} = 0.23 \times 36690 = 8,439 \text{ hunters/poachers}$$

$$\text{In Pochalla County} = 0.34 \times 15,330 = 5,212 \text{ hunters/poachers}$$

If each person kills only 1 kob/year then:

$$\begin{aligned} \text{At minimum the total number of kob removed through household} \\ \text{consumption} &= 13,651 \text{ kobs} \end{aligned}$$

However, Morjan *et al.* (2002) found out that a hunter kills between 5-11kobs in/around Boma Park during migration season. Taking the smallest of the range,  $\approx 5$  kobs per year, then, the minimum number of kobs killed for households consumption yearly will be:

$$\text{Pibor} = 5 \times 8,439 \approx 42,195 \text{ kobs}$$

$$\underline{\text{Pochalla} = 5 \times 6592 \approx 26,060 \text{ kobs}}$$

Minimum Total hunting off-take

$$\text{by the households for food} \approx 68,255 \text{ kobs/year}$$

Thus Kobs continue to provide a significant source of food to people in both of these counties. The level of local hunting appears high and its sustainability and conservation impact on kob need further long term investigation and monitoring.

### **Wild food plants collection**

Households were asked, were they involved in collection of wild food plants in the Park? About 64% of the respondents in Pibor indicated that their households were involved in the collection of wild food, while only about 36% from Pochalla indicated yes (Fig 7.29). People in Pochalla grow crops and fish more than the Pibor communities.

Therefore the Pochalla households don't rely entirely on consumption of wild plants as much as the Pibor households.

However, the consumption of wild food was significantly different between the areas ( $\chi^2 = 9.775$ ,  $df = 8$ ,  $p > 0.05$ ). Households were asked whether there are risks involved in collection of wild food. In both areas about 60% of the respondents indicated that getting attacked by unknown people was the main risk, followed by getting robbed at about 30% of the respondents and getting arrested by game rangers is minimal at less than 10% of the respondents in both areas (Fig 7.30). However there was significant difference in their responses ( $\chi^2 = 13.978$ ,  $df = 2$ ,  $p = 0.001$ ). The households were also asked, what is the level of contribution of wild food to their livelihoods? The majority of the respondents in both areas indicated contribution of wild food plants to household livelihood is not significant ( $\chi^2 = 9.775$ ,  $df = 8$ ,  $p > 0.05$ ) it ranges between 1-5% in both areas, while sometimes could reach 20 – 25% sometimes (Table 7.8).

### **Human perception on the Boma National Park and the kob migration**

Households were asked about the existence of the Boma National Park and whether wildlife from the Park affects their household livelihoods? Wide knowledge about the existence of the Boma National Park (BNP) was significant among the respondents in the study area ( $\chi^2 = 4.917$ ,  $df = 1$ ,  $p < 0.027$ ); where more than half of the respondents knew the location of the Parks boundaries from their villages (Fig. 7.31)<sup>5</sup>.

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<sup>5</sup> There has not been any relocation of villages which existed in the areas of the Park. Following park establishment in 1978, there is no documentation to show that relocation was in the program.

However, the park's boundaries are not demarcated on the ground, and since there is no active conservation/patrolling, it is difficult to evaluate this.

Some respondents indicated that they have actually been entering into the park for various reasons (Fig 7.32) including hunting, livestock grazing, wild food collection and grass collection (Fig 7.33). There was significant differences in their responses ( $\chi^2 = 0.518$ ,  $df = 3$ ,  $p > 0.05$ ).

Households were also asked whether wildlife from the Park affects their livelihoods. More than half of the respondents indicated that wildlife from the Boma National Park do significantly affect their household livelihood ( $\chi^2 = 7.3$ ,  $df = 2$ ,  $p < 0.05$ ). These effects ranged from crop damages from wildlife in Pochalla to livestock predation and human attacks (Fig 7.34) mostly in Pibor side of the BNP.

Households were asked whether they like the continued existence of the Park. The majority of the respondents (Fig 7.35), significantly approved of or supported the existence of the Boma National Park ( $\chi^2 = 20.763$ ,  $df = 3$ ,  $p < 0.000$ ). Although their answers were significantly positive in both areas, few in the Pibor side indicated that they don't like the existence of the Park (Fig 7.35).

Households were asked whether Boma Park Managers consult with them on matters relating to the Park or wildlife therein. Slightly more than half of respondents indicated that park managers consult and talk to them (Fig 7.36) about the park at times ( $\chi^2 = 0.276$ ,  $df = 2$ ,  $p > 0.05$ ). Nearly half of the respondents, however, indicated that no consultation being done about the Park matters. The households also were asked whether anyone has explained to them about the rights and obligations of people living in/around National Parks? Large number of respondents (Fig 7.37) indicate that they have not heard

about their rights, privileges, and obligations – less than 50% of households in one county have heard about these and less than 60% of households in the other ( $\chi^2 = 0.782$ ,  $df = 1$ ,  $p > 0.05$ ). It is also not certain what they understand their rights and privileges to be from what they have been told, this remains to be investigated further. They were also asked whether they are aware of the National Parks and Wildlife laws and regulations of South Sudan? The respondents differed significantly in their knowledge of South Sudan's National Parks Laws ( $\chi^2 = 7.635$ ,  $df = 1$ ,  $p < 0.01$ ). Large number of the respondents in Pibor was not aware of such laws (Fig 7.38) due to absence of conservation work in the area, while majorities in the Pochalla area were knowledgeable about the existence of the National Park Law and some regulations and special orders issued about the park because some people talked to them about it (7.39). Households also were asked whether they approve the continued existence of the Boma National Park. Slightly above 50% of the respondents from both areas indicated that their households approved of the continued existence of the park ( $\chi^2 = 1.803$ ,  $df = 1$ ,  $p > 0.05$ ) (Fig 7.40) but they haven't elaborated this opinion; while about 40% in each area indicated disapproval of the Park. Those who approved the continuation of the park indicated that they would be willing to move with their livestock away from the boundaries of the Park ( $\chi^2 = 0.001$ ,  $df = 1$ ,  $p > 0.05$ ) (Fig 7.41) if particular conditions are met. They have significantly stressed several conditions, such as allocation of new lands and provision of social services ( $\chi^2 = 9.117$ ,  $df = 2$ ,  $p < 0.01$ ). Some respondents also demanded monetary compensation should such a move happen (Fig 7.42).

### **Perception about the Conservation NGOs operating in the Boma National Park**

Households were asked whether they know of any NGO working in Boma National Park, what they do and whether there is any change in the park resulted from their work<sup>6</sup>? A large number of respondents in both areas (Fig. 7.43) indicated that they don't know of any NGO working in the Park; and there was a significant difference in their responses ( $\chi^2 = 0.271$ ,  $df = 1$ ,  $p > 0.05$ ). Those who knew about the NGOs operating in the Park indicated that they don't know what programs those NGOs were working on ( $\chi^2 = 2.775$ ,  $df = 1$ ,  $p > 0.05$ ) (Fig 7.44). They also indicated that their communities have not been receiving any benefits from NGOs working in their area (Fig 7.45), with no significant difference in their responses ( $\chi^2 = 0.516$ ,  $df = 1$ ,  $p > 0.05$ ). Regarding positive changes in the park and wildlife populations therein since the admission of the NGOs, respondents differed significantly between the two areas ( $\chi^2 = 10.411$ ,  $df = 1$ ,  $p = 0.001$ ), where a large number of the respondents from Pochalla have seen such changes while many in Pibor didn't see any new change resulting from NGO work in the park (Fig 7.46).

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<sup>6</sup> The Wildlife Conservation Society (WCS) is exclusively working to develop the Boma National Park and the entire Jonglei Landscape as well as the neighboring Eastern Equatoria State, since 2007. Frankfurt Zoological Society had been there in early 1980s but evacuated due to the civil war. The New Sudan Wildlife Society operated there (2000 – 2006); as well as the Catholic Relief Services. Other humanitarian NGOs had been there also.

## **Discussion**

The study captured nearly equal number of both sexes. The survey work revealed that communities in/around Boma Park are characterized by the typical African male domination of their societies where family and household care is entirely left for women, while men are busy with cattle rustling, hunting and tribal fights. Most community members are agro-pastoralists who keep cattle for traditional purposes, mostly used for prestige, show of wealth status, dowry payment and so forth. This is typical of Murle on the western side of the park. On the other hand the Anuak who live north of the Park, around the Guom wetlands where the migratory kob spend most of the dry season, are of traditional farming background, keep less cattle than the Murle. They practice peasant style of farming where people cultivate food crops around their homesteads. Typically the farm production is not enough to sustain their households for more than a few months after harvest. Usually hunger gaps hit the area in the dry season pushing the local population to depend on bush meat, from the White-eared kob in particular, to close the hunger gap till the next harvest.

The study revealed that the phenomenon of the extended family (household) is common among the communities in the study area; in fact it is a common African tradition throughout South Sudan where people stay with and are supported by their relatives or friends. But, here in this rural setting around the Boma National Park, it is unusually prevalent because of the instability and insecurity resulting from cattle rustling, tribal raids and fights which, often leave behind many orphans and widows for their relatives to take care of. In such circumstances given lack of income sources, insufficient family crop production, and lack of food subsidies the easiest way to sustain an extended



household is through hunting for bush meat and wild food plant collection (non-timber forest products).

A large number of respondents in the study villages of Pibor County were from a military background; in fact some are still active soldiers while others belonged to local militia groups who are yet to be disarmed. The firearms they carry are mostly used for cattle rustling, tribal fights and hunting kob during the migration seasons. Frequent cattle rustling in the area often leads to bitter inter-tribal fighting. The most recent have been the Murle-Nuer fights, which, started in the form of cattle raiding attacks and counter attacks during the time this study was being conducted (2010-2012). However, it eventually degenerated into a full Murle rebellion against the government demanding a separate State outside the Jonglei State. It appears that their demand has been met as the government has offered a peaceful settlement in March, 2014 in which they have been granted what is called greater Pibor administrative authority to be headed by an equivalent of a State Governor.

Throughout the study area most people are living in poverty status, even though a small number of households have been described by their community as being wealthy. Their wealth status is not in terms of monetary or fixed assets, as known elsewhere in the world, but rather it is being expressed in terms of number of cattle they own, the number of wives they are married to and the number of children they produced. The cattle they own is not bred under modern husbandry farms but rather kept in strict traditional ways. A good number of such cattle wealth might have actually been rustled from other neighboring communities and, therefore, are also vulnerable to be rustled back anytime by original owners or other raiders from the surrounding landscape. Such wealth is not

easily converted to other economic benefits or for poverty alleviation among the households. For example, productions from these cattle (milk, meat, etc.) are not being used economically to improve the households' status. Their main uses are for cultural purposes e.g. traditional dowry and fines settlements. So households actually remain poor despite how much cattle wealth they own and thus in the end depend on poaching and wild food collection most of the year round. This is consistent with Bennett (2002) who reported that many tropical forest people rear livestock primarily for cultural reasons. They only sell them during emergencies and only eat them at ceremonial or other special occasions rather than using them for daily subsistence. Bonnington *et al.* (2007)<sup>7</sup> summarized the effect of livestock grazing and encroachment on large mammal assemblages in Tanzania. However, occurrence of similar effects on kob in Boma has to be studied in detail carefully. This paper has been cited in order to keep the situation in Boma under alert that something went wrong in other places, so managers should take care early enough and find out suitable approaches to deal with this matter.

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<sup>7</sup>Bonnington *et al.* (2007)<sup>7</sup> suggested that livestock encroachment has an adverse effect on large mammal assemblages in the Kilombero Valley, Tanzania. They further documented that extensive livestock encroachment is like illegal hunting in that it is likely to become a threat to the large wild mammal populations in many ways including 1) causing direct grazing competition, 2) persecution of wild populations by the herders' dogs, and 3) poaching of wildlife by herders and the potential spread of disease from livestock and wildlife.

Households in the study area live in fear of tribal fights, cattle rustling, child abduction and so forth. Such risks render their lives insecure and unstable. This instability may prevent people from cultivating enough food for their livelihoods. This stimulates demand for wildlife and wild food plants in order to survive.

The widespread poverty in the area contributes negatively to education and less than half of children in a household attend school. Reasons cited were mainly domestic work; referring mostly to cattle keeping and cultivation. There is a lack of schools in the study areas. Parents who have never been to school may not be keen to take their children to schools in distant villages. Also they would prefer boys to remain at home taking care of cattle rather than attending school. As for girls they are usually married off at young age, sometimes as young as 12 years in the Murle areas. The study also revealed that there are many day-to-day risks in the area. Placing the children in school are exposing them to the risk of abduction and other forms of insecurity. Combinations of such factors within the communities kill the aspirations of children, leaving many of them uninterested in going to school. Lack of an educated population leaves a gloomy future for the area's people and for its wildlife. Some hope can be found in that some of the households who were displaced during the war and took refuge in the neighboring countries managed to put some children in school. If children are not attending schools the society will not change, they will just inherit their grandfathers' ways of earning a livelihood. In that case, there is no movement for positive change in the socio-economic status of the area.

Households usually cultivate food crops and produce the commonly known staple food crops in South Sudan, sorghum and maize, in small sized farms near their

homestead. But, this is mostly common in Pochalla. In Pibor there is little cultivation because of the high insecurity experienced in the area. Some common factors hindering household agriculture production in the study area include: 1) lack of modern tools for cultivation, 2) lack of improved seed varieties, 3) frequent droughts, and 4) insecurity. Therefore, households only produce a little food which sustains them for short periods during the year, thus creating frequent hunger gaps in the area and consequently driving them to poaching. This is similar to the findings of Leon and Montiel (2008) in Yucatan where reduction in agricultural activities gives people more time for hunting. They added that hunting, timber and non-timber forest products are extracted by the rural communities in Yucatan to diversify their natural resources use.

Households in the study areas keep cattle for prestige and traditional purposes. There is no modern husbandry, and livestock are managed using traditional practices. Households in Pochalla are mostly agro-pastoralists have fewer animals, and concentrate on cultivation. Households in Pibor are pastoralists and keep lots of cattle. People from that area practice cattle rustling and raid their neighboring communities. They are also raided in turn, creating insecurity and recurrent tribal fights. In these circumstances residents do little agriculture and livestock production and hence resort to poaching to sustain their livelihoods. During the dry season thousands of these cattle are driven to the Guom swamps where kobspend their season as well.

Fishing was found to be practiced at larger scale by households in the northern side of the Park than in the other areas of the Park. This is because the Anuaks have a higher preference for fish than their neighbors. They fish in and around the Guom swamps; Oboth and Kong kong Rivers have adequate waters throughout the year. These

watershed areas represent the dry season range for the migratory kobs. Being agro-pastoralists, the Anuak fish a lot in this area and hunt kob in the dry season.

During food shortage times, especially in the dry season, households resort to wild food plant collection from the surrounding bush and inside the Boma National Park. These wild foods include wild rice, *balanites egyptica*, *ziziphus spina-christi*, *tamarindus indica*, *borasus africana* fruits and seedlings, shea flesh and shea nut etc. Some of these plant products are in the form of edible fruits while others are processed and cooked through complex traditional processes. Wild foods are usually collected and prepared for household members by women. Household uses of wild food plants were studied in large areas of South Sudan, including Boma, by a USAID funded group in late 1990s, but their findings remain unpublished. Wild food plants have nutritional and medicinal values and indeed helped many people survive in the rural areas of South Sudan when famine struck in 1998.

Households in the study area consume a lot of meat from both domestic livestock and hunted from the wild animals. They hunt wildlife both in and around the Boma National Park. Some of the common areas where they go for hunting kobs during the migration season include the Guom swamps and Kongkong River in the up north of the Boma National Par; and Kengen River along the western boundary of the Park and Kobach in Gomorok area, which lies some distance west of Pibor Town but it is an important corridor for the kob migration. This is an indication that the Boma Park boundaries are porous and unprotected. Through a simple exercise, this study quantified the level of hunting mortality affecting kob population while in the dry season range and reached a conservative estimate of about 90,000-100,000 kobs possibly killed

every year for household livelihoods in/around the Boma Park. It is a conservative estimate based on generalizing an average minimum number of kobs killed from the number killed by a local hunter in the area to all regional hunters. However, this does suggest how important the migratory kob is for the food security and livelihoods of the indigenous peoples in and around the national park. On the other hand, however, this estimate will raise conservation concerns for the long term future of the kob migrations given the availability of small firearms in these areas, as well as the lack of wildlife enforcement and other conservation and management activities. And the potential for the level of hunting to increase as migrants return and others are resettled in the area.

The heavy dependence of the indigenous people in/around the Park on wildlife for meat is an old-time tradition, one driven by: 1) the poverty level in the area, 2) lack of agriculture production in the area, 3) the ease of accessibility to meat through poaching and cattle rustling; and 4) the lack of law enforcement, and cultural and social values. Apparently there is no one to stop them from hunting; even if game rangers appear in the area the locals who are also armed rarely heed their instructions. Local people widely believe that God created these animals for them to live on. This is an indication of the lack of any incentive other than free food in the wild. It is not uncommon to witness that household daily meals are kob meat only. Illegal hunting in/around the Park has been made easier in recent decades due to the availability of firearms, especially the AK47 rifle, which has been the main assault rifle used by the warring armies and militia groups during the civil war. Household members' hunt frequently during the kob migration season near their villages, then preserve the meat to be consumed during the rainy season where kob have gone far away and even human movement becomes limited in the black

cotton soils which become muddy with the rains. Some hunters kill more animals than what their families consume and they tend to sell/exchange bush meat in the larger settlement areas like Boma and Pibor; and often such bushmeat from kobs reach illegal markets in Juba. Firearms were easily acquired when the government of the then Sudan, was encouraging counter insurgencies and was arming local militia to fight along its army against the rebel Sudan People's Liberation Army which was fighting for the independence of South Sudan. Others also bought their firearms locally from soldiers. Now the disarmament exercise started by South Sudan government, has stalled; and until it is completed the illegal firearms will continue to be used in poaching, cattle rustling and tribal fights.

Despite the difficult life households live in and around the Boma National Park it appears that park residents are supportive of the existence and purpose of the Park. They recognize the importance of the park and expressed willingness to cooperate with management decisions aimed to protect and develop the park and its wildlife. It seems that the harsh life and lack of development in the area are the most important among the driving factors behind encroachment and poaching within the boundaries of the park<sup>8</sup>.

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<sup>8</sup>Hunting in National Parks is not permitted by law. In the past, before 1980s, rural communities anywhere in South Sudan were allowed seasonal subsistence hunting in designated places under supervision of chiefs and game wardens, but right now this practice don't exist. Indigenous people who hunt usually go on their own and some of them often kill animals indiscriminately. The new National Parks and Wildlife conservation policy has a section on community conservation but it is yet to be implemented.

Some negative sentiments were voiced by several respondents including frustration stemming from living under the harsh environment. They indicated conditions could be improved if development and social services could be provided by the government authorities. The positive attitude that Boma Park communities expressed may be partially due to the fact that the Comprehensive Peace Agreement which ended the civil war with north Sudan and paved the way for the independence of South Sudan, has provisions that given 2% of oil income to the communities from whose areas oil is being extracted. Since then the communities in the Boma area, especially the Murle, have been expecting to be given 2% from income generated from the wildlife industry within their areas whenever such revenues start flowing. However, conservation strategies should recognize both the positive and negative perceptions that communities have of protected areas and work to foster and integrate diverse values in order to more accurately reflect the reality and complexity of people's lives (Allendorf 2007).

Conservation policies and laws should ensure that local communities living around the Park receive adequate attention with regard to conservation programs designed for the area. Conservationists and managers should ensure that community interests and benefits are incorporated in park management plans and in their execution. Currently wildlife conservation in the country is run with many gaps including the absence of community conservation programs. Even the NGOs operating in South Sudan and in the Boma National Park in particular, are yet to implement community projects in



their programs. Therefore, it is high time and of prime importance that there should be policy change in this regard.

The responses by households about the role NGOs working in the Boma National Park indicated that such NGOs are working in isolation from the local people in and around the Park. The majority of survey respondents indicated that they were unaware of existence of NGOs and or of their work. In fact, it is not uncommon to hear from conservation NGO workers in South Sudan statements such as “We work with the government”. One almost never hears in a conversation with conservation NGO workers in South Sudan where they can proudly say “we work with community”. The stress on work with government usually meant to show off that they are well connected and powerful. But in the context of conservation work it is unfortunate that conservation NGOs don’t have community components running in their programs especially in the Murle areas where most of the destructive illegal killing<sup>9</sup> of kob takes place. In the real sense the responses from households does not mean that they actually don’t know about conservation NGOs working in the park, but rather it’s a reflection of poor relationships between the people and some of the NGOs working in the Park, or that the people might be unhappy due to unfulfillment of expectations created by earlier

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<sup>9</sup>Murle youth go in groups and camp in the park to shoot kobs and eat and dry meat to carry home. Often when kob meat is seen not fatty, it is thrown away and another kob is killed, and so forth till they get back to the village. Such illegal activity is very destructive to the wildlife population in the Park.

encounters between NGO workers and community leaders. This is in conformity with Ite's (1996) findings in the Cross River National Park in Nigeria. In fact, it is a typical case of the concentration of NGO's resources and power in the hands of a few, which gives such individuals the sense of empires, in the sea of poverty, as explained by Frazier (2006).

The newly enacted Wildlife Conservation and National Parks Policy stresses the inclusion of local community interests in conservation programs where they occur. Therefore, conservationists and managers should ensure that conservation programs in the Boma National Park must include the interests of the indigenous communities.

### **Challenges faced by the indigenous communities in the study area**

There is clear over dependency on wildlife for livelihood sustenance due to lack of food resulting from poor crop production, frequent droughts, lack of tools and seeds, as well as the existence of some negative cultural traditions e.g. the tradition of keeping domestic livestock for family prestige. Thus the indigenous communities widely engage in hunting during the kob migration season to stock meat for food during the long rainy season. It is made easier for them due to availability of firearms, the lack of awareness and absence of effective enforcement of the wildlife conservation laws. Effective communal management of hunting, including traditional norms, has only remained with the Anuak Community, and not within other tribes. The current situation is now worse, in terms of wasted wildlife, than it used to be 20-50 years ago when subsistence hunting was by done through traditional methods of hunting.

Lack of basic infrastructure like roads, hospitals and schools isolate the communities from the rest of the country and deny them access to basic services of food,

health and education. Poor roads also hinder game rangers from patrolling the park effectively. Illiteracy in these areas is among the highest in South Sudan, curtailing modern civilization and, as a result, people of the area can only believe in their traditional norms.

Cattle rustling and tribal fights are real challenges faced by the entire community of Pibor County resulting in loss of their cattle wealth and next of kin. Pibor County is drained by seasonal streams which fill in the rainy season and dry up in the dry season. Hence during water shortages in these streams the nomads go far from their homes searching for water, and in this process clashes with other neighboring tribes e.g. the Nuer, Dinka, Jie and Toposa. During such movement in search of water and grazing, they kill wildlife species for food and also kill predator species for protection of cattle.

Politically there are complaints from among people of Pibor County of deliberate marginalization within the Jonglei State. This is attributed to the frequent cattle rustling, women and child abduction amongst them and their neighboring communities. This makes the people from neighboring communities fear interacting or going to Pibor county even for employment. Hence the people of Pib or County feel discriminated against and are denied access to social services that are supposed to have been delivered by the state government.

### **Conclusions**

The boundary of the Boma National Park is largely contained within Pibor and Pochalla Counties of Jonglei State and the Kapoeta East County of the Eastern Equatoria State in the extreme south. The Boma Park region remains one of the most undeveloped parts of South Sudan. People there live in the most profound backwardness and poverty.

A majority of them still make their livelihood from gathering, and hunting. Cattle rustling and abduction of women and children are common phenomena of the area. They believe that wildlife and specifically White-eared kob have been created by God for them to live on. In fact, kob not only provides local people with meat for food, but also gives them skin for clothing and matt for sleeping. The local environment is strictly two seasons (dry and wet) whereby during the four months of the dry season people move with their livestock to Guom Swamps and intersect there with the kob migration. Therefore, it is difficult to do ecological conservation only without addressing the needs of the indigenous people therein.

#### General Conclusion

Results of this study discussed above reveal that the indigenous communities living in/around Boma National Park differ in their culture, traditions and norms of life between Pibor and Pochalla Counties; and this relates to the way they relate to, interact with and impact on the migratory kob antelopes. Therefore, development of management plans and actions taken afterwards should be participatory and take into consideration this diversity.

#### **Conservation and Management Implications**

The following recommendations are suggested to improve the situation on the ground:

The recently reviewed and passed Wildlife Conservation and Protected Areas Policy document contains sections on community engagement as well as sections on law enforcement. It is, therefore, recommended that conservation managers should review current conservation programs of the Park, should there be any in place, or else they

should develop new programs taking into consideration the interests of the indigenous communities to meet their aspirations and engaging them and encourage their participation in wildlife conservation in effective ways. Several previous studies have made similar recommendations e.g. Stem *et al.* (2003), Fortein and Gagnon (1999) on social impacts of national parks in Quebec, Canada; Kahurananga and Silkiluwasha (1997) on community benefit and future of Trangire National Park. In addition there are also relevant IUCN policies, decisions of the Parties to the Convention on Biological Diversity (including the CBD's Programme of Work on Protected Areas), and applicable provisions in international human rights treaties and declarations.

The existing conservation policies and laws in South Sudan should be reviewed to meet the demands and challenges facing conservation of the migratory kob and other species. Such laws should be translated into indigenous languages and disseminated to the communities living and interacting with the kob migration as well as other species. Once more peace and security prevails in the area it will (hopefully) become possible to have more interaction between the park staff and communities through face-to-face interviews and direct discussions; and this is more effective.

Awareness and sensitization programs to reshape peoples' thinking about the kob migrations and benefits of the migration should be organized frequently with participation of community elders/leaders. The Ministry of Wildlife Conservation and Tourism together with NGOs working in South Sudan national parks should engage in creating awareness about the importance of wildlife to the indigenous communities and to the entire country at large. Wildlife clubs should be re-established in schools as was the case in the 1970s and 1980s so that information dissemination and awareness building

can easily reach out to the wider community. Developments of School programs (and youth programs for children who aren't in school) are very important and are often neglected. Conservation strategies should aim should for a higher level of awareness and respect for nature (Stem *et al.* 2003)

The game rangers should be well trained and equipped with the necessary tools needed for law enforcement to combat poaching. Known traditional poachers should be recruited in the ranger force and trained to gradually turn into friends of conservation. Since the Boma Park is large enough making it difficult for effective patrols given the size of ranger force deployed there at present time, lessons from "Village Game Scout" in Serengeti National Park of Tanzania (Holmern *et al.* 2007) can be given a trial here. Village chiefs can also be given honorary law enforcement role in areas within their jurisdiction, as has been shown to be potentially valuable by the success stories in Garamba National Park in the Congo DRC as reported by de Merode *et al.* (2007). In such situation the village chiefs to enforce customary law or new national park regulations that integrate customary law regarding hunting and other land uses.

The Ministry of Tourism and Wildlife Conservation should develop community programs and promote in alternative livelihood programs such as agriculture, animal husbandry and production, ecotourism, etc. in order to help change the traditional keeping of livestock for economic benefit and livelihood of the households. Out of these ecotourism would have been the best to economically reward the communities given the potentials of Boma National Park. Unfortunately, given the current development status of the Park and its surrounding areas it is hard to say whether it should start ecotourism generally or a community-based ecotourism where the community has high degree of

control over the activities taking place (Kiss 2004, Scheyvens 1999). What communities should be empowered whereby the indigenous people and other disadvantage groups will be benefiting from the ecotourism (Scheyvens 1999). Tourism is also far from an ideal entry-level business for rural communities with little previous experience. It is competitive and demanding and can take years to get off the ground, and even people with considerable experience can fail to make a profit (Kiss 2004). One direct way to share benefits with communities is through the entrance fees. In Sagarmatha (Mt. Everest) National Park (Stanley Steven per. Comm. 2014) up to 50% of the park entrance fee goes to community conservation and development programs through projects defined and operated by the communities. This is up to half a million US\$ per year. Another way to share benefits is by direct, secure, budget allocation to villages and village-initiated programs as part of the annual government park budget allocation.

There is need for construction of roads network to connect important areas within the park to facilitate easy movements of ranger forces patrols as well as to promote ecotourism industry.

The national government needs to address issues of marginalization, tribal discrimination and basic services delivery through assessments and relevant interventions.

The government should assume the responsibility for the Park development. The role of the NGOs over the nine (9) years has focused on research and data collection but has not contributed to substantial progress in terms of infrastructure through financial allocation for the Park operations and creation of park infrastructures such as roads, trails, interpretive centers and exhibits (Fortain and Gagnon 1999). The Ministry of Tourism

and Wildlife Conservation should persuade the government to allow recruitment of young professional staff to be deployed in the Park and execute these recommendations. The government should invest funds from its resources or loans from multi-lateral institutions. The government should review agreements signed regarding Boma National Park so that funds can be used to promote better conservation, community empowerment and economic development. Only with such interventions can the long term sustainability of Boma Park be ensured.

### **Literature cited**

- Allendorf, T. D. (2007). Residents' attitude towards three protected areas in southwestern Nepal. *Biodivers. Conserv.*, **16**: 2087-2102.
- Bennett, E.L. (2002). Is there a link between wildlife and food security? *Cons. Biol.*, **16**(3): 590-592.
- Bonnington, C., Weaver, D. and Fanning, E.(2007). Livestock and large wild mammals in the Kilombero Valley, in southern Tanzania . *Afr. J. Ecol.*, **45**: 658-663.
- Bouare, O. (2006). A policy tool for establishing a balance between wildlife habitat preservation and the use of natural resources by rural people in South Africa. *Afr. J. Ecol.*, **44**: 95-101
- de Merode, E., Smith, K. H., Homewood, K., Pettifor, R., Rowcliffe, M. and Cowlishaw, G. (2007). The impact of armed conflict on protected area efficacy in Central Africa. *Biol. Lett.*, **3**: 299-301.
- Deng, L. (Overall Team Coordinator). (2001). *The Impact of Conflict on the Boma National Park: The Status of Food Security, Wildlife and Livestock*. SA/CB – STAR (USAID/ USDA/ PASA, Nairobi.



- Ezebilo, E.E. (2010). Community-based preference for economic incentives to promote biodiversity conservation in a tropical rainforest. *Int. J. Environ. Res.*, 4(3): 501-506.
- Fortin, M-J. and Gagnon, C. (1999). An assessment of social impacts of national parks on communities in Quebec, Canada. *Environmental Conservation*, 26 (3): 200–211.
- Frazier, J. (2006). Biosphere reserves and the “Yucatan” syndrome: another look at the role of NGOs. *Landscape and Urban Planning*, 74: 313–333
- Fryxell, J. M. (1985). *Resource limitation and population ecology of the White-eared kob*. A PhD Thesis. University of British Columbia, Canada.
- Hanley, N., Shorgen J.F. and White, B. (2007). *Environmental Economics: In Theory and Practice*. 2nd edn. Palgrave Mcmillan, New York, USA. pp332-341.
- Holmern, T., Muya, J. aand Roskaft, E. (2007). Local law enforcement and illegal bushmeat hunting outside the Serengeti National Park, Tanzania. *Environmental Conservation*, 34(1): 55 – 63.
- Ite, U. E. (1996). Community perceptions of the Cross River National Park, Nigeria. *Environmental Conservation*, 23(4): 351-357.
- Kahurananga, J. and Silkiluwasha, F. (1997). The migration of zebra and wildebeest between Trangire National Park and Simanjiro plains, Northern Tanzania, in 1972 and recent trends. *Afr. J. Ecol.*, 35: 179-185.
- Kaltenborn, B. P., Nyahongn, J. W. and Tingstad, K. M. (2005). The nature of hunting around the western corridor of Serengeti National Park, Tanzania. *Eur J. Wildl. Res.*, 51: 213 – 222. DOI 10.1007/s10344-005-0109-9.
- Kiss, A. (2004). Is community-ecotourism a good use of biodiversity conservation fund?

*Trends in Ecology and Evolution*, 19(5): 232-237.

Lamprey, R. H. and Reid, R. (2004). Expansion of human settlement in Kenya's Maasai Mara: what future for pastoralism and wildlife? *J. Biogeogr.*, **31**: 997-1032.

Leon, P. and Monteil, S. (2008). Wild meat use and traditional hunting practices in a rural Mayan community of the Yucatan Peninsula, Mexico. *Hum. Ecol.*, **36**: 249-257.  
DOI 10.1007/s10745-007-9139-0

Lewis, B.A. (1972) *The Murle: Red Chibes and Black Commoners*. In: Evans-Pritchard et.al. ed. Oxford University Press, UK.

Mefit-Babtie, S. (1983). *Development studies in the Jonglei canal area: Final report*. Vol.5. Wildlife Studies, Mefit-Babtie SRL, Glasgow, Rome and Khartoum, and Executive Organ of the National Council for Development of the Jonglei Canal Area, Khartoum, Sudan, Ministry of Finance and Economic Planning, Government of the Democratic Republic of the Sudan.

Ndibalema, V.G. and Songorma, A. N. (2007). Illegal meat hunting in Serengeti: dynamics in consumption and preferences. *Afr. J. Ecol.* **46**:311-319.

Scheyvens, R. (1999). Ecotourism and the empowerment of local communities. *Tourism Management*, **20**: 245-249.

Population Census Council, (2009). *5<sup>th</sup> Sudan Population and Housing Census 2008: Priority results*. Submitted to the Presidency, by the Central Bureau of Statistics and the Southern Sudan Centre for statistics, Census and evaluation, Khartoum-Juba, Sudan.

Stem, C.J., Lassoie, J. P., Lee, D. R., Deshler, D. D. and Schelhas, J.W. (2003).

Community participation in ecotourism benefits: The link to conservation practices and perspectives. *Society and Natural Resources*, **16**: 387-413.

DOI: 10.1080/08941920390190041.

Willimot, S. G. (1956). Soils and Vegetation of Boma Plateau and Eastern District of Equatoria. *Sudan Notes and Records*, **32**: 9-20.

Table 7.1. Human population size in the counties in and around the ungulate migration in eastern South Sudan (Population Census Council 2009).

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County	Population size
Pibor	148,475
Pochalla	66,201
Akobo	136,210
Lopa/Lafon	106,161

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Table 7.2. Sex ratio of respondents to survey questions concerning white-eared kob migrations in eastern South Sudan, (Population Census Council 2009).

Area	Name	Male		Female	
		Number	Percent	Number	Percent
County	Pibor	67	35	27	14
	Pochalla	51	26	50	25
Total		118	61	77	39

Table 7.3. Sex ratio of respondents to survey questions concerning white-eared kob migrations in eastern South Sudan, (Population Census Council 2009).

Area	Name	Male		Female	
		Number	Percent	Number	Percent
Payam (District)	Gogol Thin	67	35	27	14
	Ngom	0	0	1	0
	Pochalla	51	26	49	25
Total		118	61	77	39

Table 7.4. Sex ratio of respondents to survey questions concerning white-eared kob migrations in eastern South Sudan, (Population Census Council 2009).

Area	Name	Male		Female	
		Number	Percent	Number	Percent
Pochalla	Buong	6	3	13	7
	Apara Ngom	13	7	11	6
	Ojangbai	12	6	10	5
	Twado	0	0	1	1
	Logri	3	1	1	1
	Achari	2	0	6	3
	Terlul	5	2	2	1
	Batagela	4	2	4	2
	Bermeth	4	2	2	1
	Returnees	2	1	0	0
Pibor	Pibor	38	2	10	5
	Pibor West	3	2	0	0
	Pibor East	11	6	11	6
	Hai Mattar	2	1	3	2
	Hai Jokor	8	4	0	0
	Hai Chok	5	3	3	2
Total		118	61	77	39

Table 7.5. Showing how often households consume meat per week  
in the study areas.

Frequency of household's meat consumption  Days/week	Pibor		Pochalla	
	n	%	n	%
1	41	51.25	44	68.75
2	27	33.75	16	25
3	7	8.75	3	4.69
4	2	2.5	1	1.56
5	3	3.75	0	0
Total	80	100	64	100



Table 7.6. Showing percentage levels of contribution fishing for the households livelihood as indicated by respondents in the study areas.

Level of fishing as contribution to household's %/Livelihoods consumption	No. of Respondents	
	Pibor	Pochalla
1	0	3
2	2	0
3	2	0
5	1	0
40	0	1
99	0	1
<b>Total</b>	<b>5</b>	<b>5</b>

Table 7.7. Showing percentage levels of contribution of hunted meat for the households livelihood as indicated by respondents in the study areas.

Level of contributions of hunted meat to household's livelihood % /monthly consumption	No. of Respondents	
	Pibor	Pochalla
15	1	0
20	1	0
50	0	4
70	0	1
80	0	3

Table 7.8. Level of contribution of wild food plants to household livelihoods.

Level of contributions of wild food plants to the household's livelihood % /monthly consumption	No. of Respondents	
	Pibor	Pochalla
1	2	2
5	1	3
10	0	1
15	2	0
20	2	0
25	0	1
30	1	0
40	1	0
50	1	0

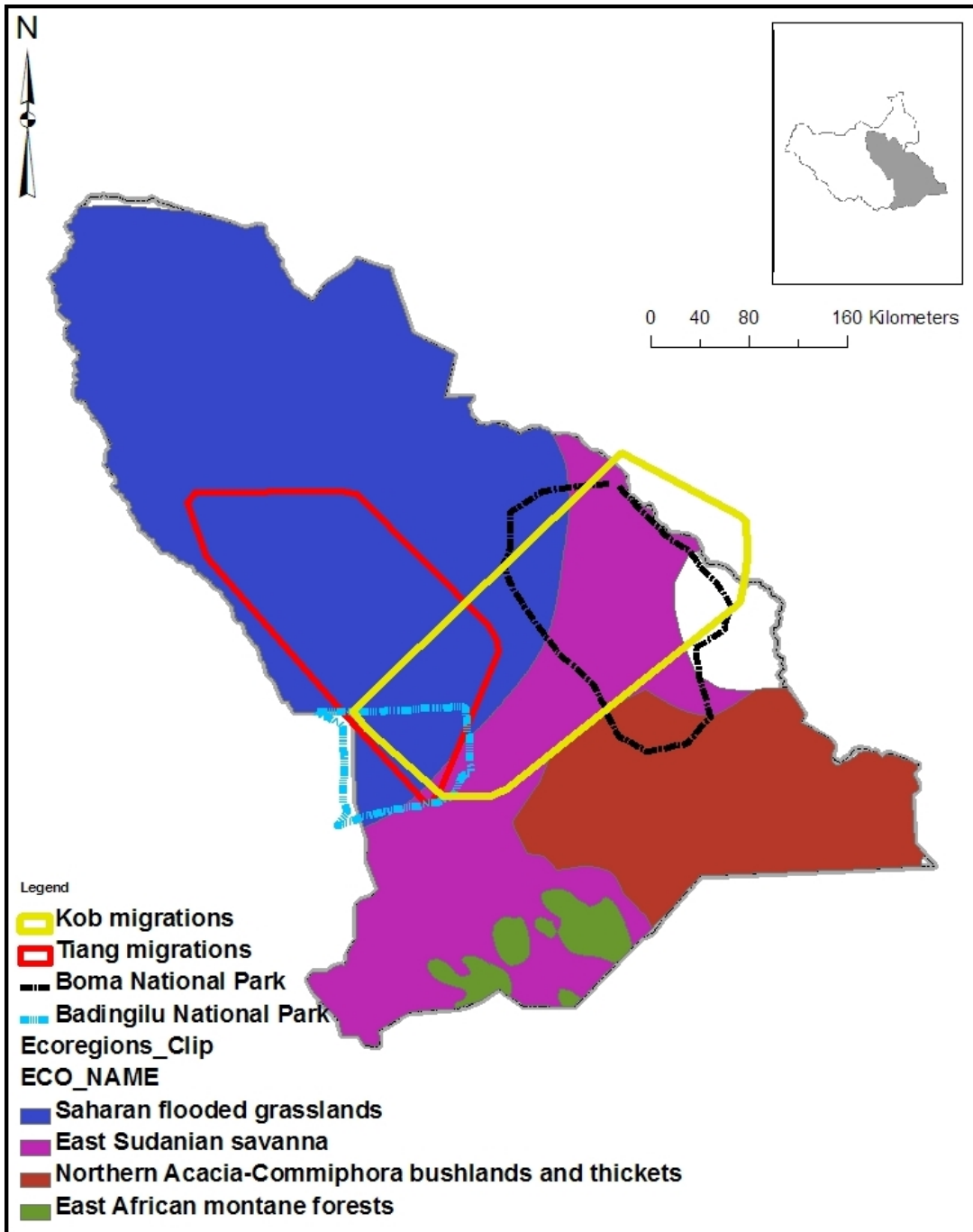


Figure 7.1. Study area map showing the major ecological zones and the migration ranges.

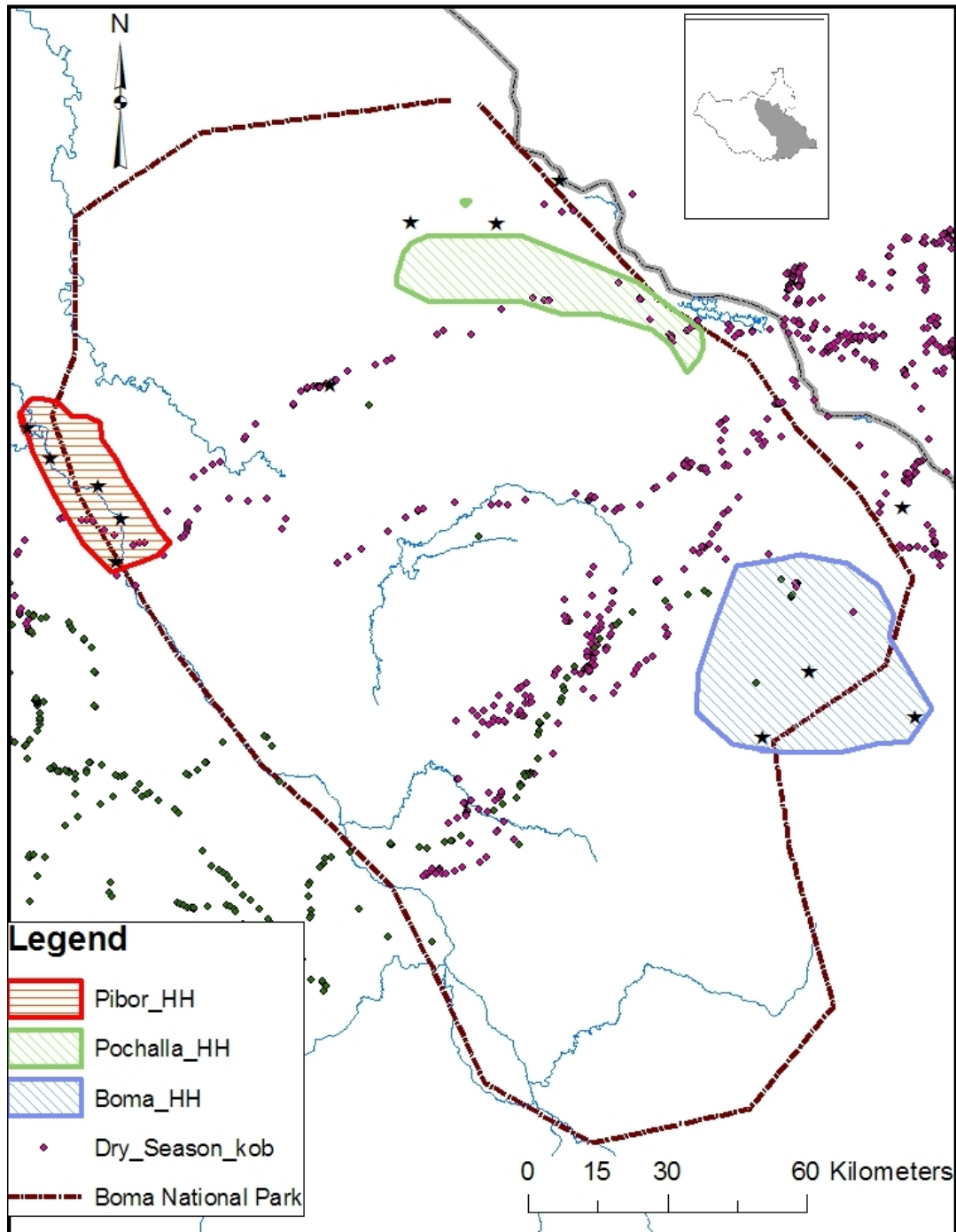


Figure 7.2. Map of the Boma National Park showing the study sites Pibor and Pochalla where the surveys were conducted, but surveys were not done at Boma due to security concerns as explained in the methods section.

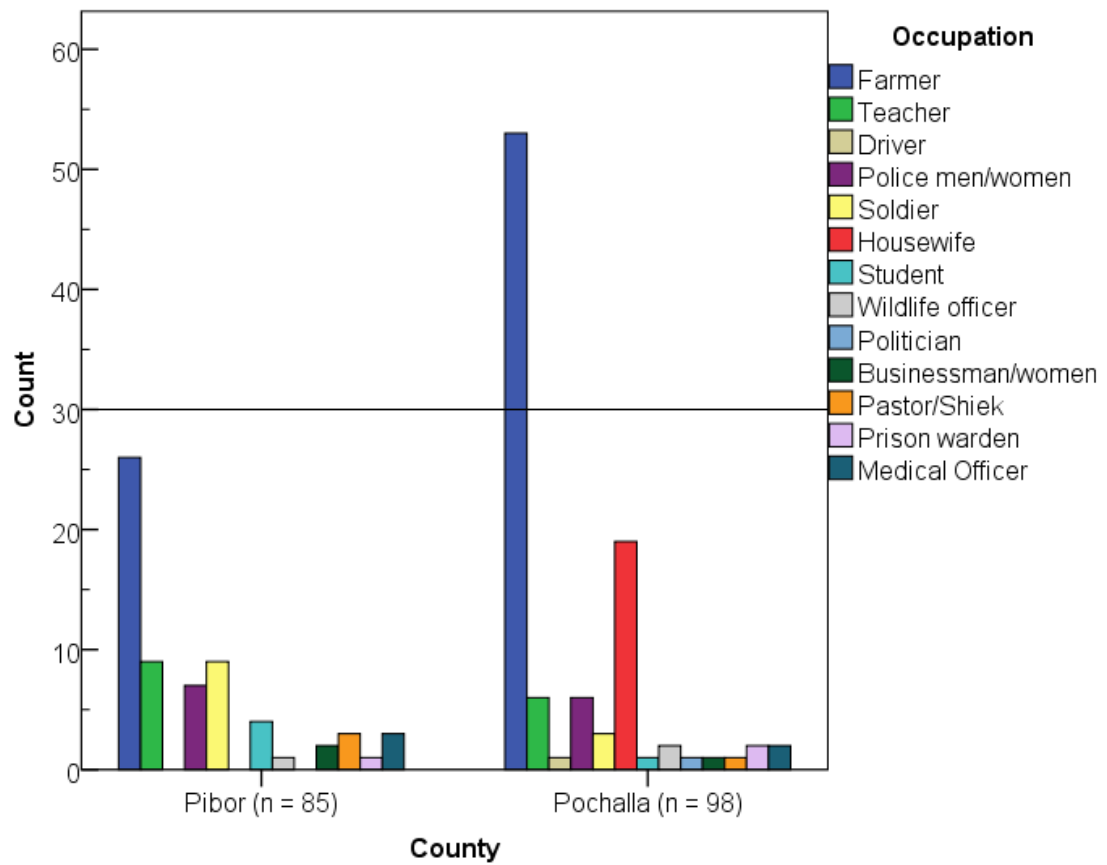


Figure 7.3. Occupation distribution of the respondents in the two counties

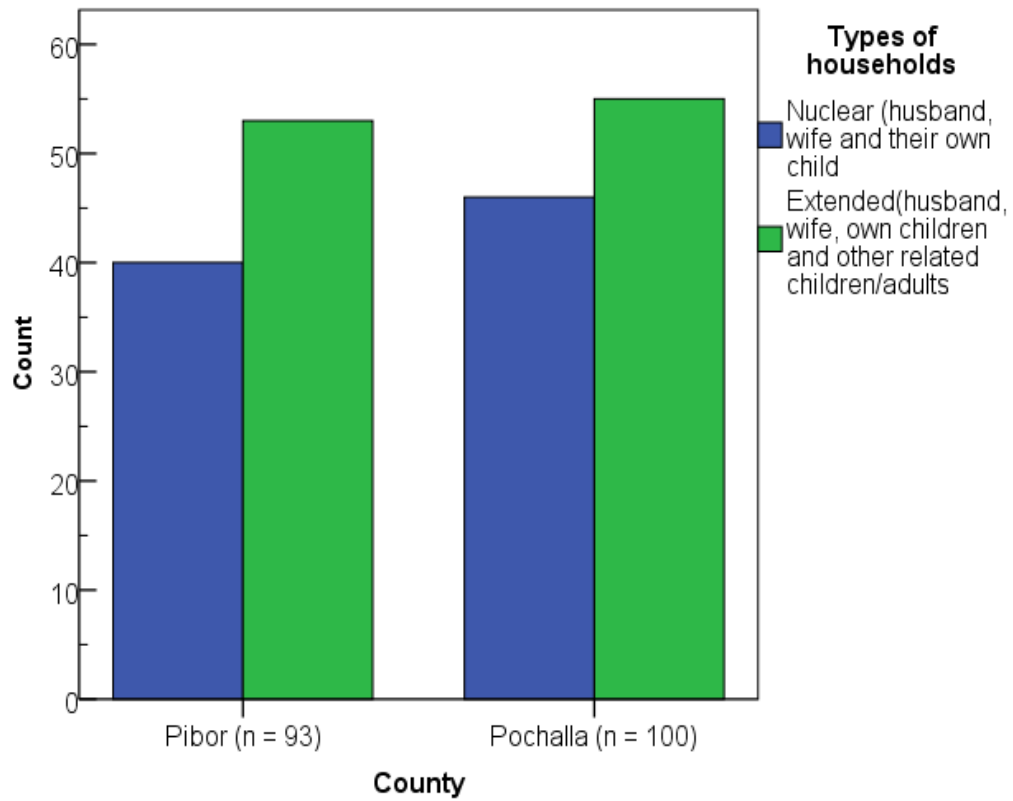


Figure 7.4. Types of households surveyed in the study area.

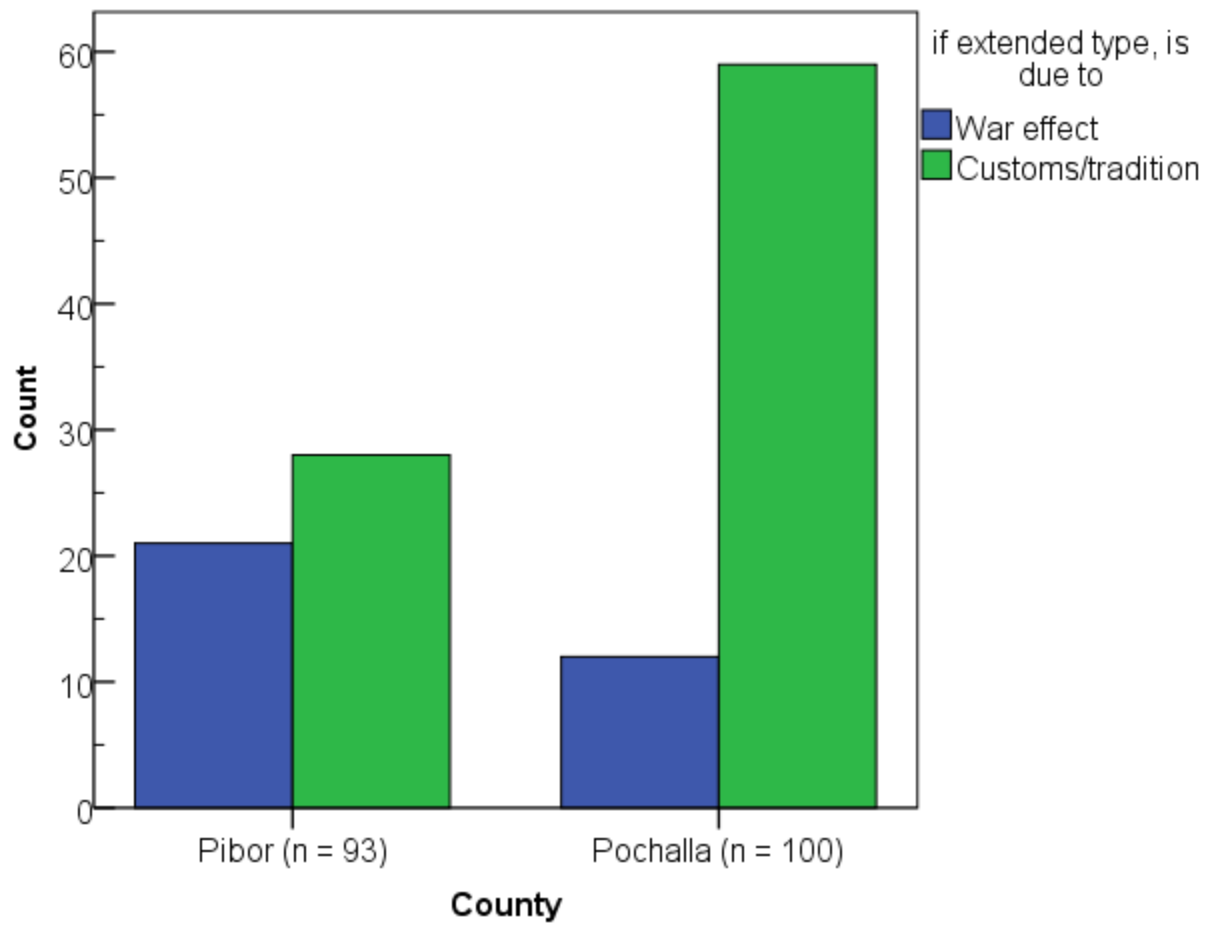


Figure 7.5. Reasons for extended household types



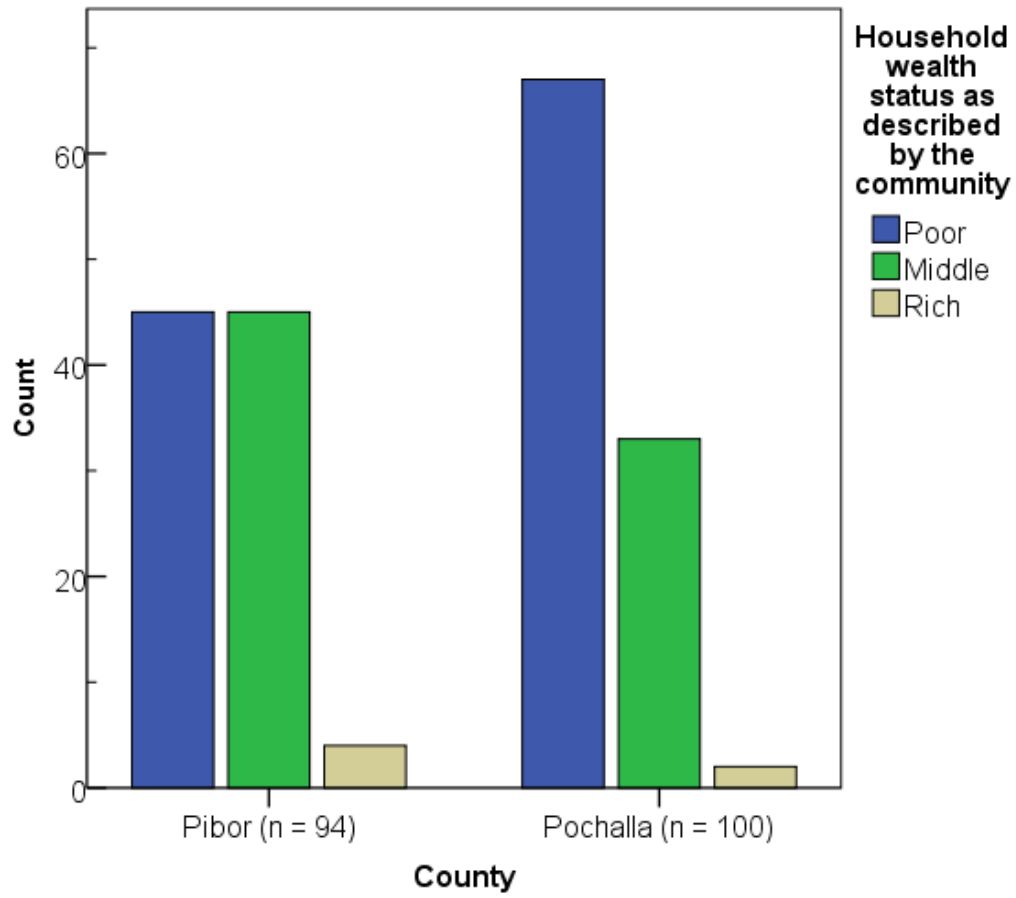


Figure 7.6. Household wealth as described by the local community.

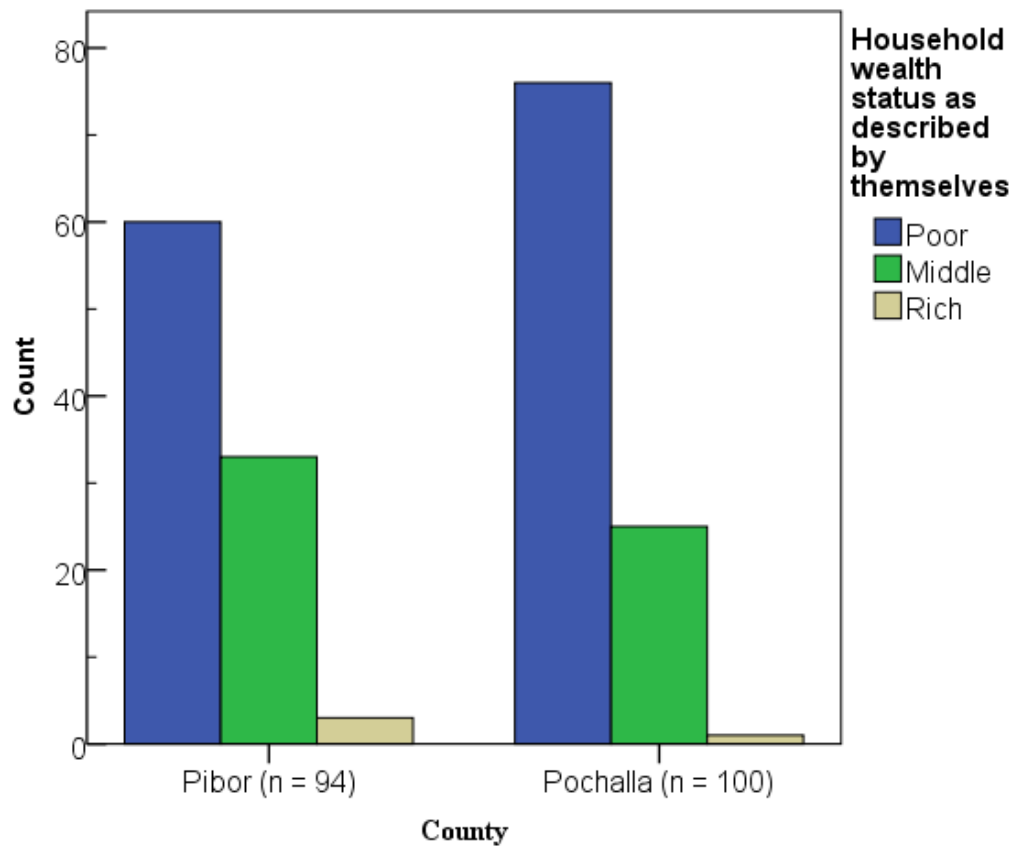


Figure 7.7. Household wealth status as described by themselves

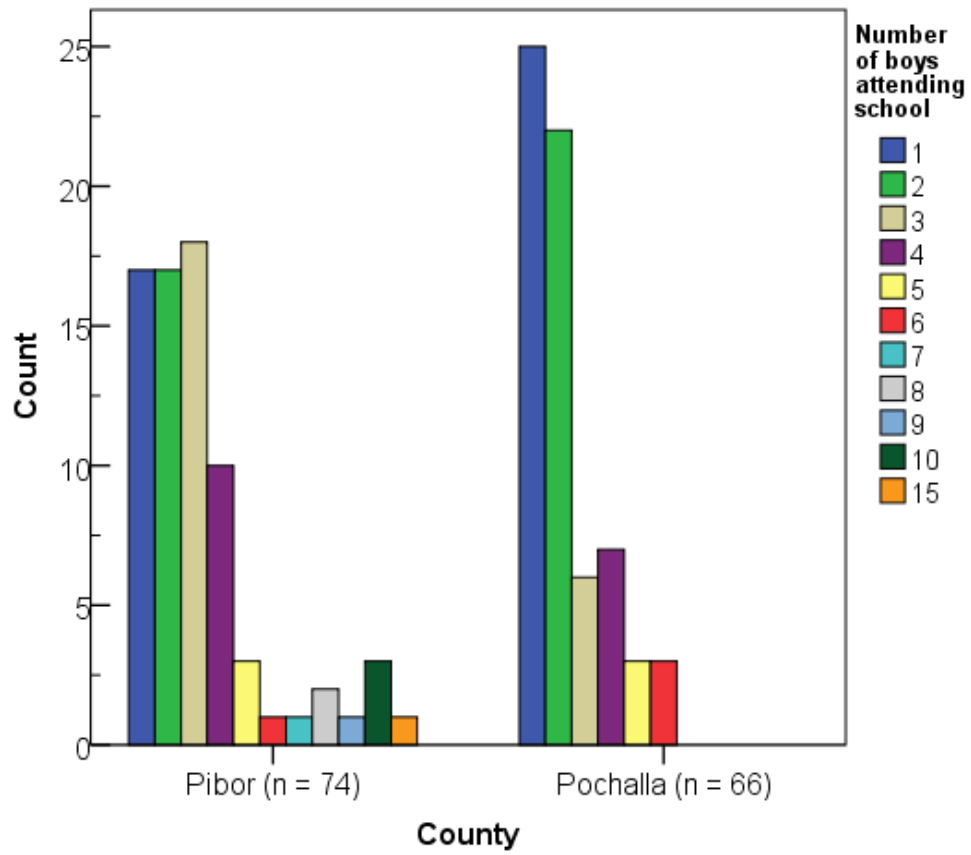


Figure 7.8. Number of children (boys) attending school

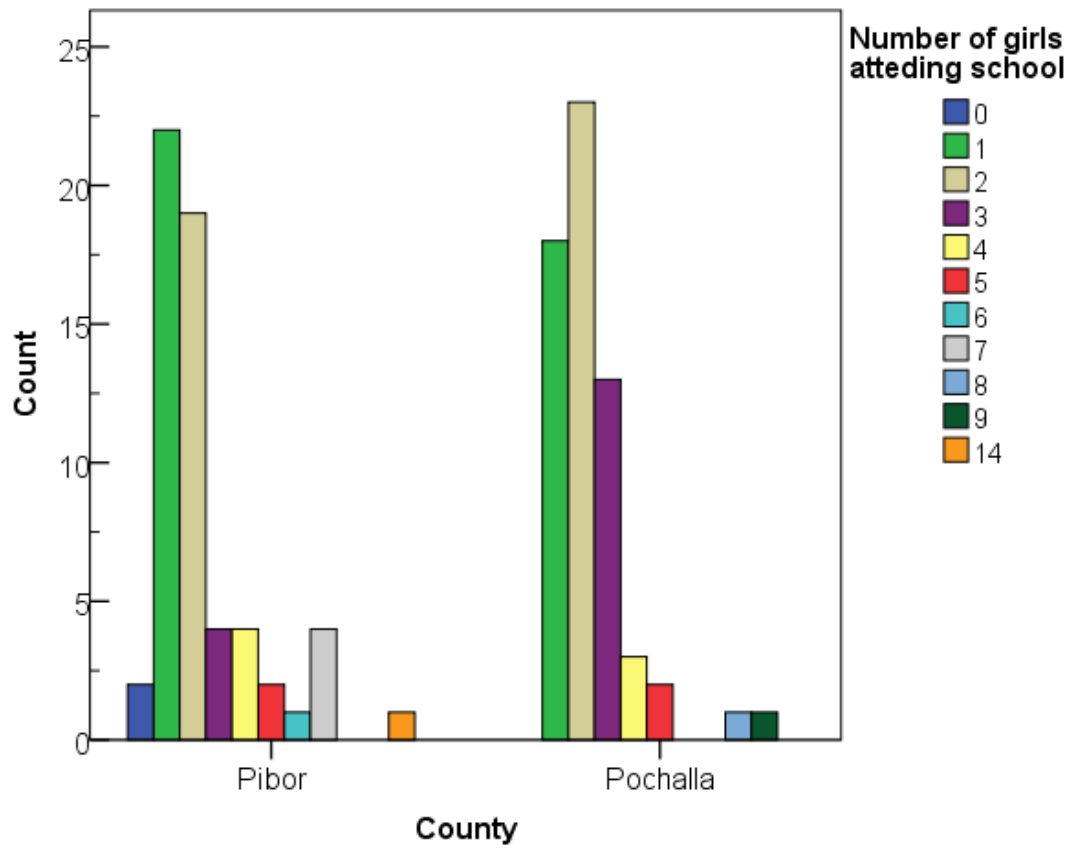


Figure 7.9. Number of children (girls) attending school

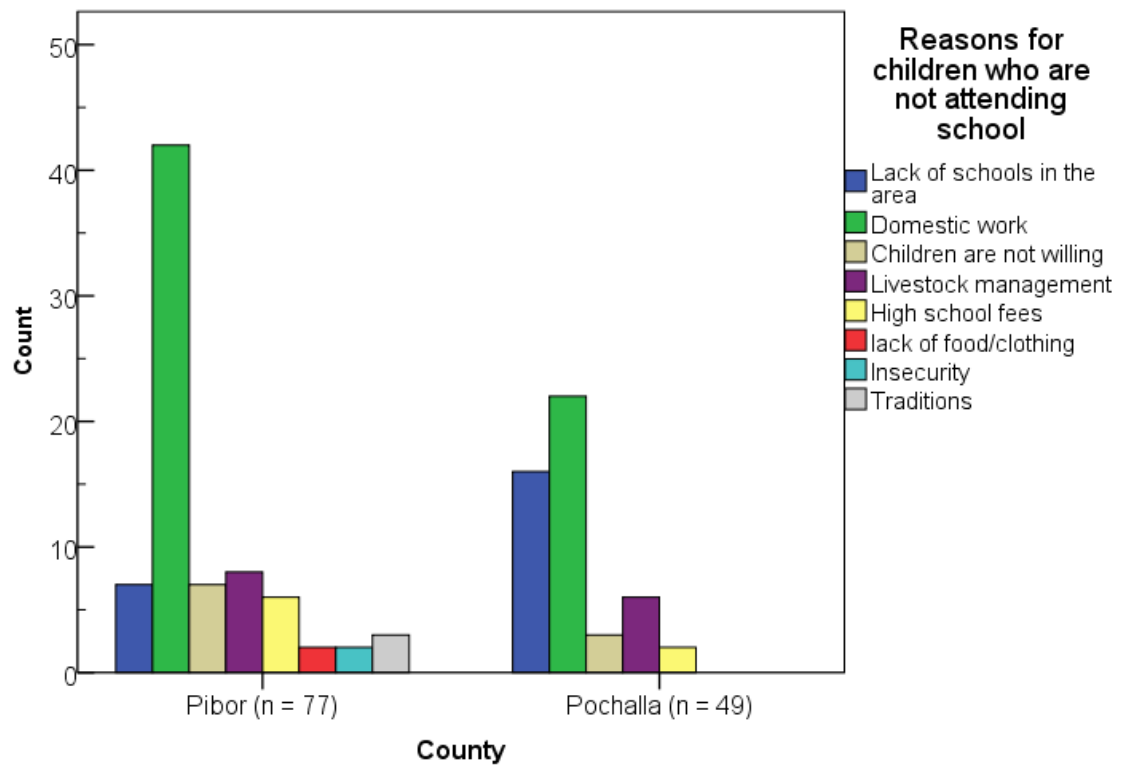


Figure 7.10. Reasons for children not attending schools at school age.

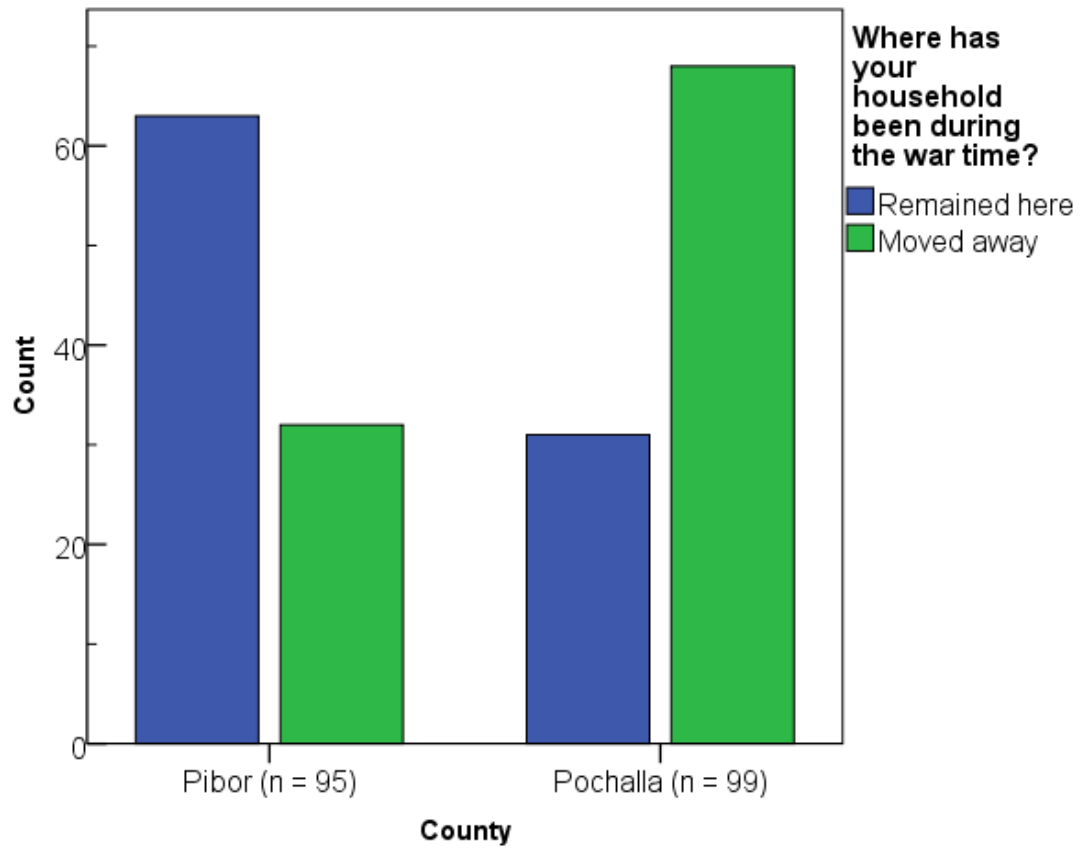


Figure 7.11. Household displacement during the civil war (1983-2005).

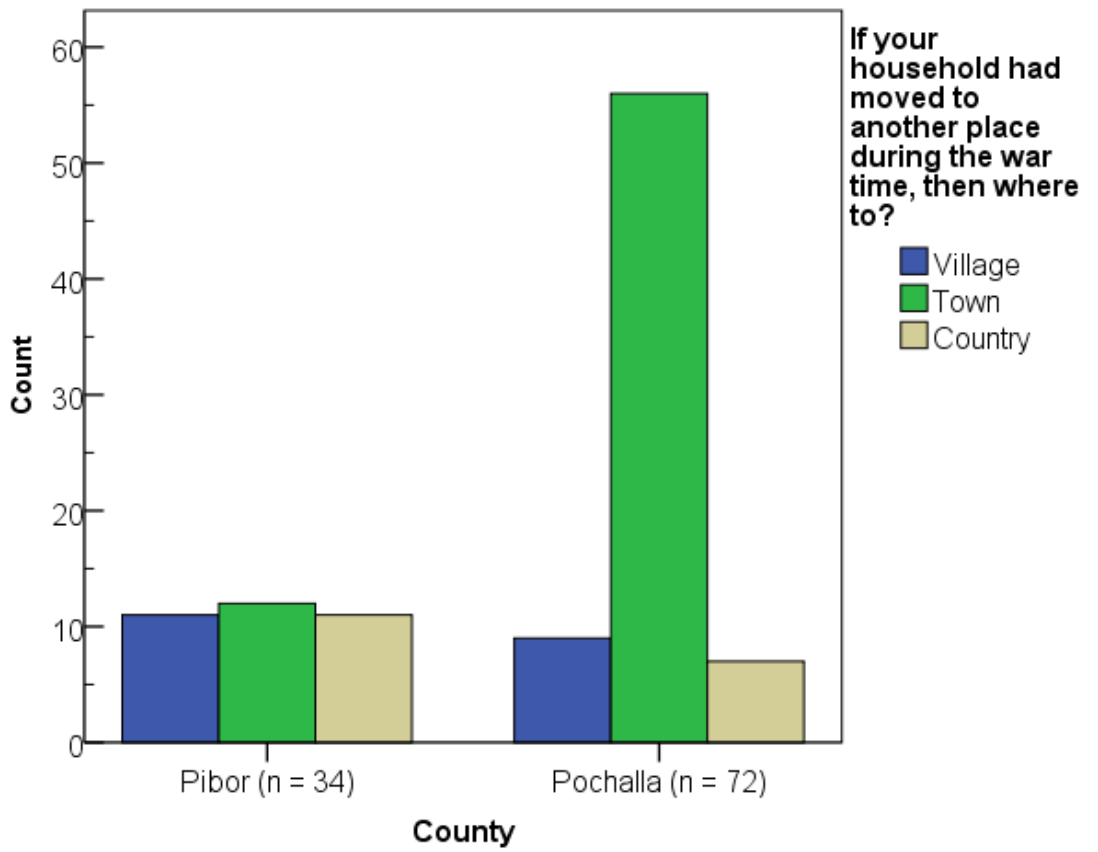


Figure 7.12. Household movements during the civil war.

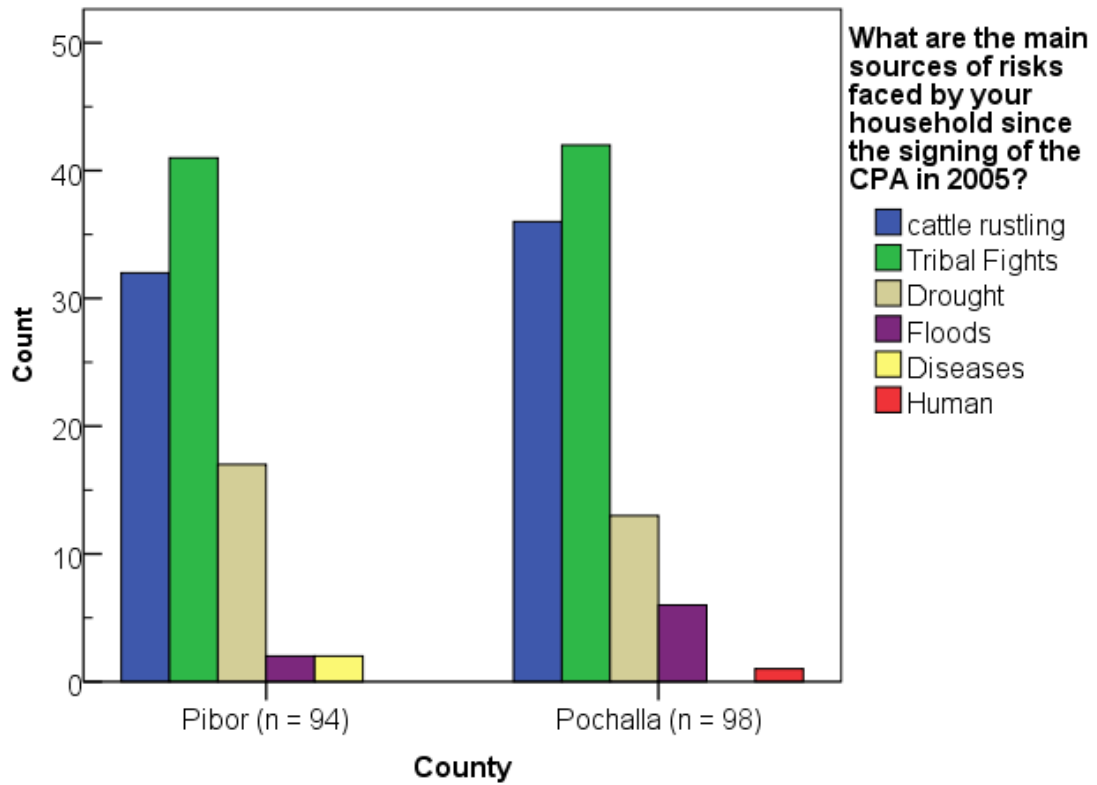


Figure 7.13. Main sources of risk facing households since the signing of the Comprehensive Peace Agreement in 2005.



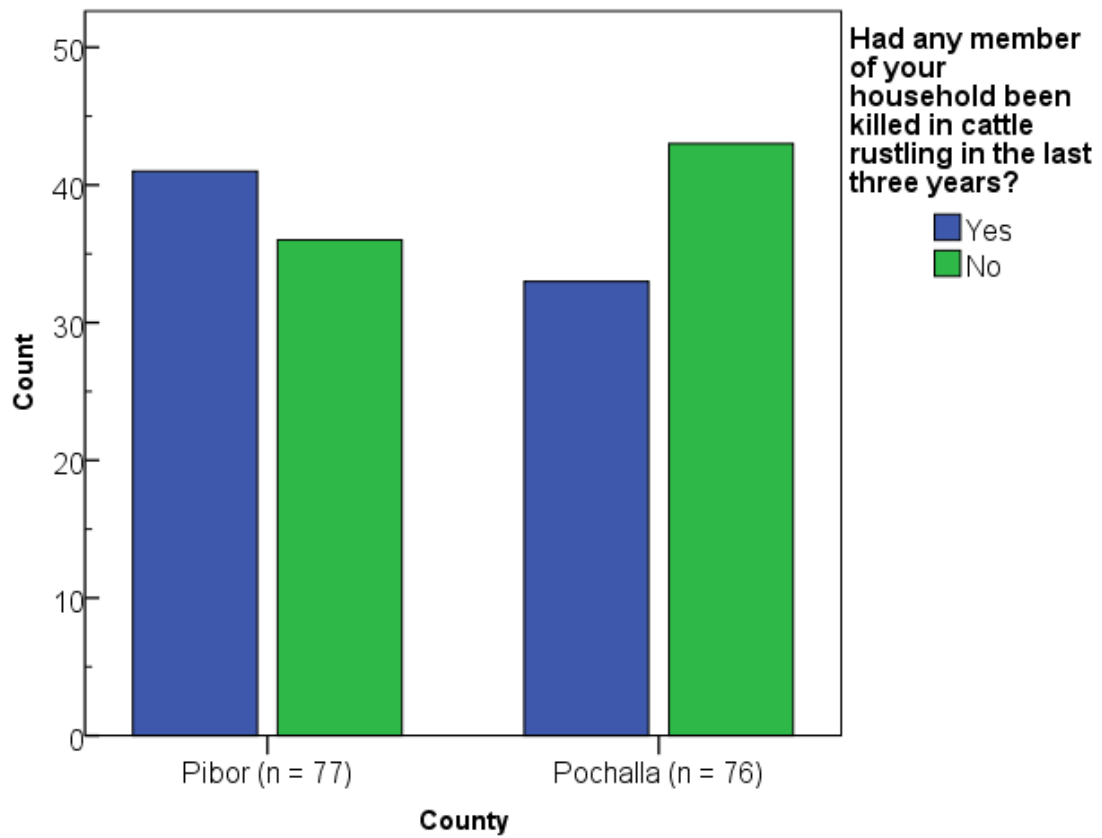


Figure 7.14. Loss of household members during cattle rustling.

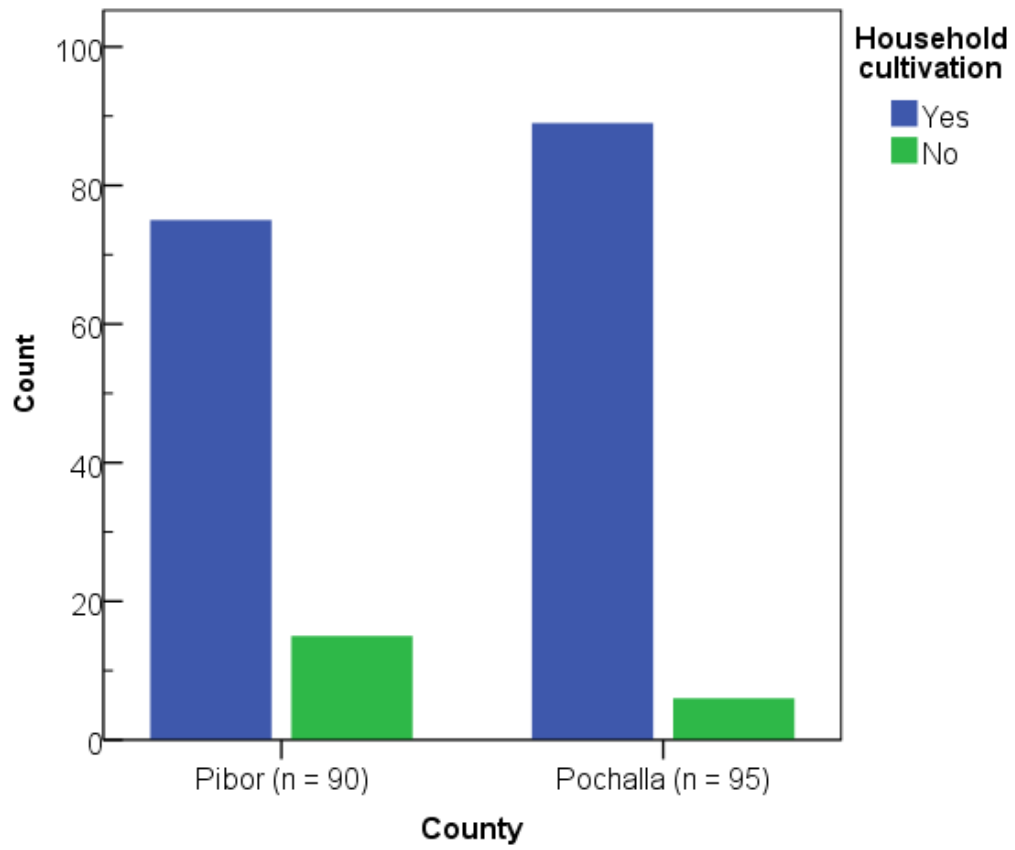


Figure 7.15. Involvement of households in agriculture/cultivation.

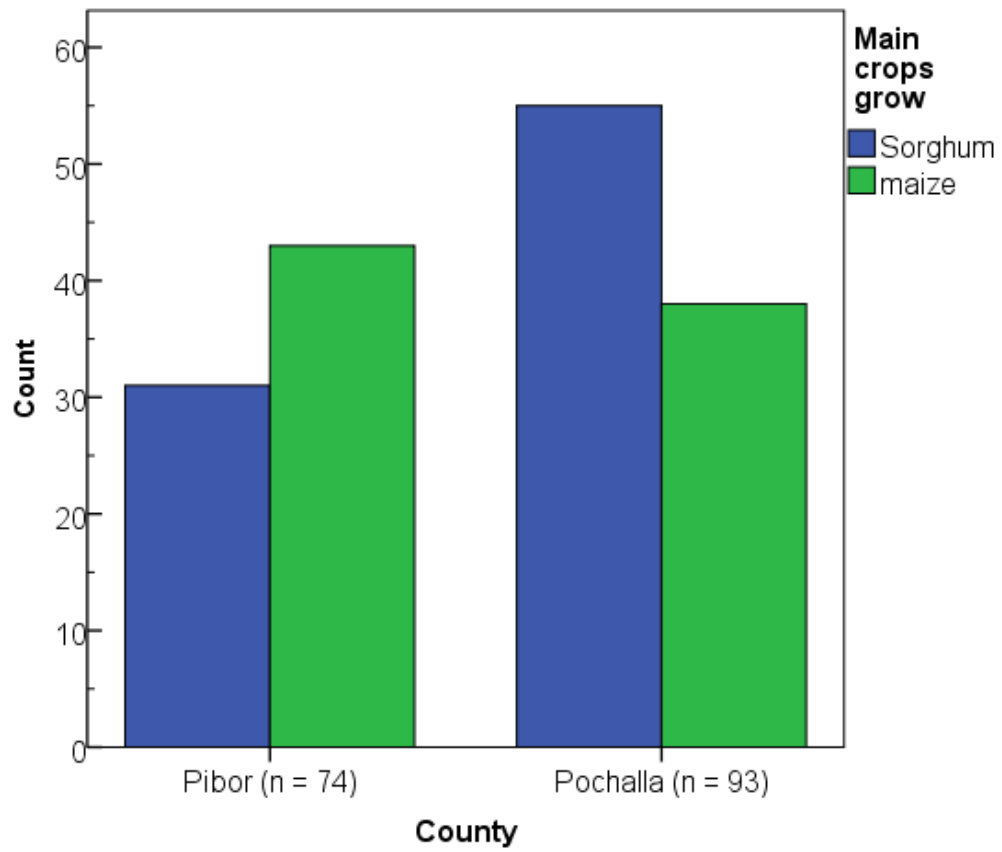


Figure 7.16. Main food crops grown by households.

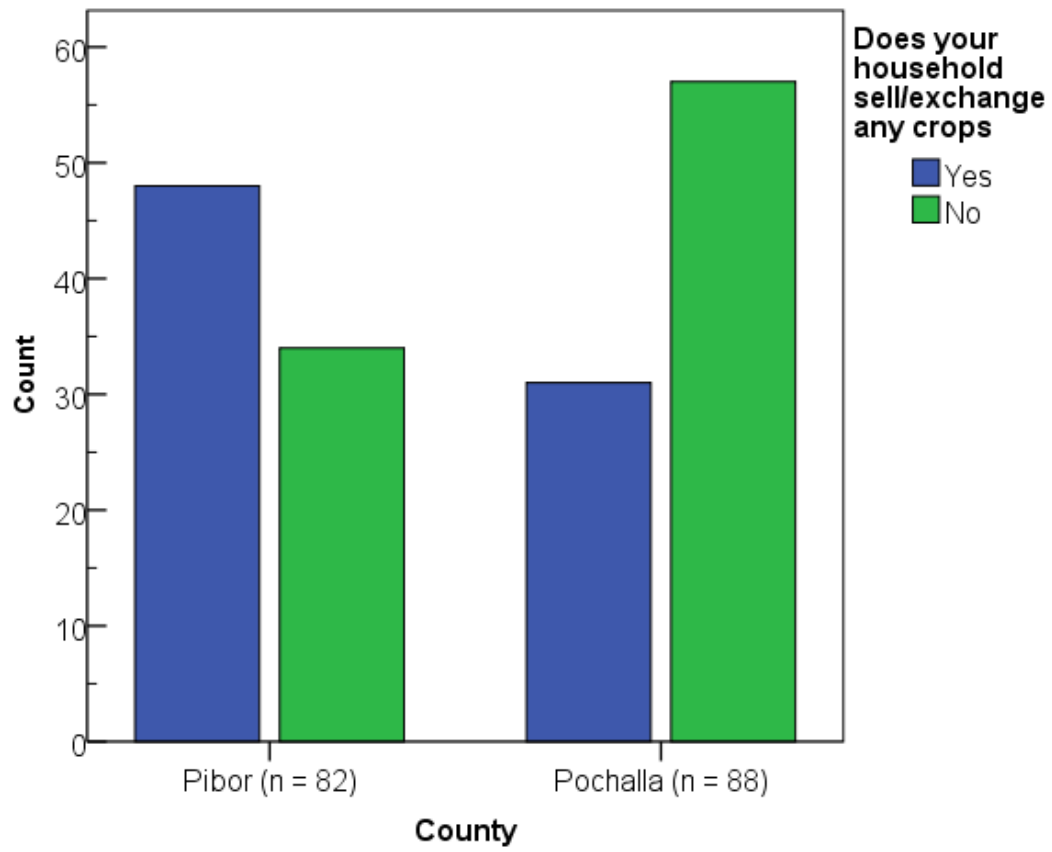


Figure 7.17. Selling/exchanging of locally grown crops in the local market.

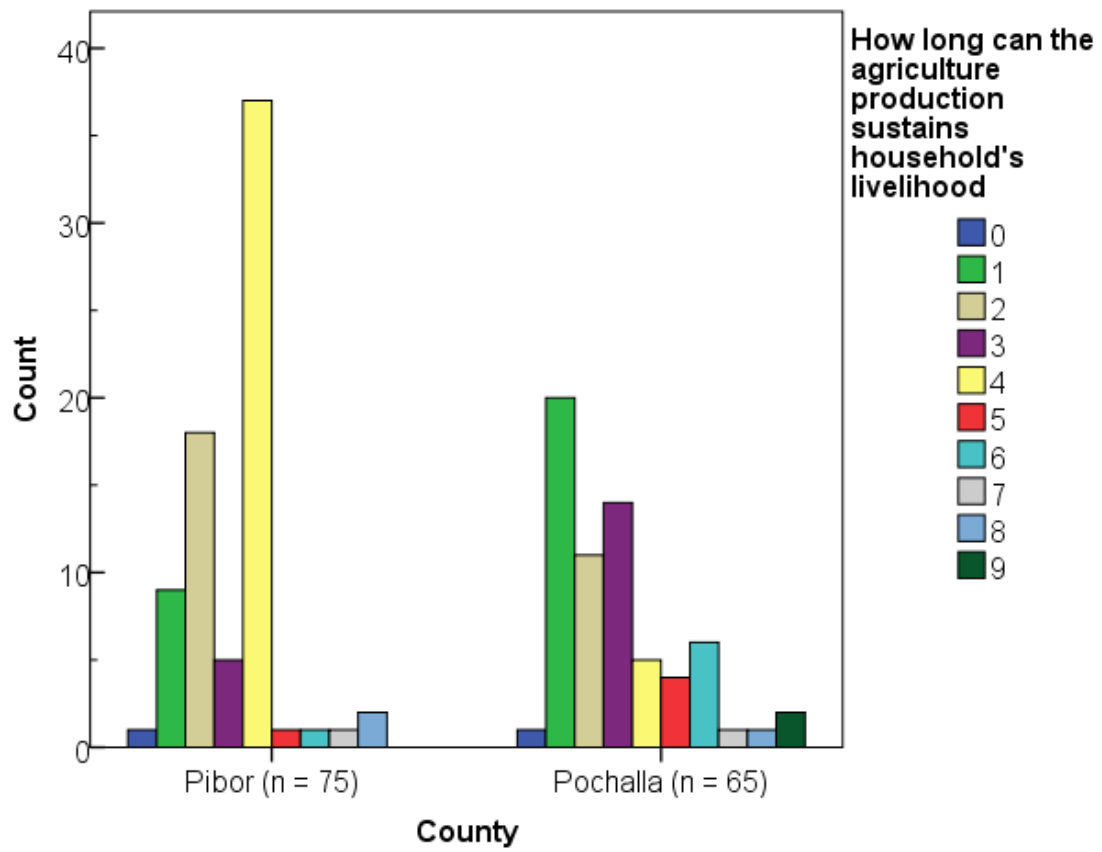


Figure 7.18. Agricultural production and household livelihood sustenance.

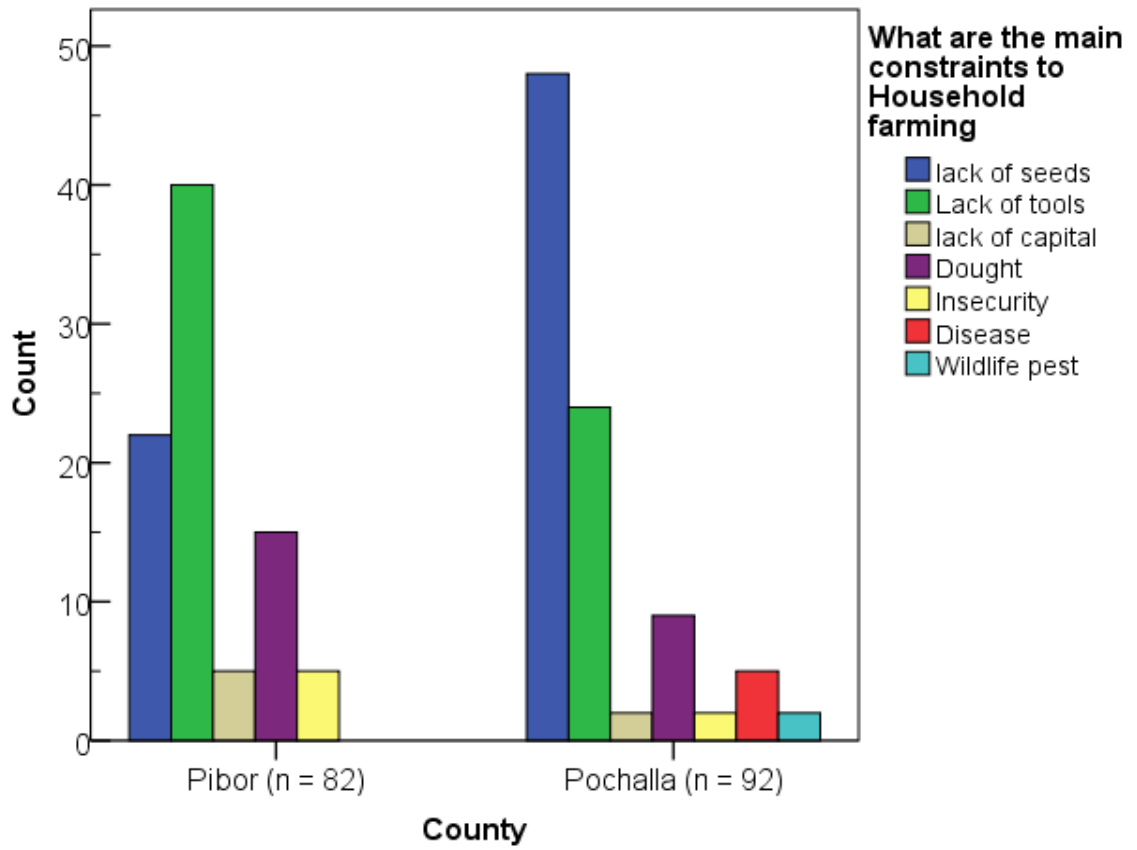


Figure 7.19. Constraints to household farming.

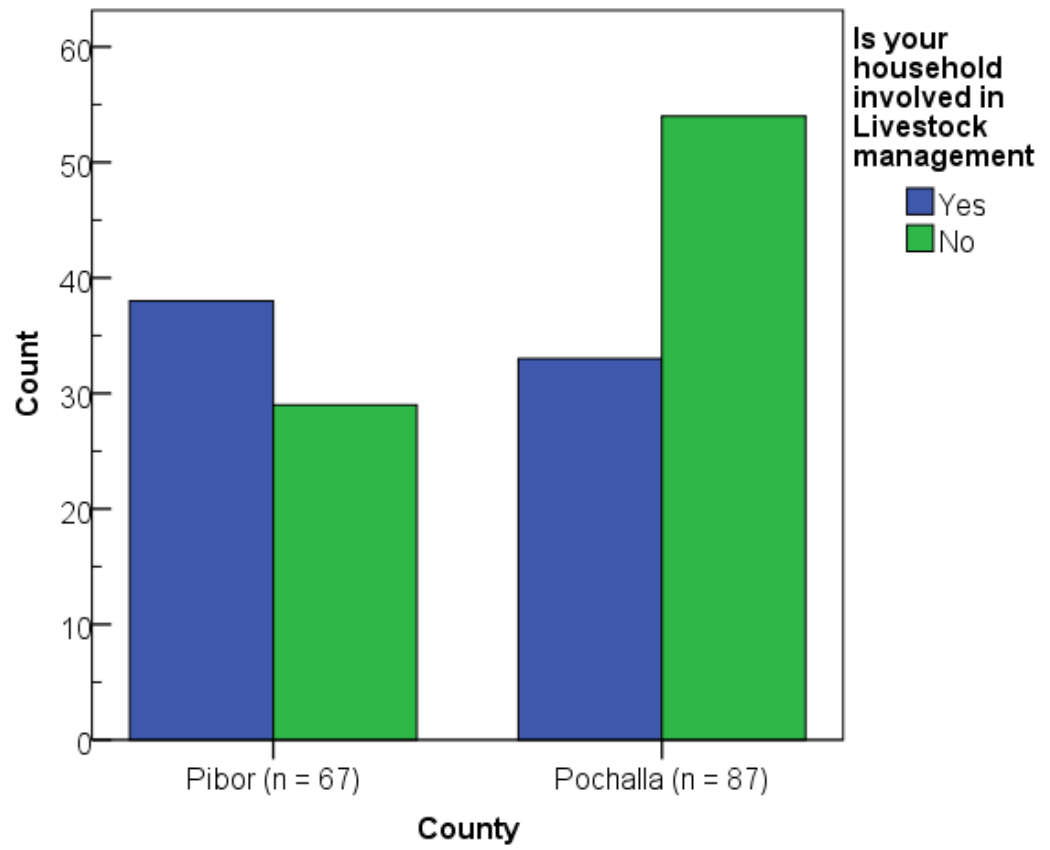


Figure 7.20. Household involvement in livestock management

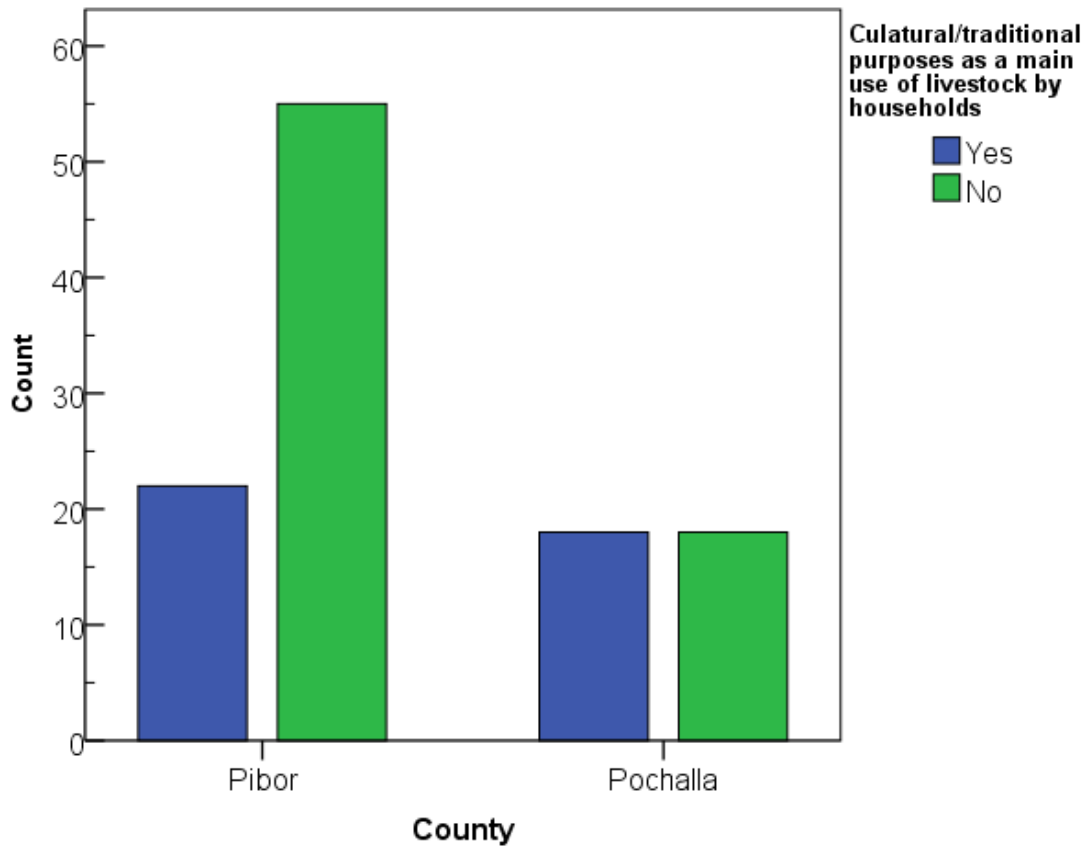


Figure 7.21. Livestock management for traditional use vs commercial husbandry



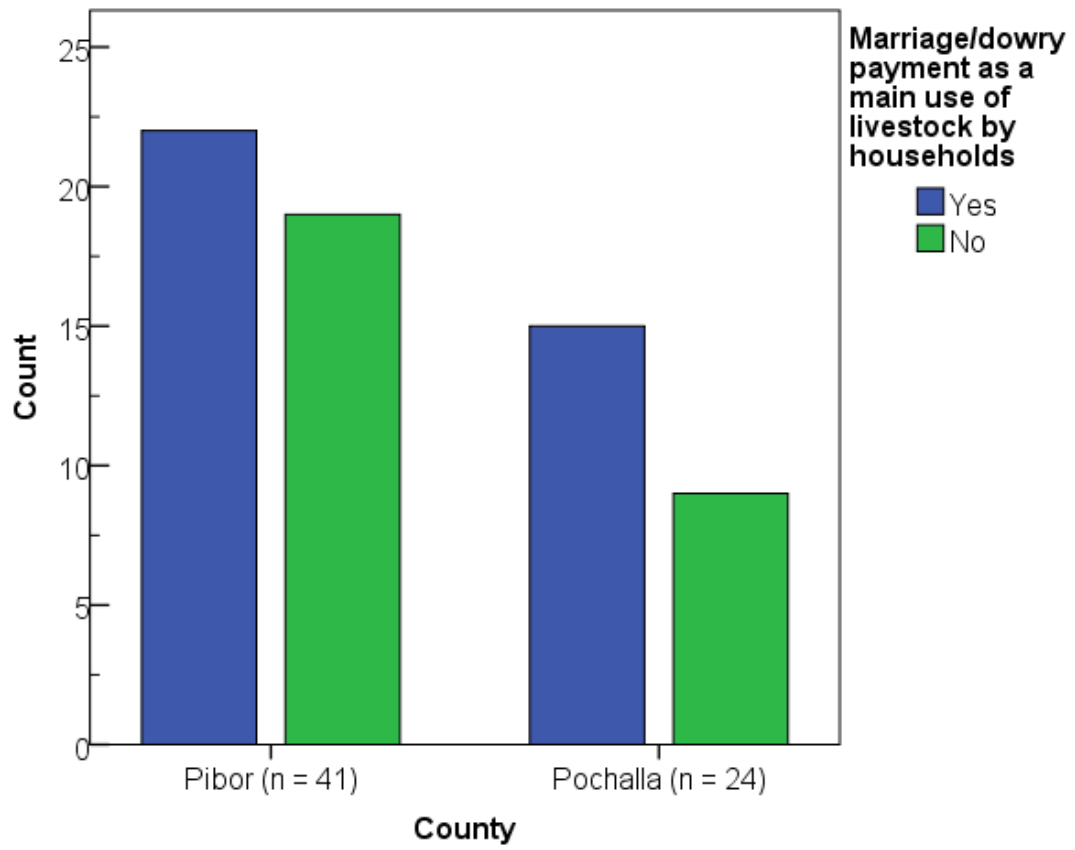


Figure 7.22. The use of livestock for marriage/dowry by households.

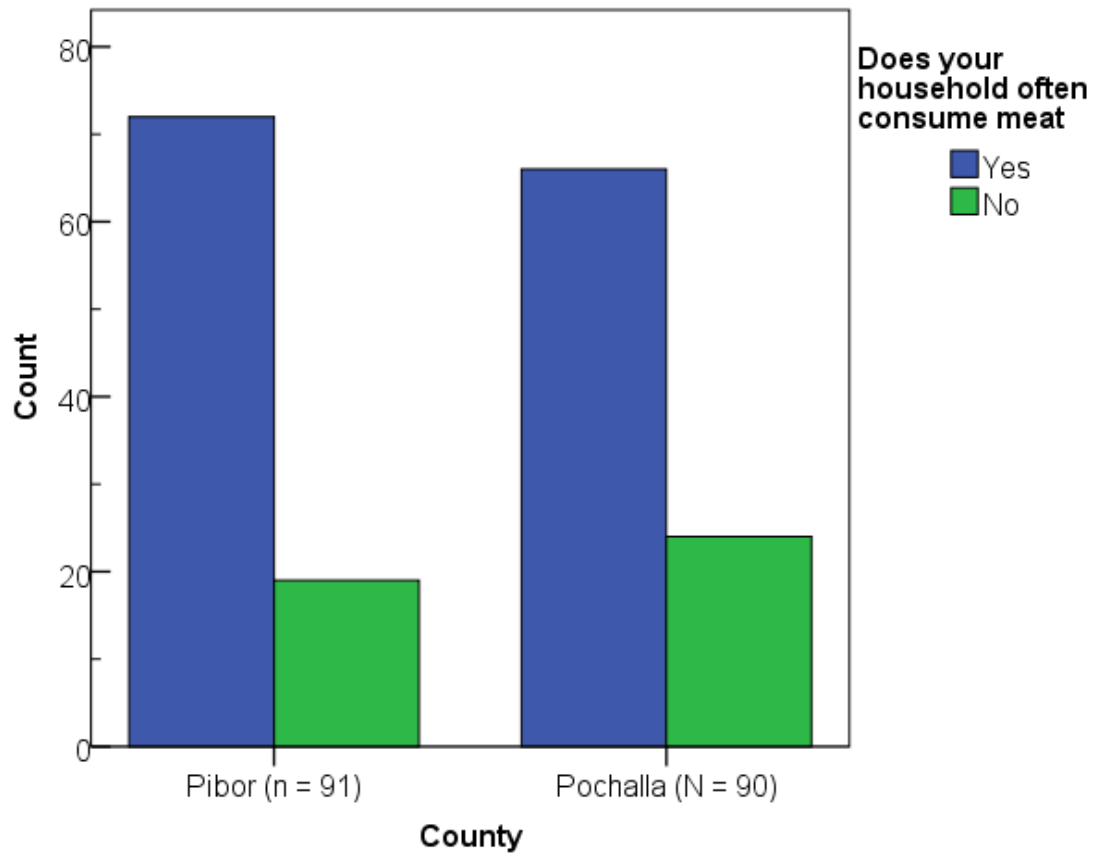


Figure 7.23 Household's meat consumption habits

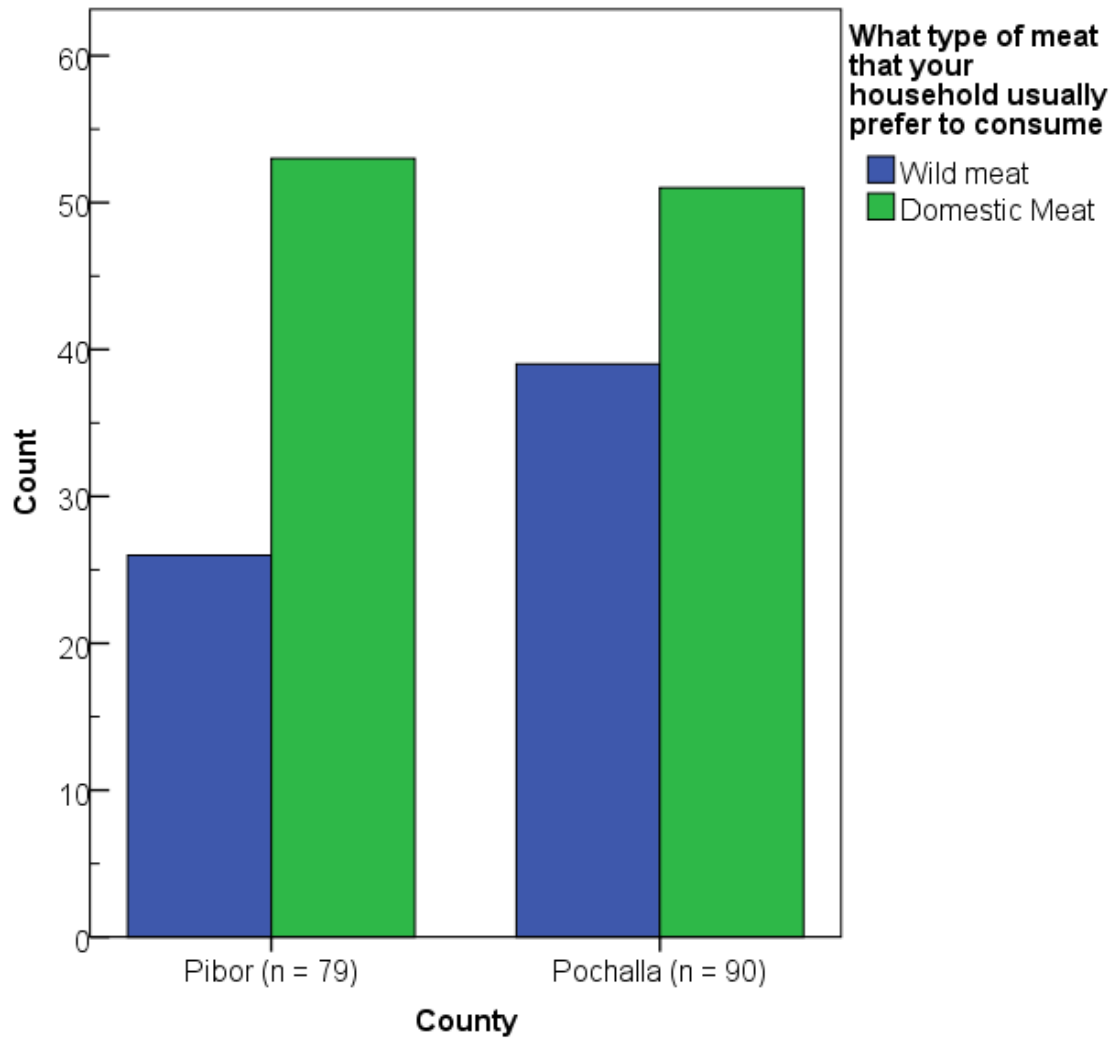


Figure 7.24. Household Meat consumption preferences for domestic or wild meat.

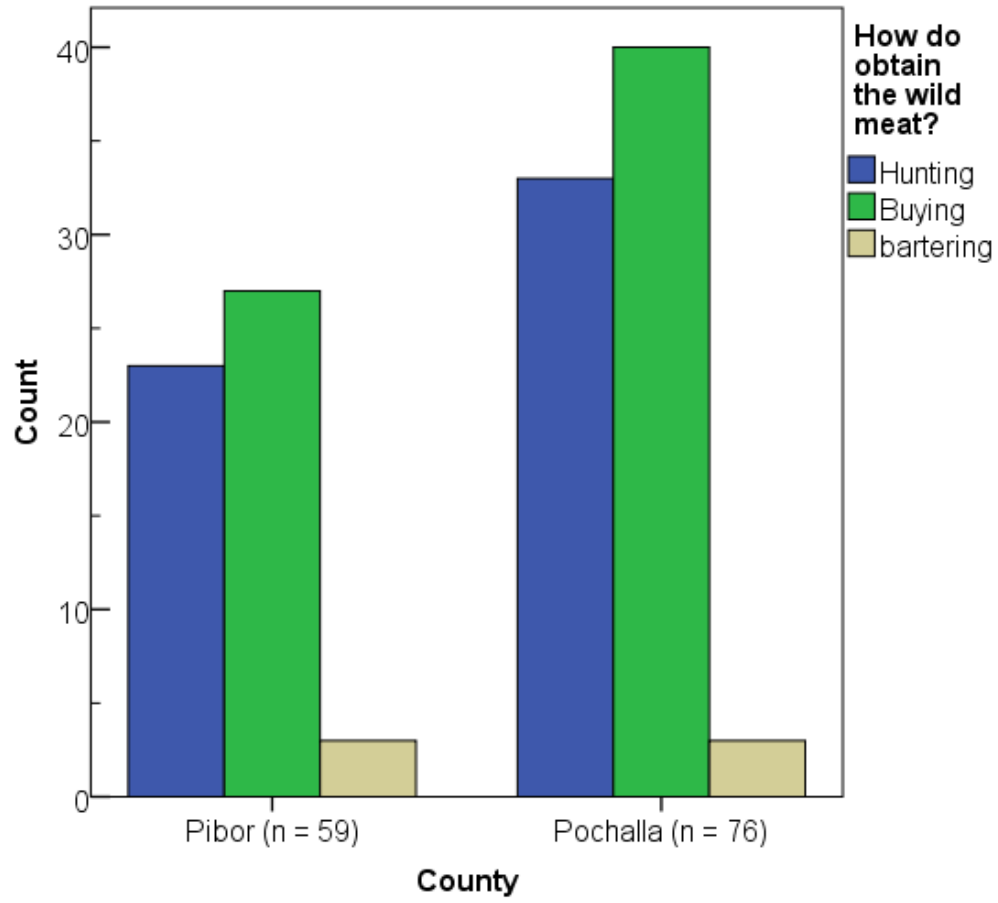


Figure 7.25. Means of obtaining wild meat for household consumption.

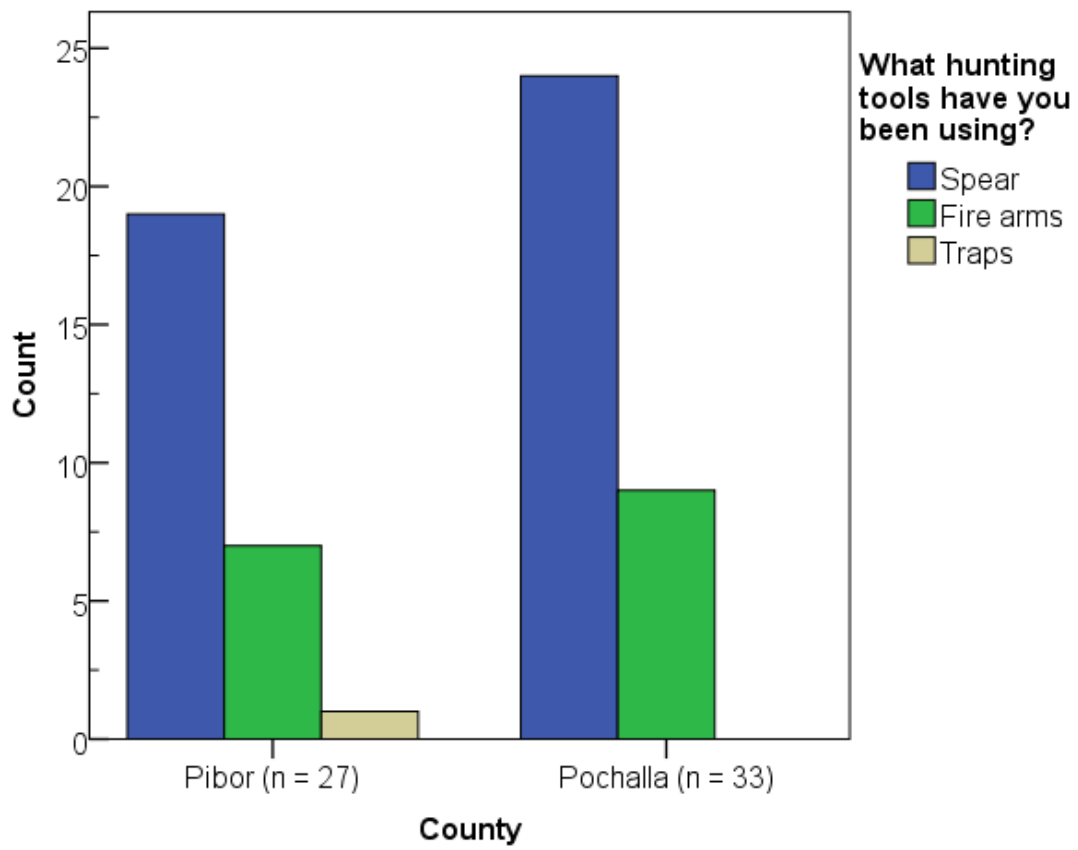


Figure 7.26. Hunting tools used by household members who hunt.

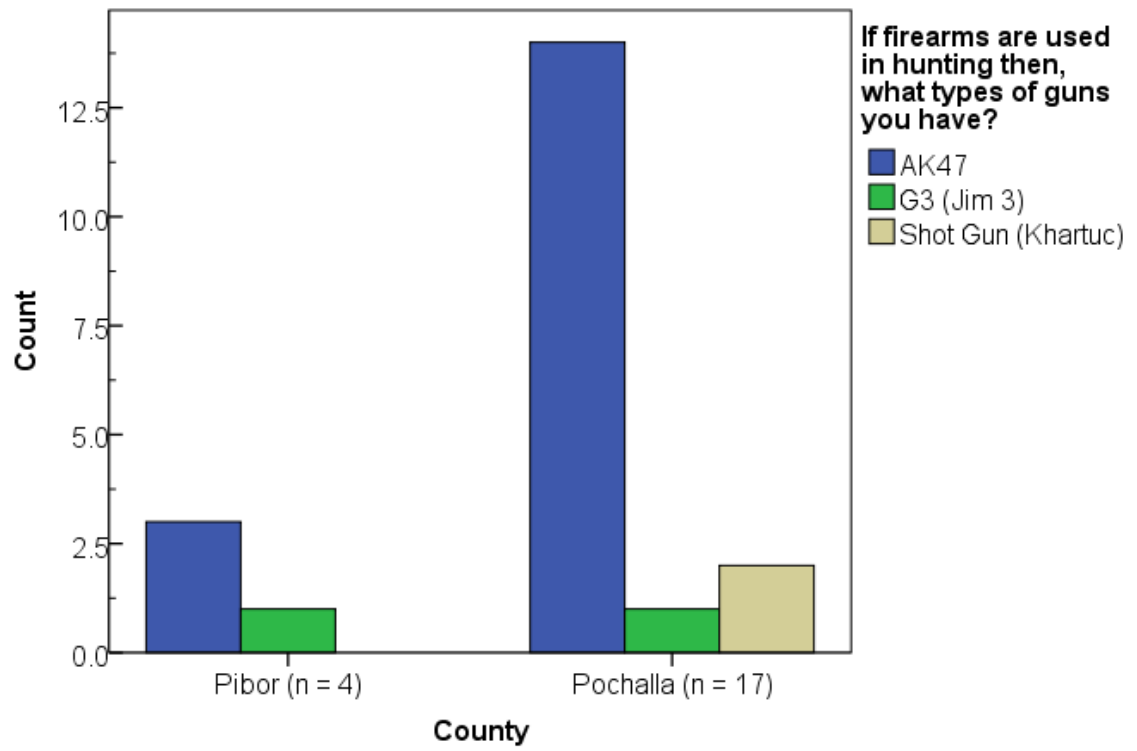


Figure 7.27. Types of firearms used by household members for hunting wildlife meat

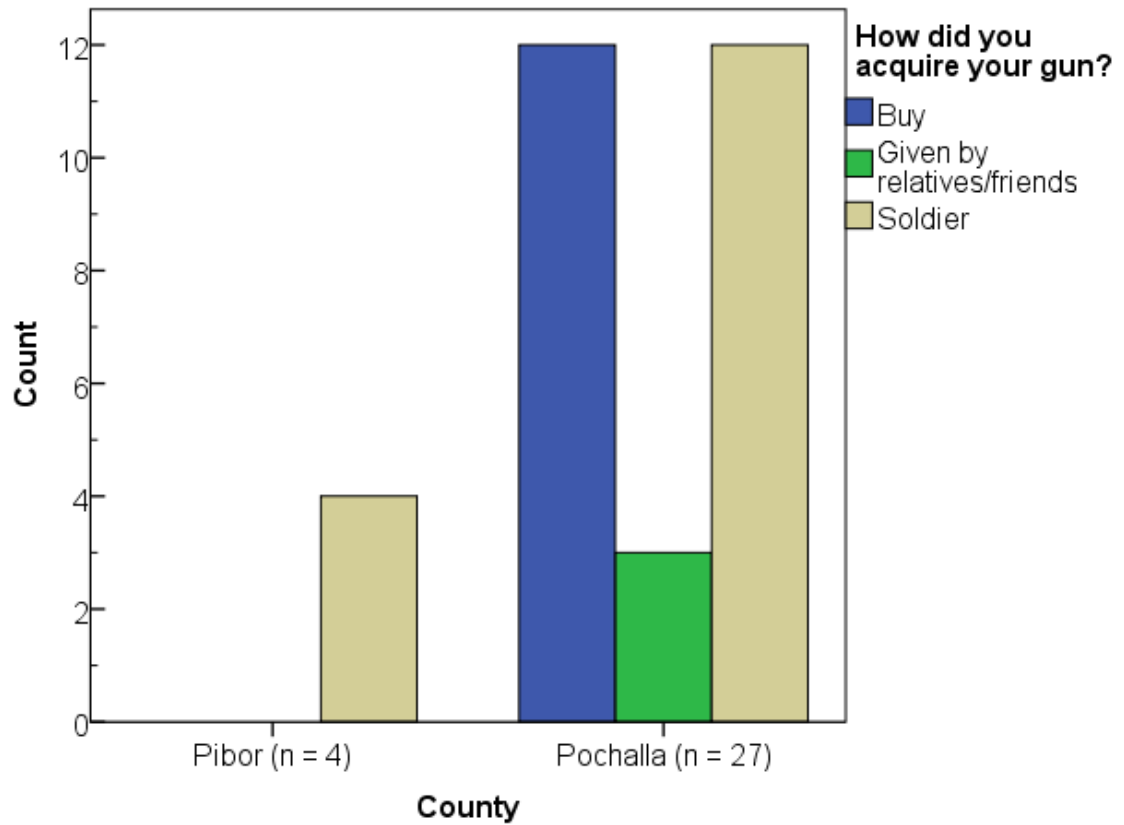


Figure 7.28. Sources from which household members obtain firearms used in hunting

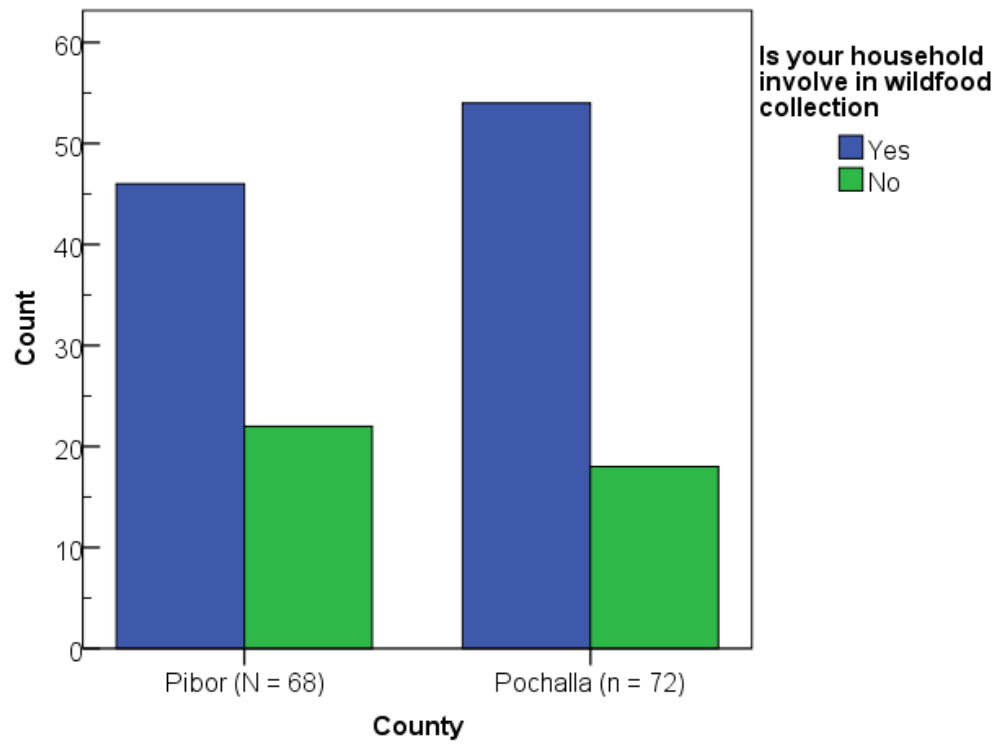


Figure 7.29. Household involvements in wildlife food collection in/around Boma National Park



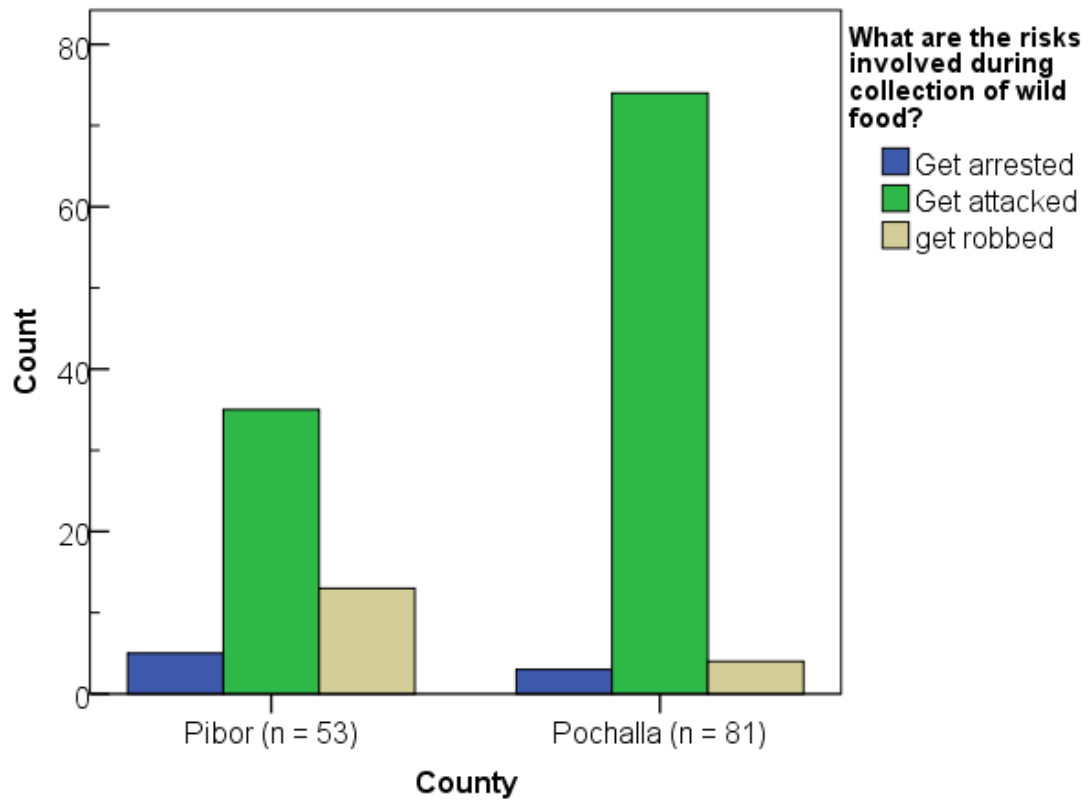


Figure 7.30. Risks that household member face while collecting wild food plants inside Boma National Park boundaries.

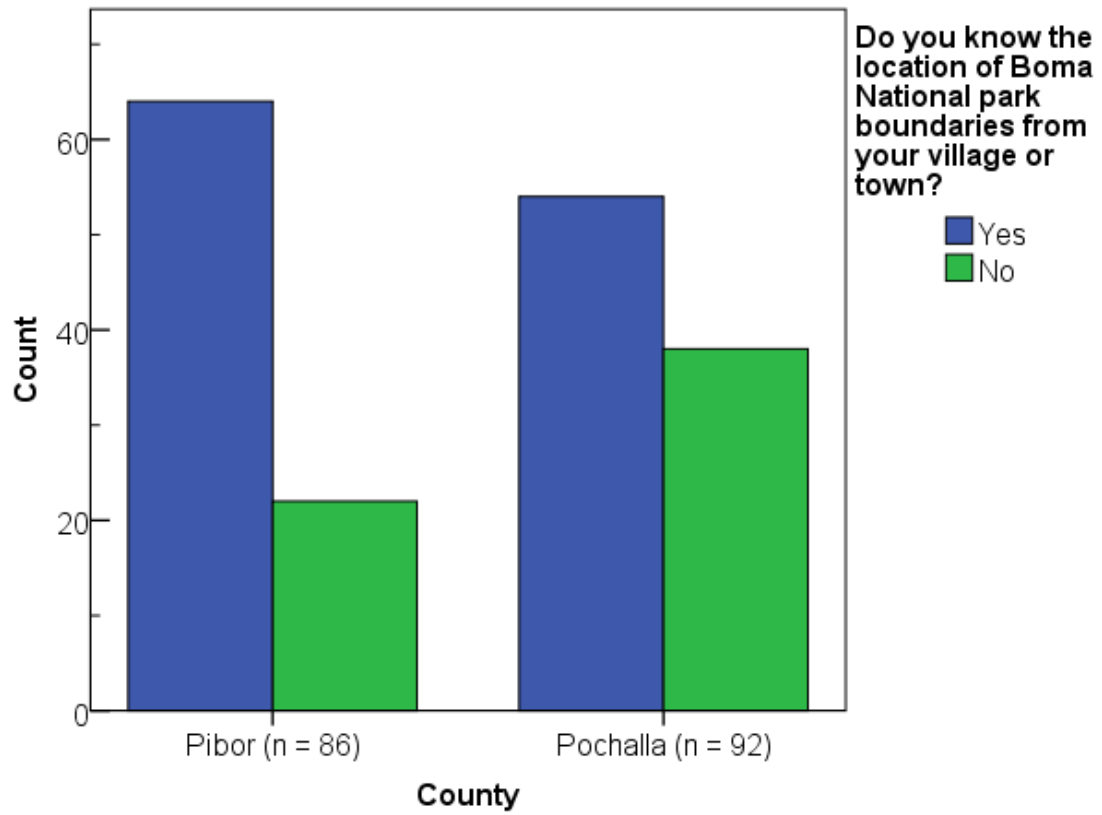


Figure 7.31. Knowledge of household members concerning the boundaries of Boma National Park.

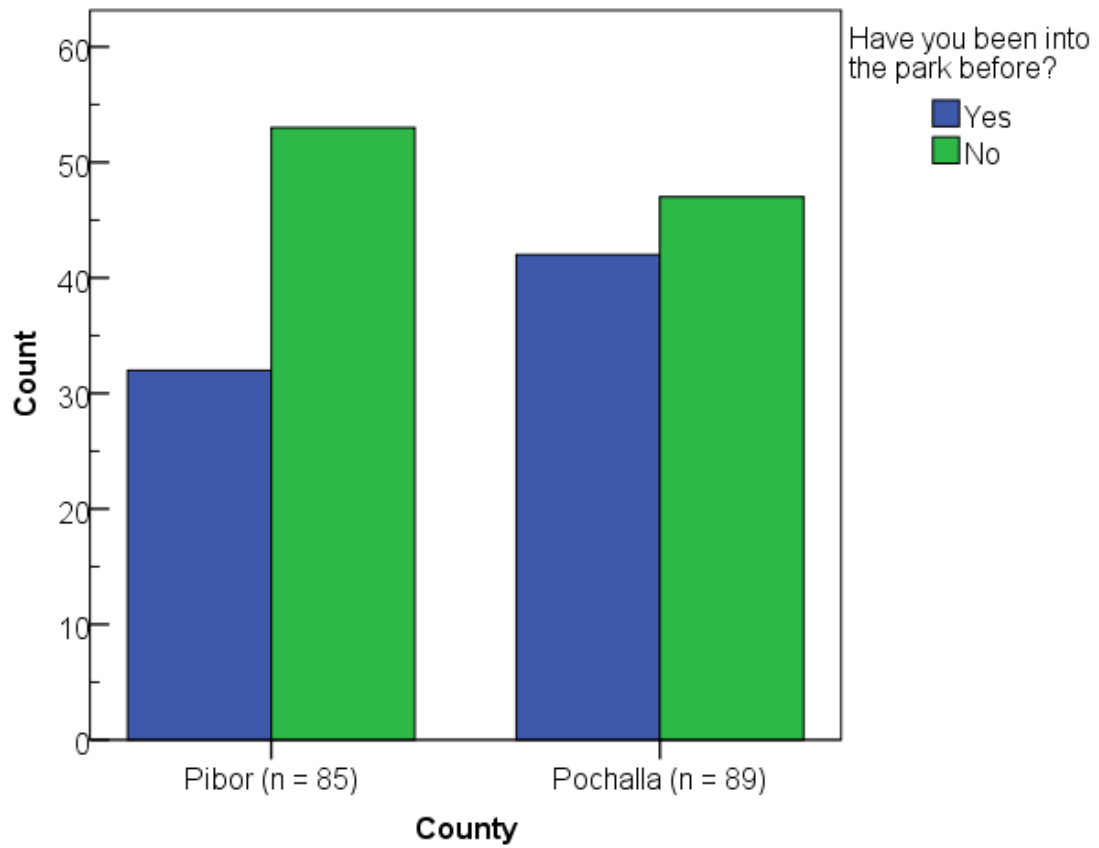


Figure 7.32. Frequency of household members trespassing the Boma National Park boundaries.

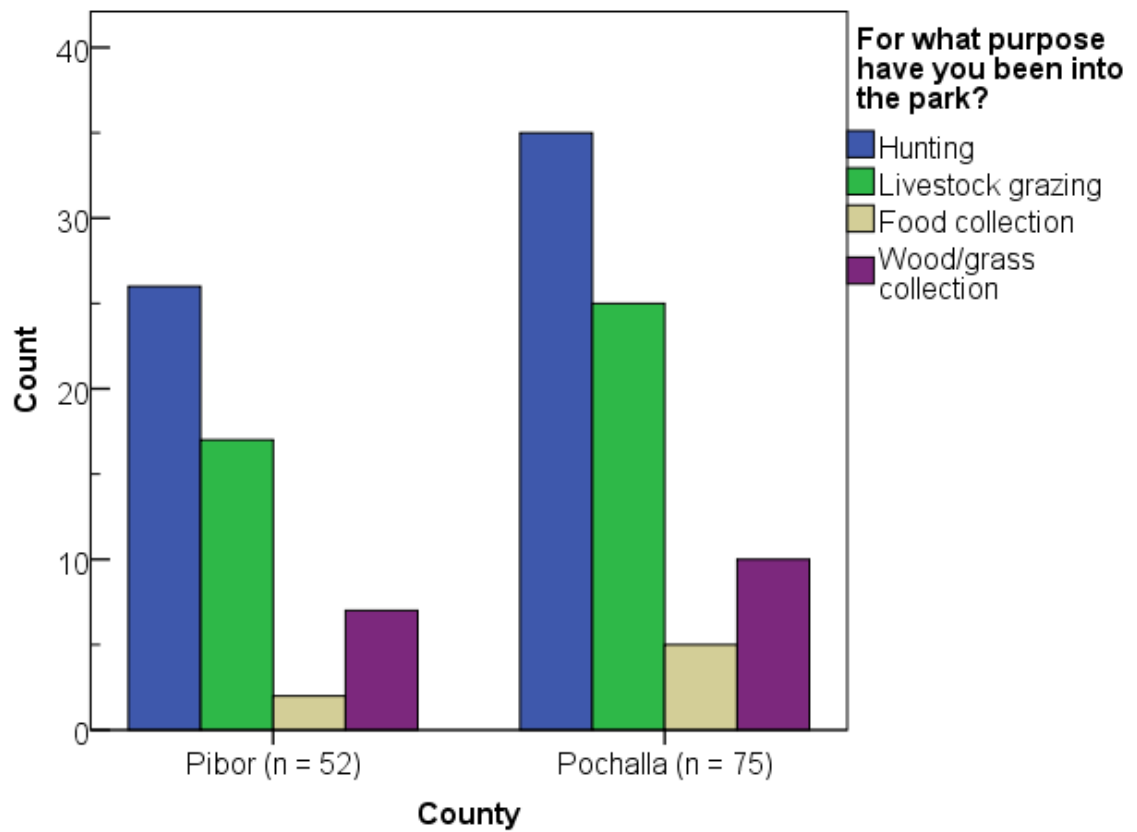


Figure 7.33. Reasons why household members trespass into Boma National Park.

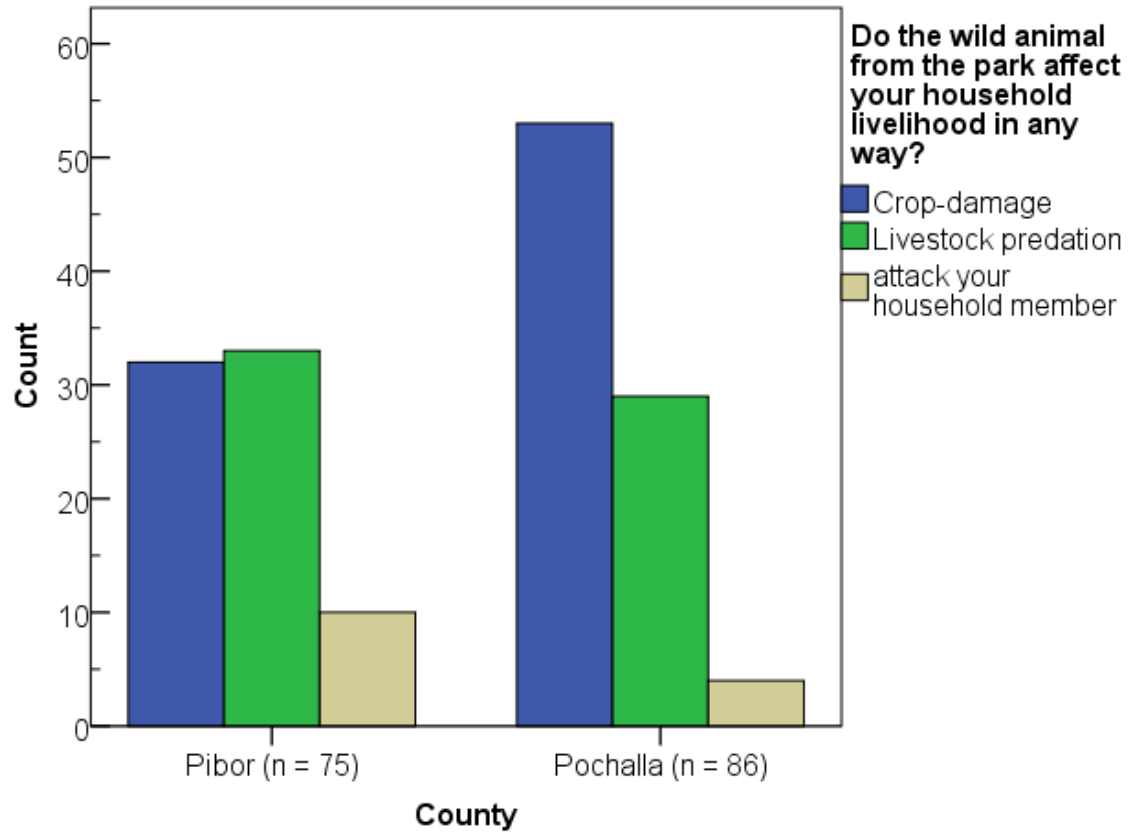


Figure 7.34. Wildlife damage to household livelihoods around Boma National Park.

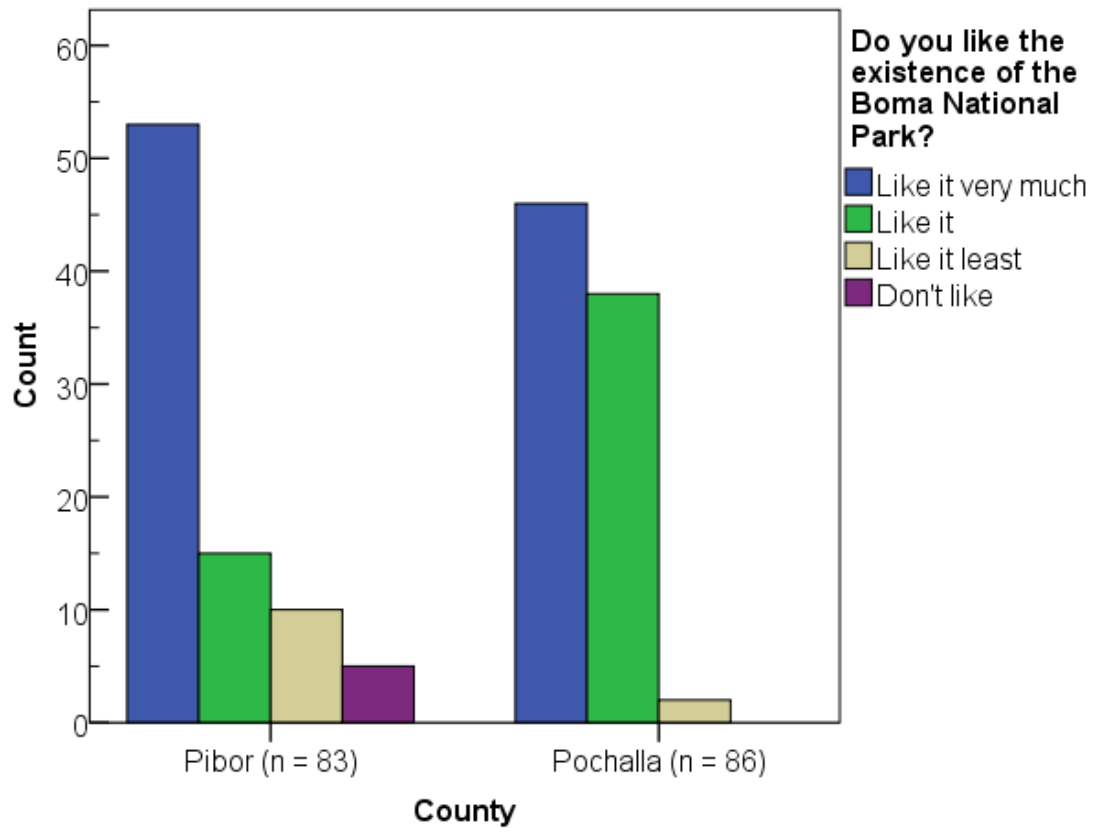


Figure 7.35. Perception of the household members about the existence of the Boma National park

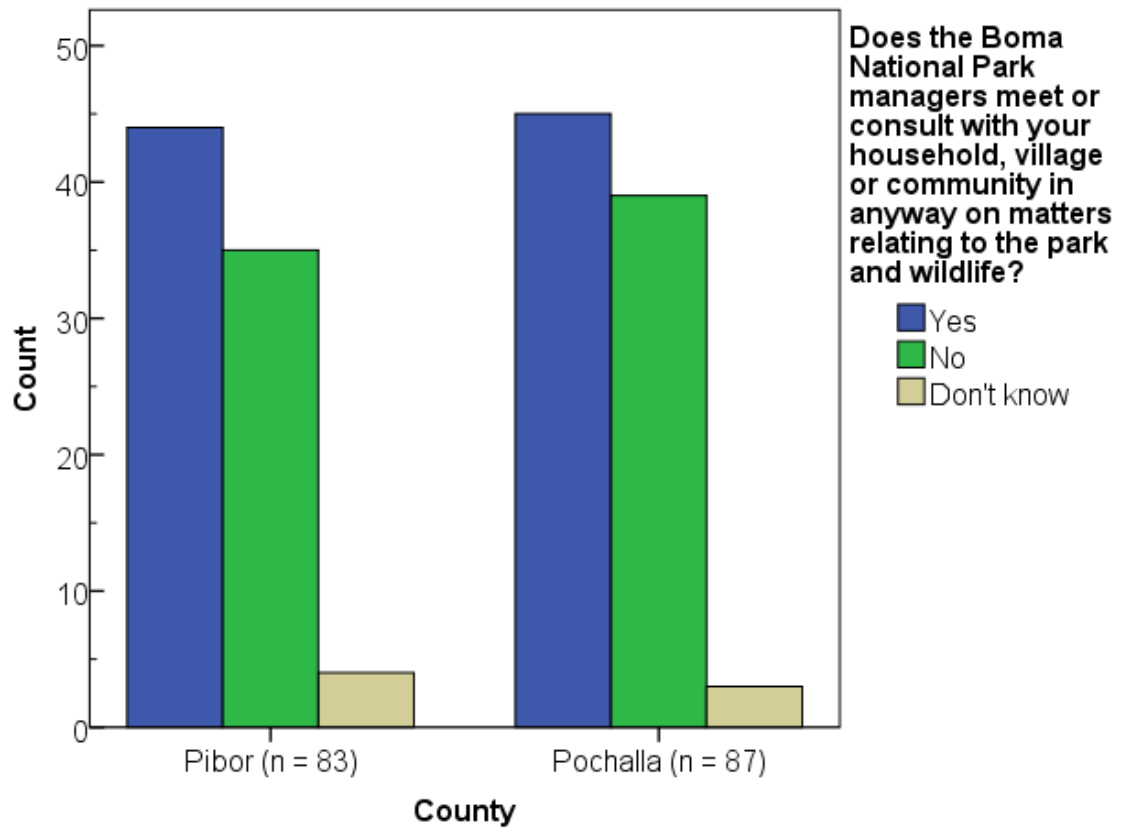


Figure 7.36. Interactions/consultations between Park managers and the surrounding households.

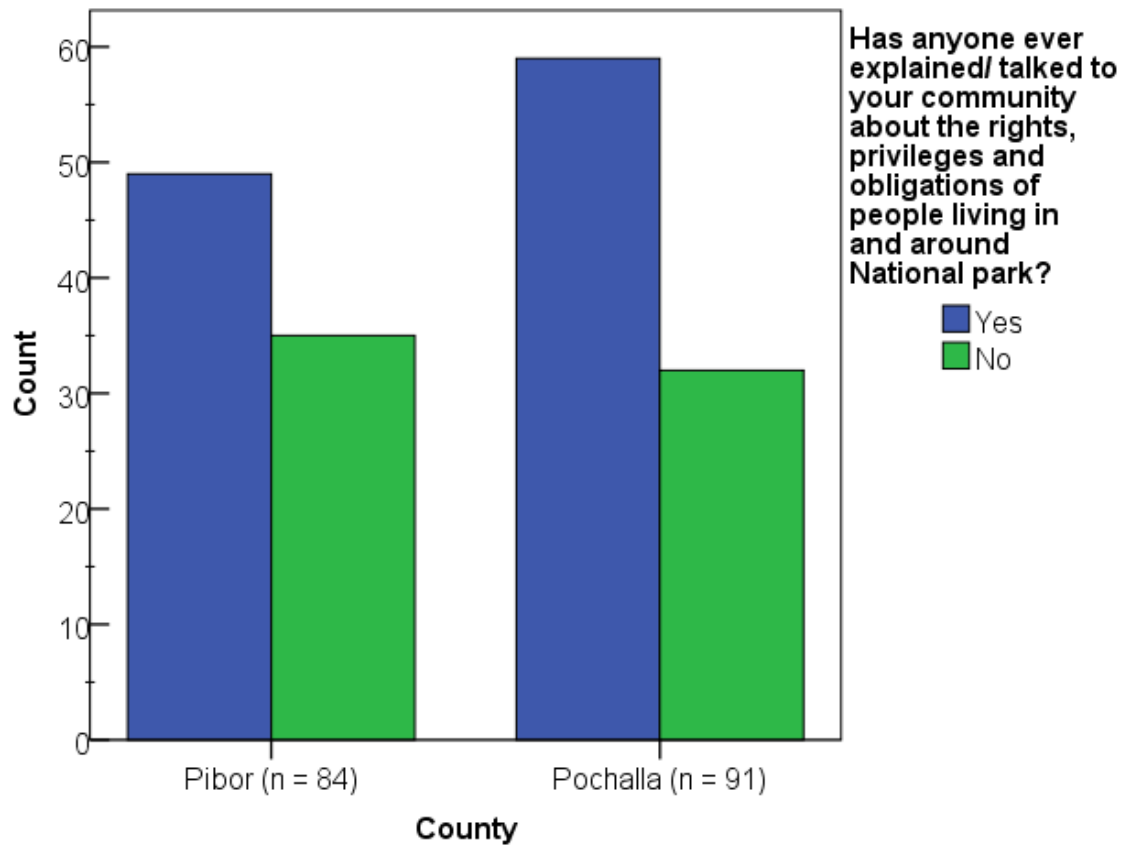


Figure 7.37. Engagements of the communities living in/ around the Boma National Park in the management issues of the Park



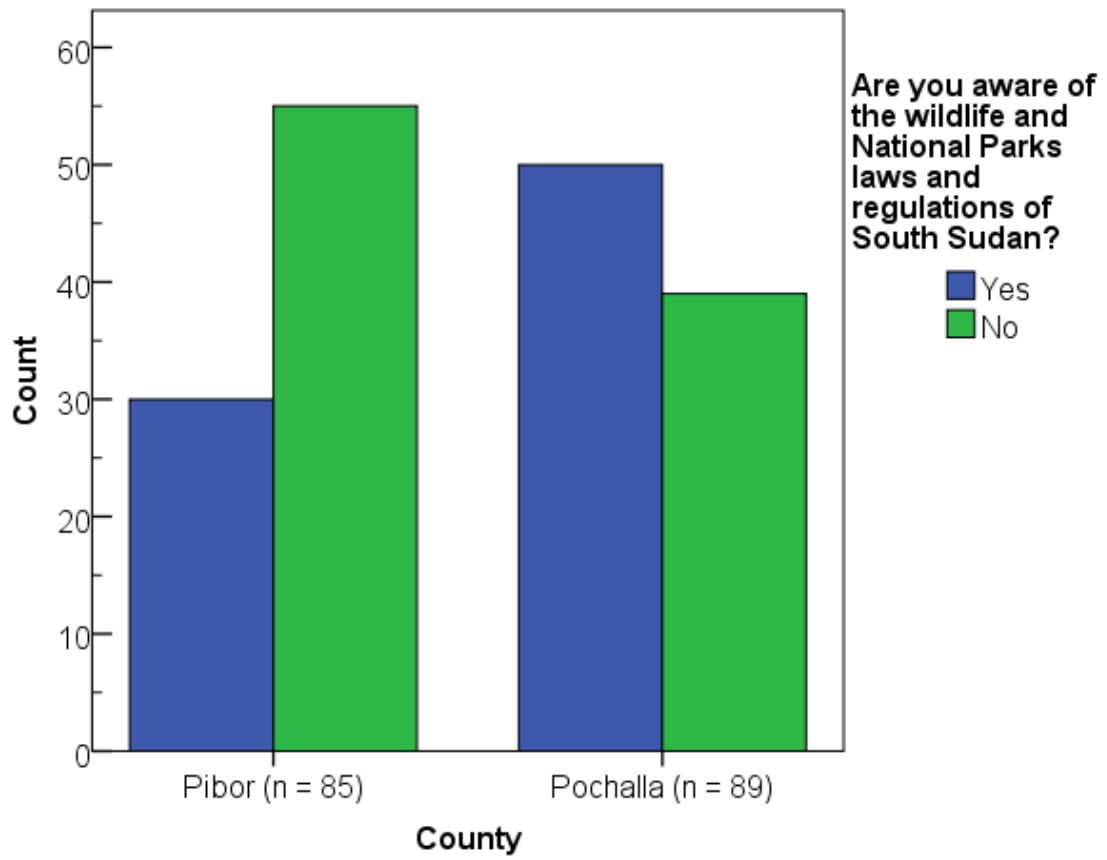


Figure 7.38. Household knowledge of South Sudan National Parks laws and regulations.

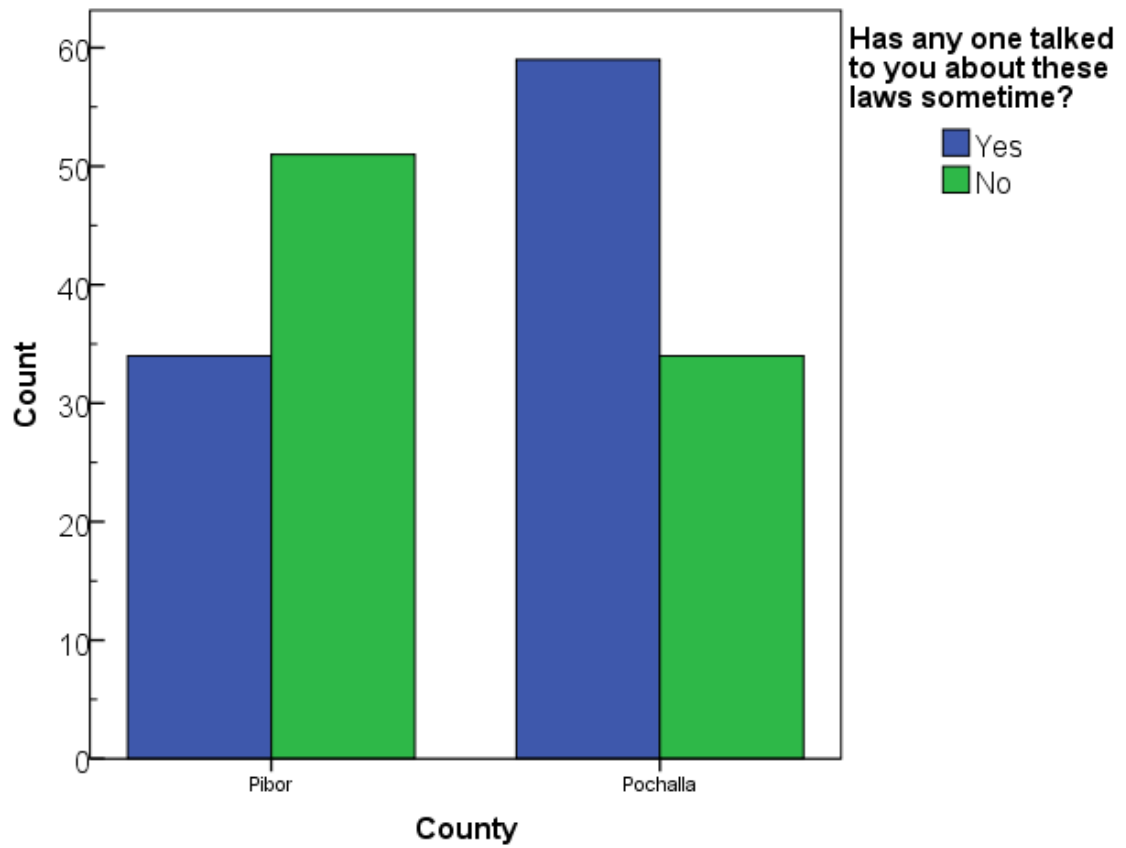


Figure 7.39. Community engagement and consultations by the Park management

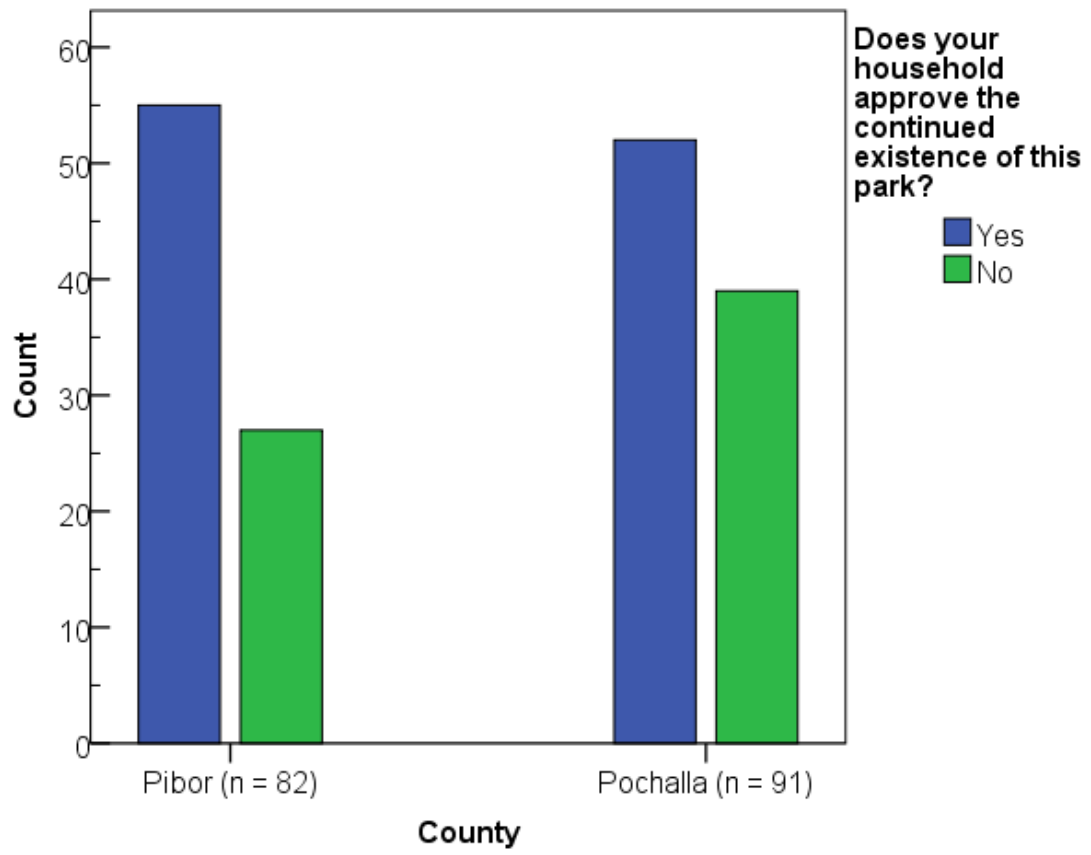


Figure 7.40. Household approval of the existence of Boma National Park.

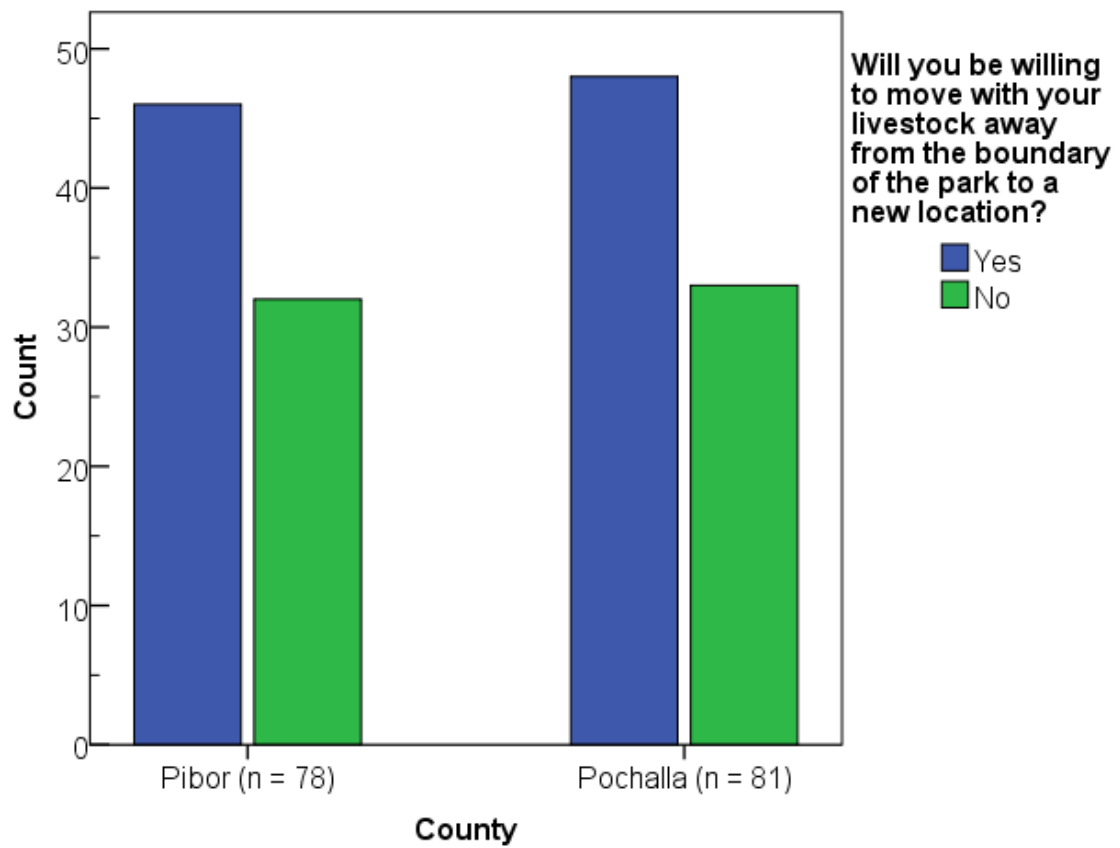


Figure 7.41. Household willingness to move away from the boundaries of Boma National Park to new locations.

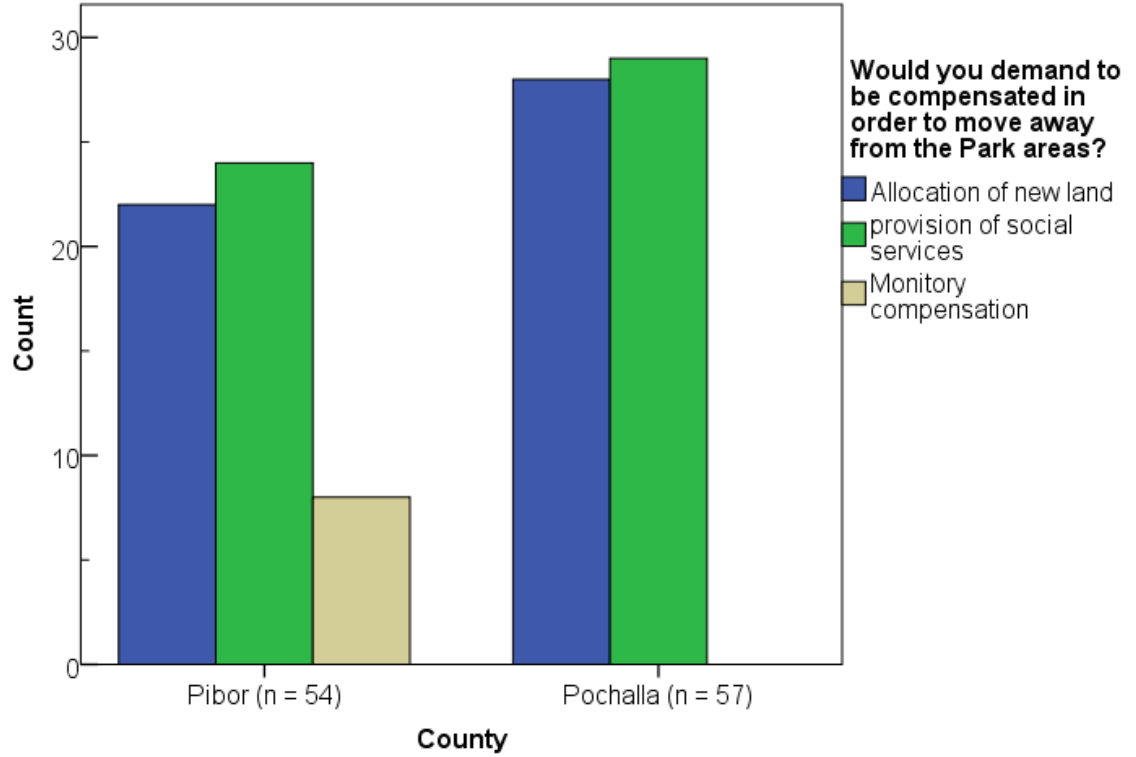


Figure 7.42. Types of compensations that households are likely to ask if they have to move away from Boma National Park and its surrounding areas.

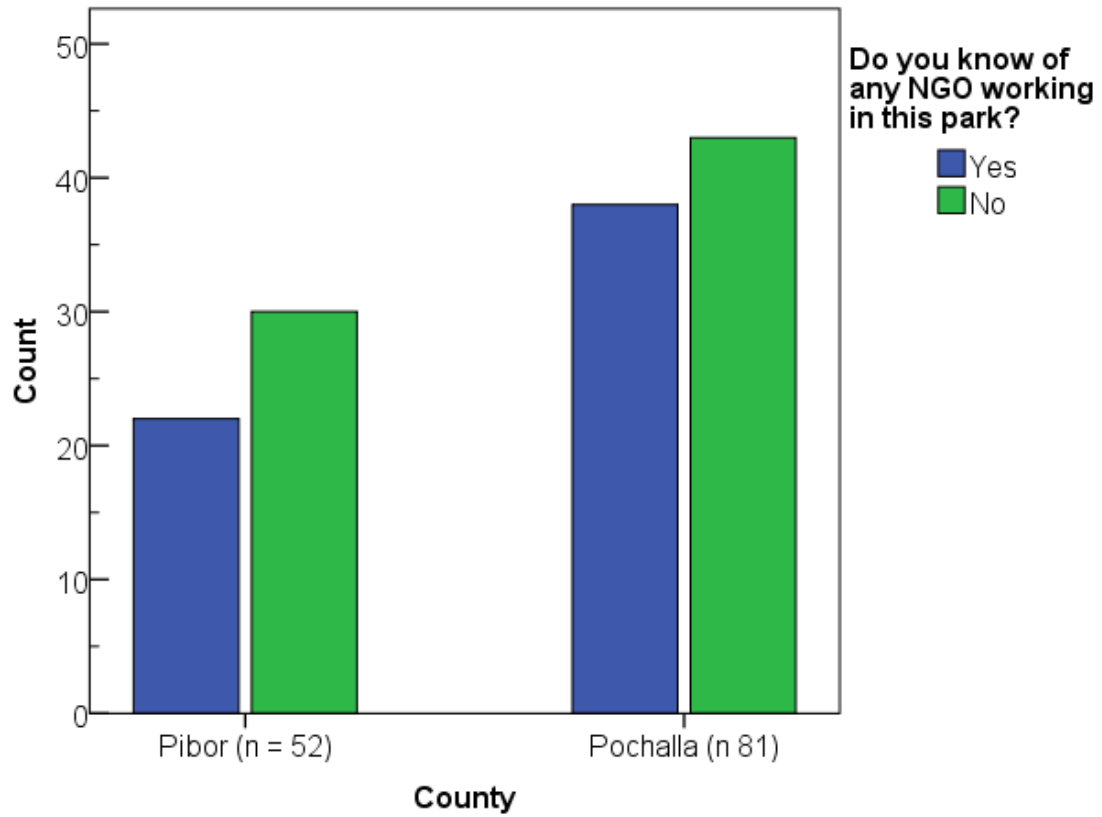


Figure 7.43. Household knowledge of conservation NGOs operating in Boma National Park.

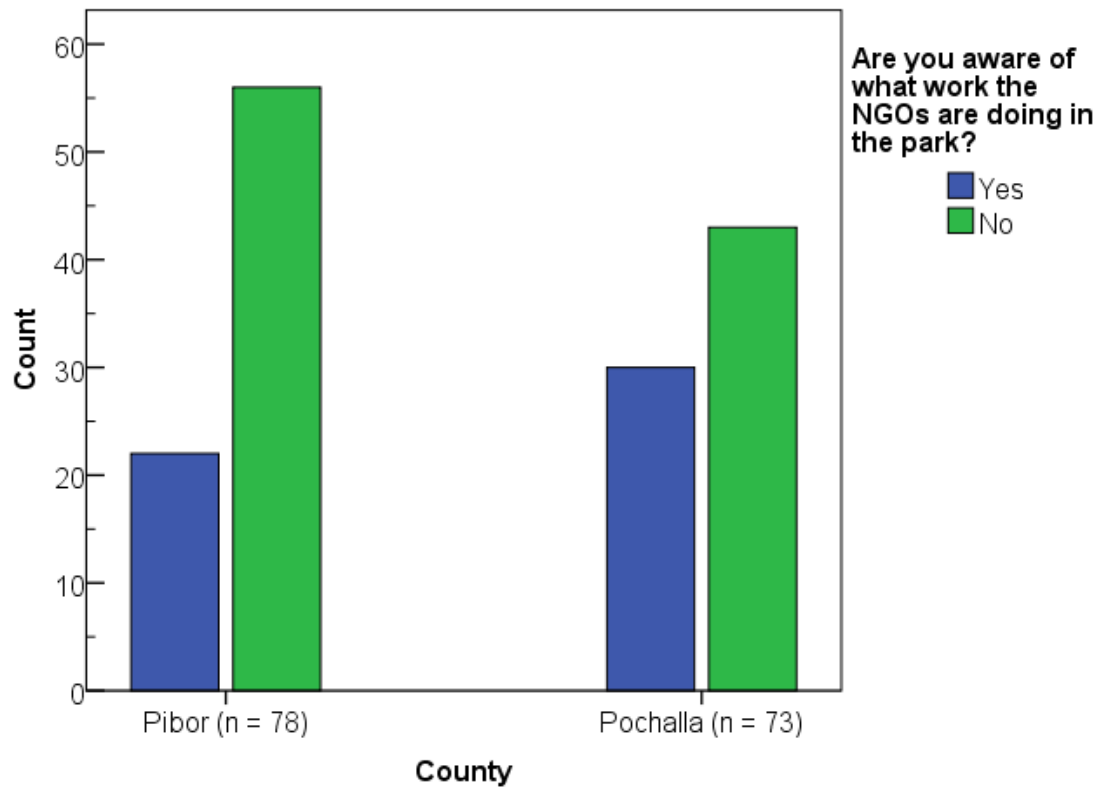


Figure 7.44. Knowledge of the work of conservation NGOs in Boma National Park.

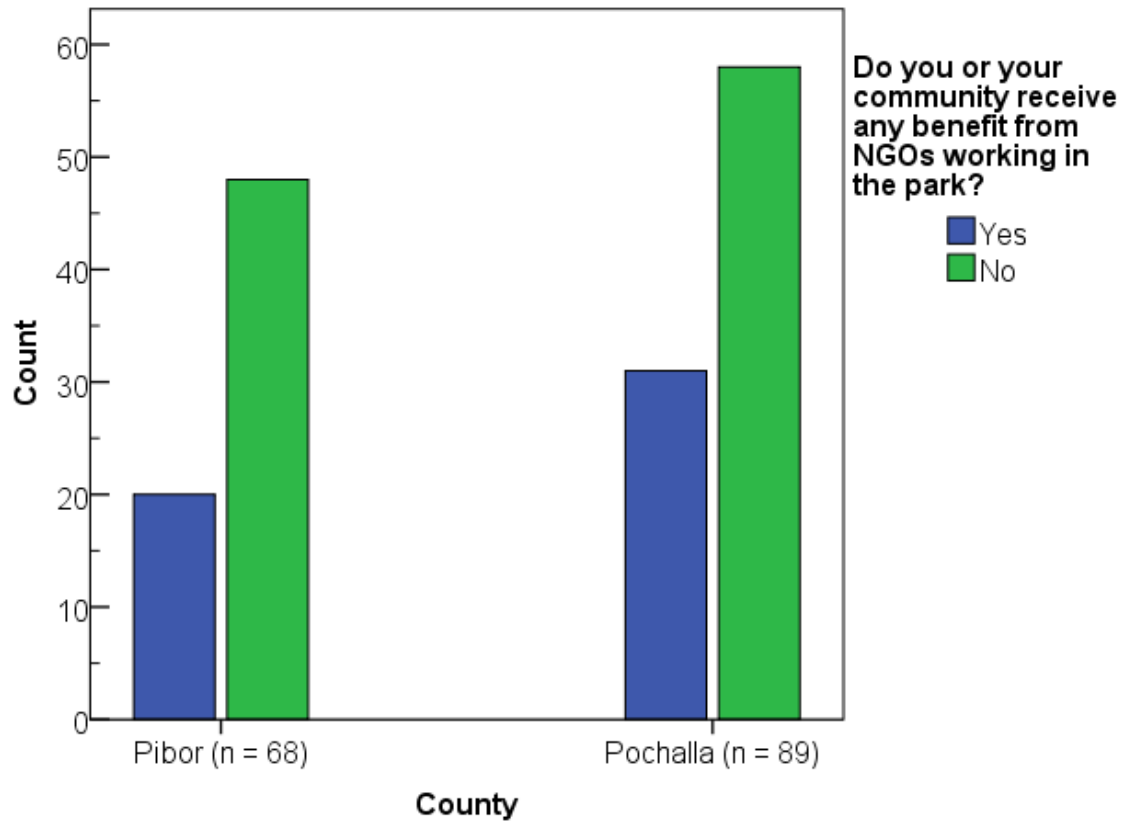


Figure 7.45. Benefits households receive from conservation NGO work in Boma National Park.



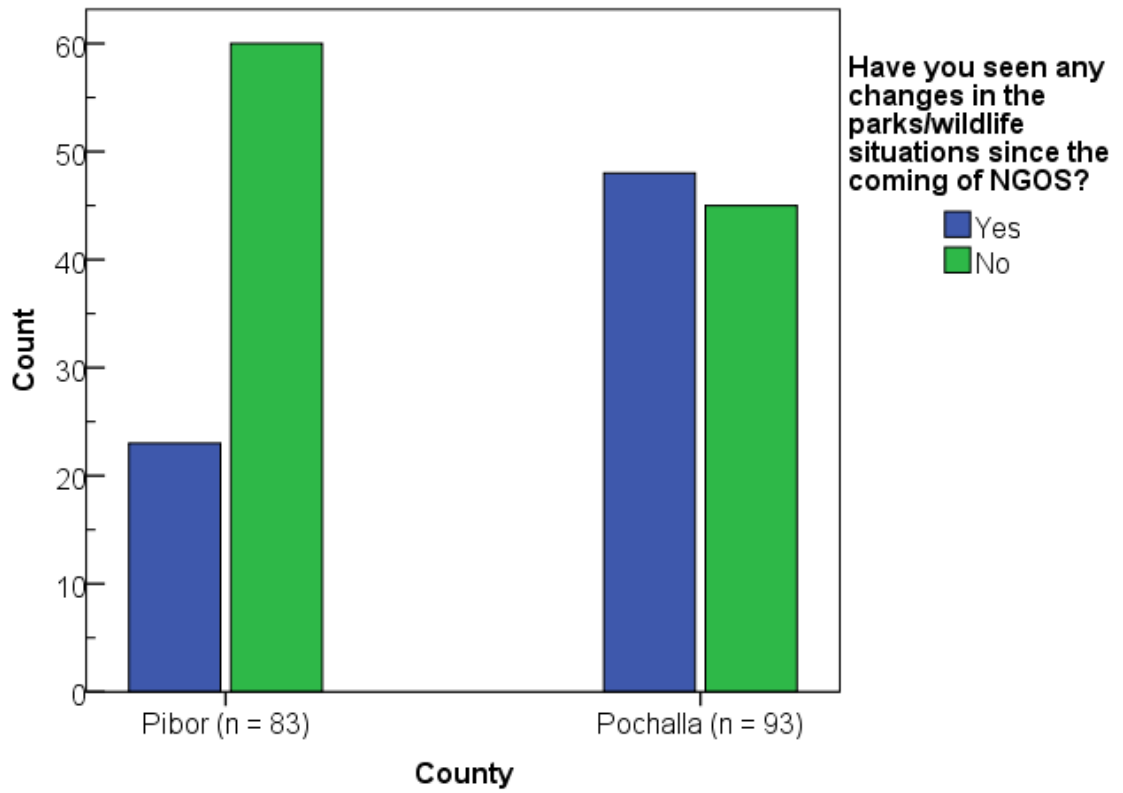


Figure 7.46. Household perceptions of accomplishments of NGOs in Boma National Park.

## CHAPTER 8

### GENERAL CONCLUSION AND RECOMMENDATIONS

This study revealed that kobsare still abundant and that their migration between two seasonal ranges still appears vibrant. Although these seasonal ranges are within boundaries of protected areas, they are in reality only partially protected due to absence of patrols and law enforcement. The corridors between the seasonal ranges are only partially protected by environmental conditions and inaccessibility, but the situation will not remain the same in the future. Land pressure threats from increasing human settlements, development of towns, and potential development projects such as oil exploration and extraction are imminent. Also, indigenous peoples live in and around the Boma National Park where the kob migration comes into closest contact with humans. These people live in dire poverty and lack development, so depend to large extent on kob and park resources for their livelihoods. Their dependency on kob has always been traditional but now this relationship has changed and killing of kob has increased due to the proliferation of firearms in the area. Therefore, the following actions are recommended for the sustainable conservation of kob and their migration:

Law enforcement and patrols must be strengthened in and around the protected areas encompassing the seasonal ranges of the kob migration. Law enforcement officers and rangers should be rigorously trained and equipped with modern communications and suitable means of mobility and reconnaissance. As well as being trained in community interaction skills. Training and professional development program for these protected areas should be continuously updated. Young wildlife professionals and school

leaders especially indigenous people should be recruited, trained and deployed in the Parks to execute wildlife conservation programs.

Areas of seasonal ranges and range overlap should be legally gazetted for protection to secure their long term conservation from other land uses that would eventually come into these areas. Inclusion of the conservation and subsistence economic significance interests of the kob migration in future land use plans that might affect the migration ecosystem must happen.

The government should urgently initiate the development of a conservation strategy and national action plan for the kob migration by preparing management plans for both the Boma and Badingilu National Parks, through participatory approach that include community meetings; and then mobilize resources for implementation and periodic updating of these management documents.

The newly passed wildlife conservation policy document should be enacted by the Parliament and implemented, and it also should be updated as needs arise. Such laws should be translated into indigenous languages and disseminated to the communities that live and interact with the kob migration, as well as with other wildlife species.

Regular monitoring of kob population trend and their habitat use, especially in the core seasonal ranges, must be implemented. Kob migration depends on water resources and forage availability in the dry season range at the Guom swamps. This area should be well studied and conserved. Suitable measures be developed and readied for eventualities of natural catastrophes such as long-term climate change effects.

The Boma and Badingilu National Parks are at the extremes of the migration cycle and should be protected and developed to the standards so that generate income

from tourism/ecotourism to justify their existence and enhance protection of the migration. The Government of South Sudan should lead development of Parks in a serious manner. The government should handle the infrastructure development and law enforcement in order to create enabling environment for other partners to work therein. Partners should handle other aspects of conservation such ecological monitoring, and community awareness. And community-based conservation programs, which ideally should be carried out by communities not only in partnership with NGOs but with the park itself

Future detailed studies should be conducted to generate knowledge about the ecological processes (such as vegetation productivity, habitat suitability, water courses, competition, etc.) that affect key habitats within the seasonal ranges of the kob migration.

Peace and stability is vital factor for the conservation and management of wildlife. For one reason or another previous and recent armed conflict in South Sudan during the recent decades always concentrated in the region where kob migrations occurred. It is therefore important for the people and government of South Sudan that the root causes of social and political grievances be addressed once and for all so that conservation of white-eared kob and wildlife in general can take effect and play its role in the economic development of the country.

Development projects envisioned in areas near the migration ecosystem should take serious account of migration corridors and seasonal ranges. For example, the government has unveiled a 10-year strategic plan for road construction across the country, and some of these roads cut through kob migration routes. Thus wildlife conservationists and managers should

undertake proper impact assessment to determine the most effective conservation measures for kob.

Engagement and participation of indigenous communities in BNP and BdNP management communities is essential for building awareness and cooperation. This includes creation of alternative livelihood sources such as ecotourism programs. Also needed are provisions for the security of livestock and the elimination of cattle rustling, abductions and killings among local communities and their neighbors. Wildlife clubs should be re-established in schools, as was the case in the 1970s and 1980s, so that information dissemination and awareness building can easily reach out to the wider community. School programs (and youth) programs for children who aren't in school are very important and are often neglected.

## REFERENCES

- Agbelusi, A. (1991). Variations in activities of Senegal Kob (*Kobus kob kob*, Erxeleben 1777) during daylight period in an enclosure at Kainji Lake Research Institute range farm, New Busa, Nigeria. *Afr. J. Ecol.* **29**: 353-355.
- Agbelusi, A. (1989). Feeding-habits of the Senegal Kob (*Kobus kob kob*, Erxeleben 1777) under Ranching conditions and in the wild. *Applied Animal Behaviour*, **23**(3): 179-185.
- Allendorf, T. D. (2007). Residents' attitude towards three protected areas in southwestern Nepal. *Biodivers. Conserv.*, **16**: 2087-2102.
- Amubode, F.O. and Akossim, C.A. (1989) Kob number and habitat characteristics of riparian vegetation in Nigeria wooded savanna. *Afr. J. Ecol.* **27**: 291-296.
- Baasch, D. M., Tyre, A. J., Millspaugh, J. J., Hygnstrom, S. E. and Vercauteren, K. C. (2010). An evaluation of three statistical methods used to model resource selection. *Ecological Modelling*, 221: 565-574.
- Balmford, A. (1992). Social dispersion and lekking in *K. k. thomasi*. *Behavior*, **120**: 177-191.
- Balmford, A. and Turyaho, M. (1992). Predation risk and lek-breeding in *K. k. thomasi*. *Anim. Behav.*, **44**: 117-127.
- Balmford, A., Albon, S. and Blakeman, S. (1992). Correlates of male mating success and female choice in a lek-breeding antelope. *Behav. Ecol.*, **3**(2): 112-123.

- Beck, J. L., Peek, J. M. and Strand, E. (2006). Estimates of elk summer range nutritional carrying capacity constraints by probabilities of habitat selection. *J. Wildl. Management*, **70**(1): 283-294.
- Bennett, E.L. (2002). Is there a link between wildlife and food security? *Cons. Biol.*, **16**(3): 590-592.
- Beyer, H. L. (2004). Hawth's Analysis Tools for ArcGIS. Available at <http://www.spatial ecology.com/htools>.
- Bhola, N., Ogutu, J. O., Piepho, H-P., Said, M. Y., Ried, R. S., Hobbs, N. T. and Olf, H. (2012). Comparative changes in density and demography of large herbivores in the Masai Mara Reserves and its surrounding human-dominated pastoral ranches in Kenya. *Biodivers Conserv*, **21**: 1509-1530.
- Birungi, J. and Arctander, B. (2000). Large sequence of mitochondrial DNA genotypes of the control region within populations of the African antelope, kob (*Kobus kob*). *Molecular Ecology*, **9**: 1997-2008.
- Birungi, J. and P. Arctander. (1997). Large sequence divergence of mitochondrial DNA genotypes of the control region within populations of the African antelope, kob (*Kobus kob*). *Molecular Ecology* **9**: 962-1083.
- Bodendorfer, T., Hoppe-Dominic, B., Fischer, F. and Linsenmair, K. E. (2006). Prey of leopard (*Panthera pardus*) and the lion (*Panthera leo leo*) in the Comooe and Marahoue National Parks, Côte D'Ivoire, West Africa. *Mammalia*: 231-246.
- Bolger, D. T., William, D., Newmark, Morrison, T. A. and Doak, D. F. (2008). The need for integrative approaches to understand and conserve migratory ungulates. *Ecology Letters*, **11**: 63-77.

- Bolstad, P. (2005). *GIS Fundamentals: A First Text on Geographic Information Systems*.  
2<sup>nd</sup> Ed. Eider Press, White Bear Lake, Minnesota.
- Bonnington, C., Weaver, D. and Fanning, E..(2007). Livestock and large wild mammals  
in the Kilombero Valley, in southern Tanzania . *Afr. J. Ecol.*, **45**: 658-663.
- Boone, R.B., Thirgood, S.I. and Hopcraft, J.G.C. (2006). Serengeti Wildebeest Migratory  
Patterns Modeled from rainfall and New Vegetation Growth. *Ecology*, **87**(8):  
1987-1994.
- Bouare, O. (2006). A policy tool for establishing a balance between wildlife habitat  
preservation and the use of natural resources by rural people in South Africa. *Afr.*  
*J. Ecol.*, **44**: 95-101
- Breuer, T. (2005a). Diet choice of large carnivores in northern Cameroon. *Afr. J. Ecol.*,  
**43**: 97-106.
- Breuer, T. (2005b). Diet choice of large carnivores in northern Cameroon. *Afr. J. Ecol.*,  
**43**:181-190.
- Bro-Jorgenson, J., Brown, M. E. and Petorelli, N. (2008). Using the satellite-derived  
normalized difference vegetation index (NDVI) to explain ranging patterns in a  
lek-breeding antelope: the importance of scale. *Oecologia*, 158: 177-182.
- Buho, H., Jiang, Z., Liu, C., Yoshida, T., Halik Mahamut, D., Kaneko, M., Asakawa, M.,  
Motokawa, M., Kaji, K., Wuc, X., Otaishi, N. Ganzorig, S. and Masuda, R.  
(2011). Preliminary study on the migration patterns of the Tibetan antelope  
(*Panthlops hodgsonii*) based on satellite tracking. *Advances in Space Research*, 48:  
43-48.



- Butt, B. (2010). Pastoral resource access and utilization: Quantifying the spatial and temporal relationships between livestock mobility, density and biomass availability in southern Kenya. *Land Degrad. Develop.*, 21: 520–539.
- Cassini, M. H. (2011). Ecological principles of species distribution models: the habitat matching rule. *Journal of Biogeography*, 38: 2057-2065.
- Clutton-Brock, T.H., Deutsch, J.C. and Nefdt, R.J.C. (1993). The evolution of ungulates leks. *Anim. Behav.*, **46**: 1121-1138.
- Coughenour, M.B. (2008). Causes and consequences of herbivore movement in
- Darmon, G., Calenge, C., Loison, A., Jullien, J-M., Maillard, D. and Lopez, J-F. (2012). Spatial distribution and habitat selection in coexisting species of mountain ungulates. *Ecography*, 35:44-53.
- de Merode, E., Smith, K. H., Homewood, K., Pettifor, R., Rowcliffe, M. and Cowlshaw, G. (2007). The impact of armed conflict on protected area efficacy in Central Africa. *Biol. Lett.*, **3**: 299-301.
- Deng, L. (Overall Team Coordinator). (2001). *The Impact of Conflict on the Boma National Park: The Status of Food Security, Wildlife and Livestock*. SA/CB – STAR (USAID/ USDA/ PASA, Nairobi.
- landscapes and ecosystems. In: K. A. Galvin *et al.* (eds.), *Fragmentation in Semi-Arid and Arid Landscapes: Consequences for Human and Natural Systems*, 45-91.
- Deutsch, J.C. (1994). Lekking by default: female habitat preferences and male strategies in *K. k. thomasi*. *Journal of Animal Ecology*, **63**: 101-115.
- Deutsch, J.C. (1992). *Reproductive strategy in a Lek breeding antelope, the Uganda kob*. A Ph.D. dissertation, King's College, Cambridge University, UK.

- Deutsch, J.C. and Ofezu, A.A. (1994). Uganda kob reproductive seasonality – Optimal calving seasons or condition-dependent estrus. *Afr.J. Ecol.*, **32**(4): 283-295.
- Deutsch, J.C. and Weeks, P. (1992). *K. k. thomasi* prefer high-visibility leks and territories. *Behav. Ecol.*, **3**: 223-233.
- Dörgeleh, W. G. (2006). Habitat suitability for tsessebe *Damaliscus lunatus lunatus* *Afr. J. Ecol.*, **44**: 329-236.
- Deng, L. (Overall Team Coordinator). (2001). The Impact of Conflict on the Boma National Park: The Status of Food Security, Wildlife and Livestock. SA/CB – STAR (USAID/ USDA/PASA, Nairobi.
- Dodd, N.L., Gagnon, J.W., Boe, S. and Schweinsburg, R.E. (2007). Assessment of elk highway permeability by using global positioning system telemetry. *Journal of Wildlife Management*, **71**(4):1107-1117.
- Dorst, J. and Dandelot, P. (1970). *A field guide to the Larger Mammals of Africa*. London: Collins.
- Estes, R. (1992). *The Behavior Guide to African Mammals: Including hoofed mammals, carnivores and primates*. University of California Press, USA.
- Estes, R. D., Atwood, J. L. and Estes, A. B. (2006). Downward trends in Ngorongoro crater ungulate populations 1986-2005: Conservation concerns and the need for ecological research. *Biological Conservation*, **131**: 106-120.
- Evangelista, P. H., Norman III, J., Berhanu, L., Kumar, S. and Alley, N. (2008). Predicting habitat suitability for the endemic mountain nyala (*Tragelaphus buxtoni*) in Ethiopia. *Wildlife Research*, **35**: 409-416.

- Ezebilo, E.E. (2010). Community-based preference for economic incentives to promote biodiversity conservation in a tropical rainforest. *Int. J. Environ. Res.*, 4(3): 501-506.
- Fay, M., Elkan, P., Marjan, M. and Grossman, F. (2007). Aerial Surveys of Wildlife, Livestock, and Human Activity in and around Existing and Proposed Protected Areas of Southern Sudan, Dry Season 2007. Phase I. Juba, Southern Sudan, Sudan.
- Fischer, F. and Linsenmair, K. E. (2006). Changing social organization and structure in an ungulate population subject to poaching and predation - the kob antelope (*Kobus kob kob*) in the Comoé National Park, Côte d'Ivoire . *Afr. J. Ecol.*, 45: 285-292.
- Fischer, F. and Linsenmair, K. E. (2002). Demography of a West African kob (*Kobus kob kob*) populations. *Afr. J. Ecol.*, 40: 130-137.
- Fischer, F. and Linsenmair, K. E. (2001). Spatial and temporal habitat use of kob antelopes (*Kobus kob kob*, Erxleben 1777) in the Comoé National Park, Ivory Coast, as revealed by Radio Tracking. *Afr. J. Ecol.*, 39: 249-256.
- Fischer, F. and Linsenmair, K. E. (2001). Decreases in ungulated population densities. Examples from the Camoê National Park, Ivory Coast. *Biological Conservation*, 101: 131-135.
- Fischer, F. and Linsenmair, K. E. (1999). The territorial system of the kob antelope (*Kobus kob kob*) in the Comoé National Park, Côte d'Ivoire . *Afr. J. Ecol.*, 37: 386-399.

- Fischer, F. (2000). Changes in group size in *Kobus kob kob* (Bovidae) in the Comoé National Park, Ivory Coast (West Africa). *Zeitschrift für Säugetierkunde*, **65**(4): 232-242.
- Fortin, M-J. and Gagnon, C. (1999). An assessment of social impacts of national parks on communities in Quebec, Canada. *Environmental Conservation*, **26** (3): 200–211.
- Frazier, J. (2006). Biosphere reserves and the “Yucatan” syndrome: another look at the role of NGOs. *Landscape and Urban Planning*, **74**: 313–333
- Fryxell, J. M. (1991). Forage Quality and Aggregation by Large Herbivores. *The American Naturalist*, **138**:478-498.
- Fryxell, J. M. (1985). *Resource limitation and population ecology of the White-eared kob*. A PhD Thesis. University of British Columbia, Canada.
- Fryxell, J.M. (1987a). Lek breeding and territorial aggression in White-eared kob. *Ethology*, **75**(3): 211-220.
- Fryxell, J. M. (1987b). Seasonal reproduction of White-eared kob in Boma National Park, Sudan. *Afr. J. Ecol.* **25**(2): 117-124
- Fryxell, J. M. (1987c). Food limitation and the demography of a migratory antelope, the White-eared kob. *Oecologia*, **72**: 83-91.
- Fryxell, J.M. and A. Sinclair. (1988). Seasonal migration by White-eared kob in relation to resources. *Afr. J. Ecol.* **26**(1): 17-31.
- Fryxell, J.M., J. Greever, and A.R.E. Sinclair. (1988). Why are migratory ungulates so abundant? *The American Naturalist*, **131**: 781-798

- Fuller, M.R., Millspaugh, J.J., Church, K.E. and Kenward, R.E. (2005). Wildlife radio telemetry. In Braun, C.E. Edition: Techniques for Wildlife Investigations and Management. 6<sup>th</sup> Ed. *The Wildlife Society*, 377-417.
- Garson, G. D. (2012). *Logistic regression: Binary and multinomial*. Statistical Publishing Associates. North Carolina State University.
- Gates, C.C., Stelfox, B., Muhly, T., Chowns, T. and Hudson, R.J. (2009). The ecology of bison movements and distribution beyond Yellowstone National Park. A critical review with implications for winter use and transboundary populations management. Faculty of Environmental Design, University of Calgary, Calgary, Alberta
- Gavashelishvili, A. and Lukarevskiy, V. (2008). Modelling the habitat requirements of leopard *Panthera pardus* in west and central Asia. *Journal of Applied Ecology*, 45: 579-588.
- Gibson, L. A., Wilson, B. A., Cahill, D. M. and Hill, J. (2004). Modelling habitat suitability of the swamp Antechinus (*Antechinus minimus maritimus*) in the coastal heathlands of southern Victoria, Australia. *Biological Conservation*, 117: 143-150.
- Giotto, N., Obsieh, D. Joachim, J. and Jean-François, G. (2009). The population size and distribution of the Vulnerable beira antelope *Dorcatragus megalotis* in Djibouti. *Oryx*, 43(4): 552-555.

- Graham, C. H., Elith, J., Hijmans, R. J., Guisan, A., Peterson, A. T., Loisele, B. A., and the Nceas Predicting Species Working Group. (2008). the influence of spatial errors in species occurrence data used in distribution models. *J. Appl. Ecol.*, 45: 239-247.
- Guedegbe, B., Verhulst, N., Van Meirvenne, N., Pandey, V.S. and Doko, A. (1992). Indications serologiques de l'existence d'un reservoir sauvage du Trypanosoma brucei gambiense dans la reserve de la Biosphere de la Pendjari en Republique du Benin. *Ann. Soc. belge med. trop.*, (72): 113-120.
- Hamel, S., Garel, M., Fest-Bianchet, M, Gaillard, J-M. and Cote, S. D. (2009). Spring Normalized Difference Vegetation Index (NDVI) predicts annual variation in timing of peak faecal crude protein in mountain ungulates. *J. App. Ecol.*, 46: 582-589.
- Hamer, T. E., Varland, D. E., McDonald, T. L. and Meekins, D. (2008). Predictive model of habitat suitability for the Marbled Murrelet in Western Washington. *J. of Wildl. Manage.*, 72(4): 983-993.
- Hanley, N., J.F. Shorgen and B. White. (2007). *Environmental Economics: In Theory and Practice*. 2nd edn. Palgrave Mcmillan, New York, USA. pp332-341.
- Harris, G., Thirgood, S., Hopcrafts, J.G.C., Croomsig, J.P.G.M. and Berger, J. (2009). Global decline in aggregated migrations of large terrestrial mammals. *Endang. Species Res.*, 7: 55-76
- Hayward, M.W. and Kerley, G.I.H. (2005). Prey preferences of the lion (*Panthera leo*). *J. Zol., Lond.*, 267: 309-322.

- Hebblewhite, M., Merrill, E.H., Morgantini, L.E., White, C.A., Allen, J.R., Bruns, E., Thurston, L. and Hurd, T.E. (2006). Is the migratory behavior of Montane elk herds in Peril? The case of Alberta's Ya Ha Tinda elk herd. *Wildlife Society Bulletin* **34**(5):1280-1294
- Hilman, J.C. and Fryxell, J.M. (1988). Sudan: from Antelope Global Survey and Regional Action Plan II. East and Northeast Africa. IUCN/SSC, 1988: Sudan Open Archive. Downloaded Thursday 26 April 2007 15:22 GMT.  
<http://www.sudanarchive.net>
- Hobbs, N. T., Baker, D. L., Bear, G. D. and Bowden, D. C. (1996). Ungulates grazing in sagebrush grassland: Mechanisms of resource competition. *Ecological Applications*, **6**(1): 200-217.
- Holdo, R. M., Fryxell, J. M., Sinclair, R. E., Dobson, A. and Holt, R. D. (2011). Predicted impacts of barriers to migration on the Serengeti wildebeest population. *PLoS ONE*, **6**(1): e16370. Doi: 10.1371/journal.pone.0016370.
- Holmern, T., Muya, J. and Roskaft, E. (2007). Local law enforcement and illegal bushmeat hunting outside the Serengeti National Park, Tanzania. *Environmental Conservation*, **34**(1): 55 – 63.
- Homewood, K., Lambin, E. F., Coast, E., Kariuki, A., Kikula, I., Kivulia, I., Said, M., Sennel, S. and Thompson, M. (2001). Long-term changes in Serengeti-Mara wildebeest and land cover: Pastoralism, population, or policies? *PNAS*, **98**(22): 12544-12549.
- Honre, J. S. and Garton, E. O. (2006). Selecting the best home range model: An Information-Theoretic Approach. *Ecology*, **87**(5): 1146-1142.

- Howell, D.C. (2008). *Fundamental statistics for the behavioural sciences (5<sup>th</sup> edition)*  
Wadsworth Publishing, Inc. pp 181-192.
- Igota, H., Sakuragi, M., Un, H., Kaki, K., Kaneko, M., Akamatsu, R. and Maekawa, K.  
(2004). Seasonal migration patterns of female sika deer in eastern Hokkaido, Japan.  
*Biological Research*, **(19)**: 169-178.
- Imbahale, S. S., Githaiga, J. M., Chira, R. M. and Said, M. Y. (2008). Resource utilization  
by large migratory herbivores of the Athi-Kapiti ecosystem. *Afr. J. Ecol.*, **46**(1): 43-  
51.
- Ite, U. E. (1996). Community perceptions of the Cross River National Park, Nigeria.  
*Environmental Conservation*, **23**(4): 351-357.
- Ito, Y.T., Miura, I.N., Lhagvasuren, B., Enkhbileg, D., Takatsuki, S., Tsunekawa, A. and  
Jiang, Z. (2006). Satellite tracking of Mongolian gazelles (*Procapra gutturosa*)  
and habitat shifts in their seasonal ranges. *J. of zool.*, **269**(3): 291-298.
- Ito, Y.T., Miura, N., Lhagvasuren, B., Enkhbileg, D., Takatsuki, A. and Jiang, Z. (2005).  
Preliminary Evidence of a Barrier Effect of a Railroad on the Migration of  
Mongolian Gazelles. *Cons. Biol.* **19**(3): 945-948.  
[http://www.jennessent.com/arcview/weighted\\_mean.htm](http://www.jennessent.com/arcview/weighted_mean.htm).
- IUCN SSC Antelope Specialist Group 2008. *Kobus kob*. In: IUCN 2011. IUCN Red List  
of Threatened Species. Version 2011.1. <www.iucnredlist.org>. Downloaded on  
**01 August 2011**.
- Jenness, J. (2004). Weighted mean of points (weightmean.avx) extension for ArcView  
3.x, v. 1.2c. Jenness Enterprises. Available at:  
[http://www.jennessent.com/arcview/weighted\\_mean.htm](http://www.jennessent.com/arcview/weighted_mean.htm).



- Jewell, K. J., Arcese, P. and Gergel, S. E. (2007). Robust prediction of species distribution: Spatial habitat model for a brood parasite. *Biological Conservation*, 140: 259-272.
- Johnson, C. J. and Gillingham, M. P. (2008). Sensitivity of species-distribution models to error, bias and model design: An application to resource selection functions for woodland caribou. *Ecological Modelling*, 213: 143-155.
- Johnson, C.J., Parker, K. L., Heard, D. C. and Gillingham, M. P. (2002). Movement parameters of ungulates and scale-specific responses to the environments. *J.Anim.Ecol.*, 71: 225-235.
- Jones, J. P. G. (2011). Monitoring species abundance and distribution at the landscape scale. *J.App. Ecol.*, 48: 9-13.
- Kahurananga, J. and Silkiluwasha, F. (1997). The migration of zebra and wildebeest between Trangire National Park and Simanjiro plains, Northern Tanzania, in 1972 and recent trends. *Afr. J. Ecol.*, 35: 179-185.
- Kaltenborn, B. P., Nyahongn, J. W. and Tingstad, K. M. (2005). The nature of hunting around the western corridor of Serengeti National Park, Tanzania. *Eur J. Wildl. Res.*, 51: 213 – 222. DOI 10.1007/s10344-005-0109-9.
- Kawamura, K., Akiyama, T., Yokota, H-O, Tsutsumi, M., Yasuda, T. and Watanabe, O. (2005). Comparing MODIS vegetation indices with AVHRR NDVI for monitoring forage quality and quantity in inner Mongolia grassland, China. *Grassland Science*, 51(1): 33-40.
- Keating, K. A. and Cherry, S. (2004). Use and interpretation of logistic regression in habitat selection studies. *J. Wildl. Manage.*, 68(4): 774-789.

- Kingswood, S.C., Kumamoto, A.T., Charter, S.J., Houck, M.L. and Benirschke, K. (2002). Chromosomes of the antelope genus *Kobus* (Artiodactyla, Bovidae): karyotypic divergence by centric fusion rearrangements. *Cytogenet Cell Genet*, **91**:128-133.
- Kiss, A. (2004). Is community-ecotourism a good use of biodiversity conservation fund? *Trends in Ecology and Evolution*, **19**(5): 232-237.
- Lamprey, R. H. and Reid, R. (2004). Expansion of human settlement in Kenya's Maasai Mara: what future for pastoralism and wildlife? *J. Biogeogr.*, **31**: 997-1032.
- Leimgurber, P., McShea, W. J., Brookes, C. J., Bolor-Erdene, L., Wemmer, C. and Larson, C. (2001). Spatial patterns in relative productivity and gazelle migration in eastern Steppes of Mongolia. *Biol. Cons.*, **102**: 205-212.
- Leon, P. and Monteil, S. (2008). Wild meat use and traditional hunting practices in a rural Mayan community of the Yucatan Peninsula, Mexico. *Hum. Ecol.*, **36**: 249-257. DOI 10.1007/s10745-007-9139-0
- Leuthold, W. (1966). Variations in territorial behavior of *K. k. thomasi* - *Adenota kob thomasi* (Neumann, 1896). *Behavior*, **27**: 215-257.
- Lewis, B.A. (1972) *The Murle: Red Chibes and Black Commoners*. In: Evans-Pritchard et.al. ed. Oxford University Press, UK.
- Lian, X., Zhang, T., Cao, Y., Su, J. and Thirgood, S. (2001). Road proximity and traffic flow perceived as potential predation risks: evidence from the Tibetan Antelope in the Kekexeli National Nature Reserve, China. *Wildlife Research*, **38**: 141-146.

- Lorenzen, E.D., Neergaard, R. De., Arctander, P. and Siegismund, H. (2007). Phylogeography, hybridization and Pleistocene refugia of kob antelope (*Kobus kob*). *Molecular ecology*, **16**(15): 3241-3252.
- Macandza, V. A., Owen-Smith, N. and Cain, J. W. (2012). Dynamic spatial partitioning and coexistence among tall grass grazers in an African savanna. *Oikos*, 121: 891-898.
- Månsson, J., Bunnefeld, N., Andren, H. and Ericsson, G. (2012). Spatial and temporal prediction of moose winter distribution. *Oecologia*, 170:411-419.
- Marjan, M. D., Ojok, L. I., Nicholas, B. B. AND Solomon, I. S. (2002). The Impact of Conflict on the Boma National Park: The Status of Wildlife, V. II - Dry Season Wildlife Counting. Unpublished report, SACB, USAID, USDA/ PASA, Nairobi. Boma National Park - Dry Season Survey.
- Mayaka, T.B., Stigter, J.D., Heitkong, I.M.A. and Prins, H.H.T. (2004). A population dynamics model for the management of Buffon,s kob (*Kobus kob kob*) in the Benoue National Park Complex, Cameroon. *Ecological Modeling*, **176**: 135-153.
- McFarland, T. M., Van Riper, C. and Johnson, G. E. (2012). Evaluation of NDVI to assess avian abundance and richness along the upper San Pedro River. *J. Arid Evt.*, 77: 45-53.
- Mefit-Babtie, S. (1983). *Development studies in the Jonglei canal area*: Final report. Vol.5. Wildlife Studies, Mefit-Babtie SRL, Glasgow, Rome and Khartoum, and Executive Organ of the National Council for Development of the Jonglei Canal Area, Khartoum, Sudan, Ministry of Finance and Economic Planning, Government of the Democratic Republic of the Sudan.

- Meisingset, E. L., Loe, L. E., Brekkum, O., Van Moorter, B. and Mysterud, A. (2013). Red deer habitat selection and movements in relation to roads. *Wildlife Management*, **77**(1): 181-191.
- Milner-Gulland, E. J., Kholodova, M. V., Bekenov, A. Bukreeva, O. M., Grachev, lu. A., Amgalan, L. and Lushchekina, A. A. (2001). Dramatic declines in saiga antelope populations. *Oryx*, **35**(4): 340-345.
- Modha, K.L. and Eltringham, S.K. (1975). Population ecology of the *K. k. thomasi* (Adenota Kob thomasi (Neumann)) in relation to the territorial system in the Rewenzori National Park, Uganda. EBSCO Publishing, 2005.
- Morrison, J.A. (1971). Morphology of corpora lutea in the *K. k. thomasi* antelope, *Adenota kob thomasi*. *J. Reprod. Fert.*, **26**: 297-305.
- Mueller, T., Olson, K. A., Fuller, T. K., Schaller, G. B., Murray, M. G. and Leimgruber, P. (2008). In search of forage: Predicting dynamic habitats of Mongolian gazelles using satellite-based estimates of vegetation productivity. *J. App. Ecol.*, **45**: 649-658.
- Muhlenberg, M. and Roth, H.H. (1984). Comparative investigations into the ecology of the kob antelope *Kobus kob kob* (Erxleben 1777) in the Cômoe National Park, Ivory Coast. *S. Afr. J. Wildl. Res.*, 1985, **15**(1): 25-31.
- Musiega, D.E., Kazadi, S-N and Fukuyama, K. (2006). A framework for predicting and visualizing the East African wildebeest migration-route patterns in variable climatic conditions using geographic information system and remote sensing. *Ecol. Res.*, **21**: 530-543.

- Musiega, D.E., Kazadi, S-N. (2004). Simulating the East African wildebeest migration patterns using the GIS and remote sensing. *Afr. J. Ecol.*, 42: 355-362.
- Muwanika, V.B., Nyakaana, S. and Siegismund, H. R. (2005). Genetic consequences of war and social strife in sub-Saharan Africa: the case of Uganda's large mammals. *African Zoology* 40(1): 107-113.
- Ndibalema, V.G. and Songorma, A. N. (2007). Illegal meat hunting in Serengeti: dynamics in consumption and preferences. *Afr. J. Ecol.* **46**:311-319.
- Newton-Cross, G., White, P. C. L. and Harris, S. (2007). Modeling the distribution of badgers *Meles meles*: Comparing predictions from field-based and remotely derived habitat data. *Mammal Rev*, **37**(1): 54-70.
- Njiforti, H.L. (1996). Preferences and present demand for bushmeat in north Cameroon: some implications for wildlife conservation. *Environmental conservation*, **23**(2): 149-155.
- Norton-Griffiths, M. (1978). Counting Animals. 2nd edn: African Wildlife Foundation, Nairobi, Kenya.
- Ogutu, J. O., Owen-Smith, N., Piepho, H. P. and Said, M. Y. (2011). Continuing wildlife population declines and range contraction in the Mara region of Kenya during the 1977-2009. *J. of Zool.*, 285:99-109.
- Ogutu, J. O., Bholá, N., Piepho, H. P. and Reid, R. (2006). Efficiency of strip and line-transect surveys of African Savanna mammals. *J. of Zool.*, **269**(2): 149-170.
- Okaeme, A.N. (1987)a. Succinylcholine Chloride overdose in western kob (*Kobus kob*). *Afr. J. Ecol.*, 25(4): 295-296.

- Okaeme, A.N. (1987)<sup>a</sup>. Succinylcholine Chloride overdose in western kob (*Kobus kob*). *Afr.J. Ecol.*, **25**(4): 295-296.
- Okaeme, A.N., Agbelusi, E.A., Mshelbwala, J., Wari, M., Ngulge, A. and Haliru, M. (1988). Effects of Immobilon and Revivon in the immobilization of western kob (*Kobus kob*). *Afr.J. Ecol.*, **26**(4): 63-67.
- Okaeme, A.N. (1987)<sup>b</sup>. First record of Paramphistomum cervi in western kob (*Kobus kob*) at the Kainji Lake National Park, Nigeria. *Afr.J. Ecol.*, **25**: 297.
- Olson, K. A., Fuller, T. K., Mueller, T., Murray, M. G., Nicolson, C., Odonkhuu, D., Bolortsetseg, S. and Schaller, G. B. (2010). Annual movements of Mongolian gazelles: Nomads in the Eastern Seteppe. *Journal of Arid Environments*, **74**: 1435-1442.
- Ottichilo, W. K., de Leeuw, J. and Prins, H. H. T. (2001). Population trends of resident wildebeest [*Conochaetes taurinus hecki* (Neumann)] and factors influencing them in the Masai Mara ecosystem, Kenya. *Biological Conservation*, **97**: 271-282.
- Owen-Smith, N., Chirima, G. J., Macandza, V. and Le Roux, E. (2012). Shrinking sable antelope numbers in Kruger National Park: what is suppressing population recovery? *Animal Conservation*, **15**:195-204.
- Pajor, T. M., Bowden, D. C. and Gill, R. B. (1995). Aerial counting experiments to estimate Pronghorn density and herd structure. *J. Wildl. Manage*, **59**(1): 117-128.
- Pepin, D., Morellet, N. and Goulard, M. (2009). Seasonal and daily walking activity patterns of free-ranging adult red deer (*Cervus elaphus*) at the individual level. *Eur. J. Wildl. Res*, **55**: 479-486.

- Petorelli, N., Côté, S. D., Gingras, A., Potvin, F. and Huot, J. (2007). Aerial survey vs hunting statistics to monitor deer density. The example of Anticosti Island, Quebec, Canada. *Wild. Biol.*, **13**(3): 321-327.
- Person, B. T., Prichard, A., Carrol, M. G., Yokel, D. A., Suydam, R. S. and George, J.C. (2007). Distribution and movements of the Teshekpuk Caribuo herd 1990-2005: Prior to oil and gas development. *Arctic*, **60**(3): 238-250.
- Pittigilio, C., Skidmore, A. K., van Gils, H. A. M. J. and Prins, H. H. T. (2012). Identifying transit corridors for elephant using a long time-series. *International Journal of Applied Earth Observation and Geoinformation*, 14: 61-72.
- Population Census Council, (2009). *5<sup>th</sup> Sudan Population and Housing Census 2008: Priority results*. Submitted to the Presidency, by the Central Bureau of Statistics and the Southern Sudan Centre for statistics, Census and evaluation, Khartoum-Juba, Sudan.
- Quinn, G.P., and Keough, M.J. (2002). *Experimental design and data analysis for biologists*. Cambridge University Press, UK. 537 pp.
- Rija, A. A. and Hassan, S. N. (2011). Population density estimates of some species of wild ungulates in Simanjiro Plains, northern Tanzania. *Afr. J. Ecol*, 49: 370-372.
- Ruggieru, R.O. (1991). Prey selection of the lion (*Panthera leo* L.) in the Manovo-Gounda St. Floris National Park, Central African Republic. *Mammalia*, t, 55, no. 1.
- Russell, R. E., Saab, V. A. and Dudley, J. G. (2007). Habitat suitability model for cavity-nesting birds in a postfire landscape. *J. Wildl. Manage.*, **71**(8): 2600-2611.

- Sager-Fradkin, K. A., Jenkins, K. J., Happe, P. J., Beecham, J.J., Gerald Wright, R. and Hoffman, R. (2008). Space and habitat use by black bears in the Elwha Valley prior to dam removal. *Norhtwest Science*, **82**: 164-178-
- Santika, T. (2011). Assessing the effect of prevalence on the predictive performance of species distribution models using simulated data. *Global Ecol. Biogeogr.*, 20:181-192.
- Sawyer, H., Kauffman, M. J., Nielson, R. and Horne, J. S. (2009). Identifying and prioritizing ungulate migration routes for landscape-level conservation. *Ecological Applications*, **19**(8): 2016-2025.
- Scheyvens, R. (1999). Ecotourism and the empowerment of local communities. *Tourism Management*, **20**: 245-249.
- Scholte, P., Adam, S. and Serge, B. K. (2007). Population trends of antelopes in Waza National Park (Cameroon) from 1960-2001: the interacting effects of rainfall, flooding and human interventions. *Afr. J. Ecol.*, 45: 431-439.
- Serneels, S. and Lambin, E. F. (2001). Impact of land-use changes on the wildebeest population in northern Serengeti-Mara ecosystem. *Journal of Biogeography*, 28: 391-407.
- Shorrocks, B., Cristescu, B. and Magane, S. (2008). Estimating density of Kirk's dik-dik (*Madaqua kirkii* Gunther), impala (*Aepyceros melampus* Lichtenstein) and common zebra (*Equus burchelli* Gray) at Mpala, Laikipia District, Kenya. *Afr. J. Ecol.*, 46: 612-619.



- Singh, N. J. and Milner-Gulland, E. J. (2011). Conserving a moving target: planning protection for a migratory species as its distribution changes. *Journal of Applied Ecology*, 48:35-46.
- Sinsin, B., Tehou, A.C., Daouda, I. and Saidou, A. (2002). Abundance and species richness of larger mammals in Pendjari National Park in Benin. *Mammalia*, **66**(3): 369-380.
- Smith, I. P. J. (2011). Resources driving landscape-scale distribution patterns of grazers in an African savanna. *Ecography*, 34: 67-74.
- Steinbauer, M. J. (2011). Relating rainfall and vegetation greenness to the biology of spur-throated and Australian locusts. *Agric and Forest Ento.*, 13: 205-218.
- Stem, C.J., Lassoie, J. P., Lee, D. R., Deshler, D. D. and Schelhas, J.W. (2003). Community participation in ecotourism benefits: The link to conservation practices and perspectives. *Society and Natural Resources*, **16**: 387-413.  
DOI: 10.1080/08941920390190041.
- Stoner, C., Caro, T., Mduma, S., Mlingwa, C., Sabuni, G., Borner, M. and Schelten, C. (2006). Changes in large herbivore populations across large areas of Tanzania. *Afr. J. Ecol.*, 45: 202-215.
- Syartinilia, S. T. (2008). GIS-based modeling of Javan Hawk-Eagle distribution using logistic and autologistic models. *Biological Conservation*, 141: 756-769.
- Thirgood, S., Mosser, A., Tham, S., Hopcraft, G., Mwangomo, E., Mlengeya, T., Kilewo, M., Fryxell, J., Sinclair, A.R.E. and Borner, M. (2004). Can parks protect migratory ungulates? The case of the Serengeti wildebeest. *Animal Conservation*, 7: 113 – 120.

- Thomas, B., Holland, J.D. and Minot, E.O. (2008). Elephant (*Loxodonta Africana*) home ranges in Sabi Sand Reserve and Kruger national Park: A five year satellite tracking study. *Plos ONE*, 3(12): e3902. Doi:10.1371/journal.pone.0003902.
- van Beest, F. M., Rivrud, I. M., Loe, L. E., Milner, J. M. and Mysterud, A. (2011). What determines variation in home range size across spatiotemporal scales in a large browsing herbivore? *J. of Animal Ecol.*, **80**: 771-785.
- Voeten, M. M., Claudius, A. D. M, de Vijver, V., Oloff, H. and van Langevelde, F. (2009). Possible causes of decreasing migratory ungulate populations in an East African savannah after restrictions in their seasonal movements. *Afr. J. Ecol.*, 48: 169-179.
- Waltert, M., Meyer, B., and Kiffner, C. (2009). Habitat availability, hunting or poaching: what affects distribution and density of large mammals in western Tanzanian Woodlands? *Afr. J. Ecol.*, 47: 737-746.
- Wang, C., Liu, Y. and Axmacher, J. C. (2009). Habitat-GIS-based models for ground beetles (*Coleoptra carbidae*) distribution in agricultural landscape. *Proceedings of the 17<sup>th</sup> International Conference on Geoinformatics*, Fairfax, VA. Digital Object Identifier: 10.1109/GEOINFORMATICS.2009.5293477
- Watson, R.M., Tippet, C.I., Rizk, F., Becket, J.J. and Jolly, F. (1977). Sudan national livestock census and resource inventory. Volume 31. Results of an aerial census of resources in Sudan from August 1975 to January 1977. Sudan Veterinary Research Administration, Ministry of Agriculture, Food and Natural Resources, Khartoum, Sudan.

- Wanzie, C.S. (1991). The present distribution and status of *Kobus kob kob* in West and Central Africa. *Mammalia* **5**(1): 79-84.
- Wanzie<sup>a</sup>, C.S. (1988). Sociability of Buffon's kob (*Kobus kob kob* Erxleben) in Waza National Park, Cameroon. *Mammalia* **52**(1): 21-33.
- Wanzie<sup>b</sup>, C.S. (1988). Mortality factors of *Kobus kob kob* (Erxleben) in Waza National Park, Cameroon. *Mammalia* **50**(3):351–356.
- Wanzie, C.S. (1986). Buffon's Kob (*Kobus kob kob* Erxleben) immobilization in Waza National Park, Cameroon. *Mammalia* **50**(2):253–262.
- Wilcove DS, Wikelski M. (2008). Going, going, gone: Is animal migration disappearing? *PLoS Biol*, **6**(7): e188. doi:10.1371/journal.pbio.0060188
- Wilmhurst et al (1999). Spatial distribution of Serengeti wildebeest in relation to resources. *Can. J. Zool*, **77**: 1223-1232.
- Willems, E. P., Barton, R. A. and Hill, R. A. (2009). Remotely sensed productivity, regional home range selection, and local range use by an omnivorous primate. *Behav. Ecol.*, **20**: 985-992.
- Williamson, D., Williamson, J. and Ngwamotsoko, K. J. (1988). Wildebeet migration in the Kalahari. *Afr. J. Ecol.*, **26**: 269-280.
- Willmot, S. G. (1956). Soils and Vegetation of Boma Plateau and Eastern District of Equatoria. *Sudan Notes and Records*, **32**: 9-20.
- Xu, J-L, Zhang, X-H, Sun, Q-H, Zheng, G-M., Wang, Y. and Zhang, Z-W. (2009). Home range, daily movements and site fidelity of male Reeves's pheasants *Syrnaticus reevesii* in the Dabie Mountains, Central China. *Wildl. Biol.* **15**: 338-334. DOI: 102981/08-032.

Young, J. K., Murray, K. M., Strindberg, S., Buuveibaatar, B. and Berger, J. (2010).

Population estimates of endangered Mongolian saiga *Saiga tatarica mongolica*: implications for effective monitoring and population recovery. *Oryx*, **44**(2): 285-292.