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Human-Wildlife Interaction in the Western Serengeti: Crop Raiding, Livestock Depredation and Bushmeat Utilisation

Thesis for the degree of Philosophiae Doctor

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Norwegian University of Science and Technology
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Preface

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Finally, my thanks to God my creator for the many privileges He has granted to me. Without Him I would not be alive to produce this thesis.

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List of papers

This Thesis consists of the following four papers:

I. Mwakatobe, A., Nyahongo, J. & Røskaft, E. (Submitted). Crop raiding by wild animals in communities surrounding the Serengeti National Park, Tanzania.

II. Mwakatobe, A., Nyahongo, J. & Røskaft, E. (2013). Livestock depredation by carnivores in the Serengeti Ecosystem, Tanzania. Environment and Natural Resources Research; Vol. 3, No. 4; 2013.

III. Mwakatobe, A., Nyahongo, J. & Røskaft, E. (2012). Bushmeat and food security: Species preference of sundried bushmeat in communities in the Serengeti - Mara ecosystem, Tanzania. International Journal of Biodiversity and Conservation Vol. 4 (14), pp. 548-559, November, 2012.

IV. Mwakatobe, A., Nyahongo, J. & Røskaft, E. (Submitted). Species identification through the taste of sundried bushmeat by local communities near the Serengeti Ecosystem, Tanzania.

Contributions

Eivin Røskaft and Julius Nyahongo contributed their ideas, planning for fieldwork, data collection and commentary on all four of the above papers.

Extended Summary

Human-wildlife conflict (HWC) is a significant problem in Africa and many parts of the world. Globally, the most frequently recorded conflicts between humans and wild animals include crop damage, livestock depredation, illegal bushmeat hunting and human death. Humans may also affect wildlife indirectly through habitat modification or encroachment and through the exchange of diseases between wildlife and domestic stock.

This thesis examines human-wildlife interactions in the western Serengeti of northern Tanzania. First, it examines the extent of crop raiding by African elephants *(Loxodanta africana)*, birds, primates, bushpigs and rodents per household per year along a gradient of distance from the protected areas, and the economic effects that this has on the households. Second, it investigates the losses incurred by the local communities due to the depredation of livestock (especially donkeys, poultry and domestic dogs) and assesses their economic effects on household incomes. Third, it investigates bushmeat preference according to different preparation processes in villagers along the same distance gradient of the protected areas. Fourth, it investigates the species identification of sundried bushmeat in villagers along a distance gradient from the protected areas.

The results of this study reveal that the distance between a village and a protected area can contributed significantly predict the village's crop loss, livestock depredation and bushmeat preferences, as well the ability of its inhabitants to recognise sun-dried and cooked meat. The closest villages to the protected areas experienced a higher frequency of crop damage and more serious damage than did villages located farther from the park.

According to all surveyed villages, primates were the most destructive animal, followed by elephants. To protect their crops from wild animals, local communities around protected areas have adopted different farming strategies.

In terms of the livestock depredation, the lowest level of depredation was found in the villages that were farthest from the Serengeti National Park. Villagers in areas close to protected land preferred to constantly guard their livestock with arrows and spears during grazing, while villagers in areas that were farther from protected areas preferred to keep their livestock in enclosures/bandas that were guarded by dogs during the nights. Disease is a major cause of livestock mortality. Importantly, the households that experienced the most livestock disease were located closest to the protected areas.

The local respondents most frequently preferred sundried bushmeat, followed by boiled bushmeat and smoked bushmeat. Beef was the most preferred sundried meat, followed by sundried impala and sundried wildebeest meat. Sundried zebra meat was least preferred among all four varieties of tested meat. This study also demonstrated that women and men recognised the bushmeat species at similar rates.

The study recommends further studies on the crop yield gap caused by wild animal raiding and on human-primate conflict in communities surrounding protected areas. For the effective protection of crop farms from wild animals, we recommend that local communities adopt a combination of methods rather than individual methods to deter wild animals from raiding the crops on their farms. Furthermore, an integrated study of livestock and wildlife diseases and their impact on the household economies of local communities would also be useful.

Based on our findings on the species preference for sundried bushmeat, we recommend further studies using a quality analysis of different varieties of processed meat (fresh boiled meat, sundried meat and smoked meat) to assess their respective nutrient levels. Lastly, this study showed that the distance from the PAs is an important factor to consider for the sustainable conservation of wildlife resources. Our findings suggest that villages in the areas around PAs should receive assistance to develop new land use strategies and implementation plans.

1. Introduction

Human-wildlife conflict (HWC) is a significant problem in Africa and many other parts of the world (Eniang et al., 2011, Mwamidi et al., 2012). It often undermines the objectives of wildlife conservation and the sustainable utilisation of natural resource initiatives (Gusset et al., 2009). HWC occurs in an extremely wide range of situations globally and involves an array of diverse species (Dickman, 2008). Such conflict has important consequences for local populations in terms of food security, safety and well-being, and also affects both the micro and macro economy and wildlife conservation (FAO, 2009).

In Africa, millions of people are dependent on the continent's great genetic, species and ecosystem diversity for their livelihoods (Samoilys and Kanyange, 2008). Sub-Saharan Africa hosts what may be the highest biodiversity in the world, which could be used to sustain and enhance human well-being in a more effective way (UNEP-WCMC, 2002). Global increases in the human population and associated increases in resource and habitat use are forcing wildlife to live in increasing proximity to humans (FAO, 2009, Ikanda, 2009, Inskip and Zimmerman, 2009). This in turn results in escalating pressure on the wildlife resources (Loibooki et al., 2002, Nyahongo et al., 2009, Mfunda and Røskaft, 2010, Santiago and Volk, 2012). In these circumstances, competition arises between the wildlife and people for space and food, often leading to HWCs.

The continued reliance of humans on natural resources, such as water, firewood, rangeland, fish, bushmeat and mined substances, for subsistence will exhaust these resources, which not only affects conservation and biodiversity but is also a threat to human welfare (Holmern, 2007). The destruction, utilisation and modification of natural habitats for the purpose of agriculture, urbanisation and industrialisation are major driving forces behind the loss of biodiversity and resource depletion worldwide (Tong and Soskolne, 2007, Sodhi et al., 2010). This will inevitably affect future conservation as most rural sub-Saharan African people are agropastoralists (who combine small-scale arable farming with animal husbandry), pure pastoralist or farmers (Holmern, 2007, Nyahongo, 2010).

The world population is predicted to increase by more than 50% in the next fifty years, from six billion in 2000 to over nine billion in 2050. Most of this increase is expected to take place in the least developed countries of Africa, Asia and Latin America (Sillero-Zubiri and Laurenson, 2001). The African population is likely to increase from its 2010 level of approximately 1 billion to 1.4 billion in 2025 and up to 2 billion in 2050, which is more than twice the population of the mid-twenty-first century (Zuberi and Thomas, 2012). Tanzania is reported to be one of the fastest growing populations in the world, and its population has increased from 9.1 million people in 1961 during Independence (URT, 2006) to 23.1 million in 1988, 34.6 million in 2002 (Packer et al., 2005) and 44.9 million in 2012, with an average annual growth rate of 2.7 (URT, 2012). In many parts of Africa, growing human populations live in close proximity to parks and protected areas (Sillero-Zubiri and Laurenson, 2001). These protected areas are meant to ensure that wildlife is conserved for the benefit of national and local economies and future generations.

The most frequent conflicts between humans and wild animals include crop damages (Nyahongo, 2007, Ogra, 2008, FAO, 2009, Kaswamila, 2009, Baranga et al., 2012), livestock depredation (Kissui, 2008, Ikanda, 2009, Inskip and Zimmerman, 2009, Msuha, 2009, Dickman, 2010, Lyamuya et al., 2013), illegal bushmeat hunting (Nyahongo, 2007, Wright and Priston, 2010), and human death (Løe and Røskaft, 2004). Humans can also affect wildlife indirectly through habitat modification, encroachment or disease exchange between wildlife and domestic stock (Cleaveland et al., 2000, FAO, 2009, Skinner, 2010, Fyumagwa, 2012). HWC due to predation also affects the population dynamics of wild carnivores near park boundaries, as it often leads to the retaliatory killing of carnivores (Kolowski and Holekamp, 2006, Kissui, 2008, Ikanda and Packer, 2008, Ukio, 2010).

1.1 Crop raiding by wild animals

Crop raiding is a serious source of conflict between local communities and the management of the adjacent protected areas (Ogra, 2008, Kaswamila, 2009, Fungo, 2011). It is becoming a widespread and complex worldwide problem (Saj et al., 2001, Nyahongo, 2007). It affects subsistence farmers by directly diminishing their primary food and cash resources and indirectly incurring a variety of social costs (Osborn and Parker, 2003, Marchal and Hill, 2009). Crop raiding by wild animals can cause substantial financial losses for farmers (Gunn, 2009, Fungo, 2011). For example, in the Budongo area of Uganda, wild animals were reported to raid an average of 25% of cassava and 19% of maize, causing serious costs to the local farmers (Naughton-Treves, 1998).

In general, crop raiding is limited to areas located within a few hundred meters of protected areas, with farther fields receiving little or no damage (Hill, 2000, Gillingham and Lee, 2003, Ole Meing'ataki, 2005, Ntalwila, 2007, Sarker and Røskaft, 2011). Crop raiding by wild animals is caused by several species that range from large mammals to smaller ones, such as birds and rodents or even insects (Rao and McGowan, 2002, Gunn, 2009, Osborn and Parker, 2003, Sitati et al., 2003).

Local communities have adopted several measures to deter crop raiding by wild animals. Some of the most common measures include guarding (Hill, 2000, Malugu, 2010), making noises (Malugu, 2010), smearing the area with cow dung, using scarecrows, wrapping with cloths (which target mainly primates), lighting fires at night, building trenches against bush pigs (*Potamochoerus larvatus)* (Kagoro-Rugunda, 2004, Fungo, 2011) and placing fences (Paterson, 2007, Malugu, 2010, Fungo, 2011, Malugu and Hoare, 2009). These methods are used either individually or in combination. The selection of the method depends on the size of the fields, the crop grown, the labour availability to guard and the vulnerability of the crop to available raiders (Fungo, 2011).

1.2 Livestock depredation by carnivores

Human-carnivore conflict is currently one of the main constraints to biodiversity conservation efforts outside many protected areas (Lyamuya et al., 2013, Nyahongo, 2007, Kent, 2011). Livestock depredation is another serious issue that wildlife managers are facing today (Ogada et al., 2003, Patterson et al., 2004, Graham et al., 2005, Thirgood et al., 2005, Zimmermann et al., 2005, Dickman, 2008, Kaswamila, 2009). The overlap of large carnivores, livestock and people produce conflicts that threaten the future viability of carnivore populations in the pastoral systems of Africa (Ogutu et al., 2005). HWC due to predation affects the population dynamics of wild carnivores near the park boundaries (Kolowski and Holekamp, 2006, Ogada et al., 2003, Sillero-Zubiri and Laurenson, 2001). In Africa, livestock predation is primarily caused by yellow baboons (*Papio cynocephalus*), leopards (*Panthera pardus*), lions (*P. leo*), spotted hyenas (*Crocuta crocuta*) (Holmern, 2007, Kolowski and Holekamp, 2006) and African wild dogs *(Lycaon pictus)* (Lyamuya et al., 2013).

Livestock predation can cause significant economic losses for pastoralists living by protected areas. For example, Patterson et al. (2004) estimated livestock predation to deplete 2.6% of the herd's economic value in a Kenyan ranch, incurring losses of $ 8749 per year. Similarly, Mishra (1997) reported an economic loss of $ 15 418 due to predation among the Indian-trans Himalayan communities, equivalent to a loss of $ 128 per family per year. Butler (2000) recorded economic loss averaging $ 13 or 12% of each household's net annual income in Zimbabwe. Depredation losses are common with cattle, sheep and goats (Inskip and Zimmerman, 2009). The loss of a single domestic animal can create serious social-economic problems for the affected family (Ikanda, 2009).

1.3 Bushmeat utilisation

Wildlife is a critically important resource, supporting the food and livelihood requirements of human communities in many biodiversity-rich areas of the world (Rao and McGowan, 2002). Bushmeat hunting has been an important subsistence activity in many rural parts of Africa throughout history (Noss, 1998, Bowen - Jones et al., 2003, Fa et al., 2002, Wilkie and Godoy, 2001)). It is reported to be an important source of dietary animal protein (Asibey and Child, 1990, Hofer et al., 1996, FAO, 1997, FAO, 2003, Robinson and Bennett, 2000, Nyahongo, 2007), income (Geist, 1988, King, 1994, Juste et al., 1995, Bowen-Jones and Pendry, 1999, Barnett, 2000, Wilkie and Godoy, 2001, Loibooki et al., 2002, Kaltenborn et al., 2005), and cultural needs (Robinson and Bennett, 2000, Nielsen, 2006) for local communities in the areas surrounding protected areas in many African counties. Bushmeat provides trophies for cultural artefacts and medicinal needs (Kaltenborn et al., 2005, Kideghesho, 2008), and it contains certain properties that are not found in domesticated animals (Peggy et al., 2009). They claim that ingesting bushmeat, especially primate meat, makes one feel stronger and more vigorous (Dresden, 2004). Wild animal-based foods are also life-saving reserves in times of food shortage, especially during long periods of drought and low crop yields (Holmern et al., 2002).

Some studies have suggested that the contribution of bushmeat may be an important factor in poverty reduction in rural areas (Hoyt, 2004, Wilkie et al., 2005). The sale of bushmeat provides a significant proportion of the incomes in rural areas. For example, a study in rural Gabon reported that hunting accounted for between 15 and 72% of the household incomes, with the proportion increasing for more remote communities (Starkey, 2004). In Tanzania, bushmeat traders earn between US$ 300 and US$ 500 per month (Damalu, 2011).

Bushmeat is often obtained illegally from land inside the protected areas (Hofer et al., 1996, Holmern et al., 2002, Loibooki et al., 2002). Hunters have a variety of methods to collect bushmeat from the wild, which include trapping, snaring, netting, the use of dogs and shooting (Noss, 1998, Bowen - Jones et al., 2003, Fa et al., 2002, Wilkie and Godoy, 2001). In Africa, different species of wild animals are utilised for bushmeat and their selection depends largely on the location, habitat type and availability of the species in the local market (Barnett, 2000, Hoyt, 2004). This typically includes ungulates, reptiles, large-bodied birds, smaller-bodied mammals and primates (Hennessey, 1995, Robinson and Bennett, 2000, Chapman et al., 2006, Willcox and Nambu, 2007, Khatun, 2010).

1.4 Wildlife corridors and buffer zones

Properly designed networks of wildlife corridors and buffer zones are important for mitigating the negative impact of habitat fragmentation, helping wildlife species adapt to climate change and reducing Human Wildlife Conflicts (HWCs). According to Hilty et al. (2006), a wildlife corridor is any space that facilitates the movement of animals or plants between two or more areas of otherwise disconnected habitats. They may be the strongest tool for protecting vital wildlife habitats and migration routes threatened by fragmentation and climate change (Heller and Zavaleta, 2009). In contrast, buffer zones are lands that are adjacent to parks and reserves where human activities are restricted to those that maintain the ecological security of protected areas while benefitting the local communities (Wells and Brandon, 1993, Wild and Mutebi, 1996, Neumann, 1997). Buffer zones have a major ecological importance for Natural Protected Areas as they impact micro-climatic regulation, physiographic and hydrologic processes, genetic diversity, etc. (Santiago and Volk, 2012). These areas are being destroyed by rapid agricultural expansion, unplanned land use strategies, unmanaged natural resource extraction, increased bushmeat trade and road building (Jones et al., 2009).

2.0 Thesis Aims

The goal of this thesis was to establish a comprehensive understanding of problems related to human-wildlife interactions in the western Serengeti.

The specific objectives of the study were:

i. To determine the extent of crop raiding by African elephants *(Loxodanta africana)*, birds, primates, bushpigs and rodents per household per year along a distance gradient from the protected areas and to analyse its economic effects on local households (PAPER I).

ii. To investigate the losses incurred by the local communities due to depredation of livestock (especially donkey, poultry and domestic dogs) and to analyse its economic effects on the income of local household (PAPER II).

iii. To investigate bushmeat preparation preferences of villagers along the same distance gradient from the protected areas (PAPER III).

iv. To investigate the species identification of sundried bushmeat by villagers along the distance gradient from the protected areas (PAPER IV).

3.0 Methods

3.1 Study area

The Serengeti Ecosystem (SE) covers approximately 25,000 km^2 on the border of Tanzania and Kenya (Fig. 1) and is defined by the movement of wildebeest (*Connochaetes taurinus)* (Homewood et al., 2001, Nelson, 2009). The eastern boundary is formed by the crater highlands and the rift valley. An arm called the western corridor stretches west to Lake Victoria, and the northern boundary is formed by the Isuria escarpments and the Loita plains of Kenya (Marealle et al., 2010). The SE, which lies between latitudes 1^0 28' and 3^0 17' S and longitudes 33^0 50' and 35^0 20' E, spans a total area of approximately 30,000 km^2 in northern Tanzania (Kideghesho, 2006). It is a highland savannah region with thorn tree woodlands and plains that are between 900 and 1,500 metres above sea level. The average annual rainfall is between 500 and 1200 mm and is lower towards the Park boundary and higher towards Lake Victoria (Campbell and Hofer, 1995). The monthly averages for the maximum temperatures in the western Serengeti fluctuate between 25^oC to 32^oC and the minimum daily temperatures are between 13^oC and 19^oC (Campbell and Hofer, 1995).

The people inhabiting this region are either agro-pastoralists or pure pastoralists (Nyahongo, 2007). Serengeti National Park (SNP) suffers from the conflict between the conservation priorities of the park and the priorities of local communities (Hofer et al., 1996, Loibooki, 1997). The human population in the western Serengeti is large and is expected to continue to increase due to both high birth rates and immigration into villages adjacent to protected areas (Hofer et al., 1996). The human population in the area is estimated to be over two million (URT, 2012). The average household size of families in this area is also above the national average of 4.8 persons per household, with a population density of 51 persons per square kilometer (URT, 2012). The growing human population, the surging food demand, and the increasing reliance on bioenergy generate a tremendous pressure to convert natural fertile lands to agricultural lands and to intensify low-intensity production systems (Kiers et al., 2008, Beringer et al., 2011). Demographic and social changes have placed more people in direct contact with wildlife: as human populations continue to grow, settlements will increasingly expand into and around protected areas (IUCN, World Park Congress 2003).

Larger populations near protected areas will threaten the survival of the Serengeti through illegal hunting (Holmern et al., 2006, Mfunda and Røskaft, 2010, Bitanyi et al., 2012a) and threats to the biodiversity in general (Bitanyi et al., 2012a, Poshiwa et al., 2013). Generally, the people in these areas live in poverty, with an average annual agropastoral income of only US$ 117; for comparison, the average national income was $ 275 in 2003 (URT, 2005). The current country's gross national per capital income in 2012 was US$ 599 (IMF, 2012), which still falls below the 2007 average of $ 952 for Sub-Saharan Africa (WB, 2008). To supplement this small income, many communities are forced to pursue off-farm activities such as illegal hunting (Kideghesho, 2006, Loibooki et al., 2002, Ndibalema and Songorwa, 2007), illegal firewood collection and charcoal burning (Mwakatobe et al., 2005). The impact of these activities on the ecosystem and natural resources will increase with the growing human and livestock populations (Loibooki et al., 2002).

The western Serengeti, which is the focus of this study, is ecologically significant as a buffer zone for SNP and as a corridor for wildlife species migrating between the Serengeti and the Maasai Mara of Kenya. These species include some 1.4 million wildebeest, 0.2 million zebra (*Equus burchelli*) and 0.7 million Thompson's gazelle (*Gazella thomsoni*) (Norton-Griffiths, 1995). The area is also ethnically diverse, with more than 20 tribes; the major tribes are the Ikoma, Sukuma, Kurya, Ikizu, Natta, Isenye, Zanaki, Zizaki, Ngoreme, Luo, Taturu and Jita tribes. The major livelihood of these tribes is maize, cassava, millet and sorghum cultivation (Nyahongo, 2007) and cattle, goat and sheep husbandry (Nyahongo, 2007, Olsen, 1998), mainly for food and cash. Although most local people are subsistence farmers, there are some ethnic differences in economic activities, which include fishing, livestock rearing, game hunting and trading (Loibooki et al., 2002).

In Tanzania, resident hunting is allowed but is restricted to Game Controlled Areas and Open Areas (MNRT, 2007). Local communities in the Serengeti are not allowed to hunt without a licence, and there is no open market for wild meat (Ndibalema and Songorwa, 2007). Trophy hunting is allowed in the game reserves adjoining Serengeti National Park and is based on a quota system that is determined annually (Baldus and Cauldwell, 2004). However, the close proximity of these communities to wildlife protected areas makes illegal hunting relatively easy and common (Bitanyi et al., 2012b). Local communities around SNP rely heavily on bushmeat that is collected illegally from the park (Ogutu et al., 2009, Sinclair et al., 2007, Campbell and Hofer, 1995, Mfunda and Røskaft, 2010).

Illegal trade in wildlife for both bushmeat and trophies presents a threat to many rare species, and it has increasingly attracted the attention of conservation authorities.

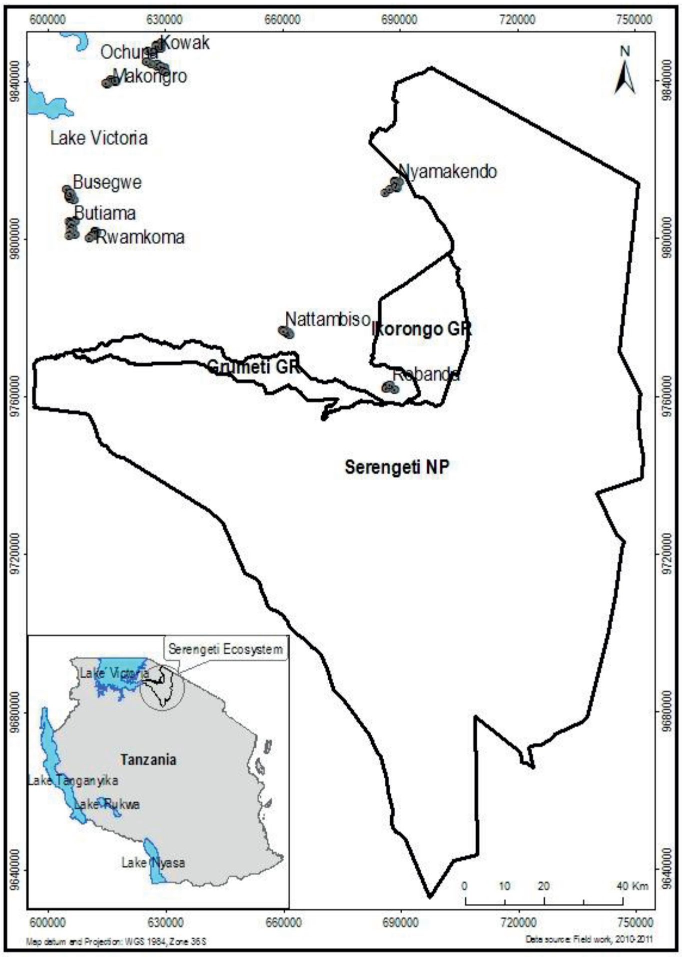

Figure 1: *Map of the study area, showing Serengeti National Park, the Grumeti and Ikorongo Game Reserves, Lake Victoria and the surveyed villages (Robanda, Nyamakendo, Nattambisso, Butiama, Busegwe, Rwamkoma, Ochuna,Makongro and Kowak are indicated with triangles).*

3.2 Data collection

The study was conducted between January 2010 and June 2011. Between January and October 2010, we administered a questionnaire to the local people of nine villages along the distance gradient from the SNP to collect data on crop raiding, livestock depredation and bushmeat utilisation (Fig. 1; Papers I, II, III & IV). The data were recorded on a record sheet about crop raiding and livestock depredation for six villages along the distance gradient from the protected areas between February 2010 and June 2011 (Papers I & II). Meat tasting experiments were conducted in January 2011 in three villages along the distance gradient from the park to collect data on both preference and the ability to identify the species of sundried bushmeat. We also conducted interviews and group discussions to assess the same information regarding bushmeat utilisation (Papers III & IV).

4.0 Main results

Paper I focus on the extent of crop raiding by wild animals per household per year along a gradient of distance from the protected areas. Paper II focuses on livestock depredation by carnivores in the Serengeti ecosystem. Papers III and IV provide highlights on bushmeat utilisation, specifically bushmeat preference as a result of different preparation processes and species identification of sundried bushmeat in villagers along the same gradient of distance.

4.1 Crop raiding by wild animals – Paper I

The results of this study suggest that the distance of a farm from a protected area is an important factor in determining the extent to which its crops will be raided by wild animals. Our results show that villages that are closest to the protected area experience higher frequencies of crop damage and greater costs of crop damage than villages located farther away from the protected areas. More serious damage was noted in villages close to the park boundary. Different wild animals were involved in the crop raiding in the surveyed villages. Primates were the most destructive animal across all surveyed villages, followed by elephants, which were particularly destructive in villages adjacent to the protected areas. Additionally, villages located closest to the protected areas were reported to have the highest mean percentage loss per household per season.

The crop type that was damaged by wild animals differed significantly among the surveyed villages. Our findings suggest that maize was the most preferred and thus the most commonly damaged crop in the area, followed by sorghum. The stages at which the crops were damaged also differed significantly: crop-raiding intensifies during the harvest time, when crops are mature, is next most common during the flowering season, followed by the growth season and seedling season. To protect their crops from wild animals, the local farmers use many different methods, which differ according to the distance of the village from the protected area. The most commonly used crop protection strategy was the constant guarding of the farm during the crop season.

4.2 Livestock depredation by carnivores – Paper II.

The results of this study indicate that the majority of respondents kept livestock and more than half reported livestock depredation. Livestock depredation differed significantly among the surveyed villages along a distance gradient from the park, with the lowest depredation rates in the villages that were farthest away from the protected area. The spotted hyena was the most destructive wild animal in all surveyed villages, followed by small carnivores (mongoose, jackals, baboons), which were destructive especially in the villages located farther away from the protected areas. Other wild animals that were reported to kill livestock included hawks, leopards, lions, and wild dogs. Spotted hyenas were reported to kill all types of livestock, from cattle to poultry. Poultry was depredated by small carnivores and hawks.

The methods used to protect livestock from wild animal depredation differed significantly according to the distance of the village from the protected area. Livestock keepers in villages located close to the protected areas preferred constant guarding with arrows and spears during grazing. The building of livestock enclosures/bandas to protect the livestock during the nights and the use of guard dogs were more commonly preferred in villages that were the farthest away from the protected areas.

The estimated cost of depredation differed significantly between the villages. The villages located closest to the protected areas reported the highest mean estimated loss per household per year compared to other villages. The total mean number of depredated livestock was one cow, goat, dog and sheep and three poultry per household per year.

However, livestock disease has been reported to be the major cause of livestock loss in the study area. The frequency of livestock disease differed significantly between the surveyed villages along the distance gradient from the park. The highest frequencies of death due to diseases were experienced in the villages that were located closest to the protected areas.

4.3 Species preference of sundried bushmeat – Paper III.

The study indicates that the majority of respondents claimed to have tasted bushmeat before and were aware of bushmeat. Sundried bushmeat was most frequently preferred by the study respondents, followed by boiled and smoked bushmeat. In terms of species preference, most respondents preferred sundried beef over other varieties of sundried bushmeat, based on its chewability, smell and taste. Beef was the most preferred sundried meat, followed by sundried impala *(Aepyceros melampus)* and sundried wildebeest meat. Sundried zebra meat was least preferred among the four tested meat samples.

Interestingly, the questionnaire results indicated that the meat preferences of the four animal species (Topi *Damaliscus korrigum*, wildebeest, impala, and zebra) and the three processing types differed significantly between villages. Sundried wildebeest bushmeat was more preferred in the close and intermediate villages, while sundried impala was more preferred the far villages. Regarding the boiled and smoked bushmeat, wildebeest meat was more preferred in the close villages, while impala bushmeat was more preferred in the intermediate and far villages. Generally, the preferred sundried bushmeat of the respondents was sundried wildebeest*,* followed by impala, zebra and Cape rabbit (*Lepus capensis)*. Other preferred sundried bushmeat were buffalo *(Syncerus caffer)*, topi, klipspringer (*Oreotragus oreotragus)*, eland *(Taurotragus oryx),* hippopotamus (*Hippopotamus amphibius*), hartebeest *(Alcelaphus buselaphus),* and African elephant. The distance of the village (in km) from SNP and the type of sample tested significantly influenced the variation in bushmeat preferences.

4.4 Species identification through the taste of sundried bushmeat – Paper IV.

The study findings reveal that communities near the Serengeti ecosystem have rich and useful indigenous knowledge of the identification of bushmeat. They use different factors to identify sundried bushmeat species, including organoleptic tests (taste and aroma), as well as the colour, patterns and structure of the meat fibres. The distance of the village from the protected area and age group of the respondents were the most important factors in the recognition of sun-dried and cooked meat. The respondents from the village closest to the protected area (Robanda) correctly identified meat to the species level more frequently than those from villages farther away from the protected area.

Respondents between 21 and 45 years old were able to identify bushmeat species more frequently than younger and older testers. Men were more likely to identify the meats to the species level than were women, although this effect disappeared in linear regression analysis. The identification of individual meat specimens differed significantly among the four species offered in the sun-dried meat taste test. Zebra meat was more frequently recognised by respondents, followed by wildebeest and impala; in contrast, beef was recognised least frequently.

5.0 Discussion

5.1 Crop raiding by wild animals

This study suggests that the distance of a farm from the protected area is an important factor in determining the extent of crop raiding by wild animals that it will experience. Our results further demonstrate that villages closest to the protected area experience higher frequencies of crop damage as well as greater costs of crop damage than villages located farther away; the most serious damage occurred in the villages that were closest to the park boundary. Damage was caused by wildlife from the park, especially elephants. Distant villages mostly suffered damage caused by primates. This is because elephants cannot move far away from the protected areas, while primates thrive in human dominated habitats as long as there are kopjes, hills and bushes in the village lands. Similar findings have been reported elsewhere (Gillingham and Lee, 2003, Hill, 2000, Ntalwila, 2007, Ole Meing'ataki, 2005, Sarker and Røskaft, 2011).

Different wild animals were involved in crop raiding among the surveyed villages. Primates were the most destructive wild animal in all surveyed villages, followed by elephants, which were especially destructive in villages located adjacent to protected areas. Elephants have previously been reported to be the most damaging animals elsewhere in Tanzania (Kaswamila, 2007, Ntalwila et al., 2003), and African elephants are known to be a significant problem for crop production in villages that are adjacent to protected areas (Kaswamila, 2007, Malugu, 2010, Malugu and Hoare, 2009, Ntalwila et al., 2003). Although this study suggested that elephants and primates were the most destructive animals, which is consistent with the results of previous studies, it differs from prior work in its finding that primates were the more destructive of the two species (Kaswamila, 2007, Malugu, 2010, Malugu and Hoare, 2009). This might be because the previous studies were concentrated in villages that were adjacent to the park boundaries, whereas this study was conducted along a distance gradient of up to 80 km from the park. Sampling several villages along this distance gradient was important for analysing the level of conflict and the responsible animals.

Our findings suggest that maize is the most highly preferred crop and was thus was the most damaged, followed by sorghum. This observation is similar to what Malugu and Hoare (2009) reported in a similar location, although they found that sorghum was preferred over maize. Mentioning the two types of crops and being able to rank them suggest that these two crops are major staple food for local communities in the area and are thus widely cultivated. Respondents reported that crop raiding intensifies during the harvest of mature crops in the wet season, followed by the flowering crop season. This finding is supported by previous studies suggesting that crop raiding is greatest during the harvest season when the crops are mature (Parker and Osborn, 2001, Malima et al., 2005, Jackson et al., 2008, Gunn, 2009, Malugu, 2010).

To protect crop fields from wild animals, the local communities around protected areas use different strategies. These strategies include guarding the farm at all times, making noises to scare the wild animals, fencing the farms, and firing guns and hunting the wild animals. This observation is supported by research on other areas in Africa with similar problems (Fungo, 2011, Hill, 2000, Kagoro-Rugunda, 2004, Malugu, 2010). Local communities in the study area developed and adopted different strategies to protect their farms because they realised that no single approach was sufficient to deter the crop raiders. Karidozo and Osbom (2007) also found that a combination of crop protective methods would protect the crops from wild animals and aid in animal conservation.

5.2 Livestock depredation by carnivores

In agreement with earlier studies (Kolowski and Holekamp, 2006, Sillero-Zubiri and Laurenson, 2001), our findings suggest that the distance of the villages from protected areas is an important factor in determining the extent of the livestock depredation by wild animals. Our results show that the villages that are closest to the protected areas experience the highest frequencies of livestock depredation. This is because a higher population of large carnivore species is found in the villages located close to the protected areas (Holmern et al., 2006).

Many other studies in Tanzania (Holmern et al., 2006, Ikanda and Packer, 2008, Kissui, 2008, Nyahongo, 2007) have found that the size of predators determines the size of the prey they hunt. Different wild animals were therefore involved in livestock depredation among the surveyed villages. The spotted hyena was reported to be the most destructive wild animal in all surveyed villages followed by small carnivores, including baboons, which were especially destructive in villages that were farther away from the protected areas.

The methods used to protect livestock from being depredated by wild animals differed significantly according to the distance of the village from the protected area. Livestock keepers in the villages located close to the protected areas preferred constant guarding with arrows and spears during grazing. The building of livestock enclosures/bandas to protect livestock during the nights and the use of guard dogs were more preferred in the villages that were the farthest away from the protected areas. This observation indicates that the livestock keepers in the farthest villages might not have sufficient grazing area, like the livestock keepers living near the protected areas, who sometimes allow their livestock to graze inside the park.

Livestock depredation causes significant economic losses in the local communities surrounding protected areas. The total estimated mean loss caused by livestock depredation found here was higher compared to that reported in the same region by Nyahongo and Røskaft (2011b). The villages located closest to the protected areas were reported to have the highest loss, which might be because the closer villages have more large carnivores than the farther villages. Such livestock loss has a significant economic impact on rural communities (Hazzah, 2006, Ikanda, 2009). The loss of a single domestic animal may place a serious social-economic burden on the affected family, as livestock are an important form of social capital and a sign of wealth within such rural communities.

Livestock disease was the most important factor that was responsible for livestock losses in the western Serengeti (Nyahongo and Røskaft, 2011a). The highest frequencies of death due to diseases were experienced in the villages located closest to the protected areas, supporting our hypothesis that livestock losses due to diseases are the highest in the villages closest to the protected areas. This might be because communities close to the protected areas graze their livestock inside the park due to the shortage of pastureland and water in their own lands, especially during the dry seasons. Such interactions between wild and domestic animals increase the risk of disease transmission (Gortázar et al., 2007). The encroachment of livestock onto protected areas for grazing might also result in wildlife habitat degradation.

5.3 Species preference of sundried bushmeat

Our results suggest that sundried bushmeat was most frequently preferred by respondents, followed by boiled bushmeat. Smoked bushmeat was the least preferred type of bushmeat. Dried bushmeat is a life-saving reserve in times of food shortage and hunger (FAO, 1997, Kaltenborn et al., 2005, Loibooki et al., 2002, Mfunda and Røskaft, 2010, Kideghesho et al., 2007) and can be easily transported from the protected areas to more distant villages. According to Holmern et al. (2002), its availability depends mainly on animal migrations, which necessitate the preservation of enough meat to both sell and consume in times of need. Sundried bushmeat can be stored and traded in both local markets and in markets that are farther away from the source (Kaltenborn et al., 2005).

Our overall results show that the respondents preferred sundried beef meat over other varieties of sundried bushmeat in terms of its chewability, smell, and taste. Overall, beef was the most preferred sundried meat, followed by sundried impala, while zebra and wildebeest were the least preferred sundried meats. This indicates that while sundried beef meat is highly preferred in rural communities, its accessibility might be a limiting factor in its consumption. Furthermore, the results from the questionnaire respondents indicated that the meat preferences of all four animal species (topi, wildebeest, impala and zebra) processed differently from three distances categories meat preferences differed significantly. This indicated that bushmeat preferences depend on the availability of an animal species, and explains why sundried, boiled and smoked impala was most preferred in the farthest villages. This finding is consistent with the reports of other authors, who have shown that bushmeat species utilisation in particular areas depends largely on the availability of species in the local markets (Barnett, 2000, Hoyt, 2004).

The present results show that in the western Serengeti, the distance of the village from SNP and the type of sample specimen were both significant contributors to the reported bushmeat preferences. Similar findings have been previously reported by other scientists (Barnett, 2000, Hoyt, 2004, Nyahongo, 2007). The species of wild animal utilised for bushmeat and the species selection within particular areas depends largely on the location, habitat type and availability of species in the local markets. According to Holmern et al. (2002), bushmeat availability depends mainly on animal migrations, which necessitate the preservation of enough meat to allow for its sale and consumption during times of hunger. This indicates that the availability of animal species in the market is a major factor in bushmeat species preference. Independent variables including gender, age class and tribe did not contribute significantly to variations in the average bushmeat preference. Our results are not consistent with the findings of other authors who have reported that bushmeat preferences also vary by tribe, cultural setting (Fa et al., 2002, Mfunda and Røskaft, 2010, Ndibalema and Songorwa, 2007) and gender (Nyahongo, 2007).

5.4 Species identification through the taste of sundried bushmeat.

Local communities around the Serengeti ecosystem use different techniques to identify the bushmeat species available for purchase in the market. These techniques include organoleptic tests, such as taste and aroma, as well the appearance, fibre patterns and texture of the meat. Our results suggest that testers could correctly identify only familiar sun-dried meats. Indigenous knowledge played a significant role in the ability to identify species accurately.

The recognition of sun-dried and cooked meat differed significantly according to the distance of the village from the protected areas and according to the age groups. The respondents from the village closest to the protected area (Robanda) correctly identified meat to the species level more frequently than those from the farthest villages. This result supports our hypothesis that people living closer to the protected areas consume bushmeat more frequently than people from more remote villages; indeed, the respondents from the distant villages had less experience with wild animals.

Age group was the second most important factor in the recognition of sun-dried meats, which also supports our hypothesis. Respondents between 21 and 45 years of age were able to identify bushmeat species more frequently than the younger and older respondents. These results are consistent with earlier reports on the ages of active bushmeat hunters elsewhere in sub-Saharan Africa (Solly, 2004, Coad, 2007, Nyahongo, 2007, Wright and Priston, 2010). The skills acquired during their daily hunting activities may contribute to their ability to identify bushmeat species. Additionally, these results are supported by studies showing that taste sensitivity decreases with age (Fukanaga et al., 2005, Nyahongo, 2007).

Men in the study area were more likely to identify the meats to the species level than women, although this effect disappeared in the linear regression analysis. Men probably identified meat species more frequently because in most African countries, the men are responsible for hunting, while the women remain at home to care for the household and the family. This observation is supported by studies elsewhere (Coad, 2007, Hofer et al., 1996, Wright and Priston, 2010, Fa et al., 2006). Nonetheless, women provide family income through trade of bushmeat products after the meat is processed and sold, either within the protected areas or in the village market. They also assist the men in the transport of the bushmeat from the forest to the villages (Loibooki et al., 2002, Solly, 2004, Mendelson et al., 2003). However, the gender differences in the rate of correct identification disappeared in the linear regression analysis, indicating that gender was not equally distributed among the age groups.

The recognition of the four types of meat samples differed significantly among the animal species. Zebra meat was more frequently recognised by the respondents than other animal species, followed by wildebeest and impala; beef was recognised least frequently.

Zebra meat may be highly recognisable because of its unique aroma and taste. Moreover, many local communities use zebra fat in their traditional medicine, to cure chest and ear pain; for this reason, zebra meat may be more familiar to the participants than the other meats (David Mashaka, 2011 personal communication).

5.5 General discussion

This study shows that the level of HWCs is higher in the villages closest to the Serengeti National Park. Local communities living closest to the PAs experience more losses from wild animals compared to those living in farther villages. This implies that the distance from PAs is an important factor relating to the sustainable conservation of wildlife resources as it plays a significant role on HWCs such as crop raiding, livestock depredation, disease transmission from wild animals to livestock and bushmeat utilisation (Papers I - IV).

Increases in the human population have resulted in many people living near PAs. One major question is: how do the people living near PAs interact with the local wildlife? Do they co-exist or fight (HWCs)? At what stage should an interaction be considered a HWC? According to Estes et al. (2012), effective conservation requires a better understanding of how humans interact with natural resources both inside and outside the protected areas. Increasing human populations near PAs has led to an extended pressure on the local natural resources (FAO, 2009, Kideghesho, 2006, Mfunda and Røskaft, 2010, Nyahongo et al., 2009). People clear wildlife habitats for agriculture and settlements (Tong and Soskolne, 2007, Estes et al., 2012, Jones et al., 2009, Sodhi et al., 2010, Ciais et al., 2011). They also encroach on the PAs illegally for livestock grazing, bushmeat hunting, firewood collection and building poles and planting grasses, all of which cause the wildlife habitats to shrink. The level of HWCs at the "hard edge" between human settlement and natural areas can be dramatic (Ciais et al., 2011, Jones et al., 2009, Kideghesho, 2006, Loibooki et al., 2002, Mwakatobe et al., 2005, Ndibalema and Songorwa, 2007). These anthropogenic impacts have resulted in the extinctions of many species and a significant reduction in the global biodiversity (Karanth et al., 2010, Zeri, 2011).

The major challenge is to find a method for using the limited available resources in a sustainable manner, even in the face of the increasing population pressure. How can we best manage and protect these natural resources? Attaining improvements in the local peoples' livelihoods, security, and health will depend on the conservation of biodiversity in healthy ecosystems (USAID, 2005). Biodiversity conservation is vital for future generations and for the maintenance of goods and services offered to human beings (Kideghesho, 2006). According to Samoilys and Kanyange (2008), the sustainable use of biodiversity has significant links to human well-being and poverty reduction, as millions of people depend heavily on the biodiversity to support their livelihoods. Considering both the importance of biodiversity to humans and other living organisms and the distance from PAs required for sustainable biodiversity conservation, one major strategy that could be employed for the purpose of conservation is the design of networks of wildlife corridors and buffer zones around PAs.

Wildlife corridors and buffer zones are important for sustainable wildlife conservation, as they serve to keep away local communities while protecting important wildlife habitats. There are restrictions of activities other than conservation. It is important to protect PAs from encroachment by local populations and from destructive activities that take place outside the park but that can affect conservation inside (Martino, 2001). Nevertheless, we must also recognise the legitimate requirements of the local population around PAs (Martino, 2001). According to Meffe and Carroll (1997), for example, defining a buffer zone as "an area in a reserve surrounding the central core zone, in which non-destructive human activities such as ecotourism, traditional (low-intensity) agriculture, or extraction of renewable natural products, are permitted." Generally, wildlife corridors and buffer zones help promote land uses and practices that are compatible with conservation and minimise edge effects, with the main objective of protecting the PAs from outside disturbance.

6.0 Conclusions and recommendations

6.1 Conclusion

The findings from this study suggest that the distance of the farms from the protected areas contributed significantly to crop losses and livestock depredation. The villages closest to the protected areas experience higher frequencies of crop damage than the villages located farther away. Primates were the most destructive animal in all surveyed villages, following by elephants, which were destructive in the villages located near the protected areas. To protect crop fields from wild animals, local communities around the protected areas use several different strategies. The lowest level of livestock depredation was found in the villages farthest away from Serengeti National Park. Local communities around protected areas use different methods to protect their livestock from depredation. Livestock keepers in villages located close to the protected areas preferred constant guarding with arrows and spears during grazing. In contrast, livestock keepers located farther from the protected areas preferred to build of livestock enclosures/bandas and use guard dogs to protect their domesticated animals. Livestock diseases are a major cause of livestock mortality. Households that experienced livestock losses due to disease were highest in villages that were closest to the protected area.

From the findings of this study, it can be further concluded that sundried bushmeat was most frequently preferred by the respondents, followed by boiled bushmeat. Smoked bushmeat was the least preferred meat. Beef was the most preferred sundried meat, followed by sundried impala and sundried wildebeest. The distance of the village from SNP and type of sample specimen tested both contributed statistically to the reported bushmeat preferences.

The results of this study revealed that communities adjacent to the Serengeti ecosystem have rich and useful techniques for the identification of bushmeat. Women and men recognised bushmeat species at similar rates. However, in general meat tasting by the local communities is a poor tool for the identification of wildlife species (also observed by Nyahongo (2007); therefore, tasting is not a recommended technique for species identification.

6.2 Recommendations

The study recommends further research on the crop yield gap that results from crop raiding by wild animals. As primates were reported to be the most destructive wild animal in all surveyed villages, we recommend a study on human-primate conflict in the communities around the protected areas. For the effective protection of crop farms from wild animals, we recommend that local communities adopt a combination of methods to deter crop raiding by wild animals, as suggested by Karidozo and Osborn (2007).

The study further recommends that to reduce livestock depredation, all conservation stakeholders should support local communities as they improve their education about livestock husbandry. An integrated study on livestock and wildlife disease and their impact on the household economies of the local communities is also highly recommended.

Based on the findings of the species preference of sundried bushmeat, we recommend further studies on the quality analysis of different processed meats (fresh boiled, sundried and smoked) to check for different nutrients. Conservation awareness campaigns should not only concentrate on villages close to the protected areas but also on farther villages, which often serve as market places for bushmeat and other illegal animal products.

The study recommends supporting the communities around protected areas with poultry- and livestock-keeping as well as aquaculture projects to supplement their dietary protein and diminish their reliance on bushmeat, thereby reducing the hunting pressure on wild animals. Based on the taste-based species identification results, we also recommend further study on the factors used by local communities to identify animal species, so that these techniques can be incorporated into the monitoring of the illegal bushmeat trade.

Lastly, the study revealed that the distance from PAs is an important factor in the sustainable conservation of wildlife resources. The study therefore recommends that villages around PAs areas should be assisted to develop better land use methods and implementation plans.

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Paper I

Crop raiding by wild animals in communities surrounding the Serengeti National Park, Tanzania

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Abstract

Crop damage is a serious source of conflict between communities and protected areas. Data for crop raiding were collected through questionnaires. Multiple response analysis were used to calculate the frequencies of type of crop damaged, levels of crop plant growth when damaged and estimated economic loss caused by damaged per household. Chi-square were applied to tests for the differences in independent variable distance from the protected area if might have influences crop raiding pattern in the study area and type of wild animals involved on crop raiding. Results indicated that distance of the farm from protected area is statistically significant towards crop raiding, primates reported to be the most destructive wild animal in the area, followed by elephants that were destructive especially in the villages located near protected area. Also, wild animals reported to cause a significant economic loss per household. We recommend further studies on the crop yield gap resulted from crop raiding by wild animals, and human – primate conflict in that community around protected areas. Lastly, for effective protection of crop farms from wild animals, we recommend local communities to adopt a combination of methods not individual method to deter crop raiding wild animals from their farms.

Keywords: Crop raiding, Serengeti ecosystem, human-wildlife conflict, wild animals

Introduction

Crop damage is defined as feeding on cultigens by wild animals that can cause substantial financial losses for farmers (Newmark *et al*., 1993; Saj *et al.,* 2001; Gunn, 2009; Fungo, 2011) and is a serious source of conflict between local communities and the management of the adjacent protected areas (Newmark *et al.*, 1994; Ntalwila *et al.,* 2003; Ogra, 2008). It is becoming a widespread worldwide and complex problem (Saj *et. al.,* 2001; Sillero-Zubiri & Swuitzer, 2001; Kajembe *et al.,* 2005; Nyahongo, 2007). It affects subsistence farmers through loss of their primary food and cash resources and indirectly through a variety of social costs (Osborn & Parker, 2003; Marchal & Hill, 2009). For example in Kibale area in Uganda, wild animals reported to raid an average crop loss of 25 % for cassava and 19 % for maize (Naughton-Treves, 1998). In general, crop raiding is reported to be limited to within a few hundred meters of protected areas, with fields further away receiving little or no damage (Hill, 2000; Gillingham & Lee, 2003; Ole Meing'ataki, 2005; Ntalwila, 2007; Sarker & Røskaft, 2011).

Crop raiding by wild animals is caused by several species that range from large mammals to smaller ones like birds, rodents and insects (Hoare, 1999; Saj *et al.*, 2001; Rao *et al.,* 2002; Osborn & Parker, 2003; Sitati *et al.,* 2003; Gunn, 2009). The animals species that are mostly cited to be responsible for crop damages in different area surrounding protected areas in Tanzania include African elephants (*Loxodonta africana*) (Ntalwila *et al.,* 2003; Kaswamila, 2007; Malugu & Hoare, 2007; Malugu, 2010), primates (Ntalwila *et al.,* 2003; Kaswamila, 2007), bushpigs (*Potamochoerus porcus*) (Newmark *et al.,* 1994; Ntalwila *et al.,* (2003), dik dik (*Madoqua kirkii*) - (Ntalwila *et al.,* (2003), bushbuck (*Tragelaphus scriptus)* (Ntalwila *et al.,* 2003), rodents (Newmark *et al.,* 1994), African porcupine (*Hystrix cristata)* (Ntalwila *et al.,* 2003), vervet monkey (*Chlorocebus pygerythrus*) - (Ntalwila *et al.,* 2003) and Cape buffalo *(Syncerus caffer)* - (Ntalwila *et al.,* 2003).

Crop raiding may be greatest during the harvest season when the crop is mature (Parker & Osborn, 2001; Malima *et al.,* 2005; Jackson *et al.*, 2008; Gunn, 2009; Malugu, 2010), but it does occur throughout the year (Walpole *et al*., 2004; Malugu & Hoare, 2007; Gunn, 2009; Ntalwila *et al.,* 2011). Mature crops may offer a high nutritional benefit to the raiding wild animals (Malugu & Hoare, 2007) and also are most palatable containing most calories that reduces the feeding time by herbivores (Ntalwila *et al.,* 2011). Most cited crops to be at most risk include cassava (*Manihot utilissima)* - (Naughton-Treves, 1998), maize (*Zea mays)* - (Naughton-Treves, 1997; Ntalwila *et al.,* 2003; Walpole *et al.,* 2004), sweet potatoes (*Ipomea batatas*) - (Ntalwila *et al.,* 2003; Walpole *et al.,* 2004), groundnuts (*Arachis hypogaea)* - (Naughton-Treves, 1997), sorghum (*Sorghum vulgare)* (Walpole *et al.,* 2004), and finger-millet *(Eleusine coracana*) - (Ntalwila, *et al.,* 2003; Walpole *et al,.* 2004). Other crops subjected to damage are beans (*Phaselous vulgaris)*, bananas (*Musa acuminata)*, tomatoes (*Lycopersicon esculentum*) and fruits (Ntalwila *et al,* 2003). According to Malugu & Hoare, (2007) the mostly raided crops in western Serengeti are sorghum and maize.

Local communities have adopted several measures to deter crop raiding by wild animals from their farms. Some of the most common measures include guarding (Hill, 2000; Walpole & Linkie, 2007; Malugu, 2010), making noises (Malugu, 2010), lighting fire at night, trenches against bush pigs (Kagoro - Rugunda, 2004; Fungo, 2011) and fencing (Paterson, 2007; Malugu & Hoare, 2009; Malugu, 2010; Fungo, 2011). These methods are used either individually or in combination. Selection of the method to use depends on size of the fields, crop grown, labour availability to guard and vulnerability of the crop to available raiders (Fungo, 2011). For example in Zimbabwe, it was noted that bees alone may not stop elephants from raiding crops, but if combined with a suite of low-tech methods and coupled with the economic potential of honey production, bees could provide another tool for rural farmers to improve their livelihoods and aid in conserving elephants (Karidozo & Osborn, 2007).

Knowledge on the nature and extent of human-wildlife conflicts is important because such conflicts tend to affect people's livelihoods (Newmark *et al.,* 1993). Monitoring of crop damage is largely limited to local reporting of incidents to the local governments and later to the wildlife authorities for an appropriate action to be taken (Hoare, 1999). Most studies on human-wildlife conflicts are based on surveys of local people perceptions of the problem and its impacts. It is recognized that perceived and actual extent of such conflicts do not match. An over exaggeration of the extent of damage is therefore the consequence (Naughton-Treves, 1998). In addition, careful documentation of the economic losses is essential to assess the extent of damage. The present study intend to determine the extent of crop raiding by elephants, birds, primates, bushpigs and rodents per household per year along a gradient of distance from the protected areas, and analyze the economical effects this has on the households. We hypotheses that the amount of crop damage by wild animals per household per year is higher in villages adjacent to protected areas than villages far away from such areas.

Study area

The study area is located in the north-eastern corner of Tanzania on the north-western Serengeti National Park (SNP) – (see Figure 1). The western Serengeti corridor extends westward to Lake Victoria ($1^{o}30'$ – $2^{o}30'$ and $33^{o}50'S$ - $34^{o}45'E$. The SNP is the central part of the greater Serengeti Ecosystem in the northern Tanzanian highlands. Rainfall in the Serengeti is seasonal and is determined by large-scale weather patterns, modified by local topography (Pennycuick & Norton-Griffiths, 1976). The rain normally falls in two periods; the short rains from November to February and long rains from March to May. There is a rainfall gradient from the dry southwest plains to the wetter northwest. Rainfall increases from 514-688 mm per year in the southeast plains through 857-976 mm per year in the central woodlands and western corridor, to 972-1100 mm per year in the north (Campbell & Hofer, 1995). The monthly averages of the maximum temperatures in the western Serengeti fluctuate between 25^{o}C to 32^{o}C (Campbell & Hofer, 1995). The Minimum daily temperature ranges between 13^{o}C and 19^{o}C.

The people inhabiting this region are either agro-pastoralists or pastoralists. The human population in the area is estimated to be over two million (URT, 2012). The main ethnic groups in the two districts are Ikoma, Sukuma, Nata, Ikizu, Jita and Kurya. There are some ethnic differences in economic activities that include fishing, livestock rearing, game meat hunting, and trading (Loibooki, 1997; Loibooki *et al.*, 2002). About 96 % of the respondents in Serengeti ecosystem depend on crop-based agriculture for their socio-economic development (Kaswamila, 2007). The crops cycle follows the rain-pattern. Maize, sorghum and millet are planted twice a year; in February - March and August-October and harvesting period is between June and July and between January and February, respectively. Livestock includes cattle, goats, sheep and poultry, although a few households keep pigs and donkeys. Western Serengeti District is one of the areas in the highly affected by massive attacks of field crops (Kaswamila, 2007). Serengeti District Council (2006), estimated crop loss amounts to 0.3% of the total district crop yield estimated at 129,670 tons of various crops.

Methods

The data were collected throughout the year from January 2010 to December 2010. Sampling included nine selected villages along a gradient of distance from the park. The selection was done in such a way that three villages were located within 10 km distance from the protected area (Robanda, Nyamakendo and Nattambisso) and the other six villages, three for each distance within 40 km (Butiama, Busegwe and Rwamkoma) and 80 km from the protected area (Ochuna, Makongos and Kowak). Data for crop raiding collected through different techniques including; key informant survey, group discussions, and questionnaires. The questionnaire interviews covered a total of 459 households who were randomly selected from the village and sub-village registers for interview. We interviewed household heads or their wives or resident adults (≥ 18 years old). The villages and sub-villages were picked based on a random-systematic selection. In terms of gender, 36.2 % of the interviewed respondents were females and 63.8 % were males for a questionnaire survey. The questions were both close-ended and open-ended aimed at extracting the respondent's opinion in an open minded atmosphere. The questionnaire addressed socio-demographic variables including crop raiding incidences, type of crops damaged and wild animals responsible for the damage, estimates of crop losses and coping strategies against crop raiding. Also, the same data were recorded in the data sheet in selected village. For each village we selected ten households whose farms were monitored for crop raiding. We hired an enumerator in each village whose work was to record any crop damage within the project villages and other villages that were not selected. We consider data obtained from non-project village as incidental and thus were analysed separately. In any incidence involving crop damage, enumerators were instructed to record and report the events to the Village Executive Office in which similar data were recorded and compiled.

Data analysis

Statistical analyses were conducted using Statistical Package for Social Sciences (SPSS, version 17). Multiple response analysis was used to calculate the frequencies of type of crop damaged, different levels of plant growth when damaged occurred and estimated loss cost of crop damaged per household. Pearson Chi-square were applied to tests for the differences in independent variable distance from the protected area (village within 10 km (closest villages), 40 km (medium villages) or 80 km (far away villages)) if that might have influenced crop raiding pattern in the study area and whether type of wild animals involved on crop raiding have relation with distance of the village from protected area.

Results

Crop raiding by wild animals based on the distance from the boundary

More than fifty four percent of respondents (54.3%, n = 451) reported to experience crop damage caused by wild animals in their farms. Frequency of crop damage differed significantly among the surveyed villages along the gradient of distance from the park (Pearson Chi-square: $\chi^2 = 6.0$, df = 2, n = 451, P = 0.05, Figure 2). The percentage of farms that experienced crop damage was higher in closest villages followed by far away villages and the least crop damage was found at the middle villages (Figure 2).

Wild animals involved in crop raiding

Wild animals involved in crop raiding differed significantly among the surveyed villages (Pearson Chi-square: $\chi^2 = 446.1$ df = 10, n = 644, P < 0.001, Figure 3). Primates reported to be the most destructive wild animal in all surveyed villages (36.8 %, n = 644) and mostly in farther villages, followed by elephants (35.1 %, n = 644) that were destructive especially in the villages located near the protected area (Figure 4). Other wild animals reported to damage crops were birds, rodents, squirrels, bushpigs, warthogs, and porcupines.

The types of crop damaged by wild animals differed significantly among the surveyed villages (Pearson Chi-square: $\chi^2 = 41.7$ df = 10, n = 703, P < 0.001, Figure 4). Maize was reported to be the most damaged crops (38.8 %, n = 703) in the study area, while Sorghum was the second most affected crop (25.7 %, n = 703). Other crops subjected to crop damages by wild animals were cassava, potatoes, finger millet, groundnuts, and beans. Stages of crop growth when damaged also differed significantly (Pearson Chi-square: $\chi^2 = 27.8$ df = 6, n = 213, P < 0.001, Table 1) whereas crop-raiding intensifies during harvest time when crops were mature (47.9 %, n = 213) followed by the flowering season (28.2 %, n = 213), then growth season (12.7 %, n = 213) and seedling stage season (11.3 %, n = 213).

Measures taken by local communities for deterring crop raiders

To protect crop fields from wild animals farmers use many different methods. Methods used to protect their farms from destruction by wild animal differed significantly by the distance of the village from the protected area (Pearson Chi-square: $\chi^2 = 13.4$ df = 6, n = 255, P = 0.037, Figure 5). The most commonly used crop protection strategy is through guarding of the farm constantly throughout the cropping season. Farmers reported to guide their farm throughout the day and night by patrolling their fields, active chasing the wild animals away from the farms using dogs and building the watch-out huts in the farms (49.8%, n = 255). Moreover, farmers reported to shout, beating drums, hunting and using firing-flashes to scare the wild animals (35.3 %, n =

255). Also, respondents reported to fence their farms by using thorn twigs, oily rugs, tieing coloured rugs (14.9%, n = 255).

Economic loss due to crop damage

Respondents were requested to produce the estimate of total cost resulting from crop damage caused by wild animals on household basis. The reported estimated cost differed significantly between the villages (Pearson Chi-square: χ^2 = 46.9 df = 10, n = 240, P < 0.001, Figure 6). The mean loss estimated in the surveyed villages was Tanzanian Shillings TSh. 34,093 per household per season (equivalent to US$ 22) this was equal to an average loss of 16.7 % (Figure 7). The villages located to the closest distance from the protected areas reported to have the highest mean percentage loss of 24.9% at a cost of TSh. 54,466 (equivalent to US$ 35) per households per season compared to other villages. The villages located far away from protected area reported to have least mean percentage loss of 11.0% compared to other villages with mean estimated loss cost of TSh 20,938 (equivalent to US$ 13.5) per household per season.

Discussion

Crop raiding by wild animals along the distance from the park boundary

The finding of this study suggests that the distance of a farm from the protected area is an important factor in determining the extent of crop raiding by wild animals. Our results show further that the closest villages to the protected area experience higher frequencies of crop damage as well as the costs of crop damage than other villages located farther where more serious damage were registered to villages which are very close to the park boundary. The damages were caused by wildlife from the park, especially elephants. Distant villages had high crop damage done by primates. This is due to the fact that elephant cannot move far away from the protected areas but primates are able to thieve well in human dominated habitats provided there are some kopjes, hills and bushes in the village lands. Also, far villages were near Lake Victoria where may be some forest fragments for the primates to live in. Similar findings have been reported earlier elsewhere (Hill, 2000; Gillingham & Lee, 2003; Ole Meing'ataki, 2005; Ntalwila, 2007; Sarker & Røskaft, 2011).

Wild animals involved in crop raiding

Different wild animals involved in crop raiding among the surveyed villages. Primates were the most destructive wild animal in all surveyed villages, followed by elephants that were destructive especially in the villages located adjacent to protected areas and have been reported to be the most damaging animals elsewhere in Tanzania (Ntalwila *et al.,* 2003; Kaswamila, 2007). Moreover, African elephants whose population expanded rapidly following the ban in ivory trade, are now become big problem in crop production economy especially in villages that are adjacent to the protected areas (Ntalwila *et al.,* 2003; Kaswamila, 2007; Malugu & Hoare, 2007; Malugu 2010). Although the result of this study reported elephants and primates as the most destructive animals for crop production, which is in agreement with previous studies, the ranking of the problem differ from those studies that rank elephant number one (Kaswamila, 2007; Malugu & Hoare, 2007; Malugu 2010). This might be to the fact that the previous studies only concentrated their studies in villages that were adjacent to the park boundaries as opposed to the current study that was conducted along the gradient of distance from the park up to 80 km farther away. Sampling villages along the gradient of distance was important to analyze the level of conflict and the responsible animals. This indicate the importance of conservationists to focus in all rural areas not in only areas close to protected areas in solving crop raiding problem.

Comparing crop types, our findings suggest that maize was the most preferred and thus was most damaged followed by sorghum in the study area. This observation is similar to what Malugu & Hoare (2007) reported in the similar location although ranking was opposite. In this study 38.8 % mentioned maize while 25.7 % mentioned sorghum while Malugu & Hoare, (2007) ranked sorghum firstly (20.8 %) and secondly maize which scored 18.9 %. Mentioning the two types of crops and being able to rank them suggest that the two crops are the major staple food for local communities in the area and thus are widely cultivated. The stage of crop growth when damaged respondents reported that crop-raiding intensifies during harvest time in the wet season when crops matured followed by flowering crops. Our finding is supported by findings from other studies done elsewhere which suggest that the crop raiding is greatest during the harvest season when the crops are mature (Parker & Osborn, 2001; Malima *et al.,* 2005; Jackson *et al.*, 2008; Gunn, 2009; Malugu, 2010). Also this result support the idea that mature crops offer a high nutritional benefit to the raiding wild animals (Malugu & Hoare, 2007; Ntalwila *et al.,* 2011).

Measures taken by local communities for deterring crop raiders

To protect crop fields from wild animals, local communities around protected areas use different strategies. These strategies included guarding farm at day and night, making noises to scare wild animals, fencing their farms, and lastly firing and hunting. This observation is supported by findings elsewhere in Africa with similar problems (Hill, 2000; Kagoro-Rugunda, 2004; Fungo, 2011; Malugu, 2010). Local communities in the study area developed and adopted different strategies to protect their farms because they realized that no single approach was efficient enough to deter the crop raiders. Karidozo & Osbom (2007) also found that a combination of crop protective methods would protect crop from wild animals and aid in conserving the animals. However, the selection of methods to use for farm protection depends on the species of animal you are dealing with. For example for chasing big animals like elephants they might use fire guns to chase them away from their farms. According to Fungo (2011), selection of the method to use depends on size of the fields, crop grown, labour availability to guard and vulnerability of the crop to available raiders (Fungo, 2011).

Economic loss caused by crop damaged

Crop raiding by wild animals cause a significant economic loss per household in the local communities surrounding protected areas. We found that the total estimated mean loss for the surveyed villages has big variation although the mean was 16.7 %. The mean percentage loss of crops is lower compared to that reported in Uganda of 25% by Naughton-Treves (1998). Kaswamila (2007), reported an the average annual crop loss and crop loss per household in five surveyed villages in Serengeti District to be 11% loss of the household income. This may indicate how crop raiding contributes to an economic loss to the local community around Serengeti ecosystem.

Recommendations

We recommend further studies on the crop yield gap resulted from crop raiding by wild animals. Secondly, as primates were reported to be the most destructive wild animal in all surveyed villages; therefore we do recommend a study on human – primate conflict in that community around protected areas. Thirdly, in order to prevent more people to move closer to the park, conservation education is highly recommended. Lastly, for effective protection of crop farms from wild animals, we recommend local communities to adopt a combination of methods not individual method to deter crop raiding wild animals from their farms as suggested by Karidozo & Osborn, (2007).

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Figure Legends:

Figure 1: Map of study area showing Serengeti National Park, Grumeti and Ikorongo Game Reserves, Lake Victoria and the surveyed villages (Robanda, Nyamakendo, Nattambisso, Butiama, Busegwe, Rwamkoma,Ochuna, Makongos and Kowak indicated with triangles).

Figure 2: Percentage of households experiencing crop damage in the surveyed villages.

Figure 3: Wild animals involved in crop raiding at different distances from the Serengeti National Park (Other wild animals includes rodents, squirrels, bushpigs, warthogs and porcupines).

Figure 4: Number of respondents reported type of crops damaged by wild animals at different distances from the park (Other crops includes, potatoes, finger millet, groundnuts, and beans).

Figure 5: Number of respondents reported copping strategies to prevent crop raiding.

Figure 6: Estimated average cost of damaged crops per household (1 US$ ≈ 1550 TShs).

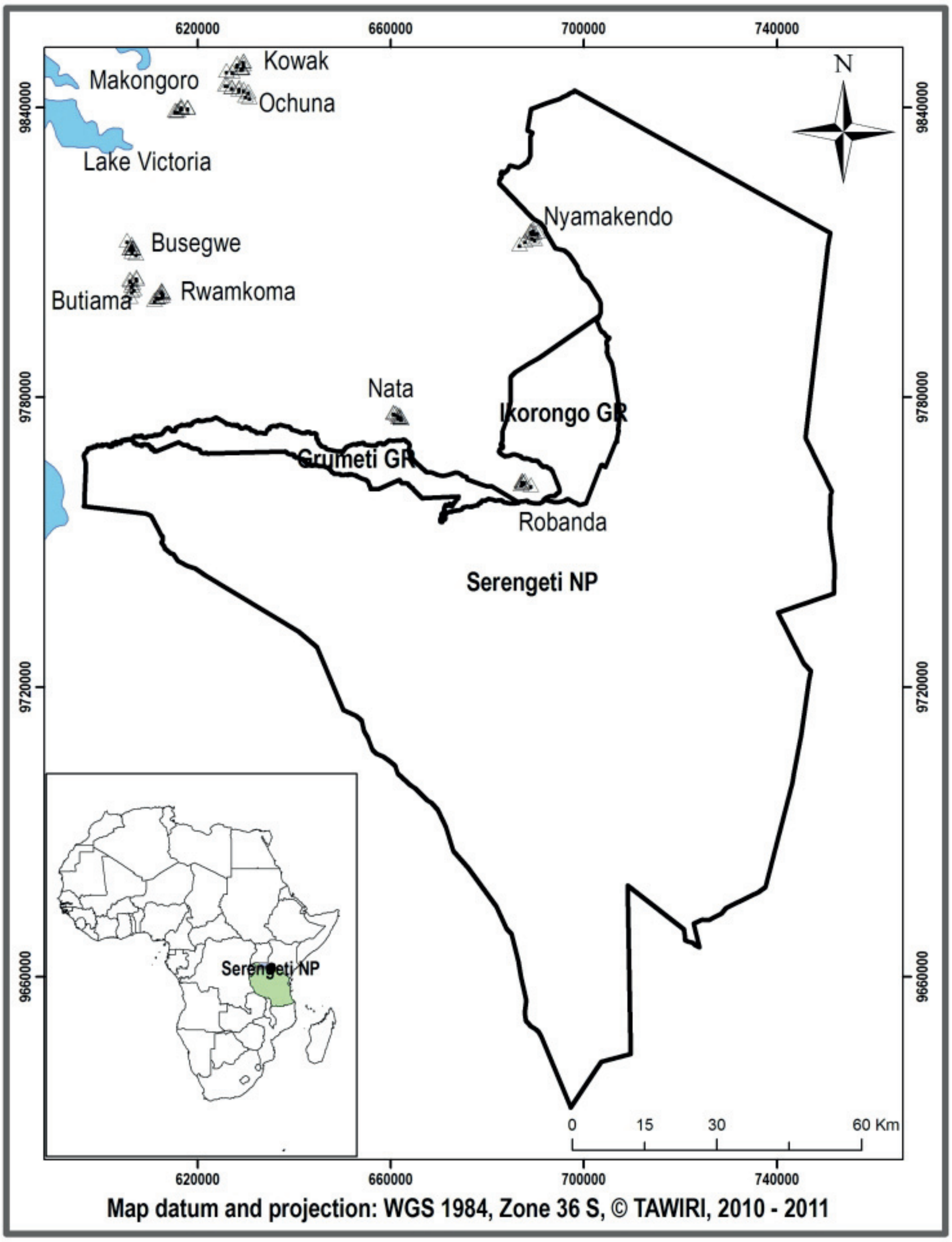
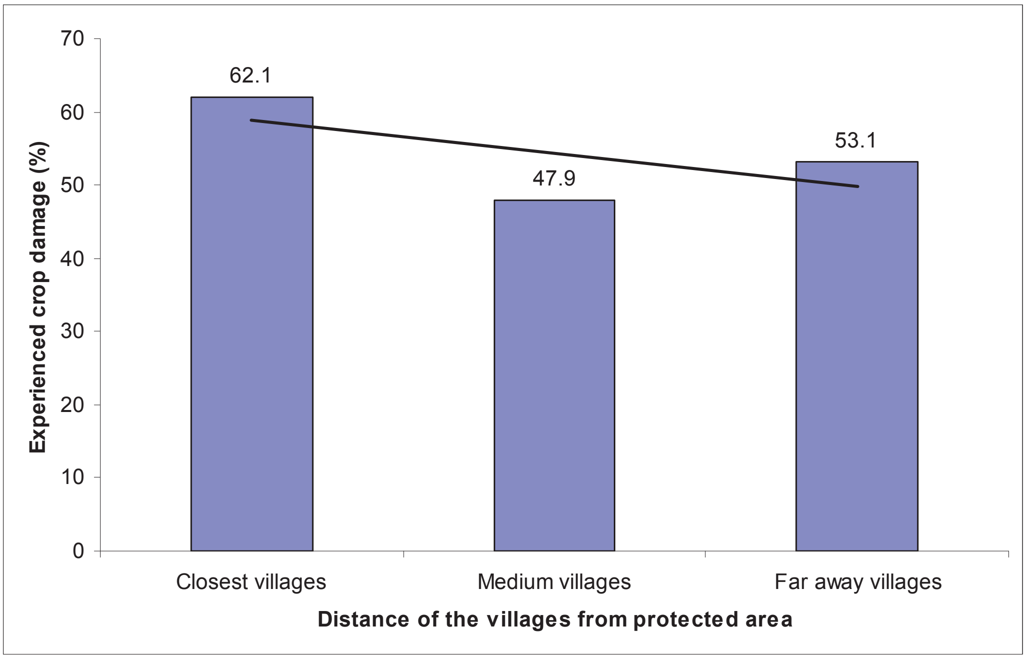

Kowak
Makongoro
Ochuna
Lake Victoria
Busegwe
Butiama
Rwamkoma
Nyamakendo
Nata
Ikorongo GR
Grumeti GR
Robanda
Serengeti NP
N
0 15 30 60 Km
620000 660000 700000 740000
9840000 9780000 9720000 9660000
Map datum and projection: WGS 1984, Zone 36 S, © TAWIRI, 2010 - 2011

Fig 1.



Experienced crop damage (%)
70
60
50
40
30
20
10
0
62.1
47.9
53.1
Closest villages
Medium villages
Far away villages
Distance of the villages from protected area

Fig.2

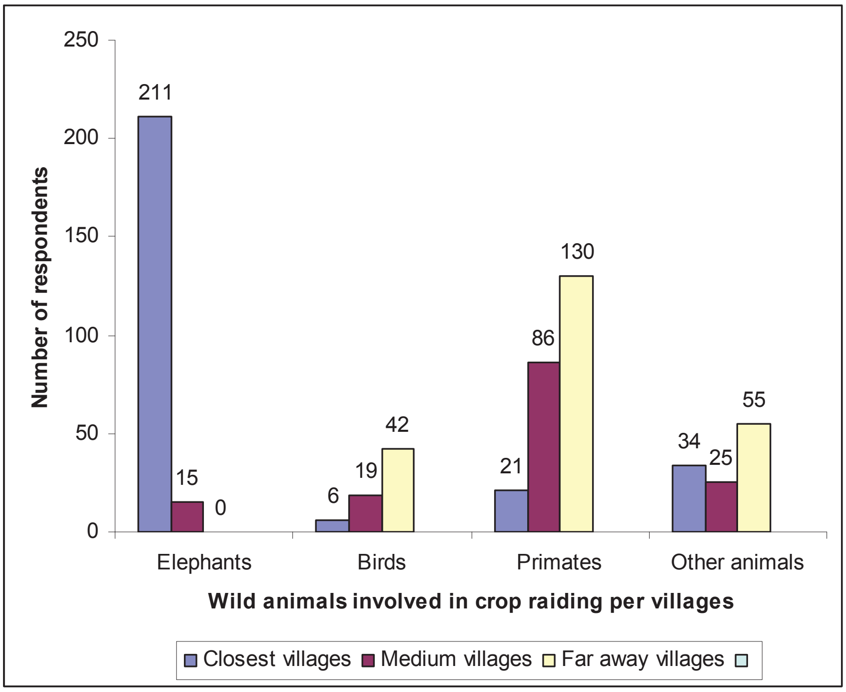
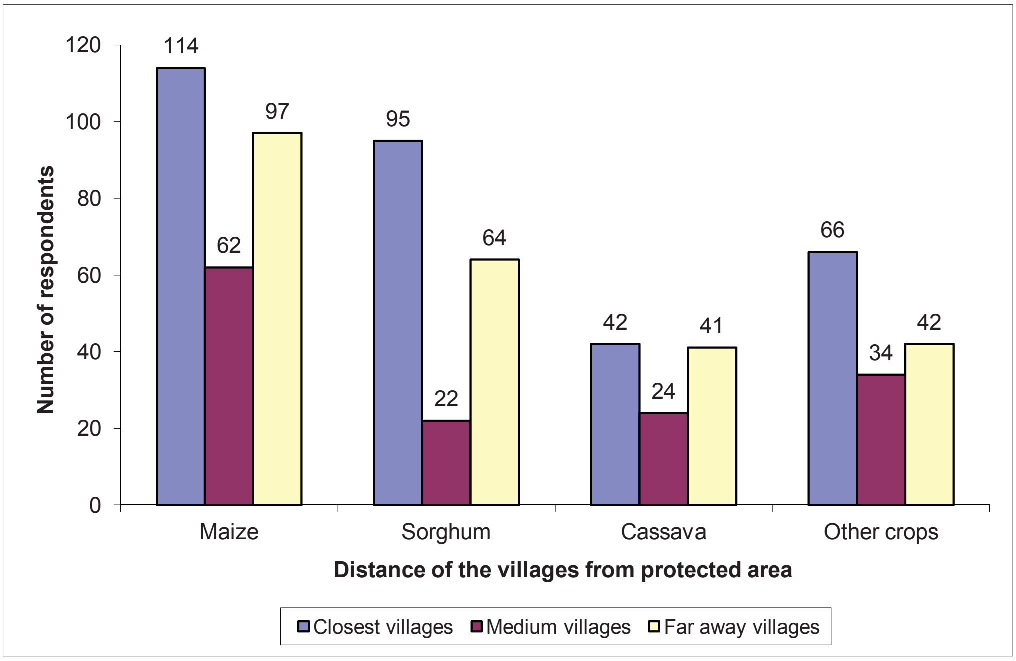

Number of respondents
250
200
150
100
50
0
211
15
0
6
19
42
21
86
130
34
25
55
Elephants
Birds
Primates
Other animals
Wild animals involved in crop raiding per villages
Closest villages
Medium villages
Far away villages

Fig.3



Number of respondents
120
100
80
60
40
20
0
114
62
97
95
22
64
42
24
41
66
34
42
Maize
Sorghum
Cassava
Other crops
Distance of the villages from protected area
Closest villages
Medium villages
Far away villages

Fig.4

Table 1: Stages of crop growth when damaged.

Villages		Stages of drop growth				
		Matured	Flowering	Growth	Seedling	Total
Closest villages	N	33	33	16	16	98
	%	33.7	33.7	16.3	16.3	100
Medium villages	N	43	6	5	4	58
	%	74.1	10.3	8.6	6.9	100
Far away villages	N	26	21	6	4	57
	%	45.5	36.8	10.5	7.1	100

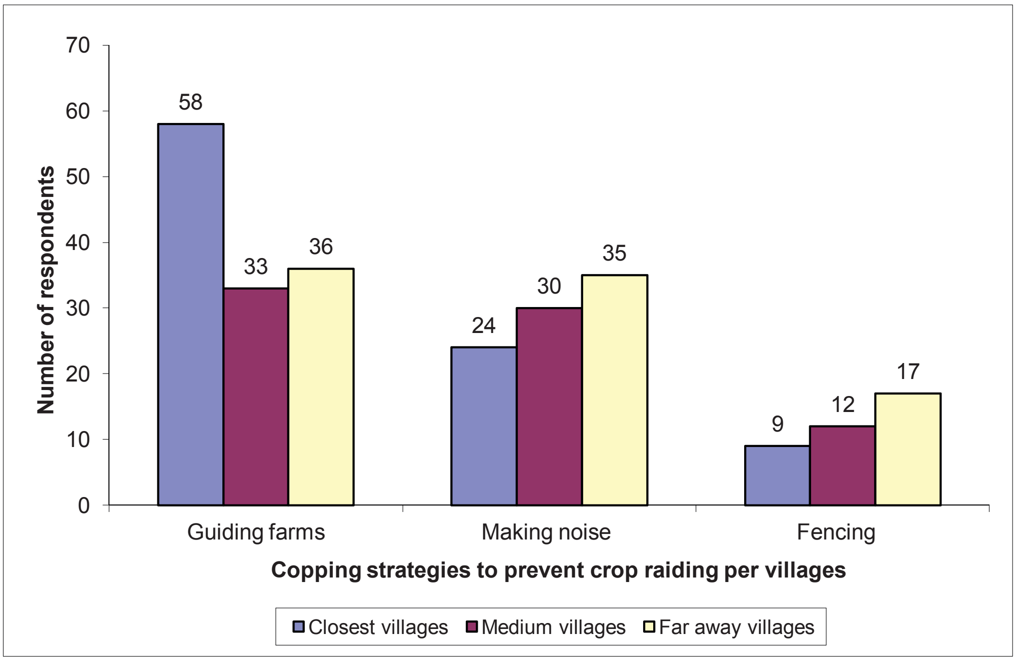

70
60
50
40
30
20
10
0
Number of respondents
58
33
36
24
30
35
9
12
17
Guiding farms
Making noise
Fencing
Copping strategies to prevent crop raiding per villages
Closest villages
Medium villages
Far away villages

Fig 5.

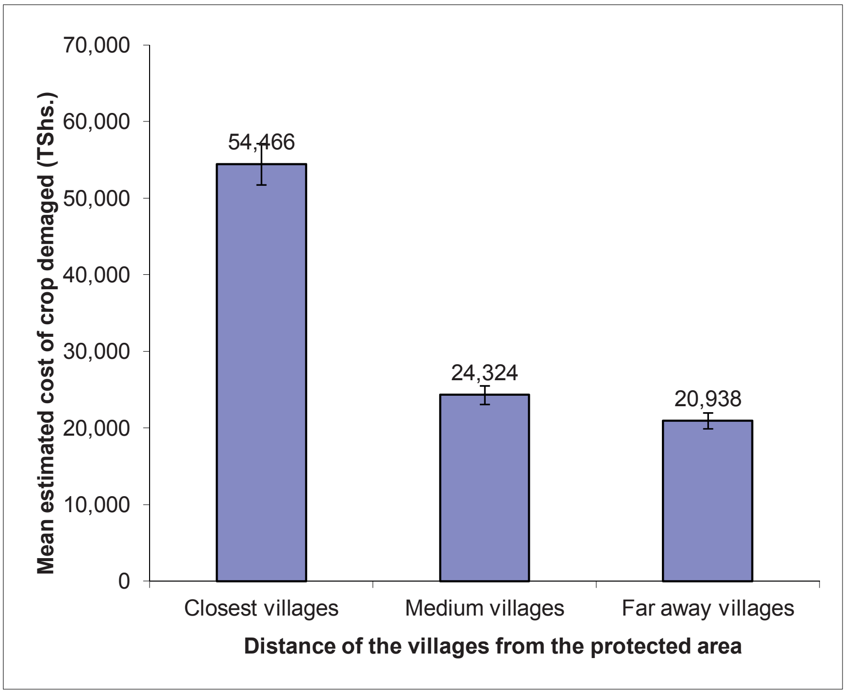

70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
Mean estimated cost of crop demaged (TShs.)
54,466
24,324
20,938
Closest villages
Medium villages
Far away villages
Distance of the villages from the protected area

Fig. 6

Paper II

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Livestock Depredation by Carnivores in the Serengeti Ecosystem, Tanzania

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Abstract

Data for livestock depredation by wild animals were collected in villages outside Serengeti National Park, northern Tanzania. We tested livestock mortality against distance of the villages from the protected area in relation to carnivore species involved, methods used to protect livestock from being depredated and frequency of livestock diseases. The results indicate that distance from the park significantly influenced livestock depredation with the lowest depredation rates in the villages farthest away. Spotted hyena (*Crocuta crocuta*) was the most destructive wild animal, followed by small carnivores (including baboons) which were most destructive in the medium and far away villages. Methods used to protect livestock from being depredated differed significantly based on the distance from the protected area. Wild animals cause a significant economic loss to households; however, livestock diseases were the main cause of livestock loss in the study area. The highest frequencies of deaths due to diseases were experienced in villages located closest to the protected area. We recommend that all conservation stakeholders support efforts of local communities to improve their enclosures, and develop education programs to improve their livestock husbandry skills. We also recommend that veterinary units be staffed with well-trained personnel, adequate facilities and substantial operational budgets to enable them to adequately function. Also, not only villagers near protected areas, but also any residents, should be helped by veterinary units. Lastly, we recommend an integrated study on livestock and wildlife diseases and their impact on household economies of the local communities.

Keywords: livestock depredation, serengeti ecosystem, human-wildlife conflict, wild animals

1. Introduction

Human-carnivore conflict is one of the main constraints to biodiversity conservation efforts outside many protected areas (Holmern, Mkama, Muya, & Røskaft, 2006; Kent, 2011; Lyamuya, Masenga, Fyumagwa, & Røskaft, 2013; Nyahongo, 2007). The most frequent type of conflict between humans and wild animals in different parts of the world are livestock depredation (Dickman, 2008; Kajembe, Mayeta, Nduwamungu, & Katani, 2005; Kaswamila, 2009; Nyahongo, 2007; Thirgood, Woodroffe, & Rabinowitz, 2005) and crop damages (Kajembe, Mayeta, Nduwamungu, & Katani, 2005; Kaswamila, 2009; Nyahongo, 2007; Sitati, Walpole, & Leader-Williams, 2003), while human fatalities are another serious consequence of such conflicts (Baldus, 2004; Ikanda, 2009; Kushnir, Leitner, Ikanda, & Packer, 2010; Løe & Røskaft, 2004; Packer, Ikanda, Kissui, & Kushnir, 2005; Quigley & Herrero, 2005). The co-existence of large carnivores, livestock and humans frequently provoke conflicts threatening the future viability of carnivore populations in African pastoral systems (Ogutu, Bhola, & Reid, 2005). Increasing human populations and associated increases in the use of natural resources and habitat are in many areas, forcing wildlife to live in close proximity to humans (Ikanda, 2009). Pastoralists keep high numbers of livestock that serve as social capital and a sign of wealth (Hazzah, 2006). According to Ukio (2010), high numbers of livestock require large pieces of land, which are increasingly unavailable due to rapid human population growth and increased land use requirements. In these circumstances, competition arises between wildlife and people for space and food resources (Dickman, 2008; Thirgood, Woodroffe, & Rabinowitz, 2005).

Human-wildlife conflict due to predation affects population dynamics of wild carnivores near park boundaries (Kangwana, 1996; Kangwana, 1995; Kolowski & Holekamp, 2006; Sillero-Zubiri & Laurenson, 2001). However, according to Ogada (2003), conflict with local people, particularly over depredation of livestock, is a major cause of population decline in carnivores, affecting both protected carnivore populations as well as those living outside of protected areas. Livestock predation is primarily caused by yellow baboons (*Papio cynocephalus*), leopards (*Panthera pardus*), lions (*Panthera leo*) and spotted hyenas (*Crocuta crocuta*) (Holmern, Mkama, Muya, & Røskaft, 2006; Ikanda & Packer, 2008; Kissui, 2008; Kolowski & Holekamp, 2006; Nyahongo, 2007; Packer, Ikanda, Kissui, & Kushnir, 2005) in many protected areas as well as outside of protected areas in Tanzania. Black-backed jackals (*Canis mesomelas*), golden jackals (*Canis aureus*), olive baboons (*Papio anubis*), and African wild dogs (*Lycaon pictus*) are other important predators (Holmern, Mkama, Muya, & Røskaft, 2006; Holmern, Nyahongo, & Røskaft, 2007; Lyamuya, Masenga, Fyumagwa, & Røskaft, 2013; Masenga & Mentzel, 2005).

A range of options exist for people attempting to decrease conflict with wildlife, including reducing the likelihood of attacks by using protective measures (such as livestock-guarding dogs and donkeys), electric fencing, improved construction of livestock enclosures, toxic collars, disruptive stimuli and other aversive techniques (Hodkinson, Davies-Mostert, Komen & Snow, 2007; Marker, Dickman, & Macdonald, 2005; Ogada, Woodroffe, Oguge, & Frank, 2003; Ukio, 2010). Improvements in livestock husbandry, such as the employment of herders and the kraaling of stock (enclosure for livestock), have been shown to considerably reduce the rates of depredation by carnivores (Ogada, Woodroffe, Oguge, & Frank, 2003). Livestock depredation promotes negative emotional sentiments towards conservation (Ikanda, 2009; Røskaft, Händel, Bjerke, & Kaltenborn, 2007). It leads to indiscriminate persecution of wildlife, in the form of retaliatory killing in retribution for losses (Ikanda & Packer, 2008; Kissui, 2008; Woodroffe & Frank, 2005).

The cost of livestock predation is greater where people's livelihoods depend entirely on livestock keeping (Ogada, Woodroffe, Oguge, & Frank, 2003). Losses due to depredation are common with cattle, sheep and goats (Inskip & Zimmerman, 2009). Loss of a single domestic animal creates serious socio-economic problems to affected families (Ikanda, 2009; Nyahongo & Røskaft, 2011). However, diseases have been reported to contribute to far more livestock losses than predation in some Tanzanian areas (Graham, Beckerman, & Thirgood, 2005; Kissui, 2008; Nyahongo, 2007; Nyahongo & Røskaft, 2011).

Predators may be attracted to feed on domestic stock when stock are taken to graze around protected areas or within their village areas; however, the number of livestock killed by predators per year per household has rarely been quantified. Ultimately, effective conflict resolution on livestock depredation requires a broad, many-sided and truly interdisciplinary approach. Conservation biologists must therefore move beyond examining the wider ecological, socio-economic and cultural conditions under which intense conflicts arise (Dickman, 2010). Therefore, this study intended to investigate the losses that local communities incur due to livestock depredation and analyse the economic effects these losses have on household income. We hypothesise that livestock losses due to depredation are higher in villages close to protected areas than in distant villages. We also hypothesised that household economic losses due to livestock depredation are higher in the villages close to the protected areas than in distant villages and that the losses due to larger carnivores are more serious in the villages close to the protected area because larger carnivores can only leave the protection of the park for short periods of time. Because diseases cause major losses in African livestock husbandry, we predicted that livestock losses due to diseases are higher in the villages close to the protected area due to frequent contact with wildlife. Finally, we tested the measures that people employ to avoid depredation.

2. Methods

2.1 Study Area

The study area is located in the north-eastern corner of Tanzania in the north-western region of Serengeti National Park (SNP) – (Figure 1). SNP covers a total area of 14, 763 km^2. The western Serengeti corridor extends westward to Lake Victoria (1°30′ – 2°30′ and 33°50′S - 34°45′E). Rainfall in the Serengeti is seasonal and determined by large-scale weather patterns, modified by local topography (Pennycuick & Norton-Griffiths, 1976). The rain normally falls in two periods; the short rains from November to February and the long rains from April to June. There is a rainfall gradient from the dry southwest plains to the wetter northwest plains. Rainfall increases from 514-688 mm per year in the southeast plains to 857-976 mm per year in the central woodlands and western corridor to 972-1100 mm per year in the north (Campbell & Hofer, 1995). The monthly averages of the maximum temperatures in the western Serengeti fluctuate between 25 °C to 32 °C (Campbell & Hofer, 1995). The minimum daily temperature ranges between 13 °C and 19 °C. The people inhabiting this region are either agro-pastoralists or pastoralists. Serengeti National Park currently suffers a high degree of conflict between conservation priorities of the park and priorities of local communities (Hofer, Campbell, East, & Huish, 1996; Loibooki, 1997). The human population of the western Serengeti is high and expected to increase due to high birth rates and immigration into villages adjacent to protected areas (Estes, Kuemmerle, Kushnir, Radeloff, & Shugart, 2012; Hofer, Campbell, East & Huish, 1996). The areas north and west of SNP are densely populated (> 70 people/km²). The human population in the Mara Region in 2001 was approximately 1.37 million, growing at a rate of 2.9% per annum (URT, 2003). The main ethnic groups in the two districts are Ikoma, Sukuma, Nata, Ikizu, Jita and Kurya. Although most people are subsistence farmers, there are some ethnic differences in economic activities, which include fishing, livestock rearing, game meat hunting, and trading (Loibooki, 1997; Loibooki, Hofer, Campbell, & East, 2002). Livestock rearing is for both meat and income (Kauzeni & Kiwasila, 1994; Olsen, 1998). Husbandry is commonly practiced in the western Serengeti, and livestock includes cattle, goats, sheep and poultry, although a few households keep pigs and donkeys (Nyahongo, 2007).

2.2 Data Collection Techniques

Data for the current study were collected throughout the year from January to December 2010. Sampling included nine selected villages along a gradient of distance from the park. Three villages were located within a 10 km distance from the protected area (Robanda, Nyamakendo and Nattambisso), three villages were within a 40 km from the protected area (Butiama, Busegwe and Rwamkoma) and three villages were within a 80 km from the protected area (Ochuna, Makongro and Kowak) (Figure 1). Data for livestock depredation were collected through different techniques: key informant survey, group discussions, and questionnaires. The questionnaire interviews covered a total of 459 households that were randomly selected from the village and sub-village registers for interviews. We interviewed household heads, their wives or resident adults (⩾ 18 years old). The villages and sub-villages were picked based on a random-systematic selection. In terms of gender, 36.2% of the interviewed respondents were females and 63.8% were males. The questions were both close-ended and open-ended aimed at extracting the respondent’s opinion in an open minded atmosphere. The questionnaire addressed socio-demographic variables including number of livestock owned, livestock depredation experiences, livestock depredation incidences, type of livestock depredated and wild animals responsible for the damage, estimates of livestock depredation, coping strategies against livestock depredation and livestock diseases experienced in the study area. The same data were recorded for the six selected villages. For each village, we selected ten households whose livestock were monitored for livestock depredation. We hired an enumerator in each village who recorded livestock predation data in the village and in other adjacent villages.

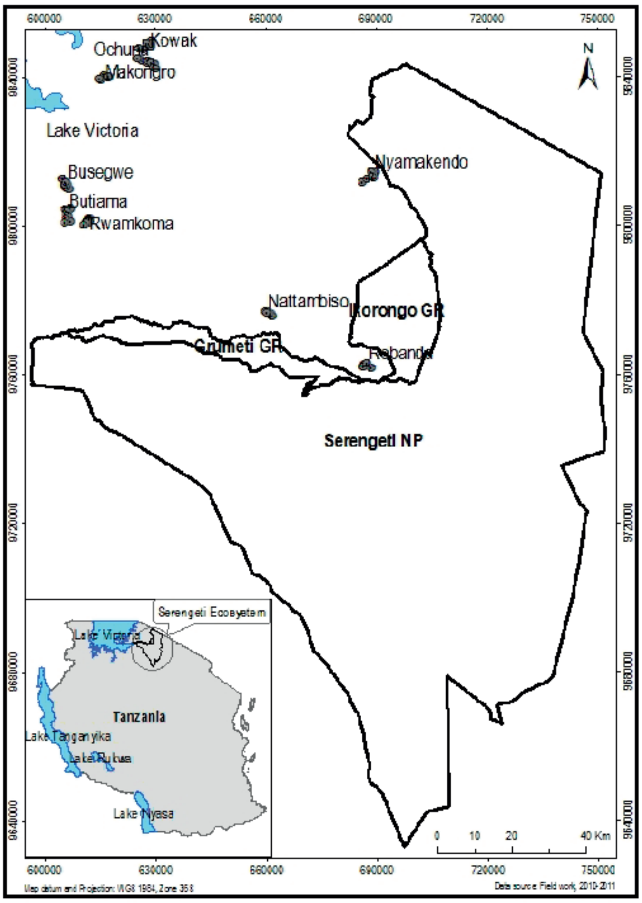

Figure 1. Map of study area showing Serengeti National Park, Grumeti and Ikorongo Game Reserves, Lake Victoria and the surveyed villages (Robanda, Nyamakendo, Nattambisso, Butiama, Busegwe, Rwamkoma, Ochuna, Makongro and Kowak indicated with triangles)

2.3 Data Analysis

Statistical analyses were conducted using Statistical Package for the Social Sciences (SPSS, version 17). Pearson's Chi-square analyses were applied to test for the differences between independent variables including distance from the protected area (village within 10 km (closest villages), 40 km (medium villages) or 80 km (far away villages) and whether this influenced livestock depredation patterns in the study area, whether carnivore species involved in livestock depredation related to the distance of the village from the protected area, different methods used to protect livestock from being depredated by wild animals and the frequency of occurrence of livestock diseases. A Multiple response analysis was used to estimate loss cost of livestock depredation per household per year.

3. Results

3.1 Livestock Depredation by Wild Animals

The majority of respondents kept livestock (85.2%, n = 452), and 58.4% (n = 385) of the respondents had experienced livestock depredation. The frequency of livestock depredation differed significantly among the surveyed villages along the gradient of distance from the park (Closest = 74.8%; Medium = 62.8% and Far away = 41.6%) (Pearson's Chi-square: $\chi^2 = 31.8$, d.f. = 2, $P < 0.001$, Figure 2).

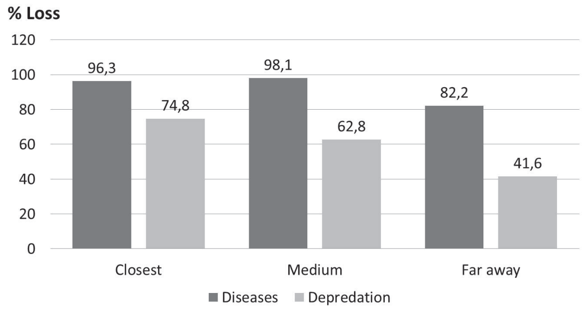

Figure 2. Percentage of households experiencing livestock disease losses and livestock depredation in relation to distances from the protected areas of the surveyed villages

3.2 Wild Animals Involved in Livestock Depredation

Wild animals involved in livestock depredation differed significantly among the surveyed villages (Pearson's Chi-square: $\chi^2 = 79.6$, d.f. = 8, P < 0.001, Table 1). Spotted hyenas were reported to be the most destructive wild animals in all surveyed villages (51.3%, n = 385), followed by other small carnivores and primates (mongoose, jackals, baboons) (32.1%, n = 385), which were most destructive in the intermediate and farther villages. Other wild animals reported to kill livestock were hawks, leopards, lions, and wild dogs. Spotted hyenas were reported to kill all types of livestock from cattle to poultry (Table 2), while other large and medium sized carnivores were mainly reported to kill cattle or goats. Poultry were depredated by small carnivores and hawks while domestic dogs were reported to be depredated by hyenas and jackals (Table 2).

Table 1. Wild animals involved in livestock depredation based on distance from the protected area

Villages		Wild animals				
		Spotted Hyena	Small Carnivores[x]	Hawks	Leopards	Lions / Wild dogs
Closest	N	85	14	6	12	12[xx]
	%	65.9	10.9	4.7	9.3	9.3
Medium	N	36	42	10	0	0
	%	40.9	47.7	11.4	0	0
Far away	N	55	54	16	1	0
	%	43.5	42.9	12.7	0.3	0
Total	N	176	110	32	13	12
	%	51.3	32.1	9.3	3.8	3.5

[x] = Small Carnivores includes mongoose, jackals and baboons.

[xx] = 8 cases of lions and 4 cases of wild dogs.

3.3 Measures by Local Communities for Prevention of Livestock Depredation

To prevent livestock depredation from wild animals, local communities around the Serengeti ecosystem use different methods. However, the methods widely used to protect livestock from being depredated by wild animals differed significantly by the distance of the village from the protected area (Pearson's Chi-square: χ^2 = 14.4 d.f. = 6, P = 0.025, Table 3). The most commonly used strategy to prevent livestock depredation was to build livestock enclosures (bandas) to protect livestock at night (39.8%, n = 231), followed by the constant guarding of livestock with arrows and spears in the field when grazing (35.5%, n = 231) and using guard dogs in the field and at night (13.9, n = 231). Constant guarding of livestock with arrows and spears in the field when livestock are grazing was the most preferred protection method against depredation by livestock keepers in villages closest to the protected area. Building livestock enclosures (bandas) to protect livestock at night and the use of guard dogs were mostly used in the villages furthest away from the protected area (Table 3).

Table 2. Wild animals responsible for specific livestock depredated

Responsible wild animals	Livestock depredated				
	Cattle	Goats	Sheep	Dogs	Poultry
Spotted hyena	√	√	√	√	√
Leopard	√				
Lion	√				
Wild dog		√			
Small carnivores [x]			√	√	√
Hawks					√

[x] = Small carnivores includes mongoose and jackals and baboons.

3.4 Economic Loss Due to Livestock Depredation

The estimated cost of depredation differed significantly among the villages along the gradient of distance from the protected area (ANOVA; F = 7.724, d.f. = 2, P = 0.001, Table 4). The total estimated mean loss for the surveyed villages caused by livestock depredation was 47,094 Tshs (equivalent to $28.60 USD) per household per year (Table 4). The villages located closest to the protected area reported to have the highest mean estimated loss (71,293 Tshs equivalent to $47.50 USD) per household per year compared to other villages. The villages located far away from the protected area reported to have the lowest estimated loss (29,066 Tshs equivalent to $19.40 USD) per household per year. The total mean number of depredated livestock was one cow, one goat, one dog and one sheep per household per year while the number of poultry was three per household (see Table 5). There were no records of depredated donkeys in the surveyed villages.

Table 3. Preventive measures to reduce livestock depredation in relation to distances from the protected area

Villages		Preventing measures				
		Building of livestock enclosures/ bandas	Guarding livestock with arrows and spears	Guarding with dogs	None	Total
Closest	N	30	38	8	10	86
	%	34.9	44.2	9.3	11.6	100
Medium	N	12	19	7	7	45
	%	26.7	42.2	15.6	15.6	100
Far away	N	50	25	17	8	100
	%	50.0	25.0	17.0	8.0	100

Table 4. Estimated cost of livestock depredation by wild carnivores per household per year

Village of respondent	Estimated cost of livestock depredated (TShs) Mean (SD) N
Closest	71,293.00 (± 10.431) N = 55
Medium	34,090.00 (± 10.000) N = 38
Far away	29,066.00 (± 5.848) N = 46
Total	47,094.00 (± 9.719) N = 139

3.5 Livestock Diseases

Overall, 91% of respondents (n = 385) reported loss because of livestock disease. The frequency of livestock diseases differed significantly among the surveyed villages along the gradient of distance from the park (Pearson's Chi-square: χ^2 = 23.7, d.f. = 2, P < 0.001, Figure 2). The frequency of households that experienced livestock loss due to disease was highest in villages located close to the protected area (Figure 2). Ninety-six percent of respondents (96.2%, n = 385) were reported to treat their livestock to cure them from different diseases.

Table 5. Number of livestock depredated per household per year along the distance from the protected area

Village		Number of livestock depredated				
		Cattle	Goats	Dogs	Sheep	Poultry
Closest	Mean	1.5	1.7	1.3	1.8	3.4
	N	18	19	15	17	65
	SD	0.78	0.87	0.45	1.03	2.82
Medium	Mean	1.0	1.1	1.0	1.0	3.4
	N	3	8	5	1	43
	SD	0.00	0.35	0.00	.	3.46
Far away	Mean	1.1	1.1	1.0	1.2	3.0
	N	8	23	2	19	56
	SD	0.35	0.34	0.00	0.37	1.92
Total	Mean	1.3	1.4	1.2	1.4	3.3
	N	29	50	22	37	164
	SD	0.67	0.66	0.39	0.80	2.74

4. Discussion

4.1 Livestock Depredation

As reported in many other studies (Kangwana, 1995; Kolowski & Holekamp, 2006; Sillero-Zubiri & Laurenson, 2001), the findings of this study suggest that the distance of the villages from the protected area is an important factor in determining the extent of livestock depredation by wild animals. Our results confirm our hypothesis that the closest villages to the protected area experience the highest frequencies of livestock depredation, and by the larger predators, such as lions and leopards. This is because a higher population of large carnivore species are found in the villages located close to the protected area (Holmern, Mkama, Muya, & Røskaft, 2006). Additionally, during the dry season when there is a shortage of pastures in village areas, livestock keepers may graze their herds near or inside protected areas, which will expose livestock to predators.

4.2 Wild Animals Involved in Livestock Depredation

Many other studies in Tanzania (Holmern, Mkama, Muya, & Røskaft, 2006; Ikanda & Packer, 2008; Kissui, 2008; Nyahongo, 2007) have reported that the size of predators determines the size of the prey they depredate. Different wild animals were therefore involved in livestock depredation among the surveyed villages. Spotted hyena was reported to be the most destructive wild animal in all surveyed villages followed by small carnivores, including baboons, which were especially destructive in villages further away from the protected area. Hyenas were reported to be responsible for all types of livestock depredation, from cattle to poultry. Poultry were mainly depredated by small carnivores (mongoose, jackals and baboons), as well as hawks, due to their size and the size of the predators in question.

4.3 Measures Taken by Local Communities for Deterring Crop Raiders

The results indicated that methods used to protect livestock from being depredated by wild animals differed significantly depending on the distance of the village from the protected area. Livestock keepers in villages located close to the protected area preferred constant guarding with arrows and spears during grazing. This may be because livestock keepers closer to the park continue moving with their livestock in pastures and sometimes engage in bushmeat hunting. The building of livestock enclosures (bandas) to protect livestock during the night and the use of guard dogs was mostly preferred in the villages furthest away from the protected area. This observation indicates that livestock keepers in farther villages might have insufficient grazing area similar to those near the protected area who sometimes graze illegally inside the park. Additionally, most local communities in the western Serengeti are agro-pastoralist; therefore, livestock keepers in the farther villages have no alternative grazing areas (especially during the farming season which requires a large portion of grazing land), forcing livestock keepers to graze relatively large numbers of livestock in small portions that are not cultivated.

4.4 Economic Loss

Livestock depredation causes significant economic losses to households in the local communities surrounding the protected area. The total estimated mean loss by livestock depredation is higher compared to that reported in the same region by Nyahongo and Røskaft (2011). However, our study included poultry and domestic dogs which were not considered in Nyahongo and Røskaft's comparative study. The inclusion of poultry and domestic dogs might have elevated the level of predation or the numbers of predators might have increased in the study area. Our data cannot confirm the latter. The villages located closest to the protected area were reported to have the highest loss which may be because closer villages from the protected area have a higher number of large carnivores compared to the villages located farther away from the protected area. This type of livestock loss has a significant economic impact on rural communities (Hazzah, 2006; Ikanda, 2009). Loss of a single domestic animal to wildlife may create serious socio-economic consequences to affected families because livestock act as social capital and a sign of wealth in rural communities.

4.5 Livestock Diseases

Livestock disease was the most important factor responsible for livestock losses in the western Serengeti (Nyahongo & Røskaft, 2011). The highest frequencies of deaths due to diseases were as hypothesised, experienced in villages located closest to the protected area. This may be due to local communities living close to the protected area who illegally graze their livestock inside the park, due to the shortage of pastures and water sources in their areas, especially during dry seasons. Interactions between wild and domestic animals increase the risk of disease transmission (Gortázar, Ferroglio, Höfle, Frölich, & Vicente, 2007). Encroachment of protected area for grazing might result in wildlife habitat degradation. Degradation and fragmentation are the main anthropogenic factors associated with the emergence of diseases in wildlife (Acevedo-Whitehouse & Duffus, 2009; Hudson, Rizzoli, Grenfell, Heesterbeek, & Dobson, 2002).

5. Conclusions and Recommendations

5.1 Conclusions

The results obtained from this study on livestock depredation by wild animals in the Serengeti Ecosystem revealed the following:

Livestock depredation differed significantly among the surveyed villages along the gradient of distance from the park, with the lowest depredation in the farthest village from Serengeti National Park.

The spotted hyena was reported to be the most destructive wild animal in all surveyed villages followed by small carnivores, which were especially destructive in the medium and farthest villages.

Local communities around protected areas use different deterring methods to prevent livestock depredation by wild animals. The most common strategy used to prevent livestock depredation was to build livestock enclosures (bandas) to protect livestock at night, followed by constant guarding of livestock with bows and arrows when grazing in the field.

Livestock depredation causes a significant economic loss in households with villages located closest to the protected area having the highest household economic losses.

Livestock diseases were the main cause of livestock mortality. There were a higher percentage of households that experienced livestock loss due to disease in villages located closest to the protected area.

5.2 Recommendations

To reduce livestock depredation in the study area, conservation stakeholders should support efforts of local communities to improve their bomas. Education to improve livestock husbandry skills is highly recommended. As diseases are reported by the majority of respondents to be the main cause of livestock loss in the area; we recommend that veterinary units be staffed with well-trained personnel, adequate facilities and substantial operational budgets to enable them to provide quality service to control, prevent, or eliminate livestock diseases. Also, not only villagers near protected areas, but also any residents, should be helped by veterinary units. There is a need for a strong and effective collaboration among conservationists, local communities, governments, and health agencies to control these diseases. Finally, we recommend an integrated study on livestock and wildlife diseases and their impact on household economies of local communities.

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Full Length Research Paper

Bushmeat and food security: Species preference of sundried bushmeat in communities in the Serengeti - Mara ecosystem, Tanzania

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Bushmeat is reported to be an important source of animal protein for people's diet and income to rural communities around protected areas. Data for bushmeat preferences among local people bordering Serengeti National Park, Northern Tanzania, were collected through various techniques, including a key informant survey, group discussions, meat taste experiments and questionnaires. Multiple responses were used to test for preferences on different processing methods of sundried bushmeat and reasons for the preference. Independent variables as chewability, smell, taste and appearance were used to test what factors that might influence species preference of sundried bushmeat. The results of this study indicate that sundried bushmeat was most frequently preferred by respondents, followed by boiled and the least preferred meat was smoked bushmeat. Beef was the most preferred sundried meat, followed by sundried impala, and then sundried wildebeest meat. Sundried zebra meat was least preferred among all four of tested meat samples. The distance of the village (in km) from SNP and type of sample specimen tested contributed statistically significantly to explain the variation in bushmeat preferences. We recommend further studies on quality analysis on different processed meat (fresh boiled, sundried and smoked) to check for different nutrients. Finally, based on our results on preference on individual species of sundried meat, sundried beef meat was mostly preferred; therefore we do recommend that communities around protected areas who are livestock keepers should be encouraged to process sundried beef meat during good environmental conditions which can be used as reserve in times of food shortage and periods of famine.

Key words: Sun-dried bushmeat, Serengeti ecosystem, preference rank, processing methods.

INTRODUCTION

Wildlife is a critically important resource, meeting the food and livelihood requirements of human communities in many biodiversity – rich areas of the world (Rao and McGowan, 2002). Bushmeat is reported to be an important source of animal protein for people's diet (Asibey and Child, 1990; FAO, 1997; FAO, 2003; Hofer et al., 1996; Nyahongo, 2007; Robinson and Bennett, 2000), income generation (Barnett, 2000; Bowen-Jones and Pendry, 1999; Geist, 1988; Juste et al., 1995; Kaltenborn et al., 2005; King, 1994; Loibooki et al., 2002; Wilkie and Godoy, 2001), and cultural needs (Nielsen, 2006; Robinson and Bennett, 2000) for local communities in areas surrounding protected areas in many African countries. Some studies have suggested that the contribution of bushmeat may be an important factor in poverty reduction in rural areas (Hoyt, 2004; Loibooki et al., 2002; Nyahongo et al., 2005; Wilkie et al., 2005). The sale of bushmeat can provide a large proportion of incomes in rural areas. A study in rural Gabon reported for example

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that hunting accounted for 15 to 72% of household incomes, with the proportion increasing for more remote communities (Starkey, 2004). Bushmeat is cheaper than domestic meat in rural areas, so it is particularly accessible to poor households (TRAFFIC, 1998). In addition to being a highly preferred food item in many areas of Africa, wild animal foods are life-saving reserves in times of food shortage and hunger (FAO, 1997).

Hunters have a variety of methods for the extraction of bushmeat from the wild which include trapping, snaring, netting, use of dogs and shooting (Bowen - Jones et al., 2003; Fa et al., 2002; Noss, 1998; Wilkie and Godoy, 2001). Bushmeat in Africa include ungulates such as forest antelopes, known as duikers (Noss, 2000; Robinson and Bennett, 2000); reptiles and large bodied birds (Hennessey, 1995); smaller bodied mammals, such as porcupines (*Erethizon dorsatum*) and cane rats (*Thryonomys swinderianus*) (Juste et al., 1995); and primates (Khatun, 2010). In West and Central Africa, bushmeat primates include monkeys and chimpanzees (*Pan troglodytes*) (Willcox and Nambu, 2007), Yellow baboons (*Papio cynocephalus*) and Black and white colobus monkey (*Colobus quereza*) (Chapman et al., 2006; FitzGibbon et al., 1996) and endangered mountain gorillas (*Gorilla beringei beringei*) (Grevengoed, 2001). Primates in West and Central Africa are reported to account for between a tenth and a quarter of all bushmeat harvested (Bowen-Jones and Pendry, 1999).

In Tanzania, local communities surrounding protected areas including the Western Serengeti, like many other poor African communities, are relying on bushmeat hunting as important activities for food security and income generation (Holmern et al., 2004; Kaltenborn et al., 2005; Loibooki et al., 2002). Traders may earn between 300 and 500 USD per months and about 66 % of the human population in Tanzania prefers bushmeat protein (Damalu, 2011). In the Serengeti Mara Ecosystem the hunters use dried meat for home consumption, sale to generate income, or bartering with other commodities (Hofer et al., 2000; Kaltenborn et al., 2005; Kideghesho et al., 2007; Loibooki et al., 2002; Mfunda and Røskaft, 2010). About 82% of the communities around Serengeti National Park consume bushmmeat and 32% are engaged in bushmeat hunting (Loibooki et al., 2002). Bushmeat is cheaper than livestock meat and therefore consumed more frequently than livestock meat (Ndibalema and Songorwa, 2007). Also, in other ecosystems like Katavi (Andimile and Eves, 2009) and Udzungwa Mountainous (Nielsen, 2006; Rovero et al., 2010) bushmeat is reported to play a significant role in the livelihood of the rural communities surrounding protected areas.

Generally, many species of wild animals are utilized for bushmeat and species selection within particular areas depends largely on location, habitat type and availability of species in the local markets (Barnett, 2000; Hoyt, 2004). Sun-dried bushmeat is known for its distinct taste, aroma, and nutritive value, and it is generally safe for consumption because it retains little or no fat as it undergoes the heating process (FAO, 1997). According to Nyahongo (2007), in Western Serengeti, communities living far away from SNP preferred beef, while people from villages close to national park boundary prefer topi and those in the intermediate villages prefer impala, which might be linked to experience and accessibility. Bushmeat trade is driven by cultural proclivity. It is traditionally cuisine, and familiarity perpetuates the preference for it (Wilkie et al., 2006). Bushmeat is reported to provide trophies for cultural artefacts and medicinal values (Kaltenborn et al., 2005; Kideghesho, 2008; Mockrin et al., 2005; Robinson and Bennett, 2000; Wilkie and Carpenter, 1999; Wilkie et al., 2005) and it contains certain properties that are not found in domesticated animals (Peggy et al., 2009). They claim that ingesting bushmeat, especially primate bushmeat, makes one feel stronger and more vigorous (Dresden, 2004).

There is evidence that different tribes prefer certain bushmeat species (Fa et al., 2002; Mfunda and Røskaft, 2010; Ndibalema and Songorwa, 2007). Its consumption in urban areas connotes devoted social economic status (Bowen - Jones et al., 2003; Wilkie and Carpenter, 1999). One such eating establishment in Nairobi is descriptively named “The Carnival” (Dresden, 2004). This commodity trade chain of bushmeat extends beyond Africa to Europe and the United States (Brown, 2006). Understanding why people eat bushmeat and the role that bushmeat consumption plays in household nutrition and income, is critical to developing politically acceptable ways to manage wildlife hunting and trading and halt unsustainable exploitation (Schenck et al., 2006). Also, understanding on the species preference on bushmeat is vital towards sustainable utilization of wildlife resources.

The aim of this study was to investigate the bushmeat preference in villages along a gradient of distance from the Serengeti National Park. We hypothesize that sun-dried bushmeat is preferred over boiled fresh bushmeat because this is the most common and most sustainable method of bushmeat processing. Furthermore, we hypothesized that sundried bushmeat was more preferred than sundried beef meat (in terms of smell, taste chewability and appearance) as sundried bushmeat is commonly used in an area.

MATERIALS AND METHODS

Study area

The Serengeti Ecosystem covers an area of 25,000 km^2 on the border of Tanzania and Kenya (Figure 1), and is defined by the movement of wildebeest (Homewood et al., 2001; Nelson, 2009). The eastern boundary is formed by the crater highlands and the rift valley. An arm called the Western Corridor stretches west to Lake Victoria. The northern boundary is formed by the Isuria Escarpments and Loita Plains in Kenya (Marealle et al., 2010). Serengeti Ecosystem is situated between latitudes 1° 28’ and 3° 17’ S and longitudes 33° 50’ and 35° 20’ E (Kideghesho, 2006). In the Western Corridor of the Serengeti National Park, illegal hunting

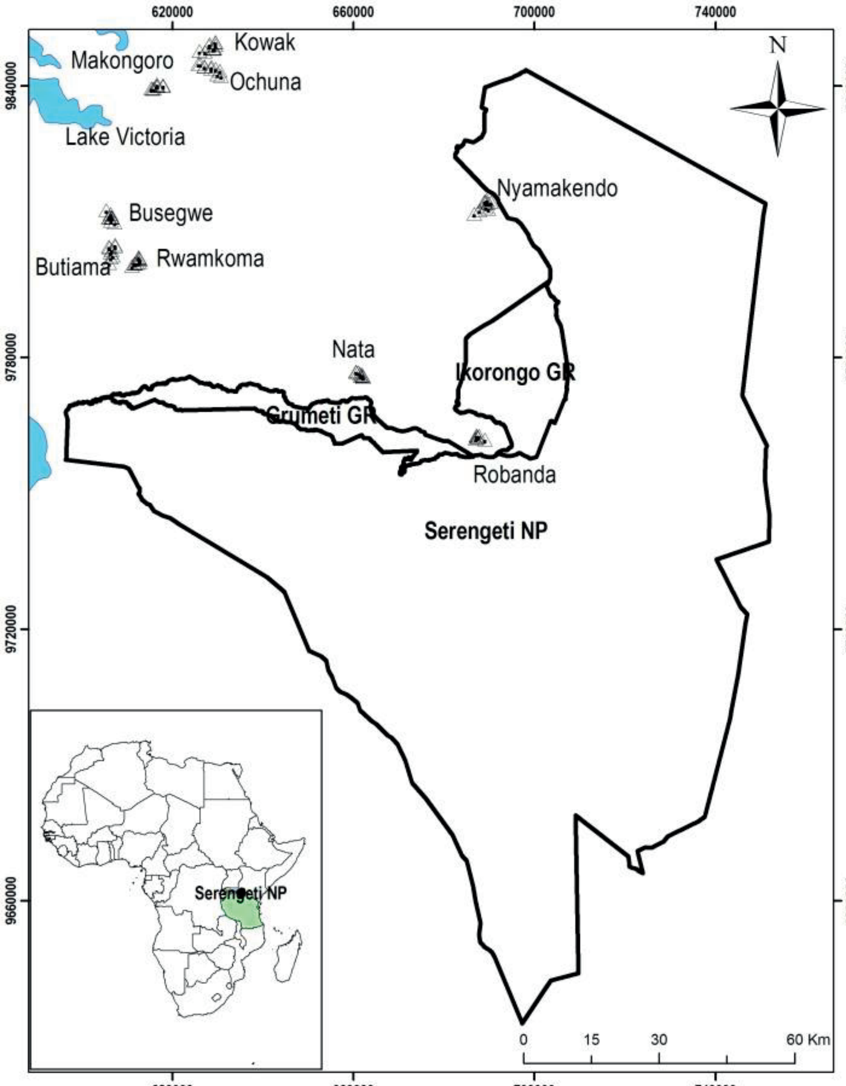

Figure 1. Map of study area showing Serengeti National Park, Grumeti and Ikorongo Game Reserves, Lake Victoria and the surveyed villages (Robanda, Nyamakendo, Nattambisso ,Butiama, Busegwe, Rwamkoma,Ochuna, Makongos and Kowak).

has been highest around densely populated areas (Holmern et al., 2002; Loibooki et al., 2002). Local communities in Serengeti are not allowed to hunt and there is no open market for wild meat (Ndibalema and Songorwa, 2007). But IUCN (1998), reported that the utilization of bushmeat was found to represent the largest economic value of wildlife, far exceeding legalized hunting, tourism or trophy values in Tanzania. Increased human populations, expansion of agricultural areas, illegal hunting and excessive trophy hunting have been identified as major threats to sustainable conservation (Bohne, 2008). The human population in the area is estimated to be over two million (URT, 2002a). The area is diverse in terms of ethnicity with over 20 tribes, the major tribes being Ikoma, Sukuma, Kurya, Ikizu, Natta, Isenye, Zanaki, Zizaki, Ngoreme, Luo, Taturu and Jita (URT, 2002b). The major livelihood strategies pursued by these tribes are cultivation (largely maize, cassava, millet and sorghum for food and cotton for cash) and livestock husbandry (cattle, goats and sheep). Although most people are subsistence farmers, there are some ethnic differences in economic activities that include fishing, livestock rearing, game meat hunting, and trading (Loibooki, 1997; Loibooki et al., 2002)

The Western part of Serengeti - the focus of this study - is ecologically significant as a buffer zone for Serengeti National Park (SNP) and a corridor for wildlife species migrating between Serengeti and Maasai Mara in Kenya. These species include some 1.4 million wildebeest, 0.2 million zebra, and 0.7 million Thompson's gazelle (Norton-Griffiths, 1995). The seasonal availability of herbivores due to animal migration affects bushmeat prices that are almost halved when the wildebeest migration arrives in village areas (Holmern et al., 2002). Much of the meat is then preserved in a form of pieces (swahili: 'kimoro'- sundried bushmeat) that permits storage and trading in markets locally or far away from the sources (Kaltenborn et al., 2005). In the Serengeti ecosystem the common large herbivore species usually utilized for bushmeat include wildebeest (*Connochaetes taurinus*), Cape buffalo (*Syncerus caffer*), impala (*Aepyceros melampus*), zebra (*Equus burchelli*), eland (*Tragelaphus orxy*), Thomson gazelle (*Gazella thomsonii*), Grant gazelle (*G. granti*) and giraffe (*Giraffa camelopardalis*). Other species include topi (*Damaliscus korrigum*), kongoni (*Alcelaphus buselaphus*), warthog (*Phacochoerus aethiopicus*), waterbuck (*Kobus ellipsiprymnus*), bush buck (*Tragelaphus scriptus*) and ostrich (*Struthio camelus*) (Campbell and Hofer, 1995; Hofer et al., 1996; Holmern et al., 2004; Mduma et al., 1998). An estimates of the number of hunted wildebeest vary annually from 40,000 (Mduma, 1996) to 118,000 animals (Campbell and Hofer, 1995).

Data collection techniques

The data were collected throughout the year from January 2010 to January, 2011. Sampling included nine selected villages along a gradient of distance from the park. The selection was done in such a way that three villages were located within 10 km distance from the protected area (Robanda, Nyamakendo and Nattambisso - closest) and the other six villages, three for each distance within 40 km (Butiama, Busegwe and Rwamkoma - intermediate) and 80 km from the protected area (Ochuna, Makongos and Kowak – far away). Data for the bushmeat preferences were collected through different techniques including; key informant survey, group discussions, meat taste experiments and questionnaires. The questionnaire interviews were conducted from January to December, 2010 and covered a total of 459 households who were randomly selected from the village and sub-village registers for interview. We interviewed household heads or their wives or resident adults (≥ 18 years old). The villages and sub-villages were picked based on a random-systematic selection. In terms of gender 36.2% of the interviewed respondents were females and 63.8% were males for a questionnaire survey and 46.7% of the respondents were females and 53.3% were males for meat test experiments, reflecting a gender consideration but not balanced. The data were collected by the main researcher, a research assistant, and field assistants conversant with the village and households, languages, and culture. The questions were both close-ended and open-ended aimed at extracting the respondent's opinion in an open minded atmosphere. The questionnaire addressed socio-demographic variables, bushmeat utilization, type of processed meat preferred mostly (fresh boiled, sundried and smoky dried) and wild animal species preferred mostly for the bushmeat in the area. Also, wild animal species preferred mostly from the list of four animals (topi, wildebeest, impala and zebra) based on different processing methods.. Meat taste experiments were done in January, 2011 in three villages randomly selected from the nine above described villages (Mwakatobe et al., submitted). Meat from three wild animal species (wildebeest, impala and zebra) and cattle (used as a control) were first sundried, then chopped into approximately the same sized small pieces and cooked using the same recipe for subsequent human taste. Meat taste experiment was done by using sundried meat only. The selection of wild animals species used in the questionnaire and meat taste experiment based on the list of mostly preferred wild animals for bushmeat in an area reported by different authors and animals which were accessible through quota for legal hunting (Campbell and Hofer, 1995; Hofer et al., 1996; Holmern et al., 2004; Mduma et al., 1998). Beef meat was used as the commonly consumed domestic alternative protein source (Nyahongo, 2007). A number of people of different age, sex and tribes were invited to taste the meat. In case of tribes, recorded tribes were grouped into two; hunter tribes (Ikoma and Zanaki) and non-hunters tribes (Sukuma, Nyaturu, Luo, Kurya, Jita) for analysis. Hunter tribes can be defined as communities that rely primarily on hunting wild animals (bushmeat) for their dietary protein. Each respondent was asked to rank by using number 1 to 4 his/her preference on whose meat was tasted (1) Prefer most, (2) Prefer (3) Moderately prefer and (4) Do not prefer. Also, animal species tested were evaluated by using hedonic factors namely appearance, smell, taste, marbling and chewability to find out if might have impacts on sundried meat preferences. We recorded the responses from the taste persons in data sheets for subsequent analyses. In the meat taste experiments, a total of 225 persons were randomly given pieces of sundried and cooked sundried bushmeat of wildebeest, impala, zebra and beef to taste and identify the species which resulted in 900 tested cases (Mwakatobe et al., submitted).

Statistical analyses

Statistical analyses were conducted using Statistical Package for Social Sciences (SPSS, 17). Multiple responses were used to test for preferences of local communities around protected areas on different processing methods of sundried bushmeat and reasons for the preference. Chi-square tests were applied to tests for the differences in the independent variables: chewability, smell, taste, marbling and appearance if might influences species preference of sundried bushmeat. Also, correlation coefficients were used to test the relationship between the same independent variables.

RESULTS

Bushmeat preference based on processing methods

Generally, the majority of respondents (84.8%, n = 459) claimed to have tasted bushmeat before and were aware of bushmeat (86.9%, n = 459). Sundried bushmeat was most frequently preferred by the respondents (49.5%, n = 459), followed by boiled (37.2%, n = 459), and smoked bushmeat (13.3%, n = 459) - (Table 1). The main reason for the preference of sundried bushmeat according to respondents was good taste, easy accessibility, chewability, good smell, not oily, and easy to cook (Table 2).

Preference on individual species of sundried meat

Respondents mostly showed a general tendency of preference for sundried beef meat over other sundried bushmeat in terms of chewability (Pearson Chi-Square; χ^2 = 64.4, df = 12, n = 897, P < 0.001, Table 3), smell (Pearson Chi-Square; χ^2 = 98.6, df = 12, n = 899, P < 0.001, Table3), and taste (Pearson Chi-Square; χ^2 =

Table 1. Percentages of various processing methods of bushmeat the questionnaire respondent's preferred (only 366 out of 459 respondents).

Village	Processing methods of bushmeat			Total
	N (%)			
	Fresh	Sundried	Smoked meat	
Robanda (within 10 km from PA)	29 (64.4)	13 (28.9)	3 (6.7)	45 100
Nattambisso (within 10 km from PA)	21 (42.9)	28 (57.1)	0 (0)	49 (100)
Nyamakendo (within 10 km from PA)	9 (27.3)	19 (57.6)	5 (15.1)	33 (100)
Butiama (within 40 km from PA)	25 (73.5)	6 (17.7)	3 (8.8)	34 (100)
Busegwe (within 40 km from PA)	11 (33.3)	18 (54.6)	4 (12.1)	33 (100)
Rwamkoma (within 40 km from PA)	9 (25.0)	21 (58.3)	6 (16.7)	36 (100)
Makongos (within 80 km from PA)	14 (34.2)	16 (39.0)	11 (26.8)	41 (100)
Kowak (within 80 km from PA)	15 (31.9)	20 (42.6)	12 (25.5)	47 (100)
Ochuna (within 80 km from PA)	3 (6.3)	40 (83.3)	5 (10.4)	48 (100)
Total	**136 (37.2)**	**181 (49.5)**	**49 (13.3)**	**366 (100)**

Table 2. Reasons for preferred sundried bushmeat process.

Reasons for preference	N	% total	Ranking
Good taste	443	65.1	1
Easy accessibility	130	19.1	2
Chewability	64	9.4	3
Good smell	18	2.6	4
Not oily	17	2.5	5
Easy to cook	8	1.2	6
Total	**680**	**100**	

The overall number of respondent exceeded 459 the total number of respondents due to multiple responses.

Table 3. Species preferences of sundried meat based on sensory evaluation.

Hedonic taste factor	Species of Sundried meat	Ranking of preferences of sundried meat N (%)				
		Prefer very much	Prefer	Moderately prefer	Do not prefer	Total
Chewability	Wildebeest	75 (34.4)	101 (46.3)	31 (14.2)	11 (5.0)	218 (100)
	Impala	90 (38.7)	103 (44.4)	34 (14.7)	5 (2.2)	232 (100)
	Zebra	63 (33.5)	86 (45.7)	34 (18.1)	5 (2.7)	188 (100)
	Beef	91 (41.9)	101 (46.5)	19 (8.8)	6 (2.8)	217 (100)
Smell	Wildebeest	91 (41.0)	91 (41.0)	36 (16.2)	4 (1.8)	222 (100)
	Impala	99 (42.6)	96 (41.6)	24 (10.8)	12 (5.2)	231 (100)
	Zebra	66 (31.9)	83 (40.1)	31 (15)	27 (13.0)	207 (100)
	Beef	115 (52.8)	86 (39.4)	13 (6.0)	4 (1.8)	218 (100)
Taste	Wildebeest	87 (39)	105 (47.1)	25 (11.2)	6 (2.7)	223 (100)
	Impala	93 (40.1)	104 (44.8)	29 (12.5)	6 (2.6)	232 (100)
	Zebra	57 (27.5)	95 (45.9)	36 (17.4)	19 (9.2)	207 (100)
	Beef	108 (49.5)	92 (42.2)	17 (7.8)	1 (0.5)	218 (100)

Table 3. Contd.

Appearance	Wildebeest	98 (46.7)	80 (38.1)	24 (11.4)	8 (3.8)	210 (100)
	Impala	113 (51.1)	74 (33.5)	24 (10.9)	10 (4.5)	221 (100)
	Zebra	78 (39.4)	65 (33.0)	35 (17.7)	20 (10.1)	198 (100)
	Beef	107 (51.2)	84 (40.2(	14 (6.7)	4 (1.9)	209 (100)

The overall number of respondent exceeded 459 the total number of respondents due to multiple responses.

92.2, df = 12, n = 900, P < 0.001, Table 3). However, appearance (Pearson Chi-Square; χ^2 = 44.7, df = 12, n = 897, P < 0.001, Table 3) was different, here beef ranked second after sundried impala meat. All over, beef was the most preferred sundried meat, followed by sundried impala and then sundried wildebeest meat. Sundried zebra meat was least preferred among all four sample of meats tested.

The correlation coefficients between hedonic evaluation factors (appearance, smell, taste, marbling and chewability) of the panel who tested sundried bushmeat were highly significant (all P < 0.01; Table 4). Thus, the same person tended to prefer the different taste methods with same frequencies. In the further analyses, therefore, we averaged preferences on hedonic evaluation factors tested.

There was a statistically significant difference in how respondents liked different bushmeat by their mean score beef being the most preferred (beef, Mean = 1.7, ± SD = 0.536; impala, Mean = 1.8, ± SD = 0.644; wildebeest; Mean = 1.9, ± SD = 0.632; and zebra, Mean = 2.1, ± SD = 0.752) (F = 15.1, P < 0.001).

When questionnaire respondents were asked on meat preferences of four animal species (Topi, wildebeest, impala and zebra) processed differently from three distances categories meat preferences differed significantly (sundried meat - Pearson Chi-square: χ^2 = 1.1, P < 0.001; boiled meat - Pearson Chi-square: χ^2 = 1.1, P < 0.001; smoky meat - Pearson Chi-square: χ^2 = 62.2, P < 0.001; Table 5). Sundried bushmeat of wildebeest was mostly preferred in close and intermediate village categories while sundried bushmeat of impala was mostly preferred in far away villages. In case of boiled and smoky bushmeat, wildebeest meat was mostly preferred in closes villages only and impala bushmeat was mostly preferred in intermediate and away villages. Also, when asked which kind of sundried bushmeat generally they preferred they responded that they mostly preferred sundried bushmeat of wildebeest followed by impala, zebra and rabbit (*Syvilagus palustris)*. Other preferred sundried bushmeat were buffalo, klipspringer (*Oreotragus oreotragus)*, eland, hippopotamus (*Hippopotamus amphibius*), hartebeest *(Alcelaphus buselaphus),* elephant *(Loxodanta africana)* and topi (Table 6).

Factors affecting preference of sundried meat

There was a significant (F = 14.8, P < 0.001) difference in average mean scores of bushmeat preference between hunter tribes (Mean = 1.9, ± SD = 0. 627) and non- hunter tribes (Mean = 1.8, ± SD = 0.696), as well as the distance of the villages from SNP (F = 15.9, P < 0.001); Busegwe (Mean = 2.0, ± SD = 0.639), Robanda (Mean = 1.9, ± SD = 0.587) and Ochuna (Mean = 1.7, ± SD = 0.714). Other demographic variables as gender and age classes did not influence the preference significantly (males; Mean = 1.9, ± SD = 0.653; females; Mean = 1.8 ± SD = 0.665; F = 3.2, p =

Table 4. Correlation coefficients (in percentages) between hedonic evaluation factors at Spearman's rho tests; (all P < 0.01).

Hedonic evaluation factor	Appearance	Smell	Taste	Marbling	Chewability
	Correlation coefficient (n)				
Appearance	1.000 (838)	0.637 (836)	0.567 (838)	0.393 (837)	0.478 (833)
Smell	- -	1.000 (878)	0.638 (878)	0.401 (873)	0.444 (870)
Taste	- -	- -	1.000 (880)	0.442 (875)	0.58.2 (872)
Marbling	- -	- -	- -	1.000 (875)	0.438 (867)
Chewability	- -	- -	- -	- -	1.000 (872)

Table 5. Meat preferences of four animal species processed differently by the members from three distances categories.

Animal species / Village	Topi	Wildebeest	Impala	Zebra	Total	Pearson Chi- Square
	N (%)					
Closest villages	31 (25.2)	40 (32.5)	18 (14.6)	34 (27.6)	123 (100)	
Intermediate villages	3 (3.0)	43 (43.4)	41 (41.4)	12 (12.5)	99 (100)	χ^2 = 1.1, p < 0.001
Far away villages	8 (6.0)	40 (26.9)	53 (39.5)	34 (25.5)	135 (100)	
Closest villages	37 (28.9)	39 (30.5)	37 (28.9)	15 (11.7)	128 (100)	
Intermediate villages	4 (4.1)	29 (29.9)	52 (53.9)	12 (12.4)	97 (100)	χ^2 = 1.1, p < 0.001
Far away villages	6 (4.5)	43 (32.1)	62 (46.3)	23 (17.2)	134 (100)	
Closest villages	28 (25)	33 (29.5)	32 (28.6)	19 (17)	112 (100)	
Intermediate villages	8 (9.2)	27 (31.0)	40 (46)	12 (14.3)	87 (100)	χ^2 = 62.2, p < 0.001
Far away villages	10 (7.4)	40 (29.4)	61 (45.1)	25 (18.4)	136 (100)	

Table 6. Ranking of species by respondent based on preference.

Most preferred species' sundried meat	N	%	Ranking
Wildebeest *(Connochaetus taurinus)*	228	26.6	1
Impala *(Aepyceros melampus)*	205	23.9	2
Zebra *(Equus burchelli)*	111	13.0	3
Rabbit (*Syvilagus palustris)*	79	9.2	4
Buffalo *(Syncerus caffer)*	73	8.5	5
Topi (*Damaliscus korrigum)*	55	6.4	6
Klipsringer *(Oreotragus oreotragus)*	42	4.9	7
Eland *(Taurotragus oryx)*	22	2.5	8
Hippopotamus (*Hippopotamus amphibius*)	20	2.3	9
Hartebeest *(Alcelaphus buselaphus)*	17	2.0	10
Elephant *(Loxodanta africana)*	4	0.5	11
Total	**856**	**100**	

The overall number of respondent exceeded 459 the total number of respondents because of multiple responses.

Table 7. Linear regression Coefficients with the general taste of sundried meat as dependent variable with Village, sample specimen, gender, age class and tribes as independent variables.

Model		Unstandardized coefficient		Standardized coefficients	t	P
		B	Std. error	Beta		
1	(Constant)	2.288	.108		21.104	.000
	Village	-.156	.040	-.193	-3.884	.000
	Sample specimen	-.040	.020	-.068	-2.048	.041
	Gender	.015	.048	.012	.321	.748
	Age class	-.016	.024	-.022	-.666	.505
	Tribe groups	.006	.066	.004	.091	.927

0.072; age classes; < 20 years; Mean = 1.9, ± SD = 0.618; 21 – 40 years; Mean = 1.9, ± SD 0 =713; 41 -60 years Mean = 1.9, ± SD = 0.652, and > 60 years; Mean = 1.8, ± SD = 0.580; F = 0.4, P = 0.737).

A linear regression coefficient analysis indicated that both the distance of the village from SNP (t = -3.884, p < 0.001) and type of sample specimen (t = -2.048, p = 0.041) tested as independent variables, contributed statistically significantly to the amount of variation in bushmeat preferences. However, other independent variables as gender, age class and tribe (Table 7) did not contribute significantly to the variation in average bush meat preference (Table 7).

In case of preferences on the sample specimen of sundried meat (type of sundried meat tested) the same trend was observed as above. There was a significant (F = 16.3, P < 0.001) amount of variation in average mean scores between hunter tribes (Mean = 2.0, ± SD = 0. 597) and non- hunter tribes (Mean = 1.7, ± SD = 0.633); as well as the distance of the villages from SNP (Busegwe; Mean = 2.1, ± SD = 0.633; Robanda; Mean = 1.9, ± SD = 0.538, and Ochuna; Mean = 1.7, ± SD = 0.638; F = 11.1, p < 0.001). The differences between demographic variables such as gender and age classes were very small and insignificant (males, Mean = 2.9, ± SD = 0.619; female, Mean = 1.8, ± SD = 0.634; F = 5.0, P = 0.260; age classes; < 20 years; Mean = 1.9, ± SD = 0.0.625, 21 – 40 years; Mean = 1.9, ± SD = 0.705; 41 -60 years Mean = 1.9, ± SD = 0.576, and > 60 years ; Mean = 1.7, ± SD = 0.424;. F = 0.596, P = 0.618).

DISCUSSION

Preference of bushmeat based on processing methods

Our results suggest that sundried bushmeat was most frequently preferred by respondents followed by boiled bushmeat while smoked bushmeat was the least preferred type of bushmeat. The reasons for the preference of sundried bushmeat are in line with the findings of other authors. It is cheaper than domestic meat in rural areas, so it is particularly accessible to poor households (Loibooki, 1997). It is .used as life-saving reserves in times of food shortage and hunger (FAO, 1997; Hofer et al., 2000; Kaltenborn et al., 2005;

Kideghesho et al., 2007; Loibooki et al., 2002; Mfunda and Røskaft, 2010). Also, hunters prefer the sundried meat in the bush due to the fact that in the tropical countries sun is usually available. Dried meat can be easier transported from protected areas which are usually far from the villages and accessible in the distant villages. On other hand boiled or smoked meat requires the hunters to take the fresh meat to villages which is costly and will not go far before the meat rot. Finally, it has distinct taste and aroma, and it retains little or no fat (FAO, 1997). According to Holmern et al. (2002), its' availability depends mainly on animal migrations, which necessitate preservation of enough meat for sale and for consumption in times of hunger. Sundried bushmeat can be stored and traded in the local markets or far away from the sources (Kaltenborn et al., 2005).

Preference on individual species of sundried meat

Our overall results show that respondents preferred sundried beef meat over different sundried bushmeat in terms of chewability, smell, and taste. All over, beef was the most preferred sundried meat, followed by sundried impala and then sundried wildebeest meat. Sundried zebra meat was least preferred among all four samples of meat tested. This result is slightly similar to that reported by Nyahongo (2007), overall preference rank in the two-species comparisons was beef, closely followed by topi and impala. Zebra and wildebeest were the least preferred species. This indicates that sundried beef meat has a highly preferred quality in rural communities but accessibility might be a limiting factor. Therefore, our results indicate that local communities have long term experience with beef as it is commonly used as alternative source of protein during the non-hunting season. Also, results from questionnaire respondents indicated that meat preferences of four animal species (Topi, wildebeest, impala and zebra) processed differently from three distances categories meat preferences differed significantly. This indicated that bushmeat preferences of animal species depend on availability of an animal species as sundried, boiled and smoky impala bushmeat was mostly preferred in far way villages. This result agreed with the report of other authors that species of wild animals utilized for bushmeat within particular areas depends largely on availability of species in the local markets (Barnett, 2000; Hoyt, 2004).

Factors affecting preference on sundried meat

The present results show that in the Western Serengeti the distance of the village from SNP and the type of sample specimen were significant contributors towards bushmeat preferences. Similar findings have been previously reported elsewhere by other scientists (Barnett, 2000; Hoyt, 2004; Nyahongo, 2007). Species of wild animals utilized for bushmeat and species selection within particular areas depends largely on location, habitat type and availability of species in the local markets. According to Holmern et al. (2002), bushmeat availability depends mainly on animal migrations, which necessitate preservation of enough meat for sale and for consumption in times of hunger. This indicates that availability of animal species in the market is the major factor for bushmeat species preference. Independent variables as gender, age class and tribe did not contribute significantly to the variation in average bush meat preference. Our results are contrary with findings of other authors who have found that preferences on bushmeat species also varies with differences in tribes' cultures (Fa et al., 2002; Mfunda and Røskaft, 2010; Ndibalema and Songorwa, 2007); and gender (Nyahongo, 2007).

Conclusion

(i) Sundried bushmeat was most frequently preferred by respondents, followed by boiled and the least preferred meat was smoked bushmeat.
(ii) Beef was the most preferred sundried meat, followed by sundried impala and then sundried wildebeest meat. Sundried zebra meat was least preferred among all four sample of meat tested.
(iii) The distance of the village from SNP and type of sample specimen tested contributed statistically significantly to bushmeat preferences.

RECOMMENDATIONS

We recommend further studies on quality analysis on different processed meat (fresh boiled, sundried and smoked) to check for different nutrients. Also, based on above results on preference on individual species of sundried meat, sundried beef meat was mostly preferred; therefore we do recommend that communities around protected areas who are livestock keepers should be encouraged to process sundried beef meat during good environmental conditions which can be used as reserve in times of food shortage and hunger period. This will help to reduce pressure on illegal bushmeat hunting hence sustainable utilization of wildlife resources. Also, conservation awareness campaigns should not concentrate only to villages which are close to protected areas as far villages serves as market place for bushmeat and they utilize locally available animal species illegally.

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Paper IV

Species identification through the taste of sun-dried bushmeat by local communities near the Serengeti Ecosystem, Tanzania

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Abstract

Species identification is essential in monitoring of the illegal bushmeat trade. Bushmeat species were identified using various techniques, including a key informant survey, meat tasting experiments and questionnaires. Sun-dried and cooked meat samples were offered, and each respondent was asked to identify the species. Spearman's rho was used to measure the linear relationship between the frequencies of identification of dried versus cooked meat. Kruskal–Wallis, linear regression and ANOVA tests were applied to evaluate the differences in the independent variables (village, gender and age of respondents) that might influence species identification. The results of this study indicate that communities near the Serengeti ecosystem have rich and useful indigenous knowledge on the identification of bushmeat. The correlation between the numbers of recognised items of those who recognise dried meat and cooked meat was statistically significant. The distance of the village from the protected area and age group are the most important factors in the recognition of sun-dried and cooked meat. The identification of individual meat specimens differed significantly among the four species offered in the sun-dried meat taste test. We recommend supporting the communities around protected areas with projects to supplement bushmeat protein with poultry or livestock as well as aquaculture to reduce the pressure on wild animals. Lastly, we recommend further study of the features that members of local communities use to identify animal species and find ways to incorporate them in monitoring the illegal bushmeat trade.

Keywords; Sun-dried bushmeat, Serengeti ecosystem, meat taste, species identification

Introduction

Bushmeat is an important source of animal protein for local people in the regions surrounding protected areas in many African counties (Hofer *et al.,* 1996; FAO, 1997; Nyahongo *et al.,* 2007). In Congo Basin, Koppert *et al.* (1996) estimated that in rural communities 30 – 80% of protein, and almost all of the animal protein, is provided from bushmeat. Likewise, in West African countries, bushmeat is preferred by most people and usually commands a higher retail value than domestic meat in urban markets (FAO, 1997). Bennett & Robin (2000) estimated that bushmeat provides more than 50% of the dietary protein for many African tropical forest people. Furthermore, Asibey & Child (1990) reported that bushmeat contributes up to 84% of all dietary protein in some areas in Nigeria; bushmeat also accounts for 70% and 60% of all dietary protein in Liberia and Botswana, respectively. Bushmeat provides meat for families; as source of income, it is also a common component of household economy, especially in sub-Saharan Africa (Geist, 1988; King, 1994; Juste *et al.,* 1995; Hofer *et al.,* 2000; Loibooki *et al.,* 2002; Kaltenborn *et al.,* 2005). In addition, bushmeat is cheaper than meat from domesticated animals in rural areas that are adjacent to protected areas. It is thus affordable for household consumption by the poor people in such communities (Barnett, 2000). Although bushmeat is a highly preferred food item in many countries in sub-Saharan Africa, wild animal foods are also life-saving reserves in times of food shortage, especially during long periods of drought and low crop yields (FAO, 1997; Holmern *et al.,* 2002).

In many African countries, hunting activities are traditionally undertaken mostly by men (Arcese *et al.,* 1995; Hofer *et al.,* 1996; Fa *et al.,* 2006; Coad, 2007; Wright & Priston, 2010). Women are also actively involved in the bushmeat trade, but as wholesalers and retailers, and not as hunters (Loibooki *et al.,* 2002; Mendelson *et al.,* 2003; Solly 2004). The sale of bushmeat can provide a large proportion of the incomes in rural areas; a recent study in rural Gabon reported that hunting accounted for 15% to 72% of household income, with the proportion increasing for more remote communities (Starkey, 2004). In addition, some women reported acting as porters, transporting sun-dried meat from hunting camps to local villages (Loibooki, *et al.,* 2002). The majority of individuals engaged in bushmeat hunting are adults. In Dja Reserve, Cameroon, for example, the ages of hunters ranged from 15 to 65, with a majority between 31 and 35 years of age (Solly, 2004); the hunters' age range in Lebialem Division, Cameroon, was 30 to 52 years old (Wright & Priston, 2010). A study in Gabon found similar numbers (16 to 65 years old in Dibouka and Kouagna) (Coad, 2007).

In Tanzania, bushmeat is becoming increasingly important for maintaining the standards of living, both as a protein source and as a source of cash income (Barnett 2000). In the Serengeti ecosystem (SE), hunters use dried meat for home consumption, for sale to generate income, and for bartering for other commodities (Hofer *et al.,* 2000; Loibooki *et al.,* 2002; Kaltenborn *et al.,* 2005). In the SE in Tanzania, for instance, statistical analysis revealed estimated revenue of USD 50 million from illegal trade of bushmeat in 1998. This revenue sustained the lives of approximately 66% of the local people and accounts for twice the amount earned by the formal tourism industry (TRAFFIC, 2000). According to Loibooki *et al.,* (2002), approximately 82% of the communities around Serengeti National Park (SNP) consume bushmeat, and 32% engage in bushmeat hunting. In the Katavi ecosystem (Western Tanzania), more than 70% of households reported hunting wildlife for cash, whereas less than 10% reported hunting for food while an estimated 20% of people hunt wildlife for both cash and food (Andimile & Eves, 2009). Approximately 35% of local families in the Udzungwa Mountain ecosystem (Central Tanzania) use bushmeat as a supplement to their diets, and 15% use it as an important source of food (Rovero *et al.,* 2010). In addition, it was reported that bushmeat was consumed in an average of 22% of the meat-containing meals of the respondent hunters in Udzungwa (Nielsen, 2001).

Bushmeat can be eaten fresh boiled, smoked, salted or sun-dried. Sun-dried bushmeat is known for its distinct taste, aroma, and nutritive value, and it is generally safe for consumption because it retains little or no fat as it undergoes the heating process (FAO, 1997). Its availability in the western Serengeti depends on herbivore migrations, which necessitate preservation of enough meat for sale and for consumption in times of hunger. The migration of herbivores is frequently driven by rainfall, which determines the availability of green grass, drinking water (Maddock, 1979; Fryxell *et al.,* 1988) and specific nutrients (Murray 1995). In the Serengeti, the seasonal availability of wild herbivores near the villages has also been reported to affect bushmeat prices; for example, these prices are almost halved when the wildebeest *(Connochaetus taurinus)* migration arrives near the villages surrounding SNP (Holmern *et al.,* 2002). Subsistence hunting around SNP is focused on the large and numerous ungulates (Arcese *et al.,* 1995), especially wildebeest and various species of gazelle. Other prey species include zebra *(Equus burchellii),* impala *(Aepycerous melampus)*, topi (*Damaliscus lunatus)*, warthog (*Phacochoerus africanus)*, reedbuck (*Redunca redunca)*, ostrich (*Struthio camelus)*, eland (*Taurotragus oryx*), waterbuck (*Kobus ellipsiprymnus)* and grey duiker *(Sylvicapra grimmia)* (Holmern *et al.,* 2002, Holmern *et* *al.,* 2004). According to Kaltenborn *et al*. (2005), much of the meat is then preserved in pieces (Swahili: 'kimoro'), permitting storage and trade in local and remote areas. In Monrovia, Liberia, one or two months may be invested in sun-drying meats, which are sold only when hunters need money for festivities or emergencies (CEEB, 2004). Bushmeat is packaged in units called "bodies" and placed in sacs or cribs called "kin jars" (CEEB, 2004).

Species identification is employed in a wide variety of general purpose and biological science applications (Bitanyi *et al.,* 2011). Similarly, the communities around the Serengeti have their own means of identifying sun-dried or smoked bushmeat species. According to Kajembe (1994), indigenous knowledge (IK) is a broad term that covers all knowledge that is considered to be characteristic of a given cultural group. Indigenous knowledge originated or developed naturally in a particular land, region or environment. UNEP (2008) defines IK as the knowledge of an indigenous community, accumulated over generations of living in a particular environment. It is a broad concept that includes intellectual, technological, ecological, and medical knowledge. These technologies, skills, practices and beliefs enable the community to achieve stable livelihoods.

Local communities generally have knowledge regarding the management of their natural resources that can be applied to guarantee the sustainable use and stability of these resources (Cunningham, 1991: Gupta 1991; Kajembe, 1994; Chandrakanth, *et al.,* 2004; Maponga & Muzirambi, 2007; UNEP, 2008). The current applications of this knowledge are based on methods that are handed down through generations, usually by oral instruction or other practical means (Jankulovska *et al.,* 2003; Kidegesho, 2006a; Maponga & Muzirambi, 2007).

Currently, techniques are available in both developing and developed countries for species identification through genetic analysis. These tools can be used to enhance the monitoring and control of the international illegal trade in bushmeat and ivory (Bitanyi & Eblate, 2009). In Tanzania, DNA-based methods for the identification of illegally hunted animals have limited applications. The few published cases involve restriction fragment length polymorphism analyses of meat samples from road and predator kills, as well as analyses of faeces from wild and domestic animals (Malisa *et al.,* 2005, 2006). Despite the advantages of these techniques, their expense makes it necessary to consider alternative means of identification, such as the use of indigenous knowledge. In order to better detect, monitor and control the trade of wildlife and wildlife products, more accurate and efficient methods of species identification are required (Eaton *et al.,* 2009). Such methods will be applied to quality control of food and markets, tools for tracing raw and processed products of species in commercial trading chains and providing new data for use in conservation biology and wildlife management (Bitanyi *et al.,* 2011).

The capacity for species identification may be influenced by various factors, including the distance of the village from protected areas or the gender, tribe and age of respondents. Many elderly persons report taste deficits, and several studies on age-associated changes in taste sensitivity have shown decreases with age, although the extent of loss varies depending on the taste involved (Fukunaga *et al.,* 2005). The tongue's sense of touch also plays an important role in the perception of food texture. Not only the elderly, but also those who are either taking medication and/or consume excessive alcohol and/or smoke have reduced sensitivity to taste and textures (Fukunaga *et al.,* 2005). This study aimed to explore the ability of the people in local communities around the western Serengeti to identify species by tasting boiled or sun-dried bushmeat. In particular, we tested the following hypotheses:

1. Local communities living close to protected areas are more accustomed to consuming bushmeat illegally; thus, they may be better able to identify the boiled or sun-dried bushmeat based on taste than people living further away from protected areas.
2. Men do most of the hunting activities, and women mostly involved in the bushmeat trade; thus, men may be better able to identify bushmeat species correctly than women.
3. Experience is important in bushmeat identification; thus, adults who have been hunting for time spanning many years may be better able to identify the species of sun-dried meat than the more inexperienced young individuals.

Study area

The SE covers approximately 25,000 km^2 on the border of Tanzania and Kenya (Fig. 1) and is defined by the movement of wildebeest (Homewood *et al*., 2001; Nelson, 2009). The eastern boundary is formed by the crater highlands and the rift valley. An arm called the western corridor stretches west to Lake Victoria. The northern boundary is formed by the Isuria escarpments and Loita plains in Kenya (Marealle *et al.,* 2010). The SE, which lies between latitudes 1^0 28’ and 3^0 17’ S and longitudes 33^0 50’ and 35^0 20’ E, spans a total area of approximately 30,000 km^2 in northern Tanzania (Kidegesho, 2006b). It is a highland savannah region with thorn tree woodlands and plains ranging from approximately 900 to 1,500 metres above sea level. The average annual rainfall ranges between 500 and 1200 mm, declining towards the Park boundary and increasing towards Lake Victoria (Campbell & Hofer 1995). The western Serengeti, which is the focus of this study, is ecologically significant as a buffer zone for SNP and a corridor for wildlife species migrating between the Serengeti and Maasai Mara in Kenya. These species include some 1.4 million wildebeest, 0.2 million zebra, and 0.7 million Thompson's gazelle (*Gazella thomsoni*) (Norton-Griffiths, 1995).

The human population in the area is estimated to be over two million (URT, 2012). The area is ethnically diverse, with more than 20 tribes; the major tribes are Ikoma, Sukuma, Kurya, Ikizu, Natta, Isenye, Zanaki, Zizaki, Ngoreme, Luo, Taturu and Jita. The major livelihood strategies pursued by these tribes are cultivation (largely maize, cassava, millet and sorghum for food and cotton for cash) and livestock husbandry (cattle, goats and sheep). Although most people are subsistence farmers, there are some ethnic differences in economic activities, which include fishing, livestock rearing, game meat hunting, and trading (Loibooki, 1997; Loibooki *et al.,* 2002). Previous studies have suggested that 75% of households in western Serengeti consume bushmeat (Barnett, 2000), whereas estimates of the number of wildebeest hunted annually vary from 40,000 (Mduma, 1996) to 118,000 animals (Campbell & Hofer 1995).

Materials and methods

Preparation for sun-dried bushmeat

Two forms of sun-dried bushmeat are prepared for preservation: “*Kimoro*” in Ikoma (“*Nyamasingisi*” in Luo and “*Ekimuru*” in Zanaki”) and “*Mitanda”* in Ikoma (“*Aliya” in* Luo and “*Omtanda”* in Zanaki). When the illegal bushmeat hunters kill a wild animal, they cut the meat into small pieces (“kimoro”), pound them with a stick or a smooth stone to tenderise the fibres and allow maximum penetration of sunlight so that the meat dries more quickly. The weight of each piece of “Kimoro” bushmeat varies from 1 kg to 4.5 kg, with an average of 2.4 kg. “Mitanda” hunters, however, cut meat into small strips, add salt and hang the strips on wires to sun dry. The meat is then stored for use in times of hunger, especially in the non-migratory season, and for trade. “Mitanda” meat, obtained from two sources, was used in the experiments: beef was bought from local markets, whereas meat from wild animals was obtained by shooting four mature male ungulate (1 zebra, 1 wildebeest and 2 impalas) in December 2010 in the Simanjiro Plain area. Professional hunters from Arusha and game rangers from Simanjiro Game Office hunted the animals. No untargeted animal was killed or injured. The shot animals died instantly and were immediately skinned; the meat was prepared for sun-drying in collaboration with traditional hunters from the same area.

Data collection techniques

This study employed a case-study design with a longitudinal dimension. This design allowed for collection of data from more than one time point to allow comparisons. The data were collected throughout the year, and meat tasting experiments were conducted in January 2011. Three villages along a gradient of distance from the park were selected for the meat tasting experiments. The villages were located within 10 km, 40 km and 80 km of the protected area. Households in the selected villages were widely dispersed but respondents were invited from all hamlets within the villages. Species identification data were collected through different techniques including a key informant survey, group discussions, meat tasting experiments and questionnaires. Meat from three wild animal species (wildebeest, impala and zebra) and cattle (used as a control) were sun-dried first, then chopped into small pieces and cooked. Several people of various ages and tribes, including males and females, from the selected villages were invited to test the meat. Sun-dried and cooked meat samples were arranged at random on the table, and each respondent was asked to identify the species tasted. Each respondent was asked to taste sun-dried meat from each sample before tasting the cooked meat of the same species. The correct species were revealed to each respondent after her/his completion of the tasting exercise. The respondents were asked not to share the correct answers with other respondents. A negative correlation between the number of recognised meat items and the date, while controlling for distance to SNP ($r_{partial}$ = - 0.433, N = 222, P = 0.047), indicates that the respondents did not inform any other respondents. We recorded the responses from the tasters in data sheets for subsequent analysis. In the meat tasting experiments, a total of 225 respondents were given pieces of sun-dried and cooked sun-dried bushmeat of wildebeest, impala, zebra and beef to taste and identify; in total, 900 samples were tested.

Statistical analyses

Statistical analyses were conducted using Statistical Package for Social Sciences (SPSS, 17). Spearman's rho test was used to measure the linear relationship between the frequencies of recognition of dried and cooked meat. ANOVA and Kruskal–Wallis tests were applied to test for the differences in the independent variables: distance from the protected area (village within 10 km, 40 km or 80 km), gender (female or male), and age of respondents (young, 1 – 20 years;, adult, 21 – 45 years; elderly, >60 yrs) that might influence species identification of sun-dried and cooked meat. A linear regression analysis was also used to test these independent variables.

Results

Indigenous knowledge on species identification of sun-dried bushmeat

Generally, our results suggest that it is difficult for members of local communities to identify sun-dried bushmeat species without intensive experience with the meat of that particular species. The respondents claimed that different techniques are used in identifying sun-dried bushmeat. These techniques are summarised in Table 1.

Identification of sun-dried and cooked bushmeat species

The correlation between the numbers of recognised items (0 to 4) of the respondents who recognised dried and cooked meat was statistically significant (Spearman' rho $r_{sp} = 0.932$, $N = 225$, $P < 0.001$). Thus, the same person tended to recognise the cooked and dried meat with the same frequency; in the further analyses, therefore, we averaged the two tests.

The mean meat recognition by village, gender and age group differed significantly (Table 2). The closest village to the protected area (Robanda) scored the highest mean value. Here, villagers on average recognised 2.5 (±SD = 1.0) of the 4 species that they were served. The second and third highest mean value was obtained by respondents from Busegwe and Ochuna, with 1.4 (±SD = 1.0) and 0.5 (±SD = 0.8) recognised food items, respectively (Kruskal –Wallis; $\chi^2 = 98.3$, df = 2, $P < 0.001$; Table 2). Males recognised more items (mean = 1.6 ±SD = 1.2) than females (mean = 1.3 ±SD = 1.3; Kruskal–Wallis; $\chi^2 = 4.7$, df = 1, P = 0.031; Table 2). Furthermore, there were differences in the mean number of recognised items between different age groups (Kruskal – Wallis; $\chi^2 = 23.2$, df = 2, $P < 0.001$; Tables 2), with the adult (mean = 1.8 ±SD = 1.3) recognising more items than the elderly (mean = 1.4 ±SD = 1.1) and youth (mean = 0.9 ±SD = 1.1).

A linear regression using the number of correctly identified meat items as a dependent variable and distance to SNP, gender and age group as independent variables was highly significant (adjusted $r^2 = 0.087$, F = 8.2, df = 3 and 224, $p < 0.001$). The variable explaining most of this variation was distance from SNP (t = -3.6, $p < 0.001$) followed by age class (t = 3.013, p = 0.003); gender (t = -0.222, p = 0.825) made no significant contribution to explaining the amount of variation in the identification of food items.

The identification of individual meat samples differed significantly among the four species served as sun-dried meat (Pearson Chi-square: $\chi^2 = 40.7$, df = 3, n = 900, $P < 0.001$, Table 3) and cooked meat (Pearson Chi-square: $\chi^2 = 42.9$, df = 3, n = 900, $P < 0.001$, Table 3). Zebra meat was more frequently recognised by respondents than any other animal species, followed by wildebeest and impala. Beef was the least frequently recognised species.

Discussion

Indigenous knowledge on species identification of sun-dried bushmeat

Local communities around the Serengeti ecosystem use different techniques to identify the bushmeat species in the market. These techniques include organoleptic tests, such as taste and aroma, as well as appearance, fibre patterns and textures. Nevertheless, the preparation of sun-dried bushmeat might differ among individuals or locations, which may influence the texture and aroma of the meat. Our results suggest that testers would be able to correctly identify only familiar sun-dried meats. Indigenous knowledge played a significant role in species identification. The importance of such indigenous knowledge to the sustainable use and conservation of natural resources has been previously suggested (Cunningham, 1991; Gupta, 1991; Kajembe, 1994; Chandrakanth, 2004; Maponga & Muzirambi, 2007, UNEP 2008). Indigenous knowledge is usually passed from one generation to another through oral instruction and demonstration (Jankulovska *et al.,* 2003; Kidegesho, 2006a; Maponga & Muzirambi, 2007) as opposed to written instruction, which helps to ensure that this valuable knowledge is incorporated into the lives of the younger generation.

Identification of sun-dried and cooked bushmeat species

The recognition of sun-dried and cooked meat differed significantly based on the distance of the village from the protected areas and by age groups. The testers were also of varying tribes and genders, and their degree of experience with wild animals varied. All of these factors may have influenced the species identification based on appearance, taste, aroma, fibre patterns and texture.

The respondents from the village closest to the protected area (Robanda) correctly identified meat to the species level more frequently than those from the villages farther away from the protected area. This result supports our hypothesis: people living nearer to protected areas consume bushmeat more frequently than people from more remote villages; the respondents from distant villages had less experience with wild animals. Distance from the protected area is the most important variable in explaining food recognition, which is consistent with findings that were previously acquired from a similar region (See Nyahongo 2007).

Age group was the second most important factor in the recognition of sun-dried meats, which also supports our hypothesis. Respondents between 21 and 45 years old were able to identify bushmeat species more frequently than the younger and older testers. These results are consistent with earlier reports on the ages of active bushmeat hunters elsewhere in sub-Saharan Africa (Solly, 2004; Coad, 2007; Nyahongo, 2007; Wright & Priston, 2010). Men in these age groups are likely to have growing families and greater responsibilities, making them more likely to resort to bushmeat harvesting as a means of feeding their families and providing household income. In addition, men in these age groups are more likely to have the physical capacity for hunting; boys and older men are less likely to be able to endure long runs after speared animals or away from armed rangers. Adult men may also be of a higher financial status than boys and older men, and thus, are more able to invest in traditional hunting equipment. The skills acquired during their daily hunting activities may contribute to their ability to identify bushmeat species. Additionally, these results are supported by studies showing that taste sensitivity decreases with age (Fukunaga, *et al.,* 2005; Nyahongo 2007).

Men in the study area were more likely to identify the meats to the species level than women, although this effect disappeared in the linear regression analysis. Men probably identified meat species more frequently because, in most African countries, men hunt while women remain at home to care for the household and the family. This observation is supported elsewhere (Arcese *et al.,* 1995; Hofer *et al.,* 1996; Fa *et al.,* 2006; Coad, 2007; Wright & Priston, 2010). Nonetheless, women provide family income through trade of bushmeat products after the meat is processed and sold, either within the protected areas or in the village market. They also assist men in the transport of the bushmeat from the forest to the villages. (Loibooki *et al.,* 2002; Mendelson *et al.,* 2003; Solly 2004); however, the gender differences in the rate of correct identification disappeared in the linear regression analysis, indicating that gender was not equally distributed among age groups. Further tests are therefore necessary to determine the importance of gender in bushmeat identification.

The recognition of the four types of meat samples differed significantly among the animal species. Zebra meat was more frequently recognised by respondents than other animal species, followed by wildebeest and impala; beef was recognised least frequently. Zebra meat may be highly recognisable because of its unique aroma and taste. Moreover, local communities use zebra fat in traditional medicine, to cure chest and ear pain; for this reason, the zebra meat may have been more familiar than the other meats (David Mashaka, 2011 personal communication).

Conclusions and recommendations

Conclusions

The results of this study revealed the following:

- Local communities adjacent to the Serengeti ecosystem have rich and useful techniques on identification of bushmeat. They use different methods of identifying bushmeat in the market.
- The distance of the village from the protected area and age class are the most important factors in the recognition of sun-dried and cooked meat.
- Women and men recognised bushmeat species at similar rates.
- Meat tasting by local communities is a poor tool for the identification of wildlife species (also observed by Nyahongo (2007)); therefore, tasting is not recommended as a technique for species identification.

Recommendations

We recommend supporting the communities around protected areas with poultry- and livestock-keeping as well as aquaculture projects to supplement the bushmeat protein in their diet and reduce hunting pressure on wild animals. We also recommend further study on the factors used by local communities to identify animal species so that these techniques can be incorporated into monitoring of the illegal bushmeat trade.

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Biographical sketches

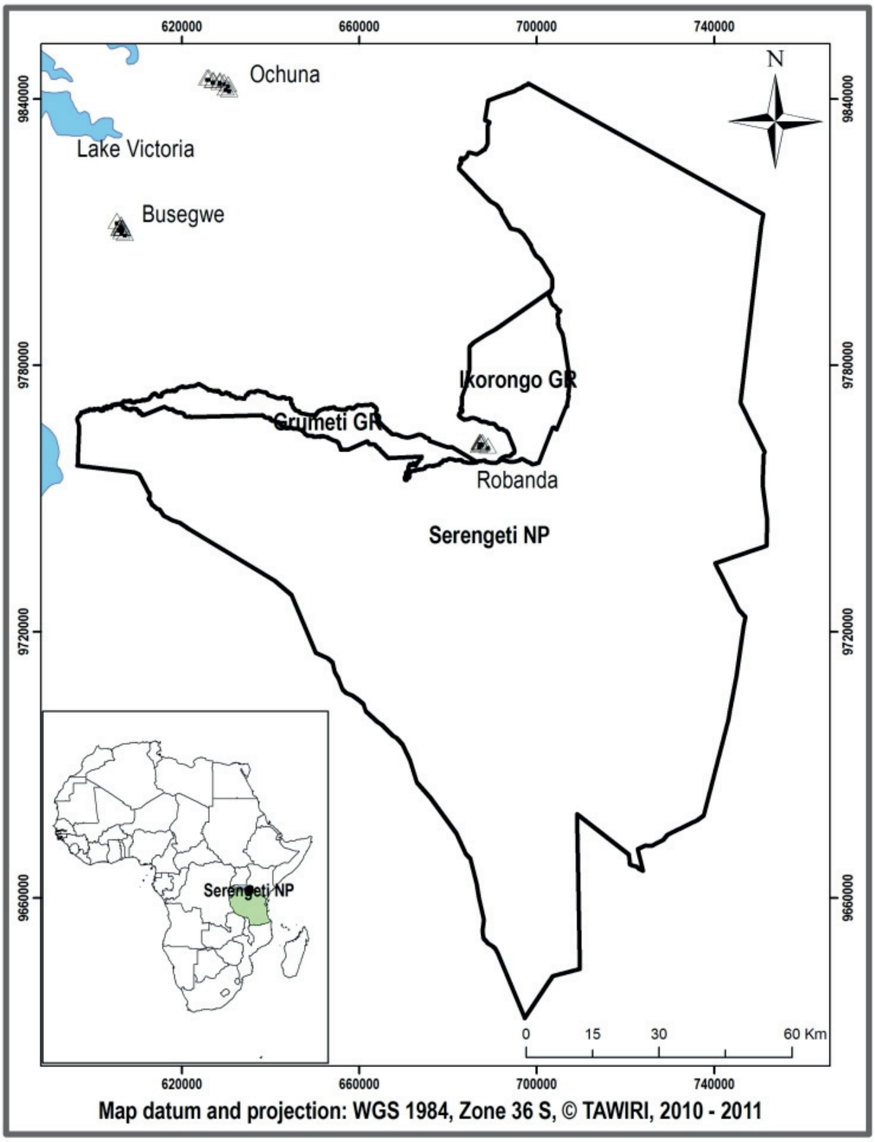
Angela Mwakatobe is interested in management of natural resources and sustainable agriculture. She is currently working as a Senior Research Officer at Tanzania Wildlife Research Institute.

Prof. Eivin Røskaft is a behavioral ecologist interested in a wide range of bird species in Europe, North America and Africa, and in the conflict between humans and mammals over the use of limited land.

Dr. Julius William Nyahongo is interested in management of natural resources and sustainable agriculture. He is a Senior Lecturer and Head of School of Natural Sciences & Mathematics, the University of Dodoma.

Figure Legend:

Figure 1: Map of study area showing Serengeti National Park, Grumeti and Ikorongo Game Reserves, Lake Victoria and the surveyed villages (Robanda, Busegwe and Ochuna)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N
Ochuna
Lake Victoria
Busegwe
Ikorongo GR
Grumeti GR
Robanda
Serengeti NP
Serengeti NP
0
15
30
60 Km
Map datum and projection: WGS 1984, Zone 36 S, © TAWIRI, 2010 - 2011

Table 1: Factors used in the identification of sun-dried bushmeat

Factors	Description
Taste	The tastes of the different sun-dried bushmeat species differ from each other. Hunters' preferences depend largely on the taste of the bushmeat.
Aroma	The smells of the different sun-dried bushmeat species differ. For examples, the strong smell of the sun-dried or cooked sun-dried bushmeat of zebras and giraffes is easily recognised by the people living near protected areas
Meat fibres	Different animal species have different meat fibre patterns and textures. For example, large animals like wildebeest have larger meat fibres than small animals like impalas. In addition, the patterns in the meat fibres of giraffes differ from those of wildebeests.
Appearance	The colours of the different species of sun-dried bushmeat differ. For example, sun-dried zebra meat is reddish in colour, compared to the darker colour of sun-dried impala meat

Table 2: Mean numbers of recognised sun-dried meats (0 to 4) by village, tribe, gender and age class.

Village	**Mean**	**N**	**SD**
Robanda (closest)	2.5	74	1.0
Busegwe	1.4	76	1.0
Ochuna (farthest)	0.5	75	0.8
Total	1.5	225	1.3
Gender			
Male	1.6	120	1.2
Female	1.3	105	1.3
Total	1.5	225	1.3
Age Class (years)			
1 – 20	0.9	74	1.1
21 - 45	1.8	99	1.3
> 45	1.4	52	1.1
Total	1.4	225	1.3

Table 3: Recognition of individual animal sun-dried and cooked meats

SN	Animal species	Percentage recognised, dried meat	Percentages recognised, the cooked meat
1	Zebra	44.9	51.1
2	Wildebeest	38.2	42.2
3	Impala	36.6	40.1
4	Beef	17.4	21.0
Pearson Chi- Square		$\chi^2 = 40.7$, $p < 0.001$	$\chi^2 = 42.8$, $p < 0.001$

[redacted]

Doctoral theses in Biology
Norwegian University of Science and Technology
Department of Biology

Year	Name	Degree	Title
1974	Tor-Henning Iversen	Dr. philos Botany	The roles of statholiths, auxin transport, and auxin metabolism in root gravitropism
1978	Tore Slagsvold	Dr. philos Zoology	Breeding events of birds in relation to spring temperature and environmental phenology
1978	Egil Sakshaug	Dr.philos Botany	"The influence of environmental factors on the chemical composition of cultivated and natural populations of marine phytoplankton"
1980	Arnfinn Langeland	Dr. philos Zoology	Interaction between fish and zooplankton populations and their effects on the material utilization in a freshwater lake
1980	Helge Reinertsen	Dr. philos Botany	The effect of lake fertilization on the dynamics and stability of a limnetic ecosystem with special reference to the phytoplankton
1982	Gunn Mari Olsen	Dr. scient Botany	Gravitropism in roots of *Pisum sativum* and *Arabidopsis thaliana*
1982	Dag Dolmen	Dr. philos Zoology	Life aspects of two sympartic species of newts (*Triturus, Amphibia*) in Norway, with special emphasis on their ecological niche segregation
1984	Eivin Røskaft	Dr. philos Zoology	Sociobiological studies of the rook *Corvus frugilegus*
1984	Anne Margrethe Cameron	Dr. scient Botany	Effects of alcohol inhalation on levels of circulating testosterone, follicle stimulating hormone and luteinzing hormone in male mature rats
1984	Asbjørn Magne Nilsen	Dr. scient Botany	Alveolar macrophages from expectorates – Biological monitoring of workers exosed to occupational air pollution. An evaluation of the AM-test
1985	Jarle Mork	Dr. philos Zoology	Biochemical genetic studies in fish
1985	John Solem	Dr. philos Zoology	Taxonomy, distribution and ecology of caddisflies (*Trichoptera*) in the Dovrefjell mountains
1985	Randi E. Reinertsen	Dr. philos Zoology	Energy strategies in the cold: Metabolic and thermoregulatory adaptations in small northern birds
1986	Bernt-Erik Sæther	Dr. philos Zoology	Ecological and evolutionary basis for variation in reproductive traits of some vertebrates: A comparative approach
1986	Torleif Holthe	Dr. philos Zoology	Evolution, systematics, nomenclature, and zoogeography in the polychaete orders *Oweniimorpha* and *Terebellomorpha*, with special reference to the Arctic and Scandinavian fauna
1987	Helene Lampe	Dr. scient Zoology	The function of bird song in mate attraction and territorial defence, and the importance of song repertoires
1987	Olav Hogstad	Dr.	Winter survival strategies of the Willow tit *Parus*

		philos Zoology	*montanus*
1987	Jarle Inge Holten	Dr. philos Botany	Autecological investigations along a coust-inland transect at Nord-Møre, Central Norway
1987	Rita Kumar	Dr. scient Botany	Somaclonal variation in plants regenerated from cell cultures of *Nicotiana sanderae* and *Chrysanthemum morifolium*
1987	Bjørn Åge Tømmerås	Dr. scient. Zoolog	Olfaction in bark beetle communities: Interspecific interactions in regulation of colonization density, predator - prey relationship and host attraction
1988	Hans Christian Pedersen	Dr. philos Zoology	Reproductive behaviour in willow ptarmigan with special emphasis on territoriality and parental care
1988	Tor G. Heggberget	Dr. philos Zoology	Reproduction in Atlantic Salmon (*Salmo salar*): Aspects of spawning, incubation, early life history and population structure
1988	Marianne V. Nielsen	Dr. scient Zoology	The effects of selected environmental factors on carbon allocation/growth of larval and juvenile mussels (*Mytilus edulis*)
1988	Ole Kristian Berg	Dr. scient Zoology	The formation of landlocked Atlantic salmon (*Salmo salar* L.)
1989	John W. Jensen	Dr. philos Zoology	Crustacean plankton and fish during the first decade of the manmade Nesjø reservoir, with special emphasis on the effects of gill nets and salmonid growth
1989	Helga J. Vivås	Dr. scient Zoology	Theoretical models of activity pattern and optimal foraging: Predictions for the Moose *Alces alces*
1989	Reidar Andersen	Dr. scient Zoology	Interactions between a generalist herbivore, the moose *Alces alces*, and its winter food resources: a study of behavioural variation
1989	Kurt Ingar Draget	Dr. scient Botany	Alginate gel media for plant tissue culture
1990	Bengt Finstad	Dr. scient Zoology	Osmotic and ionic regulation in Atlantic salmon, rainbow trout and Arctic charr: Effect of temperature, salinity and season
1990	Hege Johannesen	Dr. scient Zoology	Respiration and temperature regulation in birds with special emphasis on the oxygen extraction by the lung
1990	Åse Krøkje	Dr. scient Botany	The mutagenic load from air pollution at two work-places with PAH-exposure measured with Ames Salmonella/microsome test
1990	Arne Johan Jensen	Dr. philos Zoology	Effects of water temperature on early life history, juvenile growth and prespawning migrations of Atlantic salmion (*Salmo salar*) and brown trout (*Salmo trutta*): A summary of studies in Norwegian streams
1990	Tor Jørgen Almaas	Dr. scient Zoology	Pheromone reception in moths: Response characteristics of olfactory receptor neurons to intra- and interspecific chemical cues
1990	Magne Husby	Dr. scient Zoology	Breeding strategies in birds: Experiments with the Magpie *Pica pica*
1991	Tor Kvam	Dr. scient Zoology	Population biology of the European lynx (*Lynx lynx*) in Norway
1991	Jan Henning L'Abêe Lund	Dr. philos Zoology	Reproductive biology in freshwater fish, brown trout *Salmo trutta* and roach *Rutilus rutilus* in particular
1991	Asbjørn Moen	Dr.	The plant cover of the boreal uplands of Central

		philos Botany	Norway. I. Vegetation ecology of Sølendet nature reserve; haymaking fens and birch woodlands
1991	Else Marie Løbersli	Dr. scient Botany	Soil acidification and metal uptake in plants
1991	Trond Nordtug	Dr. scient Zoology	Reflctometric studies of photomechanical adaptation in superposition eyes of arthropods
1991	Thyra Solem	Dr. scient Botany	Age, origin and development of blanket mires in Central Norway
1991	Odd Terje Sandlund	Dr. philos Zoology	The dynamics of habitat use in the salmonid genera *Coregonus* and *Salvelinus*: Ontogenic niche shifts and polymorphism
1991	Nina Jonsson	Dr. philos	Aspects of migration and spawning in salmonids
1991	Atle Bones	Dr. scient Botany	Compartmentation and molecular properties of thioglucoside glucohydrolase (myrosinase)
1992	Torgrim Breiehagen	Dr. scient Zoology	Mating behaviour and evolutionary aspects of the breeding system of two bird species: the Temminck's stint and the Pied flycatcher
1992	Anne Kjersti Bakken	Dr. scient Botany	The influence of photoperiod on nitrate assimilation and nitrogen status in timothy (*Phleum pratense* L.)
1992	Tycho Anker-Nilssen	Dr. scient Zoology	Food supply as a determinant of reproduction and population development in Norwegian Puffins *Fratercula arctica*
1992	Bjørn Munro Jenssen	Dr. philos Zoology	Thermoregulation in aquatic birds in air and water: With special emphasis on the effects of crude oil, chemically treated oil and cleaning on the thermal balance of ducks
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1993	Geir Slupphaug	Dr. scient Botany	Regulation and expression of uracil-DNA glycosylase and O^6-methylguanine-DNA methyltransferase in mammalian cells
1993	Tor Fredrik Næsje	Dr. scient Zoology	Habitat shifts in coregonids.
1993	Yngvar Asbjørn Olsen	Dr. scient Zoology	Cortisol dynamics in Atlantic salmon, *Salmo salar* L.: Basal and stressor-induced variations in plasma levels ans some secondary effects.
1993	Bård Pedersen	Dr. scient Botany	Theoretical studies of life history evolution in modular and clonal organisms
1993	Ole Petter Thangstad	Dr. scient Botany	Molecular studies of myrosinase in Brassicaceae
1993	Thrine L. M. Heggberget	Dr. scient Zoology	Reproductive strategy and feeding ecology of the Eurasian otter *Lutra lutra*.
1993	Kjetil Bevanger	Dr. scient. Zoology	Avian interactions with utility structures, a biological approach.
1993	Kåre Haugan	Dr. scient Bothany	Mutations in the replication control gene trfA of the broad host-range plasmid RK2
1994	Peder Fiske	Dr. scient. Zoology	Sexual selection in the lekking great snipe (*Gallinago media*): Male mating success and female behaviour at the lek
1994	Kjell Inge Reitan	Dr. scient Botany	Nutritional effects of algae in first-feeding of marine fish larvae
1994	Nils Røv	Dr. scient Zoology	Breeding distribution, population status and regulation of breeding numbers in the northeast-Atlantic Great

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1994	Geir Johnsen	Dr. scient Botany	Light harvesting and utilization in marine phytoplankton: Species-specific and photoadaptive responses
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1994	Solveig Bakken	Dr. scient Bothany	Growth and nitrogen status in the moss *Dicranum majus* Sm. as influenced by nitrogen supply
1994	Torbjørn Forseth	Dr. scient Zoology	Bioenergetics in ecological and life history studies of fishes.
1995	Olav Vadstein	Dr. philos Botany	The role of heterotrophic planktonic bacteria in the cycling of phosphorus in lakes: Phosphorus requirement, competitive ability and food web interactions
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1996	Jorun Skjærmo	Dr. scient Botany	Microbial ecology of early stages of cultivated marine fish; inpact fish-bacterial interactions on growth and survival of larvae
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1996	Ingibjørg Einarsdottir	Dr. scient Zoology	Production of Atlantic salmon (*Salmo salar*) and Arctic charr (*Salvelinus alpinus*): A study of some physiological and immunological responses to rearing routines
1996	Christina M. S. Pereira	Dr. scient Zoology	Glucose metabolism in salmonids: Dietary effects and hormonal regulation
1996	Jan Fredrik Børseth	Dr. scient Zoology	The sodium energy gradients in muscle cells of *Mytilus edulis* and the effects of organic xenobiotics
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1997	Gunvor Øie	Dr. scient	Eevalution of rotifer *Brachionus plicatilis* quality in

		Bothany	early first feeding of turbot *Scophtalmus maximus* L. larvae
1997	Håkon Holien	Dr. scient Botany	Studies of lichens in spurce forest of Central Norway. Diversity, old growth species and the relationship to site and stand parameters
1997	Ole Reitan	Dr. scient. Zoology	Responses of birds to habitat disturbance due to damming
1997	Jon Arne Grøttum	Dr. scient. Zoology	Physiological effects of reduced water quality on fish in aquaculture
1997	Per Gustav Thingstad	Dr. scient. Zoology	Birds as indicators for studying natural and human-induced variations in the environment, with special emphasis on the suitability of the Pied Flycatcher
1997	Torgeir Nygård	Dr. scient Zoology	Temporal and spatial trends of pollutants in birds in Norway: Birds of prey and Willow Grouse used as Biomonitors
1997	Signe Nybø	Dr. scient. Zoology	Impacts of long-range transported air pollution on birds with particular reference to the dipper *Cinclus cinclus* in southern Norway
1997	Atle Wibe	Dr. scient. Zoology	Identification of conifer volatiles detected by receptor neurons in the pine weevil (*Hylobius abietis*), analysed by gas chromatography linked to electrophysiology and to mass spectrometry
1997	Rolv Lundheim	Dr. scient Zoology	Adaptive and incidental biological ice nucleators
1997	Arild Magne Landa	Dr. scient Zoology	Wolverines in Scandinavia: ecology, sheep depredation and conservation
1997	Kåre Magne Nielsen	Dr. scient Botany	An evolution of possible horizontal gene transfer from plants to sail bacteria by studies of natural transformation in *Acinetobacter calcoacetius*
1997	Jarle Tufto	Dr. scient Zoology	Gene flow and genetic drift in geographically structured populations: Ecological, population genetic, and statistical models
1997	Trygve Hesthagen	Dr. philos Zoology	Population responces of Arctic charr (*Salvelinus alpinus* (L.)) and brown trout (*Salmo trutta* L.) to acidification in Norwegian inland waters
1997	Trygve Sigholt	Dr. philos Zoology	Control of Parr-smolt transformation and seawater tolerance in farmed Atlantic Salmon (*Salmo salar*) Effects of photoperiod, temperature, gradual seawater acclimation, NaCl and betaine in the diet
1997	Jan Østnes	Dr. scient Zoology	Cold sensation in adult and neonate birds
1998	Seethaledsumy Visvalingam	Dr. scient Botany	Influence of environmental factors on myrosinases and myrosinase-binding proteins
1998	Thor Harald Ringsby	Dr. scient Zoology	Variation in space and time: The biology of a House sparrow metapopulation
1998	Erling Johan Solberg	Dr. scient. Zoology	Variation in population dynamics and life history in a Norwegian moose (*Alces alces*) population: consequences of harvesting in a variable environment
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1999	Kristian Overskaug	Dr. scient Zoology	Behavioural and morphological characteristics in Northern Tawny Owls *Strix aluco*: An intra- and interspecific comparative approach
1999	Hans Kristen Stenøien	Dr. scient Bothany	Genetic studies of evolutionary processes in various populations of nonvascular plants (mosses, liverworts and hornworts)
1999	Trond Arnesen	Dr. scient Botany	Vegetation dynamics following trampling and burning in the outlying haylands at Sølendet, Central Norway
1999	Ingvar Stenberg	Dr. scient Zoology	Habitat selection, reproduction and survival in the White-backed Woodpecker *Dendrocopos leucotos*
1999	Stein Olle Johansen	Dr. scient Botany	A study of driftwood dispersal to the Nordic Seas by dendrochronology and wood anatomical analysis
1999	Trina Falck Galloway	Dr. scient Zoology	Muscle development and growth in early life stages of the Atlantic cod (*Gadus morhua* L.) and Halibut (*Hippoglossus hippoglossus* L.)
1999	Marianne Giæver	Dr. scient Zoology	Population genetic studies in three gadoid species: blue whiting (*Micromisistius poutassou*), haddock (*Melanogrammus aeglefinus*) and cod (*Gradus morhua*) in the North-East Atlantic
1999	Hans Martin Hanslin	Dr. scient Botany	The impact of environmental conditions of density dependent performance in the boreal forest bryophytes *Dicranum majus*, *Hylocomium splendens*, *Plagiochila asplenigides*, *Ptilium crista-castrensis* and *Rhytidiadelphus lokeus*
1999	Ingrid Bysveen Mjølnerød	Dr. scient Zoology	Aspects of population genetics, behaviour and performance of wild and farmed Atlantic salmon (*Salmo salar*) revealed by molecular genetic techniques
1999	Else Berit Skagen	Dr. scient Botany	The early regeneration process in protoplasts from *Brassica napus* hypocotyls cultivated under various g-forces
1999	Stein-Are Sæther	Dr. philos Zoology	Mate choice, competition for mates, and conflicts of interest in the Lekking Great Snipe
1999	Katrine Wangen Rustad	Dr. scient Zoology	Modulation of glutamatergic neurotransmission related to cognitive dysfunctions and Alzheimer's disease
1999	Per Terje Smiseth	Dr. scient Zoology	Social evolution in monogamous families: mate choice and conflicts over parental care in the Bluethroat (*Luscinia s. svecica*)
1999	Gunnbjørn Bremset	Dr. scient Zoology	Young Atlantic salmon (*Salmo salar* L.) and Brown trout (*Salmo trutta* L.) inhabiting the deep pool habitat, with special reference to their habitat use, habitat preferences and competitive interactions
1999	Frode Ødegaard	Dr. scient Zoology	Host spesificity as parameter in estimates of arhrophod species richness
1999	Sonja Andersen	Dr. scient Bothany	Expressional and functional analyses of human, secretory phospholipase A2
2000	Ingrid Salvesen	Dr. scient Botany	Microbial ecology in early stages of marine fish: Development and evaluation of methods for microbial management in intensive larviculture
2000	Ingar Jostein Øien	Dr. scient	The Cuckoo (*Cuculus canorus*) and its host: adaptions

		Zoology	and counteradaptions in a coevolutionary arms race
2000	Pavlos Makridis	Dr. scient Botany	Methods for the microbial econtrol of live food used for the rearing of marine fish larvae
2000	Sigbjørn Stokke	Dr. scient Zoology	Sexual segregation in the African elephant (*Loxodonta africana*)
2000	Odd A. Gulseth	Dr. philos Zoology	Seawater tolerance, migratory behaviour and growth of Charr, (*Salvelinus alpinus*), with emphasis on the high Arctic Dieset charr on Spitsbergen, Svalbard
2000	Pål A. Olsvik	Dr. scient Zoology	Biochemical impacts of Cd, Cu and Zn on brown trout (*Salmo trutta*) in two mining-contaminated rivers in Central Norway
2000	Sigurd Einum	Dr. scient Zoology	Maternal effects in fish: Implications for the evolution of breeding time and egg size
2001	Jan Ove Evjemo	Dr. scient Zoology	Production and nutritional adaptation of the brine shrimp *Artemia* sp. as live food organism for larvae of marine cold water fish species
2001	Olga Hilmo	Dr. scient Botany	Lichen response to environmental changes in the managed boreal forset systems
2001	Ingebrigt Uglem	Dr. scient Zoology	Male dimorphism and reproductive biology in corkwing wrasse (*Symphodus melops* L.)
2001	Bård Gunnar Stokke	Dr. scient Zoology	Coevolutionary adaptations in avian brood parasites and their hosts
2002	Ronny Aanes	Dr. scient	Spatio-temporal dynamics in Svalbard reindeer (*Rangifer tarandus platyrhynchus*)
2002	Mariann Sandsund	Dr. scient Zoology	Exercise- and cold-induced asthma. Respiratory and thermoregulatory responses
2002	Dag-Inge Øien	Dr. scient Botany	Dynamics of plant communities and populations in boreal vegetation influenced by scything at Sølendet, Central Norway
2002	Frank Rosell	Dr. scient Zoology	The function of scent marking in beaver (*Castor fiber*)
2002	Janne Østvang	Dr. scient Botany	The Role and Regulation of Phospholipase A_2 in Monocytes During Atherosclerosis Development
2002	Terje Thun	Dr.philos Biology	Dendrochronological constructions of Norwegian conifer chronologies providing dating of historical material
2002	Birgit Hafjeld Borgen	Dr. scient Biology	Functional analysis of plant idioblasts (Myrosin cells) and their role in defense, development and growth
2002	Bård Øyvind Solberg	Dr. scient Biology	Effects of climatic change on the growth of dominating tree species along major environmental gradients
2002	Per Winge	Dr. scient Biology	The evolution of small GTP binding proteins in cellular organisms. Studies of RAC GTPases in *Arabidopsis thaliana* and the Ral GTPase from *Drosophila melanogaster*
2002	Henrik Jensen	Dr. scient Biology	Causes and consequenses of individual variation in fitness-related traits in house sparrows
2003	Jens Rohloff	Dr. philos Biology	Cultivation of herbs and medicinal plants in Norway – Essential oil production and quality control
2003	Åsa Maria O. Espmark Wibe	Dr. scient Biology	Behavioural effects of environmental pollution in threespine stickleback *Gasterosteus aculeatur* L.
2003	Dagmar Hagen	Dr. scient Biology	Assisted recovery of disturbed arctic and alpine vegetation – an integrated approach
2003	Bjørn Dahle	Dr. scient Biology	Reproductive strategies in Scandinavian brown bears

2003	Cyril Lebogang Taolo	Dr. scient Biology	Population ecology, seasonal movement and habitat use of the African buffalo (*Syncerus caffer*) in Chobe National Park, Botswana
2003	Marit Stranden	Dr.scient Biology	Olfactory receptor neurones specified for the same odorants in three related Heliothine species (*Helicoverpa armigera, Helicoverpa assulta* and *Heliothis virescens*)
2003	Kristian Hassel	Dr.scient Biology	Life history characteristics and genetic variation in an expanding species, *Pogonatum dentatum*
2003	David Alexander Rae	Dr.scient Biology	Plant- and invertebrate-community responses to species interaction and microclimatic gradients in alpine and Artic environments
2003	Åsa A Borg	Dr.scient Biology	Sex roles and reproductive behaviour in gobies and guppies: a female perspective
2003	Eldar Åsgard Bendiksen	Dr.scient Biology	Environmental effects on lipid nutrition of farmed Atlantic salmon (*Salmo Salar* L.) parr and smolt
2004	Torkild Bakken	Dr.scient Biology	A revision of Nereidinae (Polychaeta, Nereididae)
2004	Ingar Pareliussen	Dr.scient Biology	Natural and Experimental Tree Establishment in a Fragmented Forest, Ambohitantely Forest Reserve, Madagascar
2004	Tore Brembu	Dr.scient Biology	Genetic, molecular and functional studies of RAC GTPases and the WAVE-like regulatory protein complex in *Arabidopsis thaliana*
2004	Liv S. Nilsen	Dr.scient Biology	Coastal heath vegetation on central Norway; recent past, present state and future possibilities
2004	Hanne T. Skiri	Dr.scient Biology	Olfactory coding and olfactory learning of plant odours in heliothine moths. An anatomical, physiological and behavioural study of three related species (*Heliothis virescens, Helicoverpa armigera* and *Helicoverpa assulta*)
2004	Lene Østby	Dr.scient Biology	Cytochrome P4501A (CYP1A) induction and DNA adducts as biomarkers for organic pollution in the natural environment
2004	Emmanuel J. Gerreta	Dr. philos Biology	The Importance of Water Quality and Quantity in the Tropical Ecosystems, Tanzania
2004	Linda Dalen	Dr.scient Biology	Dynamics of Mountain Birch Treelines in the Scandes Mountain Chain, and Effects of Climate Warming
2004	Lisbeth Mehli	Dr.scient Biology	Polygalacturonase-inhibiting protein (PGIP) in cultivated strawberry (*Fragaria* x *ananassa*): characterisation and induction of the gene following fruit infection by *Botrytis cinerea*
2004	Børge Moe	Dr.scient Biology	Energy-Allocation in Avian Nestlings Facing Short-Term Food Shortage
2005	Matilde Skogen Chauton	Dr.scient Biology	Metabolic profiling and species discrimination from High-Resolution Magic Angle Spinning NMR analysis of whole-cell samples
2005	Sten Karlsson	Dr.scient Biology	Dynamics of Genetic Polymorphisms
2005	Terje Bongard	Dr.scient Biology	Life History strategies, mate choice, and parental investment among Norwegians over a 300-year period
2005	Tonette Røstelien	ph.d Biology	Functional characterisation of olfactory receptor neurone types in heliothine moths
2005	Erlend Kristiansen	Dr.scient Biology	Studies on antifreeze proteins

2005	Eugen G. Sørmo	Dr.scient Biology	Organochlorine pollutants in grey seal (*Halichoerus grypus*) pups and their impact on plasma thyrid hormone and vitamin A concentrations
2005	Christian Westad	Dr.scient Biology	Motor control of the upper trapezius
2005	Lasse Mork Olsen	ph.d Biology	Interactions between marine osmo- and phagotrophs in different physicochemical environments
2005	Åslaug Viken	ph.d Biology	Implications of mate choice for the management of small populations
2005	Ariaya Hymete Sahle Dingle	ph.d Biology	Investigation of the biological activities and chemical constituents of selected *Echinops* spp. growing in Ethiopia
2005	Anders Gravbrøt Finstad	ph.d Biology	Salmonid fishes in a changing climate: The winter challenge
2005	Shimane Washington Makabu	ph.d Biology	Interactions between woody plants, elephants and other browsers in the Chobe Riverfront, Botswana
2005	Kjartan Østbye	Dr.scient Biology	The European whitefish *Coregonus lavaretus* (L.) species complex: historical contingency and adaptive radiation
2006	Kari Mette Murvoll	ph.d Biology	Levels and effects of persistent organic pollutans (POPs) in seabirds Retinoids and α-tocopherol – potential biomakers of POPs in birds?
2006	Ivar Herfindal	Dr.scient Biology	Life history consequences of environmental variation along ecological gradients in northern ungulates
2006	Nils Egil Tokle	ph.d Biology	Are the ubiquitous marine copepods limited by food or predation? Experimental and field-based studies with main focus on *Calanus finmarchicus*
2006	Jan Ove Gjershaug	Dr.philos Biology	Taxonomy and conservation status of some booted eagles in south-east Asia
2006	Jon Kristian Skei	Dr.scient Biology	Conservation biology and acidification problems in the breeding habitat of amphibians in Norway
2006	Johanna Järnegren	ph.d Biology	Acesta Oophaga and Acesta Excavata – a study of hidden biodiversity
2006	Bjørn Henrik Hansen	ph.d Biology	Metal-mediated oxidative stress responses in brown trout (*Salmo trutta*) from mining contaminated rivers in Central Norway
2006	Vidar Grøtan	ph.d Biology	Temporal and spatial effects of climate fluctuations on population dynamics of vertebrates
2006	Jafari R Kideghesho	ph.d Biology	Wildlife conservation and local land use conflicts in western Serengeti, Corridor Tanzania
2006	Anna Maria Billing	ph.d Biology	Reproductive decisions in the sex role reversed pipefish *Syngnathus typhle*: when and how to invest in reproduction
2006	Henrik Pärn	ph.d Biology	Female ornaments and reproductive biology in the bluethroat
2006	Anders J. Fjellheim	ph.d Biology	Selection and administration of probiotic bacteria to marine fish larvae
2006	P. Andreas Svensson	ph.d Biology	Female coloration, egg carotenoids and reproductive success: gobies as a model system
2007	Sindre A. Pedersen	ph.d Biology	Metal binding proteins and antifreeze proteins in the beetle *Tenebrio molitor* - a study on possible competition for the semi-essential amino acid cysteine
2007	Kasper Hancke	ph.d Biology	Photosynthetic responses as a function of light and temperature: Field and laboratory studies on marine

			microalgae
2007	Tomas Holmern	ph.d Biology	Bushmeat hunting in the western Serengeti: Implications for community-based conservation
2007	Kari Jørgensen	ph.d Biology	Functional tracing of gustatory receptor neurons in the CNS and chemosensory learning in the moth *Heliothis virescens*
2007	Stig Ulland	ph.d Biology	Functional Characterisation of Olfactory Receptor Neurons in the Cabbage Moth, (*Mamestra brassicae* L.) (Lepidoptera, Noctuidae). Gas Chromatography Linked to Single Cell Recordings and Mass Spectrometry
2007	Snorre Henriksen	ph.d Biology	Spatial and temporal variation in herbivore resources at northern latitudes
2007	Roelof Frans May	ph.d Biology	Spatial Ecology of Wolverines in Scandinavia
2007	Vedasto Gabriel Ndibalema	ph.d Biology	Demographic variation, distribution and habitat use between wildebeest sub-populations in the Serengeti National Park, Tanzania
2007	Julius William Nyahongo	ph.d Biology	Depredation of Livestock by wild Carnivores and Illegal Utilization of Natural Resources by Humans in the Western Serengeti, Tanzania
2007	Shombe Ntaraluka Hassan	ph.d Biology	Effects of fire on large herbivores and their forage resources in Serengeti, Tanzania
2007	Per-Arvid Wold	ph.d Biology	Functional development and response to dietary treatment in larval Atlantic cod *(Gadus morhua* L.) Focus on formulated diets and early weaning
2007	Anne Skjetne Mortensen	ph.d Biology	Toxicogenomics of Aryl Hydrocarbon- and Estrogen Receptor Interactions in Fish: Mechanisms and Profiling of Gene Expression Patterns in Chemical Mixture Exposure Scenarios
2008	Brage Bremset Hansen	ph.d Biology	The Svalbard reindeer (*Rangifer tarandus platyrhynchus*) and its food base: plant-herbivore interactions in a high-arctic ecosystem
2008	Jiska van Dijk	ph.d Biology	Wolverine foraging strategies in a multiple-use landscape
2008	Flora John Magige	ph.d Biology	The ecology and behaviour of the Masai Ostrich (Struthio camelus massaicus) in the Serengeti Ecosystem, Tanzania
2008	Bernt Rønning	ph.d Biology	Sources of inter- and intra-individual variation in basal metabolic rate in the zebra finch, (*Taeniopygia guttata*)
2008	Sølvi Wehn	ph.d Biology	Biodiversity dynamics in semi-natural mountain landscapes. - A study of consequences of changed agricultural practices in Eastern Jotunheimen
2008	Trond Moxness Kortner	ph.d Biology	"The Role of Androgens on previtellogenic oocyte growth in Atlantic cod (*Gadus morhua*): Identification and patterns of differentially expressed genes in relation to Stereological Evaluations"
2008	Katarina Mariann Jørgensen	Dr.Scient Biology	The role of platelet activating factor in activation of growth arrested keratinocytes and re-epithelialisation
2008	Tommy Jørstad	ph.d Biology	Statistical Modelling of Gene Expression Data
2008	Anna Kusnierczyk	ph.d	*Arabidopsis thaliana* Responses to Aphid

		Bilogy	Infestation
2008	Jussi Evertsen	ph.d Biology	Herbivore sacoglossans with photosynthetic chloroplasts
2008	John Eilif Hermansen	ph.d Biology	Mediating ecological interests between locals and globals by means of indicators. A study attributed to the asymmetry between stakeholders of tropical forest at Mt. Kilimanjaro, Tanzania
2008	Ragnhild Lyngved	ph.d Biology	Somatic embryogenesis in *Cyclamen persicum.* Biological investigations and educational aspects of cloning
2008	Line Elisabeth Sundt-Hansen	ph.d Biology	Cost of rapid growth in salmonid fishes
2008	Line Johansen	ph.d Biology	Exploring factors underlying fluctuations in white clover populations – clonal growth, population structure and spatial distribution
2009	Astrid Jullumstrø Feuerherm	ph.d Biology	Elucidation of molecular mechanisms for pro-inflammatory phospholipase A2 in chronic disease
2009	Pål Kvello	ph.d Biology	Neurons forming the network involved in gustatory coding and learning in the moth *Heliothis virescens:* Physiological and morphological characterisation, and integration into a standard brain atlas
2009	Trygve Devold Kjellsen	ph.d Biology	Extreme Frost Tolerance in Boreal Conifers
2009	Johan Reinert Vikan	ph.d Biology	Coevolutionary interactions between common cuckoos *Cuculus canorus* and *Fringilla* finches
2009	Zsolt Volent	ph.d Biology	Remote sensing of marine environment: Applied surveillance with focus on optical properties of phytoplankton, coloured organic matter and suspended matter
2009	Lester Rocha	ph.d Biology	Functional responses of perennial grasses to simulated grazing and resource availability
2009	Dennis Ikanda	ph.d Biology	Dimensions of a Human-lion conflict: Ecology of human predation and persecution of African lions (*Panthera leo*) in Tanzania
2010	Huy Quang Nguyen	ph.d Biology	Egg characteristics and development of larval digestive function of cobia (*Rachycentron canadum*) in response to dietary treatments -Focus on formulated diets
2010	Eli Kvingedal	ph.d Biology	Intraspecific competition in stream salmonids: the impact of environment and phenotype
2010	Sverre Lundemo	ph.d Biology	Molecular studies of genetic structuring and demography in *Arabidopsis* from Northern Europe
2010	Iddi Mihijai Mfunda	ph.d Biology	Wildlife Conservation and People's livelihoods: Lessons Learnt and Considerations for Improvements. Tha Case of Serengeti Ecosystem, Tanzania
2010	Anton Tinchov Antonov	ph.d Biology	Why do cuckoos lay strong-shelled eggs? Tests of the puncture resistance hypothesis
2010	Anders Lyngstad	ph.d Biology	Population Ecology of *Eriophorum latifolium*, a Clonal Species in Rich Fen Vegetation
2010	Hilde Færevik	ph.d Biology	Impact of protective clothing on thermal and cognitive responses
2010	Ingerid Brænne Arbo	ph.d Medical technology	Nutritional lifestyle changes – effects of dietary carbohydrate restriction in healthy obese and overweight humans

2010	Yngvild Vindenes	ph.d Biology	Stochastic modeling of finite populations with individual heterogeneity in vital parameters
2010	Hans-Richard Brattbakk	ph.d Medical technology	The effect of macronutrient composition, insulin stimulation, and genetic variation on leukocyte gene expression and possible health benefits
2011	Geir Hysing Bolstad	ph.d Biology	Evolution of Signals: Genetic Architecture, Natural Selection and Adaptive Accuracy
2011	Karen de Jong	ph.d Biology	Operational sex ratio and reproductive behaviour in the two-spotted goby (*Gobiusculus flavescens*)
2011	Ann-Iren Kittang	ph.d Biology	*Arabidopsis thaliana* L. adaptation mechanisms to microgravity through the EMCS MULTIGEN-2 experiment on the ISS:– The science of space experiment integration and adaptation to simulated microgravity
2011	Aline Magdalena Lee	ph.d Biology	Stochastic modeling of mating systems and their effect on population dynamics and genetics
2011	Christopher Gravningen Sørmo	ph.d Biology	Rho GTPases in Plants: Structural analysis of ROP GTPases; genetic and functional studies of MIRO GTPases in *Arabidopsis thaliana*
2011	Grethe Robertsen	ph.d Biology	Relative performance of salmonid phenotypes across environments and competitive intensities
2011	Line-Kristin Larsen	ph.d Biology	Life-history trait dynamics in experimental populations of guppy (*Poecilia reticulata*): the role of breeding regime and captive environment
2011	Maxim A. K. Teichert	ph.d Biology	Regulation in Atlantic salmon (*Salmo salar*): The interaction between habitat and density
2011	Torunn Beate Hancke	ph.d Biology	Use of Pulse Amplitude Modulated (PAM) Fluorescence and Bio-optics for Assessing Microalgal Photosynthesis and Physiology
2011	Sajeda Begum	ph.d Biology	Brood Parasitism in Asian Cuckoos: Different Aspects of Interactions between Cuckoos and their Hosts in Bangladesh
2011	Kari J. K. Attramadal	ph.d Biology	Water treatment as an approach to increase microbial control in the culture of cold water marine larvae
2011	Camilla Kalvatn Egset	ph.d Biology	The Evolvability of Static Allometry: A Case Study
2011	AHM Raihan Sarker	ph.d Biology	Conflict over the conservation of the Asian elephant (*Elephas maximus*) in Bangladesh
2011	Gro Dehli Villanger	ph.d Biology	Effects of complex organohalogen contaminant mixtures on thyroid hormone homeostasis in selected arctic marine mammals
2011	Kari Bjørneraas	ph.d Biology	Spatiotemporal variation in resource utilisation by a large herbivore, the moose
2011	John Odden	ph.d Biology	The ecology of a conflict: Eurasian lynx depredation on domestic sheep
2011	Simen Pedersen	ph.d Biology	Effects of native and introduced cervids on small mammals and birds
2011	Mohsen Falahati-Anbaran	ph.d Biology	Evolutionary consequences of seed banks and seed dispersal in *Arabidopsis*
2012	Jakob Hønborg Hansen	ph.d Biology	Shift work in the offshore vessel fleet: circadian rhythms and cognitive performance
2012	Elin Noreen	ph.d Biology	Consequences of diet quality and age on life-history traits in a small passerine bird
2012	Irja Ida Ratikainen	ph.d Biology	Theoretical and empirical approaches to studying foraging decisions: the past and future of behavioural

			ecology
2012	Aleksander Handå	ph.d Biology	Cultivation of mussels (*Mytilus edulis):*Feed requirements, storage and integration with salmon (*Salmo salar*) farming
2012	Morten Kraabøl	ph.d Biology	Reproductive and migratory challenges inflicted on migrant brown trour (*Salmo trutta* L) in a heavily modified river
2012	Jisca Huisman	ph.d Biology	Gene flow and natural selection in Atlantic salmon
2012	Maria Bergvik	ph.d Biology	Lipid and astaxanthin contents and biochemical post-harvest stability in *Calanus finmarchicus*
2012	Bjarte Bye Løfaldli	ph.d Biology	Functional and morphological characterization of central olfactory neurons in the model insect *Heliothis virescens*.
2012	Karen Marie Hammer	ph.d Biology.	Acid-base regulation and metabolite responses in shallow- and deep-living marine invertebrates during environmental hypercapnia
2012	Øystein Nordrum Wiggen	ph.d Biology	Optimal performance in the cold
2012	Robert Dominikus Fyumagwa	Dr. Philos.	Anthropogenic and natural influence on disease prevalence at the human –livestock-wildlife interface in the Serengeti ecosystem, Tanzania
2012	Jenny Bytingsvik	ph.d Biology	Organohalogenated contaminants (OHCs) in polar bear mother-cub pairs from Svalbard, Norway Maternal transfer, exposure assessment and thyroid hormone disruptive effects in polar bear cubs
2012	Christer Moe Rolandsen	ph.d Biology	The ecological significance of space use and movement patterns of moose in a variable environment
2012	Erlend Kjeldsberg Hovland	ph.d Biology	Bio-optics and Ecology in *Emiliania huxleyi* Blooms: Field and Remote Sensing Studies in Norwegian Waters
2012	Lise Cats Myhre	ph.d Biology	Effects of the social and physical environment on mating behaviour in a marine fish
2012	Tonje Aronsen	ph.d Biology	Demographic, environmental and evolutionary aspects of sexual selection
2012	Bin Liu	ph.d Biology	Molecular genetic investigation of cell separation and cell death regulation in *Arabidopsis thaliana*
2013	Jørgen Rosvold	ph.d Biology	Ungulates in a dynamic and increasingly human dominated landscape – A millennia-scale perspective
2013	Pankaj Barah	ph.d Biology	Integrated Systems Approaches to Study Plant Stress Responses
2013	Marit Linnerud	ph.d Biology	Patterns in spatial and temporal variation in population abundances of vertebrates
2013	Xinxin Wang	ph.d Biology	Integrated multi-trophic aquaculture driven by nutrient wastes released from Atlantic salmon (*Salmo salar*) farming
2013	Ingrid Ertshus Mathisen	ph.d Biology	Structure, dynamics, and regeneration capacity at the sub-arctic forest-tundra ecotone of northern Norway and Kola Peninsula, NW Russia
2013	Anders Foldvik	ph.d Biology	Spatial distributions and productivity in salmonid populations
2013	Anna Marie Holand	ph.d Biology	Statistical methods for estimating intra- and inter-population variation in genetic diversity
2013	Anna Solvang Båtnes	ph.d Biology	Light in the dark – the role of irradiance in the high Arctic marine ecosystem during polar night

2013	Sebastian Wacker	Ph.d Biology	The dynamics of sexual selection: effects of OSR, density and resource competition in a fish