Pastoralist herding efficiency in dealing with carnivore-livestock conflicts in the eastern Serengeti, Tanzania

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ABSTRACT
Wild carnivores are often involved in conflicts with humans due to their predation on livestock. We investigated the herding efficiency of pastoralists in association with depredation on livestock in the Loliondo game-controlled area (LGCA), northern Tanzania, to identify specific herding practices that may reduce predation occurrence. Randomised face-to-face interviews were employed using semi-structured questionnaires. Our results indicate that all studied livestock herds were tended to by at least one herder. Despite the presence of herders, carnivores were found to attack livestock in half of the observed herds. Female herders experienced more attacks than male herders. African wild dogs and spotted hyenas most frequently attacked the livestock of the Sonjo tribe, whereas leopards and lions most frequently attacked livestock of the Maasai tribe. Herders carrying defensive equipment (knives and spears) reduced the number of successful carnivore attacks in the area. We recommend maintaining and improving the traditional livestock husbandry practices of using herders to reduce carnivore attacks. Moreover, increasing the number of adult male herders per herd and carrying gear might also help reduce such attacks. Using herders can potentially improve economic gains and livelihoods of local people and change their negative attitudes towards wild carnivores.

Introduction
Wild carnivores play an important role in maintaining ecosystem functions and are often a major tourist attraction. They are thus of great ecological and economic value for many protected areas in developing countries (Durant et al. 2011). However, wild carnivores have also been involved in regular conflicts with humans, especially concerning predators preying on livestock (Kaczensky 1999; Woodroffe et al. 2005; Ikanda & Packer 2008) or attacking people (Packer et al. 2005; Kaltenborn et al. 2006; Dickman 2010). Human-carnivore conflicts related to livestock predation have been reported as a major obstacle for conserving large carnivore species, particularly in the Serengeti ecosystem (Kaczensky 1999; Woodroffe et al. 2005; Ikanda & Packer 2008). Thus, this conflict poses many challenges for enhancing the conservation of large carnivore species in the Serengeti ecosystem, such as lions (Panthera leo), leopards (Panthera pardus), cheetahs (Acinonyx jubatus), spotted hyenas (Crocuta crocuta) and African wild dogs (Lycaon pictus) (Ikanda & Packer 2008; Masenga et al. 2013). The challenge arises due to the losses incurred by livestock keepers from these carnivores, such as the reduction of income expected from livestock sales (Woodroffe et al. 2005; Holmern et al. 2007), which eventually increases poverty and hunger within the society. Because domestic animals provide manure, milk and meat and are the basis of income generation, savings and social standings, livestock-keeping societies tend to have a low tolerance for the depredation behaviour of large carnivores (Holmern et al. 2007; Ikanda & Packer 2008; Masenga et al. 2013). To prevent this depredation, most livestock owners, in particular those inhabiting the Serengeti ecosystem, retaliate by killing the large carnivore species that prey on their livestock (Ikanda & Packer 2008; Masenga et al. 2013). This behaviour is one of the factors that has led to the population decline of these predators (Kolowski & Holekamp 2006; Kissui 2008). Some of the carnivore species have even suffered local extinction as a result, such as African wild dogs, as reported elsewhere (Woodroffe et al. 2005, 2007).

One of the main factors associated with this problem is the increase in the human population, which contributes to increased land conversion for agriculture and human settlements, thus reducing the natural habitats for large carnivores as well as some important ecosystem services (Msuha 2009). Moreover, the increased hunting of wild
herbivores for either subsistence, sport or trophies has led to the depletion of the wild prey species needed by large carnivores (Wang & Macdonald 2006). In addition, the requirement for most large carnivores of a large home range forces them to overlap with human activities outside of protected areas, increasing the likelihood of conflicts with farmers (Larson 2008). Some attempts have been made to reduce depredation on livestock, including the control or translocation of problem animals, and altering herding practices (Woodroffe et al. 2007).

Several studies have revealed that depredation on livestock mostly occurs at night (Maddox 2003; Ikanda & Packer 2008; Lyamuya et al. 2014b), but it also occurs during the day (Lyamuya et al. 2014b) in the Serengeti ecosystem. Temporal differences in the occurrences of these depredation events in the area, depend on the behaviour of the carnivore in question (Woodroffe et al. 2005; Kissui 2008). Some large carnivores, such as the African wild dog and the cheetah, are diurnal in nature and thus hunt or prey on livestock only during the day (Maddox 2003; Lyamuya et al. 2014a), while others such as lions are both diurnal and nocturnal (Ikanda & Packer 2008; Kissui 2008). Other large carnivores, such as spotted hyenas and leopards, are mostly nocturnal (Ikanda & Packer 2008; Kissui 2008; Lyamuya et al. 2014b). Therefore, most depredation on livestock reportedly occurs during the night in the north-western (Holmern et al. 2007; Mwakatobe et al. 2013), southern (Ikanda & Packer 2008) and eastern Serengeti ecosystems (Maddox 2003). Spotted hyenas and leopards are the main predators in the northern Serengeti ecosystem, likely because the populations of spotted hyenas and leopards are higher in that part of the ecosystem (Holmern et al. 2007). However, depredation in the Loliondo game-controlled area (LGCA) surprisingly occurs during the day. This daytime depredation is likely due to wild dogs. Although wild dogs were reported to be extinct in the Serengeti ecosystem in the 1990s (Stearns & Stearns 1999), a few individuals were recently found to have remained unnoticed in the LGCA (Marsden et al. 2012). These remaining individuals did not need to prey on livestock until recently. Wild dogs normally prefer to hunt or prey on wild prey species rather than livestock when the wild prey species are abundant (Rasmussen 1999; Woodroffe et al. 2005; Gusset et al. 2009). However, although the wild dog population has increased in the area since 2000 (Masenga & Mentzel 2005), the populations of their wild prey species have been significantly reduced compared with those found within the National Park (Rusch et al. 2005). Therefore, the intensity of wild dog predation on livestock has increased in this area over the last decades (Lyamuya et al. 2014a). Lyamuya et al. (2014a) found that wild dogs were the most common predator of livestock in the LGCA, although they never preyed on livestock that were kept in enclosures (i.e. boma’s or kraals).

In general, the practices employed to protect livestock from wild predators do not differ much among communities within the Serengeti ecosystem (Holmern et al. 2007; Ikanda & Packer 2008; Mwakatobe et al. 2013). Most livestock owners apply traditional livestock husbandry practices, such as using herders to herd their livestock during the day in the grazing fields and confining livestock to enclosures during the night (Holmern et al. 2007; Ikanda & Packer 2008; Mwakatobe et al. 2013). During the daytime, incidences of attacks on livestock by predators are low in small livestock herds when they are accompanied by herders and their dogs (Woodroffe et al. 2007). During the night, the risk of attacks is the lowest for herds that are held in enclosures with dense walls pierced by few gates, where both humans and domestic dogs are present (Gusset et al. 2009). The livestock husbandry practice of using herders has been applied since ancient times (Woodroffe et al. 2007). However, little is known about the efficiency of using such herders in reducing depredation (Fratkin 2001; Mwebi 2007; Fauvelle-Aymar & Sadr 2008) as well as enhancing the coexistence of herds and predators in the same areas.

This study investigated the effects of traditional herding practices in affecting the depredation of livestock by wild dogs in the eastern Serengeti, in order to identify herding practices that were most effective in reducing depredation and consequently reducing the retaliatory killing of this species (Masenga et al. 2013). Such understanding could contribute to enhancing livestock and predator coexistence, while at the same time improving the ecosystem services accrued from the biodiversity found in the area. Specifically, we hypothesised that adult male herders are more efficient in caring for livestock than females in both the Maasai and Sonjo cultures because only males receive general training which involves fighting against dangerous wild animals and other enemies before they become ‘Morans’ (warriors) (Mwebi 2007; Budgor 2014). In addition, we hypothesised that the Maasai tribe suffers more livestock losses to carnivores than the Sonjo tribe, as they remain closer to the park boundary where the carnivore population densities are higher (Maddox 2003; Durant et al. 2011) because the depredation on livestock increases as the distance from the park boundary decreases (Holmern et al. 2007; Mwakatobe et al. 2013). Furthermore, we hypothesised that the use of
equipment such as spears and knives as well as guard dogs will reduce carnivore depredation. Finally, we hypothesised that livestock predation will occur more frequently in herds attended by one person than in those herded by several people.

**Methods**

**Study area**

The study was conducted in the eastern Serengeti ecosystem, which includes the LGCA and Ngorongoro conservation area (NCA) (Figure 1). Maasai and Sonjo tribes inhabit the area. The Maasai are nomadic pastoralists with very few agropastoralists, whereas the Sonjo are sedentary agropastoralists (Masenga & Mentzel 2005). Therefore, the Maasai depend entirely on livestock for their economic gain. The Sonjo people do not depend entirely on livestock keeping, as they are also engaged in other economic activities, such as crop cultivation and other small retail businesses.

The LGCA is located in the Maasai ancestral land in the northern part of Tanzania along the Kenyan border. It falls under the multiple land-use conservation category where human activities are allowed, and it forms the eastern boundary of the Serengeti ecosystem. The LGCA borders the Ngorongoro highlands to the south, Serengeti National Park (SNP) to the west and Lake Natron to the east. It encompasses an estimated area of approximately 4500 km². No physical barriers separate the LGCA from the other parts of the ecosystem. Thus, animals move freely within the ecosystem. The human population for both the LGCA and NCA was estimated to reach 160,925 people in 2012 (URT 2013), and the population increases from south to north, with the highest densities around Wasso, Loliondo town and near the Kenyan border (Masenga & Mentzel 2005). In the south, a few nomadic Maasai have settled at a low density.

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 the surrounding areas (Jaeger 1982). The area exhibits a bimodal rainfall pattern, with peaks occurring in December and April and a total of 400–1200 mm of rain per annum (Masenga & Mentzel 2005). The area is dominated by open woodland and grassland. The open woodland is found mostly in the northern part on the rolling hills, interspersed with rocky outcrops. The central part includes mountains with steep slopes and densely

![Figure 1. Map of the study area in northern Tanzania.](image)
vegetated gullies. The open areas in the lowlands are either cultivated or open woodland areas. The southern portion of the area gives way to short grassland.

The government of Tanzania, through the Ministry of Natural Resources and Tourism (MNRT), formed the Wildlife Policy of Tanzania in 1998 to increase the role of local communities in managing and benefiting from wildlife on village lands, in particular in the LGCA (Stolla 2005). Community involvement has increased with the formation of Wildlife Management Areas (WMA) to implement this policy (Stolla 2005).

**Data collection**

The data were collected from July to August 2010. Randomised face-to-face interviews using semi-structured questionnaires were employed together with information from the herders in the field. Six villages were randomly selected from each tribe for data collection. In each village, 30 livestock herders (herding cattle, donkey, goats or sheep), each representing one household, were randomly selected in the grazing fields based on the recommended sample size (Sancheti & Kapoor 2003). However, not all herders could be reached due to the difficult terrains in the Sonjo area. Therefore, this study includes fewer respondents from the Sonjo tribe (n = 72) as compared to the Maasai tribe (n = 212). The researchers drove randomly into the herding fields during the day and the first herd encountered was followed to check for the presence of herders. Once the herder was discovered, the following data were collected prior to the interview: the number of herders, age and sex of the herder, and herding equipment (equipment were pooled into four categories: 1 = nothing, 2 = sticks or clubs, 3 = spears or knives and 4 = the presence of domestic dogs in addition to any of the other weapons). Moreover, the number of cattle and sheep/goats were determined via direct counting. To familiarise ourselves with the herder, a trained enumerator from their own tribe was the first to exit the car and introduce us to the herder and explain the purpose of our visit. The herder was asked to respond to a variety of questions to fulfil the purposes of our research. The information required from the herder was age, gender, if livestock had been attacked by any wild carnivore species over the last 2 months when you were herding them? In addition, the test was used to determine the differences between age classes of herders (young (3–14 years), youth (15–30 years), adults (31–45 years), and elders (>45 years), gender (males, females) and equipment used (no equipment, clubstick, knife-spear, domestic dog) to herd livestock. Furthermore, t-tests and one-way ANOVA tests were used (after testing the data on the number of livestock killed with a one-sample Kolmogorov-Smirnov test and finding their distribution to be normal) to determine the differences between the numbers of cattle, donkey, sheep or goats killed and their mean numbers in the herds.

To determine the factors responsible for the livestock loss in the area, a binary logistic regression analysis was used, with livestock attacks as the dependent variable (yes, no) and tribe, gender, age class, number of herders, herd size and herding equipment as independent variables. For all tests, p ≤ 0.05 was considered as the level of significance, and leopards and lions were pooled together in some statistical analyses because of their low numbers. The Statistical Package for Social Science (SPSS) Statistics version 20.0 for Windows (SPSS, 2011) was used to perform all of the analyses (Kirkpatrick & Feeney 2010).

**Results**

**Tribe**

All of the livestock herds (100%, n = 284) were attended by at least one herder (1 herder = 88.7% of herds, 2 herders = 9.2%, >3 herders = 2.1%; these three groups of herders were used in the further analyses). More than 50% (55.2%, n = 252) of herds that were tended with one herder had experienced attacks by large carnivores, whereas only 9.4% (n = 32) of herds with more than one herder had experienced attacks by wild carnivores (χ² = 23.8, df = 1, p < 0.001). Only 50% of the groups had experienced livestock attacks (n = 284) by wild carnivores during the 2 months preceding the survey. The Maasai herders responded ‘yes’ significantly more frequently (55.2%, n = 212) than Sonjo herders (34.7%, n = 72) when asked if their livestock had been attacked by wild carnivores (χ² = 8.20, df = 1, p < 0.01).

In 83 cases (58.5%, n = 142), at least one domestic animal was killed both among herds of Maasai
(59.8%) and Sonjo (52.0%) herders when their livestock was attacked by wild carnivores; 11.3% \((n = 16)\) of the cases ended in the death of cattle and 47.2% \((n = 67)\) of the cases ended in the death of sheep or goats. No difference was found between the two tribes in terms of the livestock killed \((\chi^2 = 0.247, df = 1, p = 0.619)\). In addition, no difference was found in terms of the livestock killed between the two tribes in the cases when at least one livestock animal was killed and in all cases of attacks, including when no livestock was killed \((t = 1.007, df = 81, p = 0.321); and t = 1.117, df = 140, p = 0.266)\) (Table 1).

The numbers of both cattle and sheep/goats in the herds were significantly higher among the Maasai than among the Sonjo herders (cattle; \(t = 4.653, df = 1, p < 0.0001\); sheep and goats; \(t = 5.058, df = 282, p < 0.0001\); Table 1). However, the number of herders did not differ between the two tribes (multiple herders pooled; \(\chi^2 = 0.147, df = 1, p = 0.702\)). Large herd sizes (101–500 individuals) experienced the most attacks by wild carnivores (60.5\%, \(n = 119\)), followed by medium-sized herds (51–100 individuals; 50\%, \(n = 26\), attacked), whereas the small-sized herds (2–50 individuals; 39.2\%, \(n = 97\)) and very large herds (>500 individuals, 40.0\%, \(n = 15\)) were infrequently attacked \((\chi^2 = 10.4, df = 3, p = 0.015)\). In addition, the very large and large herds were more frequently found among the Maasai tribemen (62.6\%, \(n = 211\)) than with the Sonjo (2.8\%, \(n = 72\)) \((\chi^2 = 105.1, df = 3, p < 0.0001)\). About 41\% (41.1\%, \(n = 142\)) of the attacks by wild carnivores resulted in no livestock being killed, while one livestock was killed in 18.3\% of the attacks, and 40.2\% of the attacks resulted in two or more livestock being killed. However, no difference in the numbers (0, 1, >1) of livestock killed was found between the two tribes \((\chi^2 = 1.820, df = 3, p = 0.611)\), or between the different herd sizes \((\chi^2 = 3.444, df = 6, p = 0.716)\).

### Carnivore species

African wild dogs and spotted hyenas were the most frequently attacking species of Sonjo’s livestock, whereas leopards and lions most frequently attacked the livestock of the Maasai tribe (Table 2). Livestock were killed most frequently when attacked by animals other than wild dogs, which were the least frequent cause of livestock death (Table 2). However, this difference was not significant \((\chi^2 = 0.029, df = 3, p = 0.103); Table 2\). As a consequence, more livestock was killed when attacked by other carnivores (ANOVA; \(F = 4.02, df = 3\) and 138, \(p = 0.009\); Table 2). Finally, the frequency of attacks that resulted in killed cattle or sheep and goats among the carnivore species did not significantly differ \((\chi^2 = 11.1, df = 3, p = 0.084)\) (Table 2).

### Gender

The frequency of carnivore attacks was significantly higher when females (62.5\%, \(n = 64\)) rather than males (46.4\%, \(n = 220\)) were herding the livestock \((\chi^2 = 5.16, df = 1, p = 0.023)\). The Maasai tribe used male herders more often (82.5\%, \(n = 212\)) than did the Sonjo tribe (62.5\%, \(n = 72\); \(\chi^2 = 12.4, df = 1, p < 0.0001\)). Nevertheless, the number of herders did not differ significantly by gender \((\chi^2 = 1.7, df = 3, p = 0.403)\).

### Table 1. Differences in number of livestock killed and herded numbers of cattle and sheep or goats between the two tribes during the over two months study in the Loliondo game-controlled area during the 2010 survey.

| Tribes | Mean | SD | n | Mean | SD | n |
|--------|------|----|---|------|----|---|
| Maasai | 2.2  | 0.9 | 70| 1.9  | 0.9 | 13|
| Sonjo  | 1.3  | 1.3 | 212| 1.0  | 1.2 | 25|

*Only when at least one livestock animal was killed.

**Including all cases of attacks (also when no livestock was killed).

### Table 2. Carnivore species involved in attacks on livestock in relation to tribe (Maasai, Sonjo), frequencies (in %) of killed livestock and number of livestock killed per attack (zeroes included; t- and \(\chi^2\) tests of differences).

| Tribe            | Maasai n attacks | Sonjo n attacks | Frequency of attacks resulting in killed livestock | Total number of killed livestock |
|------------------|------------------|-----------------|-----------------------------------------------|---------------------------------|
|                   |                  |                 | %                                           | n                               |
| Other carnivores*| 11               | 2               | 84.6                                        | 13                              |
| Leopard/lions    | 44               | 4               | 56.5                                        | 46                              |
| Hyenas           | 31               | 10              | 63.4                                        | 41                              |
| Wild dogs        | 31               | 11              | 47.6                                        | 42                              |

*Cheetah, black backed jackals and baboons.
Table 3. Frequencies of Maasai and Sonjo caring different equipment, and frequencies of answers (yes or no) from herders to the question ‘Have your livestock been attacked by any wild carnivore species in the last two months when you were herding them?’ in relation to the herding equipment they were using (number of herder responses, with percentages in brackets; differences were tested with chi-square tests).

| Answer | Tribe | No. equipment | Club-stick | Knife-spear | Domestic dog |
|--------|-------|---------------|------------|-------------|--------------|
|        |       | n (%)         | n (%)      | n (%)       | n (%)        |
| Yes    | Maasai| 25 (11.8)     | 99 (46.7)  | 60 (28.3)   | 28 (13.2)    |
|        | Sonjo | 4 (5.6)       | 19 (26.4)  | 45 (62.5)   | 4 (5.6)      |
| No     | Maasai| 23 (79.3)     | 83 (70.3)  | 18 (17.1)   | 18 (56.2)    |
|        | Sonjo | 6 (20.7)      | 35 (29.7)  | 87 (82.9)   | 14 (43.8)    |
| Total  |       | 29 (100)      | 118 (100)  | 105 (100)   | 32 (100)     |

$p = 0.619$). Furthermore, males attended significantly larger livestock herds (333 ± 529 SD) than females (171 ± 252 SD) (log transformed $t = 3.972$, $df = 281$, $p < 0.001$). However, the loss of livestock by female herders (1.1 ± 1.3 animals per attack) did not differ significantly from that of male herders (1.3 ± 1.2 animals per attack; $t = 0.765$, $df = 140$, $p = 0.445$).

Age class

The attack rates did not differ significantly by age class (ANOVA $F = 0.089$, $df = 3$ and 138, $p = 0.966$). In addition, the number of herders did not differ significantly with the age class (multiple herders pooled; $\chi^2 = 7.42$, $df = 9$, $p = 0.593$). In general, single herders were most frequent in the adult group (90.9%, $n = 22$ single herders) and young (90.8%, $n = 184$ single herders) rather than youth (86.4%, $n = 66$ single herders) or elders (75.0%, $n = 12$ single herders). However, these frequencies are not significantly different (multiple herders pooled; $\chi^2 = 3.515$, $df = 3$, $p = 0.319$).

Equipment

Carrying equipment (e.g. knife/spear) as a defence did not differ between the two genders ($\chi^2 = 3.070$, $df = 3$, $p = 0.381$), or between the different age classes ($\chi^2 = 10.65$, $df = 9$, $p = 0.300$). However, the frequency of carnivore attacks differed significantly by the type of equipment used by herders ($\chi^2 = 75.3$, $df = 3$, $p < 0.0001$; Table 3). The lowest attack rate was found among the herders that protected their livestock with knives or spears compared with the three other groups of equipment (Table 3). Although the frequency of attacks that ultimately resulted in livestock death did not differ between the two tribes, the frequency of using different weapons differed significantly between the two tribes ($\chi^2 = 27.2$, $df = 3$, $p < 0.0001$; Table 3).

A logistic regression test with livestock attacks (yes or no) as a dependent variable found that herding equipment ($B = 0.739$, Wald = 19.38, $df = 1$, $p < 0.0001$), herd size (log transformed) ($B = −0.763$, Wald = 10.56, $df = 1$, $p = 0.001$), gender ($B = −0.843$, Wald = 6.46, $df = 1$, $p = 0.011$) and the number of herders ($B = 1.080$, Wald = 5.92, $df = 1$, $p = 0.015$) were all significant independent variables in explaining the attack rates ($\chi^2 = 55.90$, $df = 4$, $p < 0.0001$, Nagelkerke $R^2 = 0.239$). Age class and tribe did not add any significant values in explaining this variation.

Discussion

Differences in livestock depredation experienced by the Maasai and Sonjo pastoralists

This study revealed that all of the livestock herds visited during the day out in the field between both the Maasai and Sonjo tribes were attended by at least one herder. The use of herders is an ancient tradition in livestock husbandry practice used by many pastoralist societies worldwide to move their livestock to good pastures and areas containing sufficient water (Galvin et al. 2004; Grillo 2012; Little et al. 2012). Later on, herders were also used as a means of reducing livestock loss through depredation (Little et al. 2012) as well as theft (Nyahongo 2007). According to Ogada et al. (2003), livestock husbandry similar to that practiced for generations by the local Maasai and Sonjo pastoralists, was very effective at reducing the conflict between predators and livestock farmers. Therefore, it improves tolerance and thus builds up positive attitudes about the conservation of wild carnivores wherever they coexist with livestock (Ogada et al. 2003; Woodroffe et al. 2007). Because our survey was carried out during the day, it was clear that the herders from both of the tribes spent more time with their livestock in the field, as found in previous studies, and thus depredation on livestock was less likely to occur (Ogada et al. 2003; Woodroffe et al. 2007). This was because the use of herders is a time-tested tradition that had proved to be successful in alleviating predation (Gese 2003). In addition, the use of herders was an indication that both the Maasai and Sonjo tribes used
grazing lands daily to feed their livestock by accessing the natural resources in the Serengeti ecosystem (Kideghesho 2010; Schmitt 2010). Therefore, this access improves their livelihoods and thus enhances the conservation goals of the area.

Although both the Maasai and Sonjo tribes use herders, half of the herders reported that they had experienced livestock attacks by wild carnivores in the preceding 2 months. Furthermore, the Maasai herders reported to suffer more attacks from wild carnivores than the Sonjo herders did. This supported our hypothesis that the Maasai tribe suffers more losses of livestock to carnivores than the Sonjo tribe, as they occur closer to the park boundary (Lyamuya et al. 2014a) where the carnivore population densities are higher (Maddox 2003; Durant et al. 2011). Previous studies have found that events of depredation on livestock increase as the distance from the park boundary decreases (Holmern et al. 2007; Nyahongo 2007; Mwakatobe et al. 2013). In addition, the Maasai tribe used single herders more frequently than the Sonjo tribe, which is likely to be another reason for the increased frequency of attacks. This finding also supported our hypothesis that livestock predation will occur more frequently on herds that are tended by one herder than those tended by several herders. However, herders were only able to prevent the killing in approximately 40% of the carnivore attacks. In those attacks, sheep and goats were more frequently killed than cattle, most likely because most of the attacks were by carnivore species other than lions (Ikanda & Packer 2008).

As a result, according to the theory of reasoned action (Ajzen & Fishbein 1980), attacks by wild carnivores would create negative attitudes among the Maasai and Sonjo tribes towards the conservation of large carnivores in their areas. In most cases, it was found that humans behave negatively towards large carnivores when such animals kill their livestock or attack people (Løe & Roskaft 2004; Yirga et al. 2011; Carter et al. 2014); hence, large carnivores are suffering as a consequence of such attitudes which usually undermines management and conservation efforts (Ikanda & Packer 2008; Yirga et al. 2011; Carter et al. 2014). Therefore, the use of herders has the potential to improve economic gains and livelihoods of local people as well as possibly changing their negative attitudes (Maddox 2003). Furthermore, the numbers of both cattle, sheep and goats in the herds were significantly higher in the Maasai than in the Sonjo areas because the former are pastoralists and therefore keep large livestock herds as insurance against adverse environmental conditions that might cause loss, which is corroborated by previous reports (Galvin et al. 2004; Little et al. 2012). Despite this difference, the average number of livestock killed per attack did not differ between the two tribes or the different herd sizes. This could be attributed to the lower sample size obtained from the Sonjo tribe compared to the Maasai tribe because the Sonjo lives in highland areas separated by more hills and mountains nearby which reduced the visibility of herders, whereas the Maasai mostly live in lowland areas with fewer hills/mountains nearby.

**Carnivore species involved in attacks on livestock**

Our results also revealed that a variety of carnivore species attacked the livestock, although more carnivore species were involved in the Maasai area. This finding is attributed to the fact that the Maasai tribe resides closer to the park boundary, where the density of wild carnivores species is higher (Maddox 2003) than in the area inhabited by the Sonjo tribe (Lyamuya et al. 2014a). This high number of reported livestock attacks might put the conservation status of large carnivores in danger in the area (Masenga & Mentzel 2005), and previous studies have found that depredation on livestock is among the main reasons for most pastoralist communities not supporting the conservation of large carnivores (Ikanda & Packer 2008; Kissui 2008; Masenga et al. 2013). In addition, medium-sized carnivore species more frequently attacked livestock in the Maasai area compared to the Sonjo area, most likely because the Maasai herders keep a higher number of goats and sheep than the Sonjo, which increases the chances of depredation (Lyamuya et al. 2014a). In addition, medium-sized carnivores more frequently killed livestock than large carnivore species because they prey on sheep/goats, which are easier to hunt and kill than cattle. Furthermore, leopards and lions were responsible for more attacks in the Maasai area than in the Sonjo area. The densities of these animals are higher near the park boundary (Maddox 2003; Durant et al. 2011); hence, the higher amount of incursions against the Maasai than the Sonjo tribe (Holdo et al. 2010; Lyamuya et al. 2014a). Conversely, African wild dogs and spotted hyenas were most frequently responsible for attacking the livestock in the Sonjo area. African wild dogs attacked the Sonjo tribe more than any other carnivore species because they are the most common carnivore species found in that area. This species is the dominant carnivore species in the human-dominated landscapes in the Loliondo area (Lyamuya et al. 2014a). Our study investigated herding efficiency throughout the day, from the morning to the evening, when most of the depredation on livestock was reported to occur by this species in the area (Lyamuya et al. 2014a).
Impact of age and gender of herders on carnivore attacks on livestock

Reported attacks by large carnivores were significantly more frequent when females were herding. This finding concurs with our hypothesis that adult male herders are more efficient in caring for livestock than females because males, rather than females, receive general training which involves fighting against dangerous wild animals and other enemies. This is true in both the Maasai and Sonjo cultures (Mwebi 2007; Budgor 2014). Furthermore, this finding might be of importance to the conservation of large carnivores as, according to Marchini and Macdonald (2012) in their theory of planned behaviour, female herders might pass on their negative attitudes and disfavour of large carnivore conservation to their husbands and children as a result of incurred costs from predation on livestock. However, we note that female herders have also been found in other studies, for instance in Peru, where girls rather than boys are tending the livestock (Van den Berge 2009; FAO 2013).

The loss by female herders when attacked was, however, not higher than that of male herders in our study, most likely because there were fewer female herders than the male herders in the area. A study by the FAO (2013), found that males were generally more involved in herding activities than females, which agrees with our findings. Our results revealed that very few female herders were found in groups of two to four in both tribes. Furthermore, the Maasai tribe used more male herders in proportion to females, which agrees with our findings. Our results revealed that very few female herders were found in groups of two to four in both tribes. Furthermore, the Maasai tribe used more male herders in proportion to females than the Sonjo tribe, most likely because of the division of labour within the Maasai society directs young male Maasai to herd their livestock, while females perform other domestic tasks, such as caring for children and fetching water and firewood (Mwebi 2007; Kirkbride & Grahn 2008). Thus these differences could influence the results.

In addition, the presence of female herders in our study was probably due to the increasing number of men seeking employment away from home to supplement progressively more fragile incomes (Kirkbride & Grahn 2008).

Influence of equipment used by herders on attacks on livestock

In our study, we found a significant effect of equipment used by herders. Most attacks occurred when herders lacked the equipment to protect their livestock from attacks by wild carnivores. In addition, herders that were equipped with bush knives and spears experienced the fewest attacks, suggesting that they were more serious in caring for their livestock than those who lacked a weapon. These results partially supported our hypothesis that the use of equipment, such as spears and knives, would reduce carnivore predation. The Maasai herders were found to primarily use clubs and sticks, whereas the Sonjo tribe herders mostly used bush knives and spears. Despite this difference, we did not identify an effect of the tribe. Surprisingly, the use of herding equipment did not differ between gender or age class. Such knowledge of how predation can be reduced could help to improve the conservation of wild carnivores in this area.

Conclusions and management implications

Our results suggest that both the Sonjo and the Maasai tribes in the Serengeti ecosystem cared for their livestock while grazing because all of the visited livestock herds were attended by at least one herder. Despite that, attacks on livestock by wild carnivores still occurred regularly because herders lacked weapons to protect their livestock from the attacking carnivores. Additionally, most of the herders in the Maasai tribe tended large herd sizes and were
therefore unable to protect them. However, the carrying of defensive equipment (e.g., knives and spears) by herdsmen reduced carnivore attacks in the area. Therefore, we recommend that traditional livestock husbandry practices be maintained and improved as well as increasing the number adult male herdsmen per herd.

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