

Comparing data of different survey methods for sustainable wildlife management in hunting areas: the case of Tarangire–Manyara ecosystem, northern Tanzania

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Received: 2 November 2005 / Accepted: 13 November 2006 / Published online: 10 January 2007
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Abstract Cost–benefit considerations of wildlife monitoring are essential, particularly, in areas outside national park boundaries, where resources for conducting wildlife censuses are scarce, but that, at the same time, are subject to high pressure for wildlife utilization, such as hunting. Large mammal survey data from various sources were collated and analyzed to investigate which methods are best suited for monitoring purposes at low cost in the Tarangire–Manyara ecosystem, northern Tanzania. Our results indicate that primary data (from aerial and road transects counts) that involve direct species observations, although sometimes very expensive, are required for establishing the status of the target

species in terms of density or population size. Concomitantly, secondary data from various sources, such as interviews, hunting quota, and damage reports, obtained over wide areas and over longer periods of time, can provide important information on presence/absence and distribution of species within an area. In addition, the study revealed that hunting quotas set did not correlate with species abundance/numbers from the primary data surveys for most of the large mammals hunted within the ecosystem. For a better conservation and management of wildlife, in particular with respect to the forthcoming formation of Wildlife Management Areas, we propose an integrated approach to wildlife monitoring using primary and secondary data sources through the involvement of local people's knowledge.

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Keywords Hunting quota · Large mammals ·
Survey methods · Tarangire–Manyara ecosystem ·
Wildlife Management Areas

Introduction

The Tarangire–Manyara ecosystem, in northern Tanzania, which is part of the Maasai Steppe, is among the richest areas in East Africa regarding wildlife diversity and abundance, hosting large populations of wild herbivores including the largest population of elephants (*Loxodonta africana*; Lamprey 1964; Borner 1985; Tarangire Conservation Project—TCP 1997). During the dry season, huge herds of migratory species, mainly elephants, buffalo (*Syncerus caffer*), wildebeest (*Connochaetes taurinus*), zebras (*Equus burchelli*), and eland (*Taurotragus oryx*), migrate to the permanent waters of the Tarangire River, which is situated inside Tarangire National Park (TNP) and which, during this season, is the only reliable source of

water within the ecosystem. However, in the last decade, there has been a growing concern about the declining population of some important migratory species, e.g. hartebeests (*Alcelaphus buselaphus*), Grant's gazelles (*Gazella granti*) and Thompson's gazelles (*G. thomsonii*), within the ecosystem (Caro et al. 1998; Tanzania Wildlife Conservation Monitoring—TWCM 2000; Kideghesho et al. 2000). The ecosystem also hosts some rare and endangered species, like greater kudu (*Tragelaphus strepsiceros*), lesser kudu (*T. imberbis*), African hunting dog (*Lycaon pictus*), and cheetah (*Acinonyx jubatus*; IUCN 1996; Hilton-Taylor 2000). In addition, the ecosystem represents one of the most critical areas for wildlife–human conflicts in Tanzania, such as crop raiding, predation of livestock, and sometimes, also injuring or killing of people by wildlife. These problems are associated with the intensification of agricultural activities and human encroachment on protected areas, which have interrupted several of the traditional large-mammal migratory routes (Borner 1985; Mwalyosi 1991; Moe et al. 1992; Newmark 1996; Galanti et al. 2000; Shombe-Hassan 2000).

Outside national parks, the tourist hunting industry is among the major sources of the Tanzanian wildlife-generated income, which is currently operating mainly through foreign safari companies. However, the industry generates inadequate income to the local communities, although these are the legitimate landholders (Leader-Williams et al. 1996; Baldus et al. 2001; Baldus and Cauldwell 2004). In addition, issuing of permits to Tanzanian citizens and residents, against payment of a modest fee for hunting of common game species for their own consumption and/or trophies, provides no economic returns both to the government and to the local communities (Baldus and Cauldwell 2004). Moreover, although concessions for tourist and hunting by residents are based on quotas, planned harvest of wildlife is only rarely based on reliable estimates of population size of the various game species (Caro et al. 1998; Baldus and Cauldwell 2004; Whitman et al. 2004).

In areas of Africa where wildlife is not totally protected, abundant species are often used for consumption, cultural practices and belief (e.g. young Maasai men use to kill a lion for pride or to become warriors), or hunted to protect crops or to control dangerous animals. Such management should preferably be based on some understanding of the ecological processes regulating population dynamics and structure and the species' migratory movements (Fryxell and Sinclair 1988), the extent to which wildlife–human conflict, and the rates at which wildlife can be harvested without decreasing population growth rates (Georgiadis et al. 2003). Basic questions are: How much wildlife is available in a given area, what is the population carrying capacity, where does it occur and/or migrate to during the wet and dry seasons, and what are the most suitable methods to collect these data? In Tanzania,

official wildlife census (herein referred to as primary data) generally covers, mainly, national parks and game reserves (in this case, TNP and Lake Manyara National Park—LMNP) and only portions of surrounding areas that are utilized by the majority of the migratory species and where hunting operations take place (e.g. Lolikisale game-controlled area and some open areas; Msoffe 2003). However, information on wildlife presence and distribution from various other sources (in this study, referred as secondary data) are available from these areas. This information is, however, fragmented, not organized in databases, and of poor or uncertain reliability, even at the level of species identification (e.g. in Swahili, the term 'swala' is used for more than one species of antelope). Due to high financial and human resource costs involved in primary data collection (e.g. aerial counts), it is impossible to organize additional large-scale wildlife monitoring, also, over vast non-protected areas: In this study, the only possibility to improve data quality (and quantity) is to collect and pool secondary data from a number of sources and to obtain a more comprehensive knowledge on wildlife distribution and abundance before planning for a primary survey.

So far, no attempt has been made to organize and create a database on key migratory wildlife species from both primary and secondary data sources within the Tarangire–Manyara ecosystem. In this study, we assess the congruency of primary data (direct field observations of species concerned, mostly from TWCM aerial census) and secondary data. The latter contain species-specific information collected from different sources in the study area, which does not necessarily involve direct field observations at a particular time. Secondary data are obtained from Wildlife Division (Tanzanian state organization responsible for game management), hunting companies and their employees, and the local people residing in the study area. Our objectives were (1) to collect and organize primary and secondary wildlife data from different sources into a geographical information system (GIS)-linked database, (2) to assess levels of agreement between these data, and (3) to investigate which methods are best suitable for wildlife monitoring purposes at low cost in northern Tanzania.

Materials and methods

For this study, we concentrated on four key migratory wildlife species: the African elephant, buffalo, wildebeest, and zebra. We also used data of other important herbivores, such as the greater and lesser kudu, oryx (*Oryx gazella*), eland, hartebeest, and gerenuk (*Litocranius walleri*), and four large carnivores, which often follow the migratory herbivores, viz. lion (*Panthera leo*), cheetah, leopard (*P. pardus*), and African hunting dog. We used GIS ARCView version 3.2 (Campbell 1991; Environmental System Re-

search Institute—ESRI 1996) for mapping our database created in Microsoft Access (MDB) using both spatial and non-spatial data sources (Burrough and Rachel 1998).

Study area

The Tarangire–Manyara ecosystem is situated in northern Tanzania in the Arusha and the new Manyara Regions and extends more than 35,000 km². It is surrounded by the Serengeti, Mount Meru, and Kilimanjaro ecosystems. The western boundary is the edge of the rift valley; the southern boundary (at 5°15'S) is characterized by bushy areas; the eastern boundary runs from 37°00'E in the southern portion to 36°35'E in the northern portion, pointing towards the Kenyan border; and its northern boundary follows the border between Kenya and Tanzania. The study area rises from about 1,000 m a.s.l. in the southwest to 2,660 m in the northeast. About 75% of the area is flat, 22% is rolling to moderately dissected, and 3% is hilly. It is drained by rivers that empty into Lake Manyara and Lake Burungi. Lake Burungi is mainly fed by the Tarangire River, which drains parts of Babati, Kondoa, and Simanjiro districts. The river is fed by both surface runoff and ground water recharge. The region has a semiarid climate, with mainly a single period of rainfall from February to May (average: 650 mm year⁻¹), normally followed by a dry spell and short rains in November–December. Mean maximum temperature is 27°C and minimum temperature 16°C (TCP 1997). The study area is characterized by arid savannah with scattered tree growth dominated by *Acacia* and *Commiphora* species. The most important vegetation types include a combination of riparian woodland, *A. tortilis* parkland, wetlands, and a seasonal flood plain, *Acacia–Commiphora* woodland, riverine grassland, *Combretum–Dalbergia* woodland in well-drained soils, *A. drepanolobium* woodland mostly in black cotton soils, rocky hilltop outcrops (kopjes) vegetation, deep gully vegetation, and the rest is grasslands with scattered baobab trees (TANAPA 2001).

We gathered data in a more restricted area, which is TNP, and the surrounding districts (Babati, Kiteto, Kondoa, Monduli, and Simanjiro, Fig. 1), identified in the past as important dispersal areas for the key migratory wildlife species (Lamprey 1964; Borner 1985). In the northwest lies LMNP, on the north and east are the Lolkisale and Simanjiro game-controlled areas, and to the southeast lies the Kitwai open area.

Primary data sources

Primary data are from various sources, such as aerial surveys including systematic reconnaissance flights (SRF) conducted by TWCM in two dry seasons (September 1990 and October 1994) and two wet seasons (May 1988 and March 1994), to

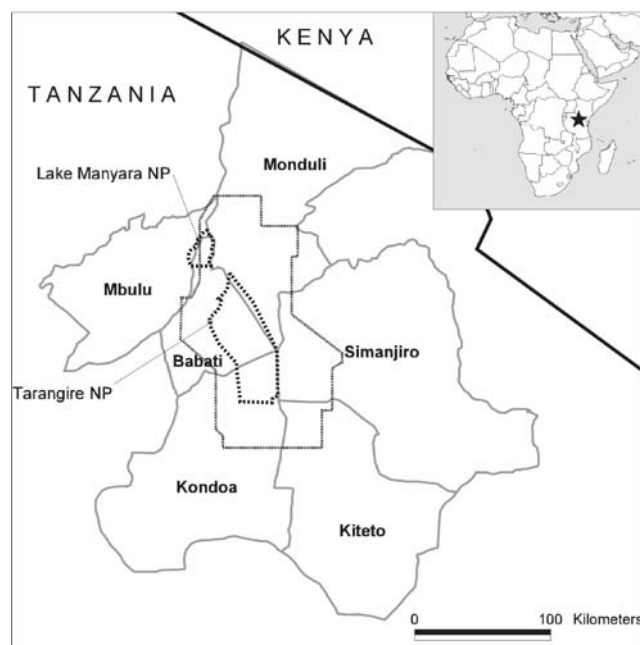


Fig. 1 Position of Northern Tanzania in Africa and map of the study area with the district boundaries and position of the Tarangire and Lake Manyara National Parks. Bold line indicates borders of area covered by all aerial surveys and road transects

determine distribution and abundance of animals and human activities (Norton-Griffiths 1978; Woodworth and Farm 1996). For SRF, the study area was divided into blocks small enough to be covered in a maximum of 4 h by flying evenly spaced parallel transects. Transects were spaced 5 min of longitude or latitude apart and flown at a constant height in a defined block. Animals were counted in a strip of a defined width, thus allowing density estimates for each species counted (Woodworth and Farm 1996). The survey covered the protected areas and areas identified as important for seasonal migrations or as seasonal habitat outside the protected areas. A second source of primary data is reconnaissance flights (RF) covering two dry season surveys (November 1995 and September 1996) and two wet season surveys (February 1996 and June 1996) employed to determine the distribution of large wild mammals and livestock (TCP 1997). RF transects were flown at an average altitude of 300 ft. Transects were oriented either north–south or east–west, parallel or perpendicular to the long axis of the protected area. When the survey was done during a migration period, transects were designed perpendicular to the migratory line for better description of the migratory wildlife groups. Transect length and time varied among surveys. Each transect was divided in sub-transects of 30 s, drawn on maps that reported endpoint coordinates to provide the pilot with GPS navigation (TCP 1997). For data analysis, each sub-transect was geo-referenced using interpolation of GPS locations automatically recorded in track files. Both SRF and RF provide reliable estimates for non-cryptic and/or

evenly distributed species, as based on the assumption that distribution of animals within the counting transect (RF) or counting strip (SRF) was the same as in other parts of the region. They were less suitable (large standard error) for animals living in large groups, such as elephant, buffalo, and livestock or for animals occupying a territory, such as lions (TCP 1997). A third source of primary data are total counts (TC) with two dry season surveys (September 1995 and October 1998) and two wet season surveys (May 1996 and February 1998), a method used only to determine distribution and numbers of elephant and buffalo (Norton-Griffiths 1978; Woodworth and Farm 1996). In this study, the entire area was surveyed. Every time an individual or a group of the target species was encountered, its GPS location was taken, herd size estimated, and photographs were taken for later counting. Surveyed areas were divided into blocks small enough to be covered in a single flight, in a maximum of 4 h, and block boundaries were supposed to correspond with visible land features to facilitate navigation. Transects were flown systematically across the block; the interval between transects was 1 min of latitude or longitude (approximately 1.8 km apart on the ground), with approximately a 900-m wide searching strip on each side of the plane, and flight height of 500–600 ft (Norton-Griffiths 1978; Woodworth and Farm 1996). The final source of primary data are road transect counts (RTC), carried out during dry seasons (years 1999, 2000, and 2001), driving a vehicle at a constant speed (about 25 km/h) along the road system, with observers counting all animals seen on both sides of the car, without limit to distance (Norton-Griffiths 1978; TCP 1997). These surveys were carried out mainly in the northern part of TNP and in some important wildlife corridors around the park, such as Manyara Ranch and Kwakuchinja. RTC were mapped using GPS locations, and each observation of wildlife species and livestock was recorded (coordinates, time, species, number of animals/species). This method provides distribution data and an abundance index ($KIA = \text{number of animals/kilometer}$, Norton-Griffiths 1978).

Secondary data sources

For logistic reasons, secondary data were organized district wise, covering areas surrounding TNP and LMNP of Babati, Kiteto, Kondoa, Monduli, and Simanjiro districts. We used three major sources of secondary data collected outside the national parks. The parks were excluded, as their staff was involved in collecting primary data, which could bias their reply to questionnaires. The first sources were interviews with hunters and operators of safari hunting companies on wildlife occurring in their blocks/hunting areas located in: (1) game-controlled areas (GCA), protected wildlife areas used mostly for tourist hunting, where people can keep livestock and do

only subsistence farming; (2) open areas (OA), outside protected areas, used mostly for resident hunting, where people can live without restriction. Further interviews were held with local people in villages within district and wards, i.e. subunits of a district consisting of several villages.

Our experience in the study area showed that local people have good knowledge on common wildlife species' distribution and trends, such as elephant, wildebeest, and lion. This might be due to the fact that these species tend to cause more problems (conflicts) when they are in the village land, such as crop and livestock damage, as compared to rare and shy species like cheetah or hartebeest.

From the information gathered from village lists, we formed the basis for stratifying the villages into: (a) villages with records of hunting; (b) villages with records of wildlife problems on human, livestock, and crops; and (c) villages with no records for either hunting or wildlife problems (questionnaire surveys—QS). Sampling of the households within a stratum in conducting questionnaires was done randomly within each village. From each household, the head of the household or, on rare occasions, a knowledgeable member of the family, usually above 18 years, was interviewed (see also National Survey of Tanzania 2000).

A second source of secondary data were hunting quotas issued to safari hunting companies directly from the Wildlife Division, Tourist Hunting Section (hunting block quota—HBQ), and to individuals/groups through District Game Offices (hunting district quota—HDQ), extracted from their records between 1990 and 2001. HBQ are indicative of the number of animals for each wildlife species authorized by the Director of the Wildlife Division for tourist hunting in respective blocks for each hunting season of the year and to the district for resident hunting. The District Game Officers supervise the quotas. The Wildlife Division estimates the number, usually based on past records from previous hunting season of realized quota (numbers actually shot). Information of wildlife quotas was obtained from District Game Officers and included species, numbers of animals of different species shot, type of hunting (tourist or resident), type of area, and its name.

A third source were reports of wildlife damage to people and their properties (WDAM), collecting information on date of event, problem species, number of wild animals involved, and the extent of damage (number of livestock killed/injured, approximate area of crops destroyed, number of people killed/injured). As a final step, we determined the location of all secondary data and linked this database to our vector-based GIS-mapping system (ARCVIEW version 3.2, ESRI 1996).

Statistical analyses

Due to some limitations inherent to the study approach (e.g. boundary problems, Msoffe 2003), secondary data were

compared with primary data at the level of district polygons. Hence, data on abundance and/or occurrence used for statistical analyses do not represent actual abundance/occurrence during a particular survey, but represent all pooled data within a district by survey for a given species in a given period (dry or wet season in each year). Distributions of numbers for buffalo, zebra, and wildebeest from both primary and secondary data deviated slightly from a normal distribution, even after natural logarithm transformation (Shapiro–Wilk's test $0.80 < W < 0.90$, SAS 1999). The data were analyzed with a generalized linear model with repeated-measures of type of secondary data within year (Proc Mixed, SAS 1999). This model allowed us to explore effects of type of primary data source, type of secondary data source (factors), and the interaction between type of secondary data and number of animals from secondary data, on the relationship between secondary data (continuous independent variable) and primary data (dependent variable). The compound symmetry residual correlation structure was selected using the Schwarz's Bayesian information criterion, where smaller values indicate better fit (Verbeke and Molenberghs 2000). For zebra, buffalo, and wildebeest, we started from a saturated model, i.e. including all fixed effects and their interactions, and performed model selection using a stepwise backward procedure. Degrees of freedom and standard errors of F - and t -tests were obtained using the Kenward–Rogers method (SAS 1999). Interpretations of the final models were based on least square means. Using nonparametric tests (Spearman rank correlations) did not change the relationships between primary and secondary data.

Secondary data for elephant (WDAM) were highly skewed: 21 out of 22 WDAM had 1 or 0 damage events, only one report had three events. Therefore, we analyzed elephant data using a logistic regression model (Proc Genmod, SAS 1999) with secondary data as dependent binary variable (positive report=1, negative report=0). We tested effects of elephant numbers revealed by primary data, type of primary data source, the interactions between numbers and primary source type, type of secondary data source, and district.

Results

Secondary data of zebras did not correlate with numbers from primary data ($n=60$ reports, $r=0.17$, $P=0.19$), and number of zebras hunted was not related with numbers counted over districts and years (Fig. 2a, $n=39$, $r=0.01$, $P=0.97$). There was no significant effect of type of secondary data ($F_{3, 48}=0.04$, $P=0.99$) or number of animals (type by numbers interaction $F_{3, 44}=0.59$, $P=0.63$; numbers $F_{1, 50}=0.08$, $P=0.78$). Also, type of primary data did not affect zebra numbers ($F_{2, 3}=0.10$, $P=0.91$), but direct

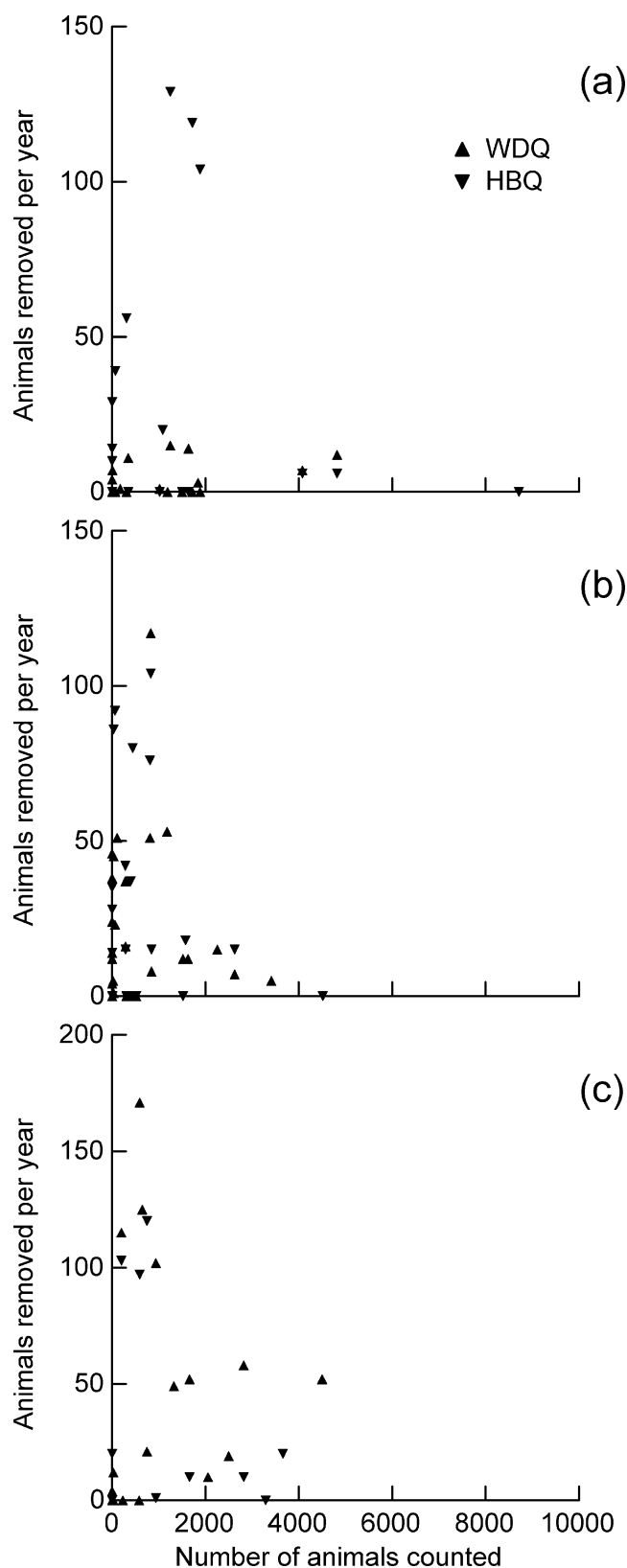


Fig. 2 Relationship between the number of animals shot per year according to Wildlife Division quota (WDQ) and hunting block quota (HBQ) and total numbers counted (from primary data sources) within the same year and district: **a** zebra, **b** buffalo, **c** wildebeest

counts of zebra numbers differed among districts ($F_{4, 51}=33.3$, $P<0.0001$). Zebra numbers were highest in Babati and Monduli districts, intermediate in Kiteto and Kondoa, and lowest in Simanjiro (Table 1).

Indices of buffalo reported by secondary data was not correlated with numbers from primary data ($n=76$ reports, $r=0.087$, $P=0.46$). There was no significant effect of type of secondary data ($F_{3, 63}=0.54$, $P=0.66$), number of animals ($F_{1, 65}=0.25$, $P=0.62$), and their interactions ($F_{3, 61}=0.16$, $P=0.92$), but direct counts of buffalo numbers differed with type of primary data ($F_{2, 11}=6.99$, $P=0.011$) and among districts ($F_{4, 65}=52.7$, $P<0.0001$). SRF and TC gave similar results, and both gave higher buffalo numbers than RTC (differences of least squares means SRF–TC -0.41 ± 0.22 , $t_{59}=-1.82$, $P=0.073$; SRF–RTC 0.77 ± 0.31 , $t_6=2.45$, $P=0.048$; TC–RTC 1.18 ± 0.31 , $t_6=3.77$, $P=0.009$). There were more buffalos in Babati than in all other districts (Table 1, all $P<0.001$). More buffalos were counted in Monduli (pairwise comparisons of Monduli with other districts except Babati, all $P<0.0001$) than in Kondoa and Simanjiro, where numbers were similar ($P=0.96$). The lowest number of buffalo was in Kiteto. Results did not change when records with no animals counted were excluded. Numbers of buffalo removed by hunting did not correlate with number of animals counted over districts and years (Fig. 2b, Spearman rank correlation $n=48$, $r=-0.16$, $P=0.27$).

For wildebeests, there was a positive correlation between numbers from primary data and secondary data ($n=39$ reports, $r=0.38$, $P=0.017$). In the generalized linear model, however, effects of type of secondary data ($F_{3, 27}=0.05$, $P=0.98$), number of animals ($F_{1, 30}=0.48$, $P=0.50$), or their interaction were not significant ($F_{3, 23}=2.24$, $P=0.11$). Also, type of primary data did not affect wildebeest numbers ($F_{2, 4}=2.02$, $P=0.24$), but direct counts of wildebeest numbers differed among districts ($F_{4, 28}=20.4$, $P<0.0001$). Wildebeest numbers were always high in Babati district, with a constant presence at lower numbers in Monduli. In Simanjiro, numbers varied strongly between years, whereas low numbers of wildebeest were counted in most years at Kondoa (Table 1). No animals were counted in Kiteto district (Table 1). There was no significant correlation between hunting quota and primary data (Fig. 2c, $n=23$, $r=0.07$, $P=0.74$).

The probability of a positive record of elephant presence using secondary data changed significantly with the type of secondary data source [selected logistic regression model with stepwise backward procedure: factor type of secondary data $\chi^2=5.99$, $df=2$, $P=0.049$; $G(x_i)=-0.56 (\pm0.44)-0.54 (\pm1.24)$ type HDQ+8.8 (±21.4) type QS]. There were no significant effects of type of primary data ($\chi^2=1.30$, $df=3$, $P=0.73$), number of elephants monitored by primary data ($\chi^2=0.025$, $df=1$, $P=0.87$), their interaction ($\chi^2=0.26$, $df=1$, $P=0.62$), or district ($\chi^2=2.22$, $df=3$, $P=0.53$). Thus, for

elephants, there was no agreement between presence/absence indices from secondary data and actual numbers from primary data (Table 1).

During aerial surveys, rare species, like lesser kudu and oryx, were more common in Babati than in other districts (Table 1). Most species tended to increase in numbers from the 1988 to the 1996 survey. Eland numbers decreased from 1988 to 1990 due to a decrease in Simanjiro District, whereas a further decrease in all districts was evident from 1990 to 1994 (Fig. 3). By 1994, however, total numbers had increased strongly (Fig. 3). This is mainly due to higher eland numbers in Simanjiro and Monduli districts (Table 1). African hunting dogs were recorded only in Simanjiro district during the 1996 RF survey, whereas in the same survey, lions were recorded in Babati and Simanjiro districts. Almost all the medium- to large-sized mammals were recorded, even shy species like cheetahs and leopards in RTCs Babati district during the RTC in the dry seasons of 1999–2001.

In QS, local people and hunters responded “present/absent” to a species in question. Hence, numbers are the total number of people interviewed in the respective districts that responded positively to the species in question and not an indication of the total number and/or abundance of the species. A total of 124 villagers were interviewed in 2000 and 2001 and 18 hunters in 2001. All species covered in this study were reported in at least one out of the five districts, and rare or endangered species, like gerenuk and hunting dog, which were rarely and/or not recorded in the primary database, were reported in all districts.

WDAM varied from one district to another (Babati 1995–2000; Kiteto 1994–1997; Kondoa 1989–1998; Monduli 1994–1999), whereas no data were collected in Simanjiro (Appendix 1). Common and/or more aggressive species, like elephants, buffalos, lions, and leopards, were reported most frequently, whereas rare species, such as hunting dogs and cheetahs, were only reported occasionally. Damage included killing and/or injuring people (by elephants, buffalos, and lions), destruction of crops (by elephants, buffalos, elands, wildebeests, and zebras), and killing of livestock (by lions, leopards, hunting dogs, and cheetahs). Leopards and lions were reported in Babati, Monduli, and Kondoa districts, with the highest number of damage by leopards in Kondoa and lion damage in Babati. Overall, the highest number of WDAM was from the Kondoa district.

HBQ were obtained from 18 out of 22 hunting safari companies that operated in the study area during this study. Ten of these were in the Monduli district. In general, number of quotas given for individual species increased in successive years for all species (Appendix 1). According to HDQ, the most hunted species was wildebeests followed by buffalos (Appendix 1 and 2). Generally, trends indicated an increase in quota given at the beginning, followed by a sudden decrease in recent years.

Table 1 Number of animals from primary and secondary data for the four major large herbivores per district and year

District	Babati		Kiteto		Kondoa		Monduli		Simanjiro	
Year/numbers	Primary	Secondary	Primary	Secondary	Primary	Secondary	Primary	Secondary	Primary	Secondary
Zebras										
1994	1,842 (SRF)	0 (WDAM) 3 (HDQ)	10	0 7	173	0 1	1,189	8 0		
1995	1,637 (RF)	0 (WDAM) 14 (HDQ) 0 (HBQ)	0	0 4 10	0	0 0 0	310	6 0 56		
1996	1,020 (RF)	0 (WDAM) 1 (HDQ) 0 (HBQ)	348	0 11 0	1,500	0 0 0	1,886	8 0 104	0	0 0 29
1999	4,075 (RTC)	0 (WDAM) 7 (HDQ) 6 (HBQ)	0	0 0 14	0	0 0 0	1,248	5 15 129	70	0 0 39
2000	4,821 (RTC)	12 (HDQ) 6 (HBQ) 0 (QS)					1,718	0 119 10		
2001	8,714 (RTC)	0 (HBQ) 1 (QS) 14 (QS)	0	0 2 10	0	0 0 0	1,085	20 10 47	0	0 4 30
Buffalos										
1994	1,628 (SRF)	0 (WDAM) 12 (HDQ)	0	2 14	20	2 5	111	12 51		
1995	2,253 (SRF)	15 (HDQ)	0	12	0	0	1,176	53	0	0
1995	4,513 (TC)	0 (WDAM) 0 (HBQ)	0	0 14	6	1 0	1,575	5 18	368	0 0
1996	1,520 (SRF)	12 (HDQ) 0 (HBQ)	2	24 0	306	0 0	811	51 76	397	0 37
1996	1,956 (TC)	0 (WDAM)	0	2	540	1	507	1	183	0
1998	2,625 (TC)	7 (HDQ) 15 (HBQ)	64	23 92	517	0 0	829	117 104	283	37 42
1999	293 (RTC)	2 (WDAM) 16 (HDQ) 15 (HBQ)	0	0 4 14	0	0 0 0	33	1 45 86	0	0 38 35
2000	845 (RTC)	8 (HDQ) 15 (HBQ) 0 (QS)					443	0 80 10	0	46 28 7
2001	3,411 (RTC)	5 (HDQ) 15 (HBQ) 1 (QS)					34	1 49 10		
Wildebeests										
1990	2,056 (SRF)	10 (HDQ)	0	0	0	0	580	0	29	0
1994	1,323 (SRF)	0 (WDAM) 49 (HDQ)	0	0 4	28	0 12	647	3 125		
1995	4,501 (RF)	52 (HDQ) (WDAM) (HBQ)					939	102 8 1		
1996	2,496 (RF)	19 (HDQ) (HBQ)			231	0	591	171 97	3,659 3,659	20
1999	1,659 (RTC)	52 (HDQ) 10 (HBQ)					197	115 103		
2000	2,822 (RTC)	58 (HDQ) 10 (HBQ)					747	21 120		
2001	3,291 (RTC)	0 (QS) 13 (HBQ)	0	0 9		2	20 45	0 25	0	
Elephants										
1994	753 (SRF)	0 (WDAM)	0	1	30	0	85	0		
1995	1,602 (TC)	0 (WDAM)	2	0	302	1	318	0		

Table 1 (continued)

District	Babati		Kiteto		Kondoa		Monduli		Simanjiro	
Year/numbers	Primary	Secondary	Primary	Secondary	Primary	Secondary	Primary	Secondary	Primary	Secondary
1995	949 (RF)	1 (WDAM)	0	0	0	0	384	0		
1996	478 (TC)	1 (WDAM)			189	1	452	0		
1996	678 (RF)	1 (WDAM)			112	1	594	0		
1998	2,221 (TC)	0 (WDAM)	11	0	155	1	992	0		
1999	517 (RTC)	0 (HDQ)	0	0	0	0	366	1		
2000	(RTC)	(QS)					898	1		
2001	1,539 (RTC)	1 (QS)					340	1		

Source of data between parentheses (indicated in Babati district). All secondary data for elephants are presence (1)/absence (0) of data (see [Materials and methods](#)). Open spaces no such data available.

Primary data: *SRF* systematic reconnaissance flight; *RF* reconnaissance flights; *TC* total counts; *RTC* road transect counts. Secondary data: *QS* number of reports for questionnaire surveys; *WDAM* damage reports; *HBQ* quota for tourist hunting in hunting block; *HDQ* quota to individuals/groups through the District Game Offices

Discussion

Overall, our results show that there is little agreement between primary and secondary data sources for the four main migratory species, zebra, buffalo, wildebeest and elephant, indicating that direct surveys (primary data), although expensive, are necessary to develop efficient wildlife management plans. In effect, for these species, primary data produced exhaustive data that could not be replaced by secondary information (see also Kahurananga 1981). Our analyses also suggest that both types of data sources have their importance: Primary data provide reliable information on distribution, density, or numbers for large, gregarious species that mainly use relatively open

habitats; secondary data are important in determining the general distribution of species and alerting managers as to whether direct surveys (*SRF*, *TC*, or *RTC*) should be done for particular species and in which areas these should be performed to save time and money. Moreover, direct census methods were often inadequate for shy and/or smaller-sized species, i.e. hunting dogs and lesser and greater kudu, whose distribution (local presence) was more reliably covered using different types of secondary data.

For wildebeests and zebras, there was no effect of type of primary data source on abundance estimates, indicating a strong agreement among primary data sources. Hence, expensive aerial surveys could be substituted with less costly road transect counts without decreasing the quality of the primary data. However, counts of buffalos differed with the type of survey: More buffalos were counted during aerial counts than with road transect counts. Although buffalo is a gregarious animal, the species prefer tall grass with bushy/woodland habitats, which is often not accessible by roads (Msoffe 2003).

Our analyses revealed, there often exist disagreement between data collected from the two categories, i.e. primary and secondary surveys. Further, abundance estimates from primary surveys did not correspond with species hunting quota obtained from secondary surveys, which indicates that data obtained from monitoring activities has not been effectively utilized for setting the quota. This is a problem, even more for shy and rare species (e.g. leopard, lesser kudu) because primary surveys do not adequately cover such species, but yet, they are important when it comes to tourist hunting.

Considering the inadequacy of each type of data source separately, we propose to conduct both direct and indirect survey methods to determine species distribution and abundance using a hierarchical approach. As a first step, existing secondary data, such as hunting quotas and wildlife damage reports, can be used as a starting point, revealing for which areas essential information on distribution/abundance of target species is insufficient or lacking. Subsequently,

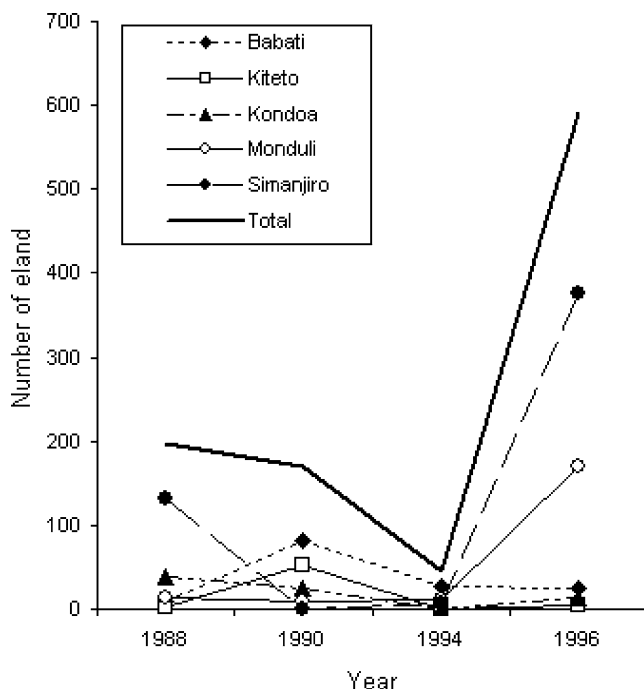


Fig. 3 Total number of elands derived from primary data in the different districts and for the whole study area (*Total*) from 1988 to 1996

standard questionnaires are recommended as a low cost method that allows gathering of missing data and can stimulate the involvement of local people in wildlife monitoring and management. Such an approach is consistent with recent wildlife policy in Tanzania, where the government declared a new countrywide approach to wildlife management, the establishment of 'Wildlife Management Areas' (WMA). The Tanzania Wildlife Policy recognizes the value of wildlife to rural people by encouraging initiatives that benefits local communities on whose land hunting and other tourism activities based on wildlife are conducted (Wildlife Policy–Section 3.3.8, 1998). Involving local people is also strongly supported by programs on community based management of natural resources or Community Based Conservation (CBC), which are being implemented in many parts of Africa, where large mammal populations still occur outside national parks or other protected areas (Grimm 1998; Songorwa 1999; Songorwa et al. 2000; Hulme and Murphree 2001). Finally, the most efficient type of survey, in terms of low economic costs and data quality, can be planned and implemented for each situation. The type of survey and area covered can then be determined based on target species, major habitat type, previous hunting quota, and the need for game and wildlife managers and researchers to obtain more detailed quantitative data in a given season and/or area. Nevertheless, it must be accepted that direct monitoring of wildlife populations, in particular the aerial census counts, is costly, given the extent of wildlife areas, but represents a crucial approach of population monitoring and remains the best method to yield reliable information on population trends. The study has shown that such a two-step approach will be essential for sustainable management of carnivores and rare ungulates, as in most of the direct surveys (primary data), the species were not observed (see also Caro et al. 1998). As a first step, presence/absence of carnivore species in each hunting block should be verified using game damage reports and questionnaires to villagers, game scouts, and hunters. As a second step, this information should be verified by planning and executing ground surveys using species-based reliable methods (Caro et al. 1998). The calling station method, with or without bait, using hyenas and/or prey sounds to attract lions has been proved useful to determine location of lion clan territories and estimate lion numbers (Bauer and Van der Merwe 2004), whereas road transect counts have been used successfully to determine/verify presence of leopards based on signs, tracks, and direct observations (Martinoli et al. 2006). Abundance of species and levels of damage could then be combined to calculate a species index on which to set a hunting quota.

We conclude that the current system of wildlife monitoring should not be abandoned, but improved, to obtain more effective animal counts on which to develop a sound basis for setting quota (Caro et al. 1998; Baldus and Cauldwell 2004).

As it is doubtful that a truly scientific basis for setting quotas will ever be developed in the complex multispecies ecosystems in Africa (Baldus and Cauldwell 2004), a combination of different survey techniques will continue to be the best option for spatiotemporal monitoring of game to determine sustainable yields. Because wildlife monitoring, both by aerial and ground surveys but also through collection of secondary data, is expensive, it is desirable that the Tanzania Wildlife Division reviews the fees for resident hunting that, for decades, have been very low, so that its return can be invested to improve the entire monitoring system. Moreover, the income generated by hunting activities provides very low economic returns for the areas and communities where resident and tourism hunting takes place. In addition, effective supervision is lacking in most cases, leading, sometimes, to misuse of quotas (Baldus and Cauldwell 2004). Up to now, local people have been almost denied direct benefits from wildlife hunting but had to pay costs incurred from problem animals on their lands (Msoffe 2003). Consequently, it is high time to implement what the Tanzania Wildlife Policy stipulates as enhancing the involvement of local communities and the use of indigenous knowledge in the conservation and management of natural resources through the development of CBC (Gillingham and Lee 1999; Songorwa 1999; Baldus et al. 2001; Hulme and Murphree 2001). This implies developing proper land use plans, searching for a balance between crop rising, livestock keeping, hunting and photo safaris, and solving actual problems of lack of local expertise by "specialized" training programs. These programs will need to (1) use traditional knowledge, which rural people have of wildlife and reconcile it with modern techniques of target species monitoring; (2) provide training of village antipoaching teams to reduce poaching and increase awareness of wild animals being a cultural asset (e.g. Grimm 1998; Gillingham and Lee 1999; Baldus et al. 2001; Baldus and Cauldwell 2004).

However, more generally, it is also essential that research and monitoring of game species are incorporated in the planning and management of the quotas in all areas (GR, GCA, OA, and WMA), where hunting activities operate, are, or could be planned for a sustainable use of the wildlife resources.

Acknowledgment This study was part of the Tarangire–Mayara Conservation project (TMCP) funded by USAID through WWF Tanzania Programme Office and Oikos Institute. Further support was provided by TANAPA, Wildlife Division, Hunting Companies, and local communities in the study area. Special thanks to Oikos Institute president, Dr. Rossella Rossi who coordinated the project and provided logistical support, to Janemary Ntalwila and the entire Oikos staff—Tanzania branch.

Appendix 1

Hunting block quota (HBQ) of the major wildlife species in the different open areas (OA) and game-controlled areas (GCA) in the study area

Table 2 HBQ of the major wildlife species

Hunting block	Year	Zebra	Buffalo	Wildebeest	Oryx	Eland	Greater kudu	Lesser kudu	Gerenuk	Hartebeest	Grants gazelle	Toms gazelle	Impala	Lion	Leopard	Hyaena
Burko OA	1995	20	10	20	12	7	3	12	12	5	20	20	15	2	4	
Burko OA	1996	25	15	25	15	6	5	12	15	6	25	25	15	2	6	0
Burko OA	1997	35	18	25	15	7	51	12	15	6	28	25	15	3	5	0
Burko OA	1998	30	16	25	14	7	5	12	15	6	28	25	15	2	3	0
Burko OA	1999	20	18	0	12	5	5	8	10	6	20	20	10	2	3	0
Burko OA	2000	25	18	20	12	6	5	8	10	6	20	20	10	2	3	0
Lake Natron–N	1995	20	6	20	10	5	1	10	30	23	24	6	2			
GCA																
Lake Natron–N	1996	20	6	20	10	5	1	10	13	3	30	23	24	2	6	2
GCA																
Lake Natron–N	1997	20	6	20	8	5	1	10	13	3	30	23	24	2	5	2
GCA																
Lake Natron–N	1998	20	6	20	8	5	1	10	13	3	30	23	24	2	3	2
GCA																
Lake Natron–N	1999	20	6	20	8	5	1	10	13	3	30	23	24	2	1	2
GCA																
Lake Natron–N	2000	20	6	20	8	5	1	11	14	3	30	23	24	2	2	
GCA																
Lake Natron–S	1997	10	6	10	9	4	1	7	7	6	15	12	10	5	5	3
GCA																
Lake Natron–S	1998	10	6	10	9	4	1	7	7	6	15	12	7	3	3	3
GCA																
Lake Natron–S	1999	10	6	10	9	4	1	7	7	6	15	12	7	3	2	3
GCA																
Lake Natron–S	2000	10	6	15	10	4	1	8	10	6	24	24	12	3	3	3
GCA																
Lolkisale GCA	1997	15	15	12	5	5	5	7	5	12	15	15	15	5	3	2
Lolkisale GCA	1998	6	10	6	3	2	3	4	3	6	8	8	8	5	3	2
Lolkisale GCA	1999	15	15	15	5	5	5	7	5	12	18	13	15	4	3	4
Lolkisale GCA	2000	15	15	15	5	5	5	7	5	12	18	18	15	4	3	4
Longido GCA	1997	8	5	10	8	5	0	8	8	5	12	12	10	2	2	3
Longido GCA	1998	8	5	10	8	5	0	6	6	5	12	12	10	2	2	5
Longido GCA	1999	8	5	10	8	5	0	6	6	5	12	12	10	2	2	5
Longido GCA	2000	8	5	10	8	5	0	6	6	5	12	12	10	2	2	5
Monduli Juu OA	1995	15	6	10	8	2	9	10	15	15	4	3	3			
Monduli Juu OA	1996	15	6	10	8	2	9	10	15	15	4	3	3			
Monduli Juu OA	1997	15	8	10	8	2	9	10	0	15	15	4	0	3	3	
Monduli Juu OA	1998	15	8	10	8	2	0	9	5	0	10	10	4	0	3	3
Monduli Juu OA	1999	15	8	10	8	2	0	9	5	0	10	10	4	0	3	3
Monduli Juu OA	2000	15	8	10	8	2	0	9	6	0	10	10	4	0	3	3

Table 2 (continued)

Hunting block	Year	Zebra	Buffalo	Wildebeest	Oryx	Eland	Greater kudu	Lesser kudu	Gerenuk	Hartebeest	Grants gazelle	Toms gazelle	Impala	Lion	Leopard	Hyaena
Mto wa Mbu GCA	1996	16	26	18	16	8	10	12	14	10	42	40	28	2	6	4
Mto wa Mbu GCA	1997	16	26	18	16	10	10	15	15	10	30	30	15	2	5	6
Mto wa Mbu GCA	1998	12	15	10	6	8	12	10	3	10	20	9	8	0	4	6
Mto wa Mbu GCA	2000	10	12	12	16	6	5	10	15	5	30	30	15	3	3	4
Ngasurai OA	1995	6	0	8	6	2	0	6	6	0	10	15	5	0	2	0
Ngasurai OA	1997	6	0	8	6	2	0	6	6	0	15	15	5	0	2	0
Ngasurai OA	1998	6	0	8	2	0	0	6	6	0	12	10	5	0	2	0
Ngasurai OA	1999	6	0	8	6	2	0	6	6	0	15	15	5	0	2	0
Ngasurai OA	2000	6	0	8	6	2	0	6	6	0	15	15	5	0	2	0
Simanjiro GCA	1996	13	17	14	7	5	3	8	3	10	5	13	13	6	6	5
Simanjiro GCA	1997	20	20	20	7	8	3	10	5	10	20	20	20	3	5	5
Simanjiro GCA	1998	20	20	20	7	8	3	10	5	10	20	20	20	3	3	5
Simanjiro GCA	1999	20	20	20	7	8	3	10	5	10	20	20	20	3	3	5
Simanjiro GCA	2000	20	20	20	7	8	3	10	5	10	20	20	20	3	3	5

Appendix 2

District hunting quota (HDQ) of the major wildlife species in the study area

District	Year	Zebra	Buffalo	Wildebeest	Oryx	Eland	G. kudu	L. kudu	Gerenuk	Hartebeest	Grant	Impala	Lion	Leopard
Babati	1990	8	6	13	1	4	1	3		5	9	9	3	3
Babati	1991		8	10	1	3				5	1	1		
Babati	1992		8	11	1	3				6	11			
Babati	1993	4	18	14	2	2		3	1	3	12	7	1	3
Babati	1994	3	12	49	1	2				8	24	14		
Babati	1995	14	15	52	5	1		5		18	38	35		6
Babati	1996	1	12	19		6				12	13	17		
Babati	1997	6	29	20		2		6	4	14	21	24		4
Babati	1998	6	7	19					1	1	10	13	1	1
Babati	1999	7	16	52	1					6	17	32	1	3
Babati	2000	4	8	55	1			2	2	15	25	34		2
Kiteto	1993		13	3		6				5	20	16		
Kiteto	1994	7	14	3	1	11		2		15	25	24	2	3
Kiteto	1995	4	12	2	2	11	2	4	3	12	26	27	2	4
Kiteto	1996	11	7		6		2	6	9	6	18	8	3	4
Kiteto	1997	7	28	10	5	10	3	8	11	22	23	25	5	3
Kiteto	1998	21	23	17	11	6	1	11	15	6	33	15	2	2
Kondoa	1992	2	16	13	2	4	1		9	4	16	9	2	2
Kondoa	1993	3	11	7	1	2		3	3	8	11		1	1
Kondoa	1994	1	5	12	2	1	8	5	11					
Monduli	1993		41	68		38				62	64	76		
Monduli	1994		51	125		29				31	84	87		
Monduli	1995		53	102		22				30	77	78		
Monduli	1996		51	169		31				43	44	54		
Monduli	1997		52	121		34				46	83	69		
Monduli	1998		70	180		44				61	160	153		
Monduli	1999		58	160		52				57	174	146		
Simanjiro	1998	13	37	27	17	26	3	12	11	44	51	48	5	11
Simanjiro	1999		38	36		29				34	35	20		
Simanjiro	2000	9	46	38	13	32	3	8	12	50	37	56	7	8

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