DRY SEASON DISTRIBUTION AND DENSITY OF PUKU ANTELOPE (*KOBUS VARDONI*) IN THE KILOMBERO VALLEY FLOODPLAIN

FORDELING OG TETTHET AV PUKUANTILOPE (*KOBUS VARDONI*) I TØRKEPERIODEN PÅ FLOMSLETTENE I KILOMBERO VALLEY

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ABSTRACT

The management of wetland areas is of great concern due to the ecological, economical and environmental importance of these areas. The Kilombero Valley has one the largest wetland areas in Africa, which provides ecosystem services for hundred thousands of humans living in the area. The floodplain is 2 500 km^2, and are considered as one of the partial protected areas holding the highest wildlife density in Tanzania. The puku antilope (*Kobus vardoni*), which is a typical floodplain species, is of particular conservation interest, since the Kilombero Valley is assumed to have 75% of the remaining population. The goal of the study was to find the density of puku in relation to human disturbance and to estimate the total density, and to study how puku prefer different vegetation types.

The survey was conducted in September-October, in the middle of the dry season. The survey area covered 224 km^2 and was located at the eastern side of Kilombero River in Ulanga District. Twenty transects lines were established throughout the floodplain. The transects, with a total length of 136.5 km were surveyed in total 59 times. Totally 2769 puku were counted in 579 observations. The puku was unevenly distributed throughout the floodplain with 78 % of the puku observed in the southern part of the survey area.

The density of puku increased significantly with distance to nearest the village, while increased number of cattle and distance to water had a significant negative impact on density. Total population size was estimated by using three models. Kelkers method gave an estimate of 13 303 (SE ± 4 412) puku in the total survey area, while Distance sampling and Kings method resulted in 21 225 (SE ± 13 094) and 29 438 (SE ± 9971) puku respectively. Considering the size of the area surveyed, the estimates from all three models exceeded previous estimates.

Vegetation types was divided in four categories, short grass, tall grass, wet grass and agriculture land. Puku was observed in all types of vegetation. Short grass was the most abundant vegetation type, followed by tall grass, agriculture land and wet grass. More puku than expected was observed in short grass areas. All the other vegetation types had less puku than expected. Proportion of burned and sprouted areas did not show any significant effect on the distribution of puku.

The Kilombero floodplain is being increasingly encroached by immigrants. This survey show how the puku responds adversely to disturbance caused by human activity. The puku is totally dependent on the habitat which the floodplain provides, and even though the estimates from this survey exceed previous estimates, wise management and immediate actions are required to avoid further pressure on these wetlands.

INTRODUCTION

Wetland areas are of high biological, environmental and economic value (Dungan 1990, Turner et al. 2000). Only tropical rain forest has a higher diversity of animals and plants depending on its habitat (Osborne 2000). Through the history, wetlands have been of great value and determinative for settlement and the development of agriculture (Purseglove 1988). The importance of wetlands and the resources attached to such areas are mentioned several times in the ancient texts of many Greek writers (Gerakes 1992). More recently, serious conflicts have occurred caused by the right to use wetland areas; in Senegal a dispute between pastoralists ended up in thousand people killed and several thousand homeless in 1989 (Dungan 1990). An incident like that is influenced by several factors, but gives a picture of how valuable wetlands can be in a socio-economic perspective.

Globally, wetlands are under heavy pressure (Turner et al. 2000). In the United States, 80 percent of the wetlands are reported damaged, mostly caused by overgrazing (Belsky et al. 1999). Poor management, strong economic interest and utilization beyond what is sustainable, results in degradation of wetlands in many ways. Wetland habitat has been destroyed several places in Europe because of overfertilisation from agriculture and industrial waste (Gerakes 1992). Similarly, the lack of good management resulted in overfishing and a 30 percent reduction in the value of a wetland area in Mexico (Pearce 2005).

Wetlands serve as key habitats not only for species living there permanently, but also as temporary resting places for numerous migrating birds (Gerakes 1992, Haig et al. 1998). As a consequence of the importance and vulnerability of these habitats, the Ramsar Convention on Wetlands was signed in 1971. Wetlands are the only single group of ecosystems having their own convention. Currently, 1839 sites are designated as Ramsar sites, covering a total area of almost 180 million hectar (Ramsar 2008a).

A large and complex range of ecosystems are considered as wetland (Dungan 1990), but a general accepted definition is "*areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt including areas of marine water, the depth of which at low tide does not exceed* 6 *m"* (Ramsar 2008b). Floodplains are one of the main categories of wetland, and function as groundwater re- and discharge, flood and erosion control and nutrition retention (Dungan 1990). Floodplains also provide habitats for a large diversity of fish and wildlife species, and are attractive as agriculture land and for forage purposes (Dungan 1990, Kangalawe & Liwenga 2005). According to Kangalawe and Liwenga (2005), the Kilombero Valley wetland has one of Tanzania`s largest inland fisheries, providing essential income for many inhabitants nearby the Morogoro region.

During the last decades, Kilombero Valley has experienced an increasing amount of immigrants moving into the area (McCartney & van Koppen 2004). A socio-economic survey conducted in 2006, found that the human population increases by 3.4 percent annually (Harrison 2006). Harrison (2006) found that less than 30 percent of the head of the households was born in the village environs. In Ulanga District, where this study was executed, approximately 64 600 inhabitants live in villages adjacent to the floodplain (UDDNR 2002). In addition to regular agriculturalists and employees, also pastoralists are moving in to the area with their livestock (Haule et al. 2002, McCartney & van Koppen 2004). This composition of the many ethnic groups and tribes and their various way of living, poses challenges regarding the management of the natural resources in the area.

There is a growing concern about impacts of human encroachment on partial- and unprotected habitats (Caro 1999a). Studies examining demographic and behavioral changes among large mammals as a result of human activity, show how sensitive these species may be to disturbance like hunting and agriculture (Caro 1999b, Hoare 2000, Setsaas et al. 2007). Pastoralism has been practiced in East Africa since 1000 B.C, with an expansion the last 1000-500 years (Voeten & Prins 1999). Surveys investigating how sympatric wild and domestic herbivores use the same habitat has found different adaption among the wild herbivores to the presence of cattle. (Fritz et al. 1996, Rannestad et al. 2006, Voeten & Prins 1999). Fritz et al. (1996) found that impala (*Aepyceros melampus*) reacted adversely to the presence of cattle, while kudu (*Tragelaphus strepsiceros*) seemed unaffected. In Uganda, pastoral areas adjacent to Lake Mburo National Park had a higher density of impala, zebra (*Equus quagga*), bushbuck (*Tragelaphus scriptus*) and waterbuck (*Kobus ellipsiprymnus*) in wet season than the national park (Rannestad et al. 2006).

The puku antelope (*Kobus vardoni* Livingstone) is of great interest regarding the wetland management of Kilombero Valley because valley currently holds more than 75 percent of the remaining population (East 1998), which makes it a `flagship species` when it comes to conservation issues. Some research has been done on the species (Corti et al. 2002, DeVos 1965, Dipotso & Skarpe 2006, Jenkins et al. 2003, Rodgers 1984, Rosser 1992), but little is known about the tolerance to different kind of human activity.

The aim of this study was to find the distribution and density of the puku living in the Kilombero Valley floodplain. The distribution of puku was seen in relation to distance to villages, density of cattle, distance to nearest water source and different vegetation types.

MATERIALS AND METHODS

Study area

The Kilombero Valley (08°33′ S. 036°23′ E) is located between Selous Game Reserve and the Udzungwa Mountain National Park, in the southern part of Tanzania. The Kilombero Valley, and particularly the wetland area, has a large diversity of both plant and animal species (Kangalawe & Liwenga 2005). The Kilombero Valley floodplain was designated as a Ramsar site in 2002 (Ramsar 2008). In addition to be a biodiversity hotspot itself, the valley serves as an important migration route for large mammals between Selous Game Reserve and Udzungwa Mountain National Park (Jones et al. 2007). Mean annual precipitation is 1400 mm (WorldClimate 1993- 2008), which mainly falls in the two rain seasons March to May, and December to February.

The types of landscape ranges from typical miombi woodland (*Brachystegia* spp, *Julbernadia* spp) to different categories of grassland and evergreen forest (Bonnington et al. 2007, Hinde et al. 2001, Starkey et al. 2002). The valley holds in centre a floodplain with an area of approximately 2500 km^2 (IRA 2008). The floodplain constitutes a great part of the Kilombero Game Controlled Area (KGCA,), which covers about 6600 km^2 (Hinde et al. 2001, Jenkins et al. 2003a). Plantations of teak (*Tectona grandis*) have recently been established in the valley, with totally 4 200 hectare distributed on several plots (Bekker et al. 2004, Bonnington et al. 2007, Hinde et al. 2001).

The perennial grass *Phragmites mauritianus* is dominating along the riverside and around ponds (Starkey et al. 2002). Climbing plants like *Cissampelos mucronata* and *Ipomoea plabeia* are also associated with moist areas, while the tall perennial grass *Panicum fluviicola* is common in the main floodplain. *Panicum fluviicola* occurs in clusters reaching more than two meters in height. Species of *Cymbopogon* spp and *Hyparrhenia* spp are other tall grasses abundant in the floodplain. Shorter herbs, such as *Ludwigia abyssinica* and, *Ipomoea aquatic,* are also common, together with the shorter grass species of *Echinochloa* spp and *Eragrostis* spp (Starkey et al. 2002).

The Kilombero Valley is known to have one of Tanzania`s highest wildlife densities outside national parks and game reserves (Jenkins et al. 2003b, Starkey et al. 2002). Traditionally, large mammals like puku (*Kobus vardoni*), buffalo (*Syncerus caffer*), elephant (*Loxodonta africana*), hippopotamus (*Hippopotamus amphibius*), eland (*Taurotragus oryx*), sable (*Hippotragus niger*), common zebra (*Equus quagga*) and lion (*Panthera leo*) have been abundant.

Puku is a medium sized antelope, with females weighing from 48-78 kg and males 67-91 kg (Kingdon 2004). It is genetically similar to kob (*Kobus kob*), adapted to live in open grassland close to water (Vesey-FitzGerald 1960). Puku prefer to feed on grass and herbs like *Brachiaria latifolia, Vossi cuspidata Eragrostis* spp and *Echinochloa* spp (Kingdon 2004, Richter & Osterberg 1977, Vesey-FitzGerald 1960). Males are territorial most of the year, and the puku calves in November to March (rain season). (Goldspink et al. 1998)

Survey line transects

The survey was conducted in the riverine floodplain of the Kilombero River, in Ulanga district. The survey area was 224 km^2 and located west of the towns Itete and Lupiro (Fig.1). The fieldwork was carried out in September and October 2008, in the middle of the dry season. At the time of the survey, a greater part of the floodplain was dry and accessible for humans and vehicles.

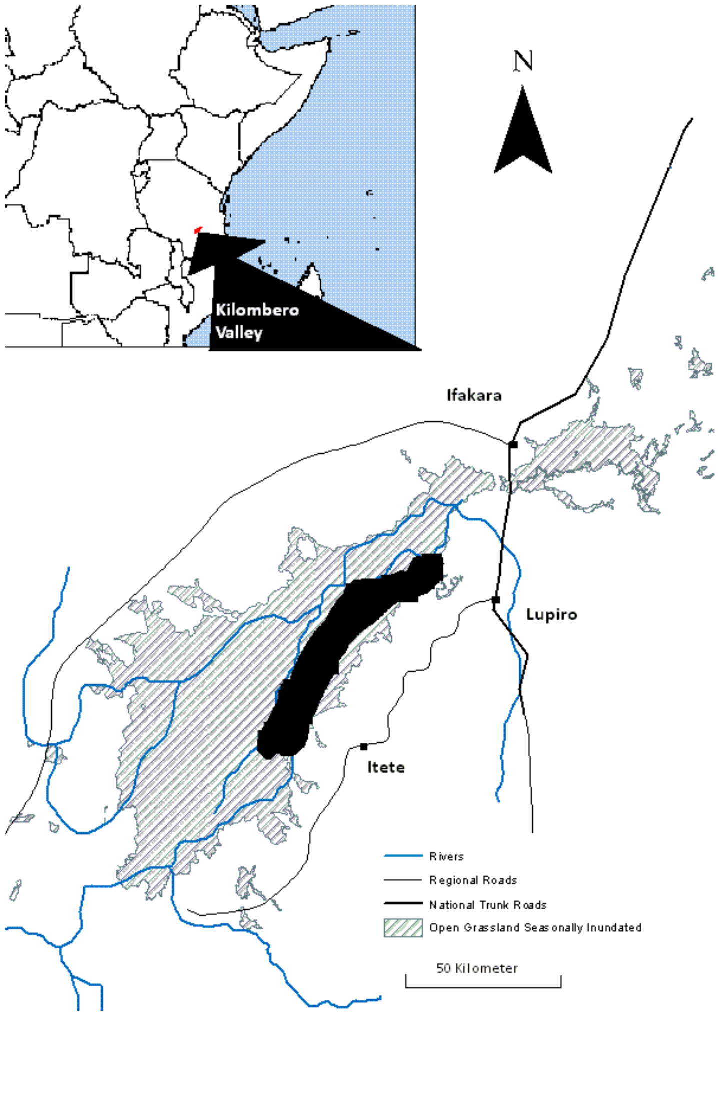


Figure 1. Survey area in the Kilombero Valley floodplain, autumn 2008.

A strip census method was chosen, establishing a total of 20 straight lines transect which were surveyed three times each, except one, which were surveyed two times. Average length of the transect lines was 2.5 km, giving a total transect distance of 136.5 km. The transects were scattered in the field with no selection for particular vegetation types, but with different distance to the surrounding villages. Their location was to some extent limited by accessibility in the floodplain.

Transects were driven either early in the morning (06:30am-10:00am) or in the evening (03:00pm-05:30pm). At this time of the day, the animals are most active and easy to spot (Caro 1999b). A 4x4 Landcruiser with two observers sitting on the roof of the car was used for optimizing the chances to see every animal along the transect. Every time an observer spotted an animal, we stopped the vehicle and noted the size of the group, perpendicular distance to the transect line, vegetation type and distance to water. Both domestic animals and puku were counted, and for every observation the GPS position were taken. An electronic rangefinder was used to find the perpendicular distances.

Both single individuals and groups of animals were recorded as one observation. A group was defined as individuals being within 50 meters to the nearest neighbor (Caro 1999a). The perpendicular distance to a group were measured from the transect line to the center of the group (Setsaas et al. 2007).

Vegetation types were divided in four categories; short grass, tall grass, wet grass and agriculture land. In the field, areas with majority of the grass shorter than 1.5 meter, was considered as short grass. Areas of grass with an average height over 1.5 meter were noted as tall grass, while green grass surrounding ponds and streams was wet grass.

Data analysis

Distribution of the puku was analyzed by a multiple linear regression model with forward selection. The different variables were; distance to water, distance to village, density of cattle and the impact of burning and sprouting. Only significant variables ($p<0.05$) were included in the model. The distribution of puku was log transformed to achieve a normal distribution required for conducting regression analysis.

An estimation of the total population was done by using three different models. In a field test of strip census methods done by Robinette et al. (1974), Kings method (Leopold 1933) and Kelkers method (Kelker 1945) both gave good results and were recommended. Kings and Kelkers method were selected and given by:

$$\text{Kings : } \quad \check{N} = \frac{nA}{2L\check{R}}$$

$$\text{Kelkers : } \check{N} = \frac{n''\mathrm{A}}{2L\check{D}}$$

where $\check{N}$ is estimated population size, A = area to be censused, Ď = estimated threshold distance beyond which some animals were probably missed, L = length of census line, n = number of animals seen, n´´= number of animals seen within 2Ď, Ř= mean sighting distance. Ď was found to be 179 meters (Fig.2)

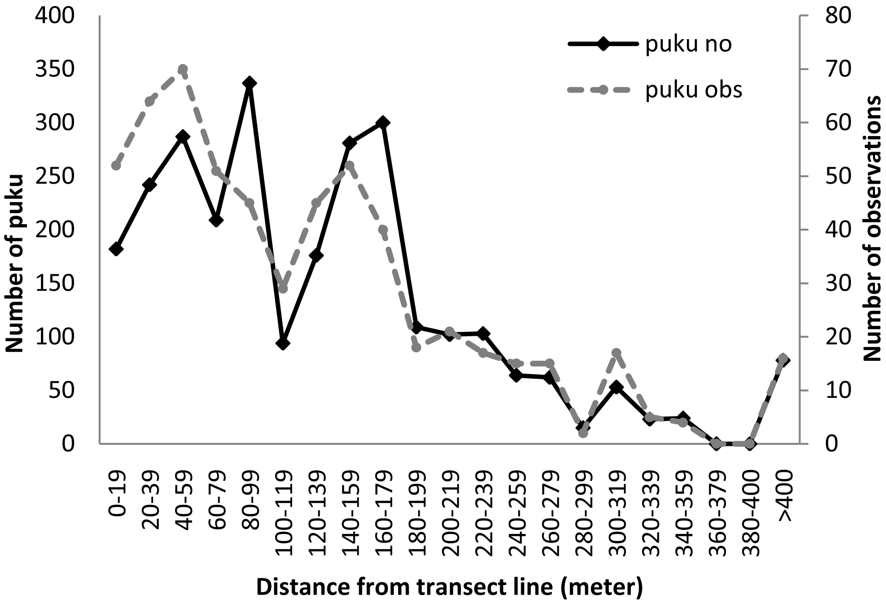


Figure 2. Number of puku and observations of puku detected from transect line in the Kilombero Valley floodplain autumn 2008.

The third model used for estimating the population size was Distance sampling, using the software program DISTANCE 5.0 (Thomas et al. 2006). The Distance sampling model is given by:

$$\check{N} = \frac{n}{2\mu L}$$

where $\check{N}$ = estimated population size, n = number of objects counted on k transects ($\sum_{i=1}^{k} n_i = n$), L = total length of k transects ($\sum_{i=1}^{k} l_i = L$) and μ = the distance from transect line which as many objects are detected beyond μ, as are missed within the μ of line. The default estimators, half normal with cosine expansion was used, recommended by Buckland et al. (2001).

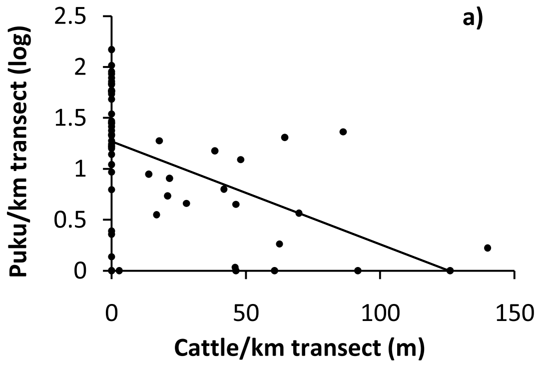
To test for significant difference between expected use and actual selection in different vegetation types, a Chi-square goodness-of-fit analysis was used. Bonferoni z-test with 90 percent confidence interval was used to determine habitat preference, according to Neu et al. (1974). Sample size was tested by $np(1\text{-}p) \geq 5$, where p is proportion observed in each habitat and n is total number observed (Neu et al. 1974). Size of the area and distances between the different observations and villages were measured by using ESRI® ArcMAP™ 9.2. (ESRI Inc. 1999-2006).The vegetation map used in the software program was received from the Institute of Resource Assessment (IRA) at the University of Dar es Salaam. The GPS unit was a Garmin Vista CX, with quoted accuracy <15 meter (Garmin 2006).

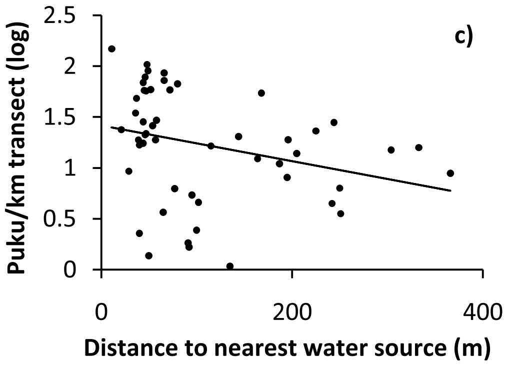
RESULTS

Distribution

Puku occurred in patches throughout the floodplain, in numbers ranging from single individuals to clusters of 41 counted animals with a mean of 4.8 (SD = 5.7). Cattle were mostly observed in large herds, up to 200 individuals (mean = 47.2, SD = 40.8). Puku was observed in 19 of 20 transects, ranging from 1.8 to 147.9 (mean = 30.8, SD = 31.5) puku per kilometer of transect. Cattle was seen in 11 of 20 transects, ranging from 2.8 to 140 (mean = 18.4, SD = 32.7) cattle per kilometer of transect. Both puku and cattle were observed in all types of vegetation.

The density of puku increased with distance to village and decreased with increased number of cattle and distance to water (Fig.3). These three variables had all a significant effect in the regression model (Table 1) while burning and sprouting did not have any significant effect on the distribution of puku.





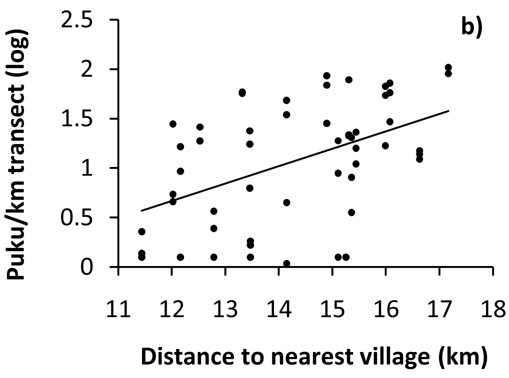


Figure3. The number of puku along the transect decreased with **a**) number of cattle/km transect (ΔR^2=24.5), increased with **b**) distance to nearest village (ΔR^2= 19.5), and decreased with **c**) distance to water (ΔR^2=7.26) in Kilombero Valley floodplain autumn 2008. The final multiple regression model was: puku/km(log) = - 0.938 + 0.171 distance to village – 0.0075 cattle/km – 1.772 distance to water. (F= 16.83, df= 3,51, R^2=51.8, P<0.001).

Table 1. Linear regression model of the effect of cattle/km, distance to nearest village, distance to nearest water source and burned and sprouted on the density of puku in the Kilombero Valley floodplain autumn 2008. A forward selection was conducted, but only those variables showing significance (P<0.05) were included in the model.

Explanatory variables	β	SE	df	t	P
Cattle/km	-0.008	0.002	51	-3.73	<0.001
Distance to nearest village	0.171	0.035	51	4.92	<0.001
Distance to nearest water source	-1.772	0.663	51	-2.67	0.01
Burned and sprouted	0.156	0.187	48	0.83	0.409

Density

Altogether, 2767 puku were counted, distributed on 579 observations. Seventy-eight percent of the puku were observed in the southern part of the survey area. The three different models all gave different estimate of the population size in the survey area (Table 2).

Table 2. Population estimates (±SE) of puku in autumn 2008, by Kings and Kelkers method and by Distance sampling in survey area (224km^2) located in Kilombero Valley floodplain.

Area	Method		
	Kelkers	Distance	Kings
Per km^2	59 (18)	95 (41)	131 (42)
Survey area	13 303 (4412)	21 225 (13 094)	29 438 (9971)

Vegetation preferences

The observations of animals were not equally distributed throughout the different vegetation types ($\chi^2 = 32.960$, d.f. = 3; $P < 0.001$). A Bonferoni z-test (CI=90%) show a preference for short grass (Table 3), while wet grass and agriculture land had a significant lower proportion of puku observed relative to availability. Only the number of observations done in tall grass is as expected due to availability. The different vegetation types were unequally distributed along the transect line. Agriculture land was only present along the edge of the floodplain, and only in two of the transects. Tall grass occurred in patches in the floodplain, while wet grass was found related to ponds, streams and other areas with water. The occurrence of burn and re-sprouting was also registered along the transect, to test whether puku had preferences for such areas.

Table 3. Selection of vegetation type by puku in Kilombero Valley floodplain autumn 2008. The availability is shown in percent together with proportion of observation (when all groups where counted as one observation irrespective of group size) and proportion of puku observed. A 90 percent Bonferoni confidence interval on proportion of occurrence is given in parentheses. Significant selection or avoidance is indicated by **+** and **–** respectively.

Vegetation type	Proportion of total distance	Proportion of observations in each vegetation type (CI=90%)	Proportion of puku observed in each vegetation type (CI=90%)
Short grass	73.0	78.2 (±3.9) +	82.6 (±1.6) +
Tall grass	17.3	19.3 (±3.7)	15.4 (±1.5) -
Wet grass	4.0	1.2 (±1.0) -	1.3 (±0.5) -
Agriculture land	5.7	1.2 (±1.0) -	0.8 (±0.4) -

DISCUSSION

In the Kilombero Valley flooplain, puku responded adversely to human disturbance. The number of puku increased significantly with distance to villages. Surveys done in Kasanka National Park in Zambia show similar results , where the abundance of puku increased with distance from the access points and toward the centre of the park (Goldspink et al. 1998). Different access opportunities to the floodplain could also be worth to consider regarding human disturbance. Several roads have been constructed in connection with the teak plantations which have been established close to the floodplain in the northern part of the survey area. A developed infrastructure will facilitate many types of human activity in the floodplain like farming and poaching, and increase disturbance of the puku.

Puku is totally dependent on the habitat which the floodplain provides, especially during dry seasons (Vesey-FitzGerald 1960). Similarly, surveys investigating the distribution of puku along the Chobe riverfront in Chobe National Park, northern Botswana, found that 91 percent of all observations were made in the floodplain (Dipotso & Skarpe 2006). Counting of large mammals in the Kilombero Valley, surveying the miombo woodland, evergreen forest and teak plantations did not report any large numbers of puku in contrast to other large mammals (Bonnington et al. 2007b, Hinde et al. 2001). On the other hand, dung counts and spoor observations in areas adjacent to the floodplain, show a significant use of agriculture land during wet season (March-May) (Jenkins et al. 2002).

The puku antelope, as well as other wildlife species using the floodplain, demands dry land as refuge when the wetland floods (Jenkins et al. 2002, Jenkins et al. 2003, Vesey-FitzGerald 1960). Opposed to most other large mammals living in the area, the puku does not migrate far but remain on the edge of floodplain. During this time of the year, farmers are out cultivating their fields which are in, or adjacent to the floodplain (Hetzel et al. 2008). Surveys conducted in the Kilombero District shows that the wet season is the most insecure time of the year for the households, resulting in intensified use of non-agriculture resources like puku (Boisen 2009, McCartney & van Koppen 2004). These concurrent circumstances may result in periodical high poaching activity, with puku as an available food resource for humans

An anti-poaching team is established in connection to a hunting camp located in the southern part of the survey area, keeping supervision with wildlife and human activity. The anti-poaching team were established because of high poaching activity, especially during the 1980`s (Starkey et al. 2002). In Selous Game Reserve, anti-poaching control has proved to be efficient (Baldus et al. 2001), and should therefore be regarded to have some effect. Unfortunately there have been reports of violent actions and aggressive methods executed by such teams both in Kilombero Valley and other places in Tanzania (Kaltenborn et al. 2005, Starkey et al. 2002). The importance of local support regarding management of the wetland has been emphasized, and training of anti-poaching personnel is one of the objectives in the Kilombero Integrated Management Plan for the Ramsar Site (Booth et al. 2008).

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Areas with high density of cattle are avoided by puku. Previous censuses in Kilombero Game Controlled Area show the same tendency in that puku and cattle avoid each other (Bonnington et al. 2007a, Corti et al. 2002). The great number of pastoral immigrants moving in to Kilombero Valley combined with increased seasonal agricultural activity, has put parts of the area under severe pressure (Harrison 2006, Haule 1997). Despite this, we observed puku and cattle grazing only few meters away from each other. From the observations, it seems that puku tolerate low numbers of cattle (Fig. 3a), but suddenly drops at a certain density of cattle (>90 cattle/km transect). Such thresholds have been found in other surveys investigating how wildlife respond to human disturbance (du Toit et al. 2004) . The few shepherds observed out in the floodplain, were seen in the northern part of the survey area. Given that puku associate cattle with humans, it might not only be the cattle itself that leads to avoidance, but an emphasizing effect of the connection to humans.

Numbers of observed puku declined significantly with increased distance to water. There was a tendency of less water ponds and rivers further north, giving longer transects without interruptions of streams and ponds (> 6 km). High density of heavy grazers in floodplains and riparian habitats, may change the soils structure and ability of keeping water (Kauffman & Krueger 1984, Rauzi & Hanson 1966, Trimble & Mendel 1995). Changes in water quality in ponds and streams (Jansen & Healey 2003) and vegetation composition (Belsky et al. 1999, Jansen & Robertson 2001) are also associated with high level of grazing pressure. Such changes in habitat structure due to cattle grazing may be indirect effects, which negatively influence the distribution of puku.

The estimates of the total population size differ both between the three different models used, as well as from previous estimates. Kelkers method, which came up with the most conservative estimate (59 puku km^{-2}), has shown in other studies to be the most accurate strip census method (Robinette et al. 1974). When using Kelkers method, only animals observed within an effective strip width (in this survey 179 m.) are included. Such a method will increase the probability of counting all animals within the strip width and give a correct estimate based on those observations. On the other hand, a demarcation will exclude a lot of observations, especially in an open landscape like a floodplain.

Kings method gave the highest estimates with 131 puku km^{-2}. Kings method use mean sighting distances, and not an effective strip width like Kelkers. Using mean sighting distances gives the advantage of including animals which have been scared away before seen inside the effective strip width. A survey conducted in open grassland counting blesbok (*Damaliscus dorcas*), concluded with a 15 percent underestimation of the true population using Kelkers method compared with mean sighting distance methods like Kings (Hirst 1969). The reason for this error was animals beyond the effective strip width due to disturbance from the observers (Hirst 1969). Since we used a vehicle in our census, there is a chance that some puku had been scared away before seen by the observers. A method like Kings accounts for such problems, but can lead to an overestimation if many long distances occur.

The Distance sampling method estimated the population size to be in between Kelkers and Kings estimates, (95 puku km^{-2}) with the confidence interval including both of them (SE = 42). Distance sampling is an acknowledged and well known method for estimating wildlife densities (Focardi et al. 2005, Jachmann 2002). The floodplain offers good visibility, and animals can be spotted on long distances. Because of this, a 5 percent truncation of the uppermost observation distances was done, to achieve a better model (Buckland & Anderson 2001, Lloyd et al. 1998).

Previous land surveys conducted in the Kilombero Valley floodplain (Starkey et al. 2002) do not give any estimate useful for comparison. From the latest aerial surveys (1989-1998) in Kilombero Valley, the estimated density is 8-12 puku km^{-2}, including the whole Game Controlled Area (6 500km^2) (Jenkins et al. 2002). The estimates from all of the three models used exceeds by far these previous estimates of the puku population. This means that either we have registered a great majority of the puku living in the floodplain or that the aerial survey underestimates the true population size, or it could be a combination of these two.

The general experience when counting puku, is the patchy distribution of the animals throughout the area (Dipotso & Skarpe 2006, Goldspink et al. 1998, Rosser 1992, Starkey et al. 2002). This may make it difficult to estimate a population density in a larger area. The southern part of our survey area covers that part of the floodplain considered by the Ulanga District Department of Natural Resources to contain the highest density of puku on the Ulanga District side of the Kilombero River (nicknamed `Serengeti` by the Game Scouts). A large proportion of the puku observations were in this area, and given that the density here is much higher than the rest of the floodplain, this could lead to an overestimation of the puku density.

Aerial surveys may underestimates the size of wildlife populations (Caughley 1974, Eberhardt 1979, Jachmann 2002). A comparison of aerial counts with ground counts conducted in Lupande Game Management Area in Zambia, show an underestimation of several wildlife species comparing aerial survey with Distance sampling (Jachmann 2002). In the case of puku, Jachmann (2002) estimated the puku population to be more than twice as high using ground counts (3660 ± 366 SD) than with aerial counts (1392 ± 393 SD). Puku is a relatively small animal, hard to spot even in open grassland. This together with the patchy distribution may lead to an underestimation when using aerial surveys.

As a result of the specific factors mentioned, it is presumable to believe that previous estimates from aerial surveys are too low. The survey area (224 km^2) covers less than ten percent of the total floodplain (2 500km^2), and multiplying the Distance sampling estimate three times exceeds the estimates done by aerial counts. It is also worth to notice that the aerial survey, which included the whole game controlled area, were conducted during dry season (Jenkins et al. 2002), when puku mostly uses the floodplain. Counting animals in areas having none or few animals due to seasonal movement, may have lead to an underestimate in the previous surveys.

Half of the floodplain is on the Kilombero District, on the western side of the Kilombero River. All surveys regarding wildlife's response and distribution in connection to humans in the floodplain, have been conducted in the Ulanga District. To give a good estimate of the total population using ground counts, it is necessary to investigate the density of puku and cattle and the presence of humans also on the western side of the Kilombero River.

The short grass category was by far the most abundant class of vegetation and contained more puku than expected. In Rukwa Valley, the puku associated with short grass areas adjoining water, with the perennial herbage *Echinochloa* and *Vossia* as preferred pasture (Vesey-FitzGerald 1960). From Chobe National Park it is known that the puku during dry season graze on the stoloniferous grass *Cynodon dactylon* (Dipotso & Skarpe 2006). Species of both *Echinochloa* and *Cynodon are* registered as abundant in short grass areas in Kilombero Valley floodplain (Starkey et al. 2002).

Low numbers of observations in the other habitat categories may have several explanations. Looking at the forage quality, *Cymbogopon* and *Hyparrhenia,* which is common tall grass species, are unpalatable and indigestible (Starkey et al. 2002). According to Rosser (1992) females seek for shadow in the tall grass in the dry season. Occasionally we spotted calves hiding in this vegetation types, and clusters of puku were regularly observed standing in the edge of tall grass. The possibility of missing some animals in this vegetation type cannot be disregarded. The low number of observations in agriculture land may be explained by the need for water. Since the agricultural areas are located at the edge of the floodplain, these areas will be the first to dry out. Observations of puku in Rukwa Valley confirm this movement towards the water source as the dry season proceeds (Vesey-FitzGerald 1960).

Though there was no positive correlation between number of puku and burned areas with after re-sprouting, several studies have shown that herbivores is attracted to grassland burned and re-sprouted (Moe & Wegge 1997, Moe et al. 1990, Tomor & Owen-Smith 2002). Prescribed burning is also conducted by the hunting companies in Kilombero Game Controlled Areas to facilitate game. Likewise, observations from Rukwa Valley show that the puku preferred burned areas (Vesey-FitzGerald 1960). In the Kilombero Valley floodplain an interaction of factors could possibly explain the observation that the puku do not remain in the burnt areas where grazing quality is possibly better. With the receding water level of the floodplains towards the main channel as the autumn proceeds, the puku are likely to follow given their strong preference for proximity to water. In addition, the burnt areas begin where human activity is greatest at the edge of the floodplain, and gradually moves inwards towards the centre . Likewise, cattle densities are likely highest in the burnt areas with the best forage quality.

Except the dung counting and spoor observations by Jenkins (Jenkins et al. 2002), very little is known about the habit of the puku during wet season. From Chobe National Park it is reported that the puku switches to browsing shrubs when the floodplain is inundated, but in close proximity to the open grassland (Dipotso & Skarpe 2006).

Management implications

The puku is totally dependent on the floodplain during dry season, and demands refuge areas of dry land in wet season. This is in an inescapable conflict with the increased utilization caused by humans. Even though the estimates of the puku density previously have been underestimated, it is no doubt that the habitat demanded by puku is threatened. Today, the Kilombero Valley floodplain is comprised by Kilombero Game Controlled Area. Game controlled areas allows agriculture, fishing and settlement, which are not allowed in national parks and game reserves (Caro 1999). The first to call for attention concerning the conservation status was Rodgers (1984), claiming an obvious need for a game reserve. This conclusion has been followed up by recent researchers (Booth et al. 2008, Jenkins et al. 2002, Jenkins et al. 2003, Starkey et al. 2002).

Kilombero Valley will never be a tourist destination like the large, well known national parks and game reserves in Tanzania (Jenkins et al. 2003). Tourist hunting has been mentioned as a possible source of income, justified with the traditionally high abundance of wildlife living in the valley (Booth et al. 2008). By involving the local communities in the wildlife management, activities like tourist hunting may wake an awareness of the value of the wildlife. The major issue regarding management of partially protected areas like Kilombero Game Controlled Area, is to make the local people benefiting from it (Caro 1999, Child 1996b). Even though there are some more or less successful stories of community based wildlife management (CBWM) (Child 1996a), experience show that there are many difficulties (Songorwa 1999, Wainwright & Wehrmeyer 1998).

All population estimates conducted on puku in Kilombero Valley indicates that a certain harvest of the population is sustainable. The last five years, 30 puku are reported as legally hunted by the hunting companies operating in Ulanga District (UDDNR 2008). The true number of puku harvested in the floodplain is presumably higher, considering the seasonal poaching activity reported. Anti-poaching control may be a useful tool in protecting wildlife, but the main challenge regarding the management of the floodplain is to preserve the habitat which the puku is dependent on.

In Kilombero Valley, immigration through decades has led to large diversity of tribes and ethnic groups sharing the same resources. It has not been reported any conflicts between these groups, but regarding nature management, it is worth to consider the different values and ways of living which are represented (Haule 1997). Local involvement should always be a goal to achieve, but facing the fact that one of largest wetland areas in Sub-Saharan Africa is in danger of being damaged due to human encroachment, an increased protection status of the Kilombero Valley floodplain is inevitable

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