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Human-carnivore conflict over livestock in the eastern Serengeti ecosystem with special emphasis on African wild dogs (Lycaon pictus)

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Abstract

Human-carnivore conflict is currently one of the main constraints to biodiversity conservation efforts outside many protected areas worldwide. A survey of livestock depredation caused by wild dogs *(Lycaon pictus*) and other wild carnivore species in the Maasai and Sonjo areas outside Serengeti National Park, Tanzania over two periods between 2007/09 and 2010 using different methodologies indicated a high level of conflict. The conflict related to African wild dogs proved the most significant conflict during both periods compared with that related to other carnivores.

Wild dogs were found to cause more attacks in the Maasai area (n = 229, n = 18) than in the Sonjo area (n = 111, n = 9) over both observation periods. However, the difference in attack rates was attributed to a difference in the size of the livestock populations, as there were approximately 318,209 animals belonging to the Maasai tribe, while the Sonjo tribe had only 78,191 livestock. Therefore, wild dogs were found to exert a statistically significantly higher depredation rate (1.42 animals per 1000 per year) related to the Sonjo tribe compared with the Maasai tribe (0.72 animals per 1000 per year), as estimated only during the first period.

African wild dogs were found to be the most common predator in both areas for both periods. However, in the second period, leopards (*Panthera pardus*) and spotted hyaenas (*Crocuta crocuta*) were also found to be quite common predators in both areas.

Shoats (sheep & goats) were depredated more frequently than cattle/donkeys by wild dogs and other carnivores in the area. Livestock depredation was found to occur most frequently during evening. While shoats were found to be most frequently attacked during the wet season, cattle/donkeys were most frequently attacked during the dry season.

The results of this study recommend that traditional livestock husbandry techniques should be improved, as should the use of non-lethal control measures. Prevention and control measures for diseases that can affect both livestock and wildlife should be instituted in the area to enhance the survival rate of young animals. If possible, herders should bring their livestock back to boma before 16:00 hrs in the evening. Shoats should be more attentively looked after during the wet season. Furthermore, eco-tourism activities should be encouraged in the area. To achieve these aims, the reinforcement of wild dogs' conservation awareness programmes in the area is a possible way forward.

1. Introduction

Human-carnivore conflict over livestock is one of the most important historical cases of human-wildlife conflict. It is also a worldwide problem, exemplified by wolves (*Canis lupus*), bears (*Ursus spp.*), jaguars (*Panthera onca*), pumas (*Puma concolor*), tigers (*Panthera tigris*) and leopards (*Panthera pardus*) killing sheep in Europe and North America, cattle in south America and livestock in Asia (Ciucci and Boitani 1998; Røskaft et al. 2003; Røskaft et al. 2007; Woodroffe et al. 2005), as well as numerous carnivorous species preying on livestock in Africa (Rodney and Rinchen 2004; Treves and Karanth 2003; Woodroffe et al. 2005).

The history of these conflicts stretches back to the time when humans began to domesticate wild animals (Chen et al. 2007; Dan 2008; Diamond 1997; Driscoll et al. 2009). Before that, humans and wild animals had lived together for millions of years without serious conflicts (Woodroffe and Ginsberg 1999).

Currently, most large wild carnivore species are in global decline and one of the main reason for this is human-carnivore conflicts, especially over livestock (Woodroffe et al. 2005). The African wild dog (*Lycaon pictus*) is among the species that have declined because of such conflicts. There are currently approximately 3000-5000 individual wild dogs remaining in the wild (Masenga and Mentzel 2005; Swarner 2004b; Woodroffe et al. 2005). They have disappeared from much of their former range (Rasmussen 1999). Previously, their range was estimated to extend to 39 African countries, but today, they are found in only 14 (Woodroffe et al. 2005) (Fig. 1). This species has been completely eradicated from West Africa and is greatly reduced in Central Africa and Northeastern Africa. A relatively large population remains in Southern Africa in areas such as northern Botswana, western Zimbabwe, Namibia and in Kruger National Park in South Africa (Fig. 1, Appendix 1).

Wild dogs prefer to range widely and can cover over 1000 km^2 per day. Therefore, they usually occur at low densities. They occupy different habitats, such as grassland, wooded grassland, woodland, riverine, semi-desert, bushy-savannahs and upland forest. They mainly feed on medium-sized antelopes (Woodroffe et al. 2007b). While the dogs weigh 20-30 kg,

their prey average approximately 50 kg and may be as large as 200 kg. The weight of the prey depends on the group size (Carbone et al. 2005). In most areas, the dogs prefer to feed on impala (*Aepyceros melampus*), greater kudu (*Tragelaphus strepsiceros*), Thomson gazelle (*Gazella thomsonii*), common wildebeest (*Connochaetes taurinus*) and other small prey species. Large prey, such as buffalo (*Syncerus caffra*) and eland (*Tragelaphus oryx*), will be chased but are seldom killed by wild dogs. The IUCN Red List has categorised *L. pictus* as endangered. This prevalence of endangered wild dogs is due to diseases such as rabies, canine distemper (Fyumagwa 2010) and parvovirus, which cause most of their deaths, as well as to lethal control measures implemented by humans and competition with other large carnivores (Carbone et al. 2005; Woodroffe et al. 2005). Moreover, the decline of African wild dog populations are also related to habitat loss and fragmentation (Treves and Karanth 2003).

Wild dogs are among the most endangered species because of their depredation behaviour. Studies on African wild dogs in the Serengeti ecosystem started in the 1960s. During that time, there were more than 100 individuals in the area. However, during the 1970s, their population began to decline and had decreased to approximately 40 individuals by the end of the decade (Carbone et al. 2005). In 1985, there were only three packs frequently sighted in the area: the Salei pack, which ranged from central to south-eastern plains; the Ndoha pack, found in the western Serengeti; and the mountain pack, reaching to the most eastern Serengeti plains (Stearns and Stearns 1999). This decrease continued until 1991, when the wild dogs were completely wiped out in Serengeti National Park (SNP) (Carbone et al. 2005; Stearns and Stearns 1999). One hypothesis related to this extinction is that it was due to the outbreak of viral diseases such as rabies and canine distemper virus, induced by stress caused from intervention (vaccination, immobilisation, wild dog collaring) (Creel et al. 1997; Gascoyne et al. 1993; Stearns and Stearns 1999). Since that time, the African wild dog has not been seen in SNP, although beginning in 1993, single sex groups were observed in the wider ecosystem (Masenga and Mentzel 2005).

From 2000 onwards, livestock owners reported complaints to the Ngorongoro District Game Officer. These reports were related to the depredation of livestock by African wild dogs, mostly occurring in the eastern Serengeti ecosystem. Such complaints and observation on wild dogs led to the establishment of the Serengeti wild dog monitoring project with the aim of establishing a healthy wild dog population in SNP (Masenga and Mentzel 2005).

Studies on livestock depredation in the Serengeti ecosystem have been conducted in the northwestern (Grumeti and Ikorongo Game Reserves) and southeastern (Ngorongoro Conservation Area) parts of the ecosystem (Fig. 2). The results from the northwestern region showed that the spotted hyaena (*Crocuta crocuta*) was the main carnivore frequently causing livestock depredation. Other carnivores reported in the region are leopards, lions (*Pathera leo*), black-backed jackals (*Canis mesomelas*) (Holmern et al. 2007; Nyahongo 2007) and olive baboons (*Papio anubis*). Studies from the southeastern region showed that the lion was the leading wild carnivore species causing livestock depredation, followed by leopards and spotted hyaenas (Ikanda and Packer 2008).

Similar results were found in the northeastern Serengeti ecosystem in between 1999 and 2001, but during that time, wild dogs were not observed in the area (Maddox 2003). Other carnivore species involved in the conflicts in the northeastern ecosystem were lions, leopards, spotted hyaenas, striped hyaenas (*Hyaena hyaena*) and cheetahs (*Acinonyx jubatus*).

Wild dogs have been reported to prey on livestock near human communities, and studies have shown that lethal control is a major factor contributing to the species' current population collapse (Rasmussen 1999; Swarner 2004b). Wild dogs have large home ranges; however, because of human population expansion and the associated contraction of their habitats, they are often confined in proximity to agro-pastoral and pastoral communal land. Most of the kills by wild dogs occur outside protected areas in communal lands, though the species might sometime spend its lifetime in a protected area (Woodroffe et al. 2005). Most agro-pastoralists and pastoralists exaggerate their complaints related to livestock depredation by wild dogs, as has been found, for example, in Zimbabwe and southern Kenya (Rasmussen 1999; Woodroffe et al. 2005).

In an attempt to solve this problem in the eastern Serengeti, it has been concluded that there is a need to examine the mitigating measures used in resolving such conflicts more deeply and to investigate how humans can coexist with large wild carnivores in such areas (Swarner 2004a). Therefore, the results from the present study will assist in developing effective human-wild dog conflict mitigation strategies through a better understanding of the associated spatio-temporal conflict pattern, as well as factors that affect livestock losses in the area and the species involved (Tamang and Baral 2008). The aim of this study is,

thus, to assess the depredation patterns related to such conflicts and their magnitude in the eastern Serengeti ecosystem by focusing on the African wild dog, as well as other large carnivore species such as lions, leopards, spotted hyaenas and cheetahs.

1.1. Study Hypotheses

Wild dogs are mostly found outside SNP, where densities of other predators are low.
H 1. The wild dog is the most serious predator in the study area.

In the Maasai culture, people are more dependent on cattle and, therefore, more seriously attend to their livestock than the Sonjo people.
H 2. Livestock depredation by wild dogs should be less common among the Maasai people than among the Sonjo people.

The wet season is the time when wild dogs come down from the forested mountains to the Serengeti plains. Moreover, wildebeest migrate to the plains in this period. Hence, wildebeests will attract more carnivore species, which will compete with wild dogs for food in the area. Additionally, during this period, the Maasai usually separate their livestock from the lactating wildebeests to avoid the spread of diseases, e.g., malignant catarrhal fever (MCF).
H 3. The wet season is the season most associated with livestock depredation.

The time of day is related to the activity patterns of wild carnivores. For example, lions, spotted hyaenas and leopards are more active during the night, while wild dogs are only active during the day.
H 4. Livestock depredation will be more intense in the area during the time when the wild dogs are active, which is during daytime.

When both shoats (sheep and goats) and cattle (and donkeys) are available at the same place and thus wild dogs are able to choose between them, they will choose the smaller prey.
H 5. Wild dogs attack more shoats than cattle.

2. Materials and Methods

2.1. Study Areas

The study was conducted in the eastern Serengeti ecosystem, which includes the Loliondo Game Controlled Area (LGCA) and a small part of the Ngorongoro Conservation Area (NCA) (Fig. 2). The Maasai and Sonjo tribes inhabit the areas, with the former group being nomadic pastoralists, while the latter are agro-pastoralists and live in permanent settlements (Maddox 2003; Masenga and Mentzel 2005). Therefore, the Maasai depend entirely on livestock for their survival and for economic gain, instead of on crop cultivation. The Sonjo people also keep livestock, but they do not depend solely upon it, as they are also engaged in crop cultivation and other business activities.

Loliondo is located in the Maasai ancestral land in the northern part of Tanzania, along the border with Kenya. It is a multiple land use area and forms the eastern boundary of the Serengeti ecosystem. It borders the Ngorongoro highlands to the south, SNP to the west and Lake Natron on its eastern boundary. The LGCA encompasses an estimated area of approximately 4500 km^2, which is roughly a third of the size of SNP. There is no physical barrier separating the LGCA from other parts of the ecosystem, thus allowing free movement for animals within the ecosystem. The population of humans decreases from south to north, with the highest densities being found around Wasso, the town of Loliondo and the area near the Kenyan border. In the south, the human population mainly comprises nomadic Maasai, who inhabit the area at low density. The density of resident wild herbivores is low in the area due to overgrazing and trophy hunting activities.

The climate of the study area is mostly influenced by the Ngorongoro crater highlands, which create a rain shadow, and the hydrologic cycles of Lake Victoria, which cause temperature fluctuations between the lake and its surroundings (Jaeger 1982). It exhibits a bi-modal rainfall pattern, with peaks occurring in December and April, and a total of 400-1200 mm precipitation per annum (Maddox 2003; Masenga and Mentzel 2005). The area is dominated by open woodland and grassland. Open woodland is found mostly in the northern region on rolling hills, interspersed with rocky outcrops. In the central region, there are mountains with steep slopes and densely vegetated gullies. The open areas in the lowlands are either cultivated or open woodlands. The southern portion of the area gives way to short grassland.

2.2. Data Collection

The data for this study were collected in two different periods. The data for the first period were collected between June 2007 and June 2009. Both primary and secondary data sources were used to obtain data. The method for primary data collection followed that used by previous investigators (Johnson et al. 2006; Kolowski and Holekamp 2006; Namgail et al. 2007; Woodroffe et al. 2007a). To carry out this methodology, I used field staff either employed in partnership with local non-governmental conservation organisations or paid in whole or in part by the Serengeti wild dog monitoring project or directly recruited from the Maasai and Sonjo societies.

The researchers used enumerators selected from each surveyed village for data collection in the area. The enumerators were employed partly by the Serengeti Wild dog Monitoring Project in the eastern Serengeti ecosystem, which is funded by the Frankfurt Zoological Society for monitoring wild dog, packs in this area. Before beginning data collection, the researchers met first with the village authorities and told them about the project's aims and goals. Then, the researchers asked the village authority to inform all local people in the area that the project did not aim to provide compensation to them or to remove them from the area, but only to understand the extent of the problem and look for conflict resolution in the area. Thus, it was expected that there would not be any exaggeration or misrepresentation of their losses in the area. However, it was not completely guaranteed that this would actually be the case, as shown by other studies (Baker et al. 2008). People were informed to report any depredation event in the area as quickly as possible to either their village leaders or their enumerator in the area. Where possible the enumerators took photos of livestock remains for further verification.

Using this approach, it was expected that the data from the enumerators should be reliable. The enumerators were village representatives who knew both Swahili and their local language well. They used structured questionnaires written in both English and Swahili languages. The Swahili version was given to the field staff and was completed in the Swahili language. However, the interview was carried out using either the local language or the Swahili language based on the information expected from the interviewee, as indicated in the questionnaire. Before beginning data collection, the enumerators were exposed to the

wording of the questionnaire. They were informed what type of information they were required to fill in on the questionnaire during the interviews. Then, we went together into the field to practice data collection. After some practice, the enumerators appeared to be conversant, and they continued working in my absence. Moreover, each month for approximately two weeks, a researcher visited them to assess their progress and to collect completed data sheets. During that time, the researchers and the enumerators worked together and attempted to assess their performance in data collection.

The questionnaire surveys were aimed at exploring different aspects of depredation patterns and the perceptions and attitudes of local people towards the main species associated with conflicts in the area. The questionnaire consisted of four main sections: field staff information, carnivore information, herder information and livestock information. Information from the field staff included their names, the village's name, habitat description and other details. Then, each respondent was asked several questions to record as much information as possible. The questions were based on the number of carnivore species involved in an attack, how they initiated the attack, how the herder responded to that attack, the herder's name, the GPS location of the boma, how the was attack detected (seen/heard), the name and age of the attack witness, the number of people on guard and their ages, the number of dogs at home, the grazing area, the total number of livestock the herder was looking after, the herder's comments, the livestock species attacked, the name of the livestock owner, the date and time of the attack, the location of the attack, the GPS coordinates of the attack site, the age and sex of the attacked livestock species, cost, whether livestock were injured or killed and the time the herders and livestock left and returned to the boma (Woodroffe and Ginsberg 1999). Because goats and sheep presented almost the same body size, we grouped them together in one group referred to as shoats.

Furthermore, secondary data were obtained using face-to-face interviews and participatory observations of the employees of the wildlife department, community representatives and people who proved to have experience in conflicts with carnivores. The data obtained using this approach were the total number of the livestock stock found, as well as the number of households in the area based on 2008/9 census data.

The second period of the study was conducted from June-July 2010. During that period, the researchers collected control data to verify the enumerators' information from the first period of data collection. The data were collected based on attack occurrences over the last

two months, i.e., June-July 2010. The data were collected by employing both direct observations and questionnaire surveys. All villages where livestock depredation had been reported previously from June 2007 to June 2009 were visited again, but a different survey method was employed. The researcher randomly surveyed the whole area used for livestock grazing by driving through it. Once a group of livestock was detected, it was followed, and the researcher began to interview the herder associated with the group. In this case, the herder represented our sampling unit from the household in which he/she resides.

We aimed to sample at least 30 herders at each village. This sample size had previously been used in other studies and was successfully (Mandara 2007). Therefore, in the Maasai area, we expected to survey five villages, and thus, approximately 150 samples were expected to be collected. The landscape in the Maasai area was mostly grassland and rarely mountainous. Therefore, we were able to reach most parts of this region used for grazing livestock. Hence, we nearly met our sampling goal. However, this was not the case for the Sonjo people, as they were found to occupy mountainous and forested areas. This made it more difficult for us to reach all of their grazing areas by car and, thus, for us to locate many grazing livestock groups. Hence, we were able to collect only 60 samples from all five villages, instead of 150 samples

Each herder was chosen randomly from the grazing land. The information required from each herder or the oldest herder was his/her age, sex, the number of herders, age class, village name, GPS location, herd size, total number of cattle and shoats, if there had been any attack on their herd in the last two months, and if there had been an attack, which carnivore species were involved, which livestock species were attacked, if the attacked livestock were killed or injured, how many times they were attacked and the number of guarding dogs and type of equipment used as guarding weapons.

2.3. Data Analyses

During the survey, we collected the GPS locations for all of the Maasai and Sonjo villages within the study area and those of the attacks, and thus, we were able to calculate the distance to the closest SNP boundary, as well as to draw a study area map using ArcView 9.0 (Environmental Systems Research Institute, Redlands, CA, USA).

When analysing the obtained data, wild dog attacks were coded as one, while those caused by other carnivore species were coded as two. Other carnivore species included here were lions (29, 2), spotted hyaenas (100, 26), striped hyaenas (23, 1), leopards (100, 28), civets (*Civettictis civetta*) (0, 1), jackals (*Canis sp.*) (0, 5), cheetahs (5, 0) and olive baboons (0, 1) (numbers in parentheses are the numbers of attacks caused in period one and period two, respectively).

All analyses were performed using SPSS Statistics 18 for Windows (*http://www.spss.com*). Parametric tests were used to analyse the data when they were found normally distributed. Otherwise, non-parametric tests were used (Fowler et al. 2009; Zar 2010).

All statistical tests were two tailed, and the significance level was set at $p \leq 0.05$.

3. Results

3.1. General Results for Differences between Wild dogs and other Carnivore Species during 2007-09

3.1.1. Tribes

African wild dogs were the most common predator in both areas, being responsible for 47 % of the livestock depredation cases related to the Maasai and 99 % of the Sonjo cases. Livestock depredation by wild dogs differed between the Maasai and Sonjo tribes, with more attacks occurring in the latter group, and the difference was statistically significant (Table 1). The Maasai tribes owned 318,209 animals, while the Sonjo tribe owned 78,191 (totally 396,400) livestock in total. Therefore, wild dogs were found to be associated with a significantly higher depredation rate (1.42 animals per 1000 per year) in the Sonjo tribe than in the Maasai tribe (0.72 animals per 1000 per year) ($\chi^2 = 100.5$, d.f = 1, $p < 0.001$). A similar observation was found for other carnivore species between the two areas (Table 1). However, in the Maasai tribe, there were more incidences of other carnivore species causing livestock depredation than in the Sonjo tribe, and the difference was statistically significant ($\chi^2 = 97.8$, d.f = 1, $p < 0.001$, Table 1).

Both wild dogs and other carnivore species exhibited a higher depredation rate on shoats than on cattle (donkeys) (Table 2). Although wild dogs presented a higher frequency of shoat depredation and a lower depredation rate on cattle (donkeys) than other carnivore species, the difference was not statistically significant (Table 2). This variation was attributed to differences in population size between shoats (246,786 animals) and cattle/donkeys (149,614 animals) that existed in the area during the two periods.

3.2. Seasons

Attacks were found to occur in all four seasons of the year. However, livestock depredation differed significantly between shoats and cattle/donkeys across the four seasons ($\chi^2 = 23.5$, d.f = 3, $p < 0.001$, Table 3). Most attacks of shoats were found to occur during the wet season (1.18 animals per 1000 per year), while those on cattle were highest during the dry season (0.32 animals per 1000 per year, Table 3). The short dry season was associated with

the fewest attacks on both shoats and cattle, while the wet, short rainy seasons presented the highest attack rates for wild dogs compared with other carnivores (Table 3).

3.3. Time of the Day

The depredation patterns found for wild dogs and other carnivore species differed significantly between different times of the day ($\chi^2 = 144.9$, d.f = 4, $p < 0.001$). Wild dogs caused no attacks during the night and mostly attacked during the evening (Table 4), whereas other carnivores killed most livestock during the night and fewest in the early morning (Table 4).

The killing patterns found for shoats and cattle (and donkey) differed significantly at different times of the day ($\chi^2 = 14.5$, d.f = 4, $p < 0.001$, Table 5). However, both shoats and cattle (and donkeys) were most frequently depredated during the evening (Table 5). The killing rates found for shoats during night were approximately ten times higher than those for cattle (and donkeys), and approximately 80% of cattle (and donkeys) depredation occurred during the afternoon and evening (Table 5).

3.4. General Results for Differences between Wild dogs and other Carnivore Species during 2010

3.4.1. Tribes

Wild dogs caused more livestock depredation incidences in the Maasai tribe than in the Sonjo tribe, although the frequencies of wild dog attacks were higher in the Sonjo tribe (50.0 %) than in the Maasai tribe (24.0 %) (Table 6). The depredation rates found for wild dogs and other carnivores differed between the two tribes ($\chi^2 = 4.6$, d.f = 1, $p < 0.05$, Table 6).

3.4.2. Comparison of Livestock Depredation between the two Periods (2007-09 and 2010)

A greater number of carnivore species were found to cause livestock losses in the Sonjo tribe during the second period than during the first period (Tables 1, 6). Therefore, in the Sonjo tribe, there was a large difference between the two periods in the frequency of livestock depredation between wild dogs and other carnivores. During the first period, it was more or less only wild dogs (99.0 %) causing livestock depredation (Table 1), while during the second period, the frequencies of wild dog attacks were significantly lower, while the frequencies of attacks from other carnivore species increased (1.0 % to 50 %) ($\chi^2 = 48.7$, d.f = 1, $p < 0.001$). Other carnivore species, such as spotted hyaenas and leopards, were found to cause more attacks in the area during the latter period (Table 6).

In the Maasai area, during the first period, there were no considerable differences in the frequencies of attacks caused by wild dogs versus other wild carnivores (Tables 1, 6). However, there was a significant difference between the frequencies of attacks among other wild carnivores between the two periods (24% to 76%, respectively). Additionally, the frequencies of attacks by wild dogs were not as high as those of the other carnivores between the two periods in the study area. However, the frequencies of attacks by both wild dogs and other carnivores between the two periods in the Maasai area exhibited highly significant differences ($\chi^2 = 560.8$, d.f = 1, $p < 0.001$).

3.4.3. Comparison of Factors that might Affect Livestock Losses between the two Tribes within the two Periods (2007- 09 and 2010)

Neither the average number of herders nor their age class was found to differ significantly between the Maasai and Sonjo tribes during either of the two study periods (Appendix 2). However, the average herd size differed significantly between the two tribes during the second study period (Appendix 2), while no significant difference was found in herd size during the first study period (Appendix 2). Although no difference was found with respect to the gender of the herders during the first period, significantly more females were found to be herding in the Sonjo tribe than in the Maasai tribe during the second study period (Appendix 2).

4. Discussion

4.1. Differences between Wild Dogs and other Carnivore Species

4.1.1. Tribes

The findings of our study revealed that wild dogs are the most serious predator in both the Maasai and Sonjo tribes. This finding supports our hypothesis (H1) that wild dogs are mostly found outside the SNP where the densities of other predators are low (Creel and Creel 1996). Therefore, it was most likely that they would represent a more important factor causing livestock losses in the area compared with other predators. The behaviour of the wild dogs might have been negatively affected in the SNP by the presence of other carnivore species (Estes and Goddard 1967). Lions may directly cause pup mortality in wild dogs (Creel and Creel 1996), and other researchers have found that spotted hyaenas steal carcases at wild dogs kills through kleptoparasitism (Carbone et al. 1997; Carbone et al. 2005; Creel and Creel 1996; Estes and Goddard 1967).

Other predators, such as lions, hyaenas and leopards, were found to present higher frequencies of attacks in the Maasai tribe than in the Sonjo tribe in the two periods. This result is because the Maasai tribe lives closer to the park boundary than the Sonjo tribe, and therefore, this proximity influences the influx of different carnivore species in the area. The Maasai were found to own a higher number of livestock than the Sonjo. However, wild dogs caused more attacks to the Sonjo livestock during the first period. During the second period, leopards and spotted hyaenas increased their frequencies of attacks in the Sonjo area. This increase could be attributed either to an increase in their numbers in the Sonjo area or the transparency of the second methodology used for data collection in the area.

Wild dogs presented higher depredation rates in the Sonjo tribe than in the Maasai tribe. This result supports our hypothesis (H 2) that in the Maasai culture, people are more dependent on cattle and, therefore, more vigilant in looking after their livestock than the Sonjo people; thus, livestock depredation by wild dogs was expected to be less common among the Maasai people than among the Sonjo people, despite the fact that wild dogs were probably more common in the Maasai area. Additionally, the grazing lands used by the Maasai tribe are largely plains/grasslands, with few hills and patches of woodland, and these areas are more suitable for livestock rearing compared with those of the Sonjo tribe. The Sonjo grazing lands are mostly found on the floors of deep valleys and sometimes on the top of

forested mountains. Hence, this could reduce herding efficiency in the Sonjo tribe. Therefore, the Sonjo people are forced to engage in other economic activities, such as cultivation and business, to a greater extent than the Maasai (Masenga and Mentzel 2005).

Three depredation zones could be determined in the area. These are the areas where most of the reported attack events were recorded. In the Maasai area, two zones were determined: northern and southern depredation zones. These two zones were created because the Maasai were found to be relatively sparsely distributed in these areas. In contrasts, in the Sonjo area, only one depredation zone was determined, because the Sonjo tribe was found to be relatively aggregated in the area (Unpublished data).

4.2. Seasons

Our results showed that the wet season was the peak period for livestock depredation in the area. During that period, wild dogs caused more attacks than the other carnivores. Shoats were found to be more frequently depredated than cattle because when shoats and cattle are available in the same area, the wild dogs are able to choose between them. The same trend was found during the dry season. However, this was not the case when cattle were considered alone, as cattle were found to more to be depredated in the dry season than the wet season. This finding supports our hypothesis (H3) that a greater among of livestock depredation occurs during the wet season than in other seasons because the wet season is the time when wild dogs come down from the forested mountains to the Serengeti plains. Moreover, this is the period in which wildebeest migrate to the plains (Maddox 2003; Musiega and Kazadi 2004). During this period, wildebeest have been found to select favourable green pastures, with high nutrient content (McNaughton 1985; Musiega and Kazadi 2004; Wilmshurst et al. 1999). Such high-nutrient pastures are rarely found in areas where livestock graze because of overgrazing (McNaughton 1985). Thus, when reaching these areas, migratory species usually move along to other areas of the plains to look for green pastures, leaving behind livestock, which then become available prey species for the remaining wild dogs, as well as other carnivores in the area.

Additionally, this time of the year is the calving period for wildebeests. Calving wildebeests have been found to transmit disease to cattle when using the same areas. For example, malignant catarrhal fever disease can be transferred to cattle and has been observed to kill a large number of cattle wherever cattle use wildebeests calving areas for grazing (Bourn and

Blench 1999; Fyumagwa 2010). Hence, to avoid this, the Maasai are usually forced to separate their livestock from wildebeests. The Maasai generally move their animals from areas with favourable pastures on plains in lower regions and to highlands/hills of the plains, where the dens of wild dogs are found. In so doing, they increase their contact with the wild dogs, which, therefore, increases the rate of predation on their livestock because if wild dogs and other carnivores find fewer or no wild prey species in and area, they will be forced to prey on livestock (Woodroffe et al. 2005). Wild dogs have been found to cause repeated livestock losses when there are limited numbers of wild prey species (Woodroffe et al. 2005).

Moreover, the depredation of cattle was found to occur more frequently during the dry season than other seasons of the year because the dry season is when both wild dogs and livestock keepers move into forested mountain regions in search of food. During that time, wild dogs depend very much on forested mountains species, such as bush pigs (*Potamochoerus porcus*), dik dik (*Madoqua kirkii)*, impala, duikers (*Sylvicapra grimmia*), porcupines (*Hystrix cristata*) and lesser kudu *(Tragelaphus imberbis)*, as well as fresh, clean water for their diet, while livestock keepers look for new pastures to graze their livestock, especially cattle, as they require more food than shoats. Hence, they increase their chances of contact with wild dogs and are exposed to more wild dog attacks. This occurrence is further escalated by hunters' activities in the area, which reduce wild prey numbers and force wild dogs to shift their diet to cattle.

4.3. Time of Day

The depredation activities of wild dogs and other carnivores on livestock occur at different times of the day. This difference is related to the activity patterns of the wild carnivores in the area. For example, lions, spotted hyaenas, and leopards are more active during the night, whereas wild dogs are only active during the day (Frank et al. 2005).

As a result, wild dogs were found to attack more livestock during the evening than any other time of the day. Therefore, these results support our hypothesis (H4) that livestock depredation will be more frequent during the time when wild dogs are most active, which is during daytime. More shoats were depredated than cattle/donkeys during that time. The same pattern has been found in other surveys (Creel and Creel 2002; Frank et al. 2005; Fuller and Kat 2008; Woodroffe et al. 2005; Woodroffe et al. 2007b). However, this finding does not support previous reports of bimodal hunting behaviour in wild dogs, as they have

previously been found to hunt more during early morning and late afternoon (Woodroffe et al. 2005).

Other researchers have reported that wild dogs are usually active from 05:00 hrs onwards (Estes and Goddard 1967; Woodroffe et al. 2005). In our study, wild dogs were found to cause few attacks on livestock during the early morning because, during that time, the Maasai and Sonjo tribes have not yet begun to herd their livestock. Additionally, wild dogs have never been found to prey on livestock when they are inside their boma (Frank et al. 2005; Woodroffe et al. 2005). Therefore, wild dogs were found to begin preying on livestock around 08:00 to 09:00 hrs, when most of the herders started to take out their livestock for grazing. During this period, they have been found to prey more on wild prey than on livestock species (Woodroffe et al. 2005). However, the preying of wild dogs on livestock increased from 10:00 hrs onwards, reaching a peak around 16:00 hrs (Woodroffe et al. 2005).

The other species for which nocturnal hunting behaviour has been indicated were leopards, spotted and striped hyenas, followed by lions (Frank et al. 2005; Holmern et al. 2007; Ikanda and Packer 2008; Kissui 2008).

4.3.1. Livestock species

Our findings showed that wild dogs preyed more on shoats than on cattle (and donkeys). This is because both shoats (sheep and goats) and cattle (and donkeys) are available in the same areas, and the wild dogs are able to choose between the, supporting our hypothesis (H5) that wild dogs attack more shoats than cattle (and donkeys). They choose shoats instead of cattle (and donkeys) because of their medium size, as it has been shown in other studies that wild dogs usually select medium-sized ungulates as their prey species (Estes and Goddard 1967; Hayward et al. 2006; Woodroffe et al. 2007b). They prefer prey within a bimodal body mass range of 16–32 kg and 120–140 kg that are abundant and are less likely to cause injury when hunted. This bimodal range follows that of optimal wild dog pack sizes based on energetic costs and benefits (Hayward et al. 2006). Wild dogs kill greater kudu and Thomson's gazelle wherever they coexist, and these species are significantly preferred over other potential prey species. Impala and bushbuck (*Tragelaphus scriptus*) are also preferred prey species (Estes and Goddard 1967; Hayward et al. 2006; Woodroffe et al. 2007b).

4.4. Factors affecting livestock loss between the two periods

We found that there were no statistically significant differences between the average number of herders in the Maasai and Sonjo tribes during the study periods. However, it was observed only one herder herded most of the livestock, and these individuals were mostly children, rather than youths, adults or elders. The few number of herders observed were found to reduce the efficiency of providing full protection to the livestock herds, especially when they were out grazing. Studies in other areas have found similar problems and have recommended improved traditional husbandry practices (Ogada et al. 2003; Woodroffe et al. 2007a).

The mean herd size differed significantly between the Maasai and Sonjo tribes during the second study period. However, the Maasai had almost the same number of livestock as the Sonjo in each group during the first study period (Appendix 1). The difference found during the second study period was most likely because the observation method used in this period was better than the reporting method used during the first period.

4.5 Differences of livestock depredation between the two periods

Our results have shown that clear difference exists between the frequencies of attacks caused by both the African wild dogs and other carnivores between the two periods. The frequencies of wild dogs' depredation were found to decline in both periods between the two tribes. While on the other hand, those caused by other carnivores was found to increase in both periods and between the two tribes. This could attribute to different methodologies used in data collection with the later being more opened and transparent than the former one. In addition, wild dogs' population has shown to decline in the area. According to Masenga (2010) wild dogs' population in the eastern Serengeti ecosystem was found to increase in 2008 as compared to 2005. During that time about 132 wild dog individuals were found in the area. This number was found to decline from 2009 to below 100 individuals (unpublished data) in 2010. The decline is associated by their persecution by humans mostly by using poison as was found to occur in 2007 in the Maasai area where about 23 individuals from a pack of 26 individuals were found dead (Masenga 2010). More unrecorded killings of wild dogs might have happened but not known and this could have lead to their decline in the area.

On the other hand, the density of other carnivores may have increased in the area very recently. However, this requires more research as no recently data are available.

5. Conclusions and Management Implications

This study revealed that livestock depredation by wild dogs differed in a statistically significant manner between the Maasai and Sonjo tribes. The Sonjo people were found to suffer greater losses than the Maasai people. Wild dogs were found to cause the most livestock losses in the evening and during the wet season. Moreover, they were found to prey more often on shoats than on cattle and donkeys.

Other carnivore species, including lions, spotted hyenas and leopards, were found to be associated with attacks on livestock in the area in addition to wild dogs. Such carnivores were found to cause more losses to the Maasai people than to the Sonjo people during the first study period. However, during the second period, other carnivores, such as leopards and spotted hyaenas, were found to cause high losses to both tribes. This result could be due to the different methodologies used for data collection in the two periods, or that the wild dog population has declined.

Based on the results of this study, we recommend the use of non-lethal control measures in the management of the carnivore species in the area but do not recommend translocation measures, as such measures have been found to be unsuccessful in most cases where they have been applied (Athreya et al. 2010; Rasmussen 1999). Improved livestock husbandry practices, including increasing the number of herders to at least four instead of one, the use of more individuals older than children for herding and the use of guard dogs of an appropriate breed are recommended as means that can be used to solve these problems. We also recommend the use of other measures, such as improving human behaviour (through compensation, economic incentives, and participation), fladry, wild prey species conservation, repellents and deterrents, to reduce livestock losses in the area. Additionally, diseases that can be transmitted between livestock and wildlife should be controlled in the area.

It was found that most attacks occurred during the evening; therefore, it is recommended that if possible, the herders should bring back their livestock before at 16:00 hrs at latest. Additionally, more attention should be given to the livestock herds during the wet season, when predation risk is highest.

Finally, the rate of livestock depredation is actually very low in the area (less than one per 1000 livestock per year). Therefore, there is a need to reinforce a wild dog's conservation awareness programme. This reinforcement will assist in sensitising local people to the benefits of having wild dogs in their area. Additionally, it will assist in raising their tolerance to wild dogs and, thus, enhance sustainable wild dog conservation in the area. Moreover, ecotourism activities, such as photographic safaris, nature adventures, wildlife viewing and cultural expeditions, should be established in the area. These activities will attract a greater influx of tourists in the area and, hence, increase income and revenue for both the local people and the government. All of these measures will increase the tolerance of local people for coexistence with the wildlife in their area, as some of the costs they face due to predation from wild species can be compensated with tourism income accrued in the area.

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8. List of Tables

Table 1 - Wild dogs, other carnivore species (lions, leopards, spotted and striped hyenas) and their frequencies of livestock depredation in two different locations in the eastern Serengeti ecosystem during 2007-2009 (number of depredated cases, with percentages in brackets, and depredation rate, d/r, which is the number of attacks per 1000 livestock per year). χ^2 -test of differences in the frequency of depredation between the two areas by wild dogs and other carnivores.

	Locations				
	Maasai		**Sonjo**		
Carnivore Species		**Frequency Attacks/1000**		**Frequency Attacks/1000**	**χ^2 -Test of differences**
	n (%)	**(d/r)**	**n (%)**	**(d/r)**	**(p <**
Wild dogs	229 (47)	0.72	111 (99)	1.42	0.001
Other carnivores	257 (53)	0.81	1 (1)	0.01	0.001
Total	**486 (100)**		**112 (100)**		0.001

Table 2 - Livestock species and their associated frequencies of attack by wild dogs and other carnivore species (lions, leopards, spotted and striped hyenas) and their frequencies of livestock depredation in the eastern Serengeti ecosystem during 2007-2009 (number of depredated cases, with percentages in brackets, and depredation rate, d/r, which is the number of attacks per 1000 livestock per year). χ^2 -test of differences in the frequency of depredation between the two areas by wild dogs and other carnivores.

Carnivore species	**Livestock Species**				**χ^2 -Test of differences**
	Carnivore species	**Livestock Species**		**χ^2 -Test of differences**	**(p <**
Wild dogs	300 (60)	1.47	40 (48)	0.35	0.001
Other carnivores	208 (40)	1.02	43 (52)	0.38	0.001
Total	**508**		**83**		0.063

Table 3 - Seasons of livestock depredation by wild dogs and other carnivore species (pooled) and their frequencies of livestock depredation in the eastern Serengeti ecosystem during 2007-2009 (number of depredated cases, with percentages in brackets, and depredation rate, d/r, which is number of attacks per 1000 livestock per year). χ^2 -test of differences in the frequency of depredation between the two areas by wild dogs and other carnivores.

	Livestock species				
	Shoats		**Cattle**		**χ^2 -test of differences**
Seasons		**Frequency of Attacks/1000**		**Frequency of Attacks/1000**	
	n (%)	**(d/r)**	**n (%)**	**(d/r)**	**p <**
Short dry	47 (9)	0.23	12 (15)	0.11	0.001
Wet season	241 (48)	1.18	28 (34)	0.26	0.001
Dry season	107 (21)	0.52	35 (42)	0.32	0.001
Short rains	112 (22)	0.55	8 (10)	0.07	0.001
Total	**507 (100)**		**83(100)**		**0.001**

Table 4 - Time of day when wild dogs and other carnivore species (lions, leopards, spotted and striped hyenas) attack livestock and their frequencies of livestock depredation in the eastern Serengeti ecosystem during 2007-2009 (number of depredated cases, with percentages in brackets, and depredation rate, d/r, which is number of attacks per 1000 livestock per year). χ^2 -test of differences in the frequency of depredation between the two areas by wild dogs and other carnivores.

	Carnivore species				
	Wild dogs		**Other carnivores**		**χ^2 -test of differences**
Time of day		**Frequency of Attacks/1000**		**Frequency of Attacks/1000**	
	n (%)	**(d/r)**	**n (%)**	**(d/r)**	**p <**
Early morning	18 (5)	0.05	12 (5)	0.03	
Morning	62 (19)	0.16	32 (12)	0.08	
Afternoon	98 (29)	0.25	50 (20)	0.13	
Evening	158 (47)	0.40	69 (27)	0.17	
Night	0 (0)	0.00	92 (36)	0.23	
Total	**336 (100)**		**255 (100)**		**0.001**

Table 5 - Time of day when wild dogs and other carnivore species (pooled) depredated shoats and cattle and their frequencies of livestock depredation in the eastern Serengeti ecosystem during 2007-2009 (number of depredated cases, with percentages in brackets, and depredation rate, d/r, which is number of attacks per 1000 livestock per year). χ^2 -test of differences in the frequency of depredation between the two areas by wild dogs and other carnivores.

	Livestock species				
	Shoats		**Cattle**		**χ^2 -test of differences**
Time of the day	**n (%)**	**Frequency Attacks/1000 (d/r)**	**n (%)**	**Frequency Attacks/1000 (d/r)**	**p <**
Early morning	25 (5)	0.12	5 (6)	0.06	
Morning	86 (17)	0.42	7 (9)	0.06	
Afternoon	119 (24)	0.58	26 (32)	0.24	
Evening	187 (37)	0.92	40(49)	0.37	
Night	86 (17)	0.42	4 (5)	0.04	
Total	**503(100)**		**82 (100)**		**0.001**

Table 6 - Wild dogs, other carnivore species (lions, leopards, spotted and striped hyenas) and their frequencies of livestock depredation in two different locations in the eastern Serengeti ecosystem during 2010 (number of depredated cases, with percentages in brackets). χ^2 -test of differences in frequency of depredation between the two areas by wild dogs and other carnivores.

	Tribes		
Carnivore Species	**Maasai n (%)**	**Sonjo n (%)**	**χ^2 -test of differences (p <**
Wild dog	18 (24)	9 (50)	
Other carnivore	57 (76)	9 (50)	
Total	**75 (100)**	**18 (100)**	0.05

9. List of Appendices

Appendix 1- Estimated numbers of remaining wild dogs in Africa.

	In Protected areas	**Outside protected areas**	**Accuracy**
West Africa		-	Fair
➢ Senegal	100		
Central Africa			
➢ Cameroon	100	-	Guess
➢ Rep.	150	-	Guess
➢ Chad	50	-	Guess
East Africa			
➢ Ethiopia	100	100	Guess
➢ Kenya	150	100	Fair
➢ Tanzania	1400	500	Good
➢ Sudan	-	100	Guess
South Africa			
➢ Botswana	750	-	Good
➢ Namibia	100	300	Fair
➢ Zambia	500	-	Fair
➢ Zimbabwe	500	200	Fair
➢ South Africa	400	-	Good
Total amount	4300	1300	

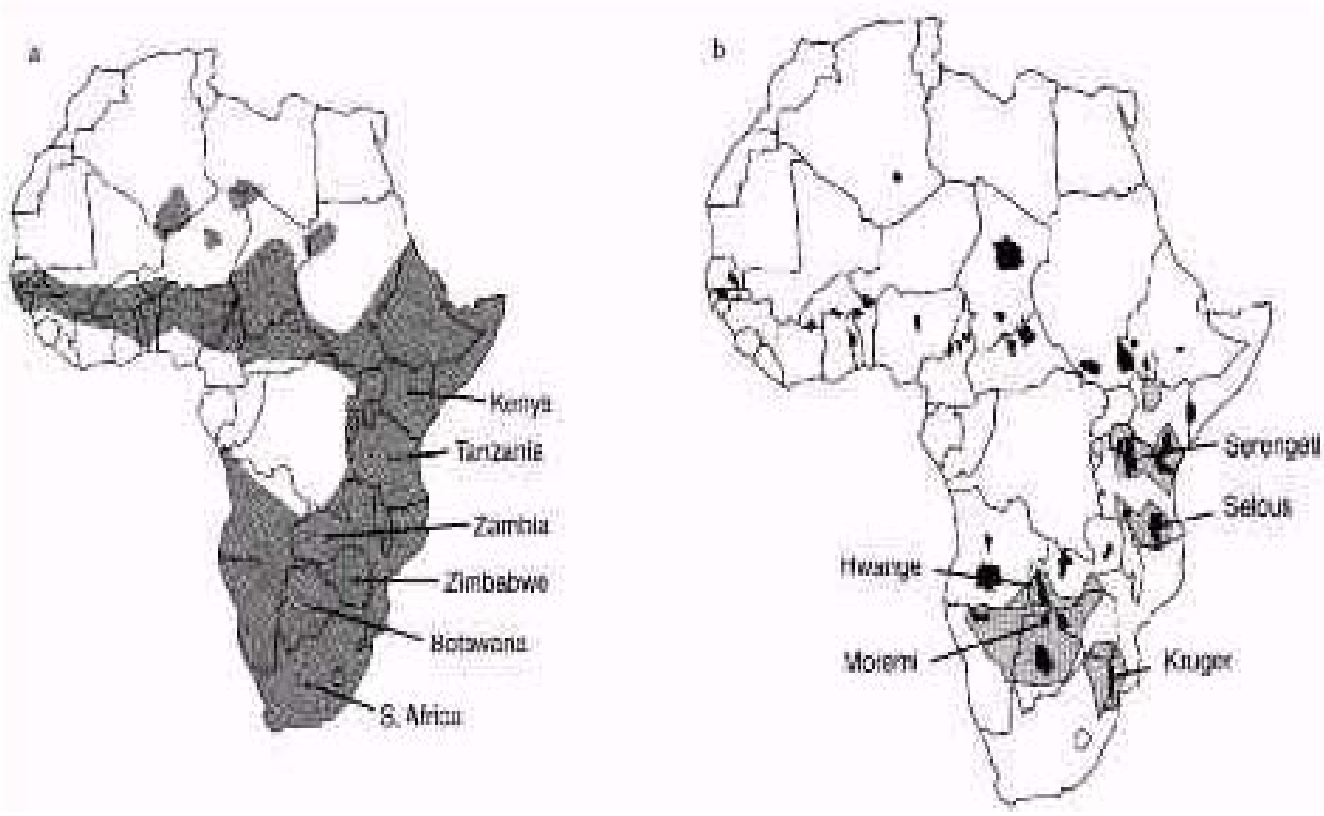
Source: Breuer (2002)

Appendix 2- Comparison of different factors that might affect livestock depredation between the two periods (2007-09 and 2010) and between the two tribes

		Locations		
		Maasai	Sonjo	
Factors	**Period**	**Mean, Std., N**	**Mean, Std., N**	**ANOVA (p=)**
No. of herders	2010	1.3 ± 0.6 (154)	1.3 ± 0.6 (61)	0.881
	2007-09	3.1 ± 7.1 (163)	1.7 ± 1.9 (29)	0.307
Age class	2010	1.6 ± 0.9 (154)	1.8 ± 1.0 (61)	0.169
	2007-09	1.9 ± 0.9 (204)	2.2 ± 1.0 (40)	0.119
Herd size	2010	382.5 ± 570.3 (154)	46.9 ± 40.0 (61)	0.000
	2007-09	278.2 ± 351.2 (166)	200.6 ± 278.6 (29)	0.260
No. of cattle	2010	143.1 ± 210.1 (141)	20.7 ± 25.5 (47)	0.000
	2007-09	97.7 ± 112.2 (169)	50.5 ± 61.8 (29)	0.028
No. of shoats	2010	269.6 ± 417.8 (144)	35.3 ± 25.5 (47)	0.000
	2007-09	176.4 ± 289.7 (166)	140.8 ± 230.1 (195)	0.532
Gender	2010	1.2 ± 0.5 (154)	1.4 ± 0.6 (61)	0.005
	2007-09	1.4 ± 0.7 (161)	1.4 ± 0.7 (28)	0.864

10. List of Figures

Fig. 1- Historical and current range of the African wild dog. The historical range of African wild dogs is shown by the stippled area (a). Countries that currently include populations greater than 100 are marked. (b) The current range of wild dogs based on sightings during the past 15 years (After Creel & Creel 1998).Source: Breuer (2002).



Source: Breuer (2002)

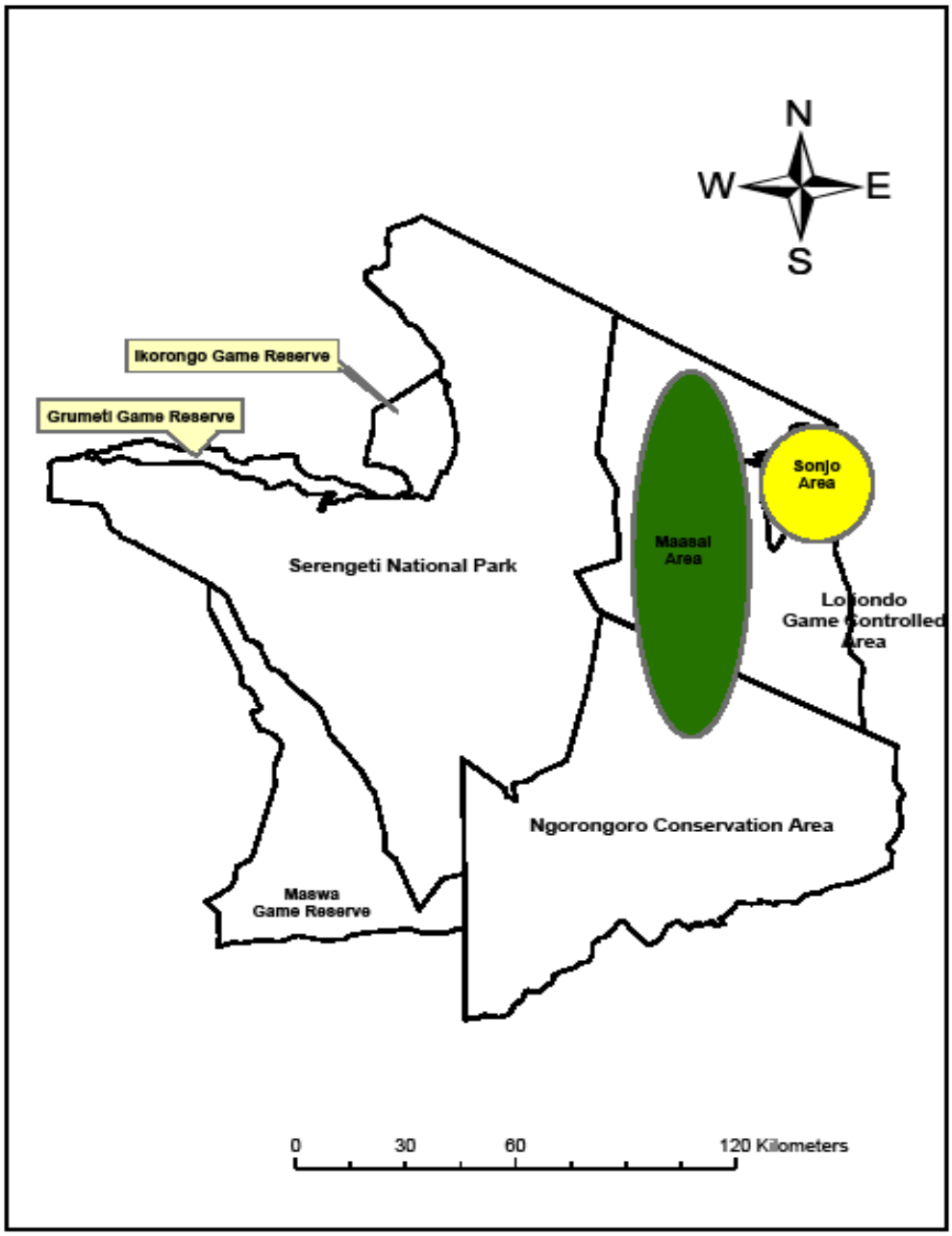


Fig. 2 - Map of the Serengeti Ecosystem showing the study areas (Maasai in green colour, Sonjo in yellow colour).

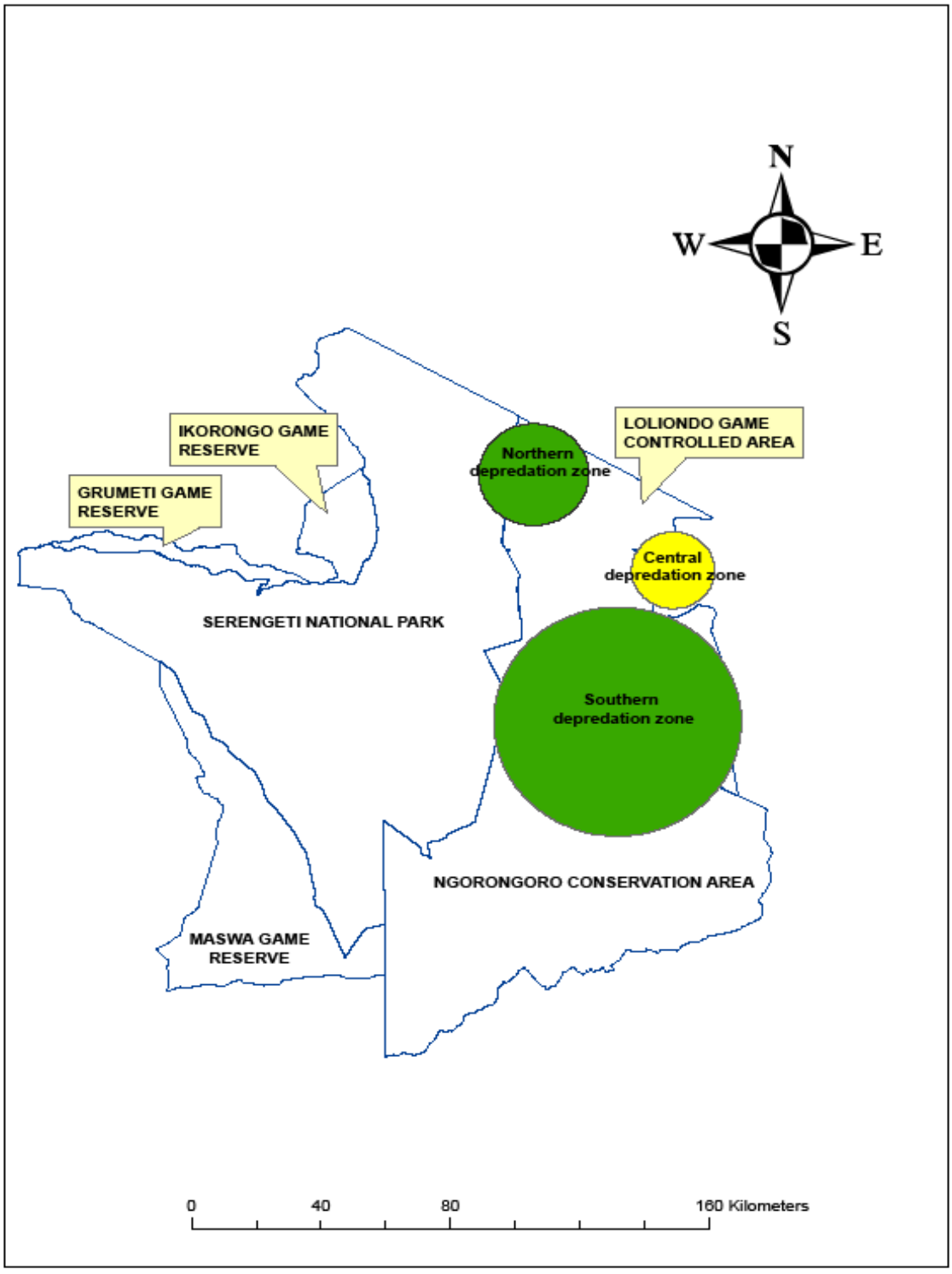


Fig. 3 - Three livestock depredation zones in the study area (Maasai in green, Sonjo in yellow).