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The impacts of humans and livestock encroachments on the habitats of mountain nyala (*Tragelaphus buxtoni*) in Munessa, Ethiopia

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Measuring the extent of humans and livestock encroachments on the habitats of the endangered mountain nyala is crucial to ensuring effective conservation, but empirical evidence is lacking. In order to examine the risk-disturbances hypothesis, we assessed and quantified the impacts of humans and livestock encroachments on the habitats utilized by mountain nyala in Munessa, Ethiopia. We estimated the activity density of livestock along transects aligned through three types of major habitat utilized by mountain nyala. In addition, stem and / or crown damage, evidence of wood use, number of stumps cut, sign of habitat use and level of grazing by livestock were quantified on each transect. We collected the field data in the wet and the dry season. Activity density of livestock was highest in the natural forest only during the wet season. Regarding the impacts of humans on the habitats of mountain nyala, both in the wet and the dry season: stem and /or crown damage was highest in the plantation; however, evidence of wood use and number of stumps cut were greatest in the natural forest. Sign of habitat use by livestock did not differ among habitat type - rather it was dispersed throughout all habitats. Overall, sign of habitat use by livestock was higher in the wet season. The intensity of livestock foraging was heaviest in the natural forest only during the wet season. The results suggest that humans and livestock encroachments forced and excluded the mountain nyala from using their optimum habitats in Munessa. The study has important management implications for the endangered mountain nyala. For example, proper maintenance and management of the Munessa forest enhances the availability and quality of habitats for mountain nyala. In addition, introducing community-based conservation efforts that allow communities to derive economic benefits may promote conservation while at the same time enhancing greater partnership and providing a solution to resource use conflicts.

Key words: Munessa forest, activity density, humans and livestock encroachments, mountain nyala.

INTRODUCTION

Humans have induced many severe and irreversible changes to the natural environment and have most probably had the biggest influence on the distribution patterns of almost all wildlife species on the surface of the earth (Saunders and Hobbs, 1991; Brooks and Balmford, 1996; Oates, 1999; Mace and Balmford, 2000; Morris and Kingston, 2002). Habitat loss and fragmentation affect the survival of wildlife species in various ways including influencing animal behavior (Nour et al., 1997; Ukizintambara, 2008), reducing of the total

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amount of usable habitats, degrading habitat quality and creating edge effects (Moenting and Morris, 2006; Evangelista et al., 2007; Atickem et al., 2011). Small population size increases vulnerability to extinction especially when human disturbances increase (Primack, 2002). The need for cultivation and grazing lands, settlement, charcoal production, commercial wood and construction materials has contributed much to the reduction of forest cover in Ethiopia (EFAP, 1994; Hundessa, 1992; Tedla 1995). In this way, the mis-utilization of wood products by the rural human communities aggravates the degradation the habitats of wildlife (Evangelista et al., 2007; Kebede, 2009). Habitat loss and fragmentation caused by human impacts is by far the largest threat to the vast majority of Ethiopia's wildlife species, including the endangered mountain nyala (Hillman, 1986, 1988, 1993; Hundessa, 1997; Evangelista et al., 2008). For example, since mountain nyala was discovered by western science in 1908, its range has probably shrunk 10 to 20% due to deforestation and habitat destruction (Malcolm and Evangelista, 2005). In addition, human populations through settlement and expanded agricultural activities have considerably reduced the availability and quality of habitats for mountain nyala (Mamo, 2007; Atickem et al., 2011). As a result, mountain nyala are confined to "sky islands" on a handful of peaks and ridges (Evangelista et al., 2007; Sillero-Zubiri, 2008). Free-range livestock grazing has strong negative impacts on native wild herbivores, their habitats, and overall ecosystem function and structure (Mishra and Rawat, 1998; Morrison et al., 1998).

Livestock usually intensively compete with wild animal species for different habitat resources including forage, water sources and space (Hansen and Reid, 1975). For example, the problem can be exacerbated by the local people's idea that high numbers of livestock generate more income and are a measure of wealth status in Ethiopia (Hillman, 1993). The resultant high livestock population densities put strain on the habitats of many wild animal species (Hundessa, 1992, 1997; Tedla, 1995). For example, when livestock population densities increase beyond the safe carrying capacity of the natural environment, they degrade the habitat and make it unsuitable for the prevailing wild herbivores (Kebede, 2009). This process is now affecting the higher elevations since agriculture is dominantly practiced in the lower reaches of the highlands of Ethiopia, and livestock often move to higher elevations for free-range grazing (Stephens et al., 2001; Evangelista et al., 2007). By selectively reducing palatable plant species, livestock grazing ultimately results in the proliferation of invasive and unpalatable plant species for wild herbivores. For example, the unpalatable plant species (*Euphorbia dumalis*) is now much more common in and around the Dinsho Sanctuary of Bale Mountains National Park as a result of livestock grazing, and in turn has reduced the availability and quality of habitats for mountain nyala in the Bale Mountains (Mamo, 2007). Livestock often alter the structure and species composition of natural vegetation. For example, in sites where livestock grazing is more extensive, the vegetation types and composition change from more diverse and suitable to less diverse and unpalatable (Mamo, 2007). Moreover, intensive livestock grazing and browsing may contribute to the reduction of primary production and the decline of woody species richness (Kebede, 2009).

Carolina and Javier (2001) noted that livestock grazing/browsing, uprooting, trampling, and high fruit/seed predations strongly affect seedling survival and the ability of understorey species to regenerate. Unrestricted livestock movements in the forest may also compact soil, destroy seeds or press them deep into the soil where they are not able to emerge easily (Hulme and Borelli, 1999; Smit et al., 2006). Neptali et al. (2001) and Wassie et al. (2009) suggested that livestock induced disturbances might be among the major factors constraining regeneration and recruitment of woody species. According to the risk-disturbance hypothesis, the effect of human and livestock disturbances on wild animals is frequently measured in terms of shifts in habitat use and other behavioral responses (Gill et al., 2001; Frid and Dill, 2002; Gilroy and Sutherland, 2007) including reduction in the quality and availability of habitats. Understanding the negative impacts of humans and livestock encroachments on the quality and availability of habitats for mountain nyala can inform decision makers and also guide conservation efforts to mitigate the conflicts between human needs and the conservation of mountain nyala. The main objective of this study was to examine the risk-disturbance hypothesis by quantifying the activity densities of livestock, and also by assessing and discussing the number and intensity of disturbances caused by humans and livestock in habitats utilized by mountain nyala in Munessa, Ethiopia.

MATERIALS AND METHODS

Study area

The study was conducted in Munessa, South-eastern Ethiopia. Munessa is situated in Oromiya Administrative Regional State at 7°13′N and 38°37′E (Figure 1). The altitude range extends from 2100 to 2700 m above sea level. The mean annual rainfall is about 1250 mm. The mean annual temperature varies from 15 to 20°C. The soils are reddish, freely draining, and of medium to heavy texture. The vegetation is composed of natural and plantation forests, where the main forest blocks are found on the escarpment and associated plateau lying between the Rift Valley lakes and the eastern edge of the Rift Valley (Teketay, 1992; Teketay and Granström, 1995). Both the natural and the plantation forests in Munessa are potentially good habitats for a variety of wild animal species including the endangered mountain nyala (Evangelista et al., 2007). We identified three major types of habitat that are used by mountain nyala over our study site: natural forest, plantation and cleared vegetation habitats (Figure 2). We briefly describe each of these three habitats as follows:

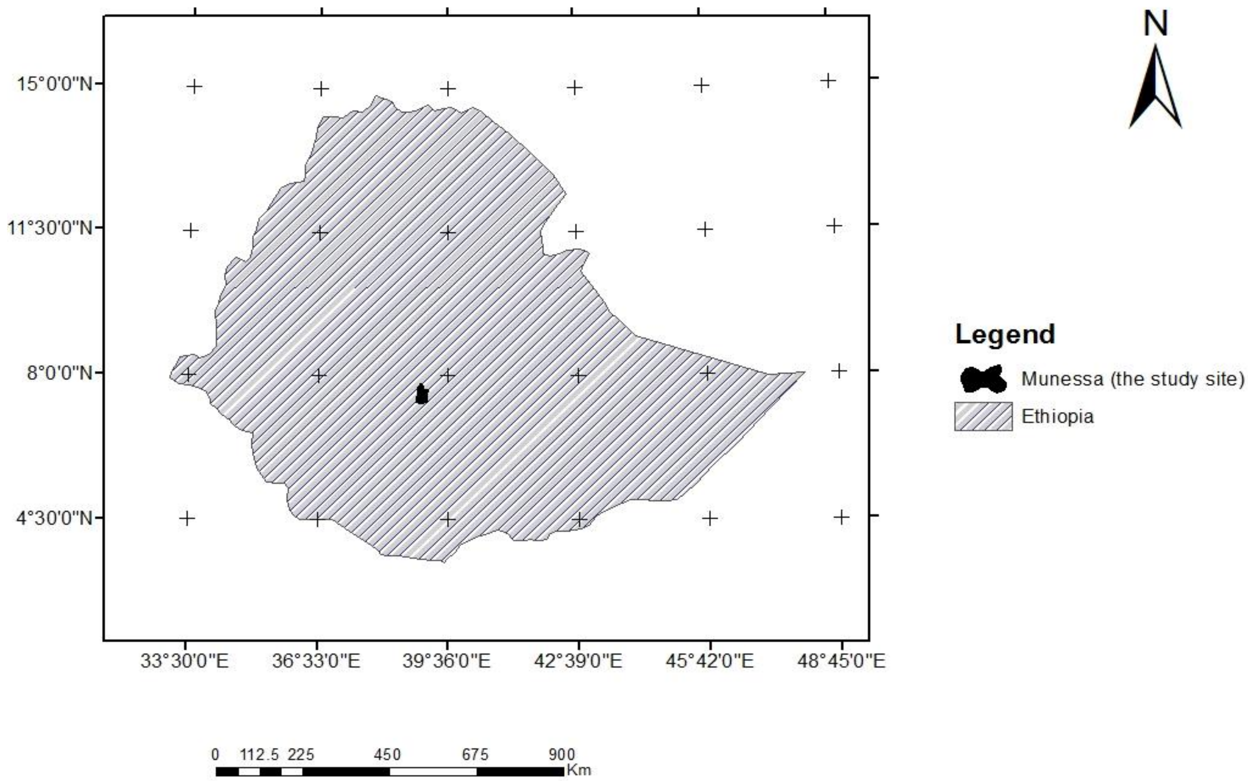

Figure 1. Location map of the study area.

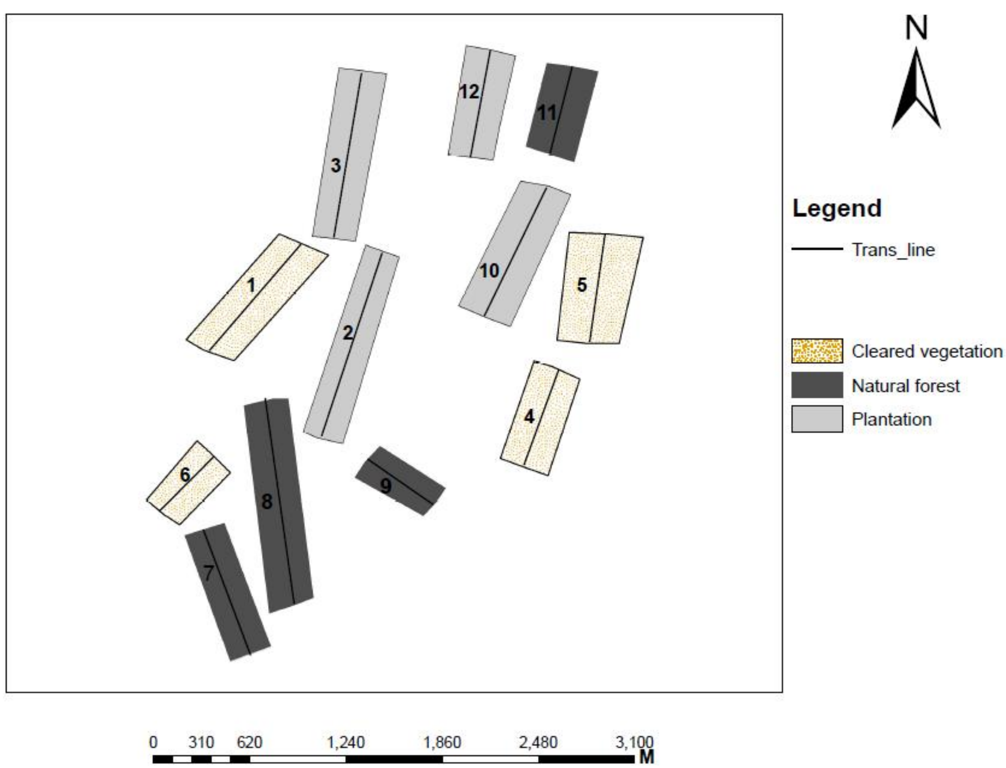

Figure 2. Map showing the sample transects aligned in each habitat (that is, cleared vegetation, plantation and natural forest).

The natural forest habitat

The natural forest habitat is situated in undulating terrain providing good escape from risk of predation and refuge for mountain nyala. It also serves as valuable cover for thermal regulation and provides a good source of palatable forages. Some of the characteristic indigenous tree species of the natural forests include *Afrocarpus falcatus*, *Syzygium guineense*, *Prunus africana*, *Bersama abyssinica*, *Aningeria adolfi-friederici*, *Hagenia abyssinica*, *Celtis africana*, *Millettia ferruginea*, and *Croton macrostachyus*. However, there are various human and livestock induced impacts on the natural forests. For example, some natural forests have been totally cleared and converted into agricultural fields, while others suffered from different influences such as heavy grazing and selective logging of economically important tree species (Teketay, 1992; Evangelista et al., 2007).

The plantation habitat

The plantation habitat is mainly composed of exotic tree species, such as *Eucalyptus globulus*, *Eucalyptus grandis*, *Cupressus lusitanica*, *Pinus patula*, *Pinus radiata*, and *Grevillea robusta.* The plantations in Munessa are potentially good habitat for mountain nyala. Although, the plantations offer a sparse herbaceous understory, they provide a very important habitat by offering escape refuge from risk of predation, valuable cover for thermal regulation, and travel corridors especially in areas where natural forests are extremely disturbed and/or limited (Evangelista et al., 2007). During our field observations, illegal tree cutting activities by local people for fuel wood and construction materials as well as free-range livestock grazing and browsing provided common threats to the plantation habitat especially in the crop growing rainy season.

The cleared vegetation habitat

The cleared vegetation habitat is characterized by relatively freely draining areas that are rich in grass and other palatable herbs. So, it serves as good feeding habitat for mountain nyala especially in the rainy season. There are also some salt licks that attract mountain nyala at night in the rainy season when people and livestock are not around. Due to lack of cover, the risk of predation on mountain nyala is expected to be highest in the cleared vegetation. Still, as most of the cleared vegetation habitat is surrounded by natural forests and plantations, it is fairly easy for mountain nyala to escape from predators such as leopard (*Panthera pardus*) and spotted hyena (*Crocuta crocuta*).

Data collection

To collect data on encroachments by human and livestock on the habitats of mountain nyala, we set out permanent walking transects with the aid of a GARMIN 75 GPS device, with each transect sampling a major existing habitat type within the study site. We established a total of 12 permanent transects that is, four transects in each habitat type (Figure 2). Following Druce (2005) and Tadesse and Kotler (2010), along each transect, we quantified the viewable area of each habitat by walking perpendicularly from a given line transect until the unevenness of the topography or the thickness of the vegetation cover no longer allowed us to view that transect. The GPS locations on both sides of all the viewable parts of each habitat type were then taken. This activity is important in determining the sample area of each habitat type along each transect walk. Following the minimum sample area proposed by Patton (1992), the sampling protocols covered 2 to 5% of the total area of the study site. Transects varied in length from 0.8 to 2.3 km, that is, the length of each transect varied with the size of each habitat patch. The total area of our study site was about 111 km^2. So, we took transect samples whose total area was 3.83 km^2, which was 3.45% of the study site.

Livestock censusing

Livestock activity densities are often used as indicators of grazing pressure on habitats (Mamo, 2007; Kebede, 2009) used by wild animals including the mountain nyala. So, along each line transect (Figure 2), through the three habitat types, activity densities of livestock (that is, numbers of cattle, horses, donkeys, sheep and goats) were counted and recorded. The censusing was carried out in the wet (June through August 2010) and the dry season (December 2010 through February 2011).

Humans and livestock encroachments on the habitats of mountain nyala

Circular plots (each with a radius of 5 m) were laid along each transect for quantifying the extent and intensity of human and livestock encroachments on the microhabitats of mountain nyala. The first plot within each habitat patch on each transect was randomly laid, but successive plots were systematically added at 100 m intervals. Following Silori and Mishra (2001) and Mamo (2007), parameters such as stem and / or crown damage (that is, presence or absence of peeled and /or damaged bark and branches removed or broken by humans), evidence of wood use (that is, presence or absence of any leftover materials after wood collection by humans), number of stumps cut by humans, and sign of habitat use by livestock (that is, presence or absence of livestock droppings and /or foot prints) were assessed and recorded in each plot laid along each transect. Within the large circular plot, a circular nested plot with a radius of 0.5 m was laid. Following Smit et al. (2006) and Mamo (2007), the intensity of browsing / grazing by livestock was quantified, and categorized as either: no evidence of browsing / grazing (0% browsed / grazed), lightly browsed/ grazed (1 to 25% browsed / grazed), moderately browsed / grazed (26 to 50% browsed / grazed), or heavily browsed / grazed (>50% browsed / grazed). The total number of sample plots for each habitat type varied with the total size of each habitat patch. A total of 109 plots were assessed (that is, 31 plots in the cleared vegetation, 41 plots in the plantation and 37 plots in the natural forest habitat).

The field data were collected in two separate seasons: June through August 2010 and December 2010 through February 2011 for the wet and dry season, respectively.

Data analysis

To estimate the activity density of livestock in each habitat type, we first created a visibility map for each transect by which we determined the sampled area. The GPS locations which were taken on both sides of the visible points for each transect were transformed into the Ethiopian coordinate system and imported into Arc GIS 9.3 program, and overlaid on the map of the study area. We then digitized the GPS coordinates of all the visible points for each transect walk using lines to make a polygon along all the transect walks. This gave us the areas of all the habitats sampled in each transect (Table 1). We incorporated the sample area information shown in Table 1 with livestock census data obtained through transect walk counting during the wet and the dry season. That enabled us to estimate the activity density of livestock in each habitat for the wet and the dry season as shown in Table 3. As grazing / browsing pressures may vary with the livestock type (that is, cattle, donkey, horse, sheep, and/or goat), livestock activity

Table 1. A summary of the twelve transect walks used in the analysis. The visible area of each habitat covered by transects is included.

Habitat type	Total visible area in all transects (ha)	Transect No.											
		1	2	3	4	5	6	7	8	9	10	11	12
Cleared vegetation	120.9	36.1	0	0	37.3	27.6	19.9	0	0	0	0	0	0
Plantation	142.3	0	37.8	38.6	0	0	0	0	0	0	38.2	0	27.7
Natural forest	119.9	0	0	0	0	0	0	29.8	45.7	18.8	0	25.6	0
Total	383.1	36.1	37.8	38.6	37.3	27.6	19.9	29.8	45.7	18.8	38.2	25.6	27.7

Table 2. A summary of the activity density of livestock in different habitat types during the wet and the dry season field surveys: Minimum, mean and maximum activity densities.

Season	Habitat type	N	Minimum density (livestock/ha)	Mean density (livestock/ha)	Maximum density (livestock/ha)	Number of livestock sightings	Sightings per transect walk (%)
Wet	Cleared vegetation	16	1.28	2.68	4.82	16	100.00
	Plantation	16	1.75	2.85	6.31	16	100.00
	Natural forest	16	1.63	5.80	11.77	16	100.00
	Total	48	4.66	11.33	22.29	48	100.00
Dry	Cleared vegetation	24	0.01	2.03	6.76	24	100.00
	Plantation	24	0.00	1.70	4.05	23	95.83
	Natural forest	24	0.46	2.37	5.96	24	100.00
	Total	72	0.47	6.10	16.77	71	98.61

Data are given in adult cattle units (ACU) to account for different species of livestock. N = number of transects sampled in that habitat type. Each transect was assessed four times (that is, once in three weeks) in the wet season and six times (that is, once in two weeks) in the dry season.

densities were calculated and converted into Adult Cattle Units (ACU), as an indicator of grazing pressure on the study site. ACU conversion followed Silori and Mishra (2001), where 1 adult cow or bull = 1 ACU; 1 calf = 0.5 ACU; 1 adult horse or donkey = 1.5 ACU and 1 sheep or goat = 0.5 ACU. Then, we could estimate the activity densities of livestock in each habitat type for the wet and the dry season as shown in Table 2.

As the data were composed of both categorical independent and continuous dependent variables, we used ANOVA to check whether livestock were exhibiting seasonal difference in their habitat use (Snedecor and Cochran, 1989). Habitat type was a predictor, and activity density of livestock was the dependent variable. Human and livestock encroachments on the habitats of mountain nyala were also analyzed using ANOVA. For all analyses, we defined the alpha value to be 0.05. We performed the analysis with STATISTICA version 10.

RESULTS

Livestock activity densities

In the wet season, the activity density of livestock in the natural forest differed from all other habitats [$F_{(2,\ 45)}$ = 13.99; $p < 0.001$). Livestock were seen in the natural forest in every transect survey (≈100.00%) and achieved their greatest maximum activity density there (11.77 livestock/ha; Table 2). Livestock also achieved their highest mean activity density in the natural forest (5.80 livestock/ha) (Table 2; Figure 3). However, livestock activity density did not differ among habitats in the dry season. Overall, livestock activity density was higher [$F_{(1,\ 114)}$ = 18.27; $p < 0.001$] in the wet than the dry season (Table 3).

Humans and livestock encroachments on the habitats of Mountain Nyala

The extent of stem and / or crown damage of vegetation by humans differed among habitats in both the wet [$F_{(2,\ 106)}$ = 21.76; $p < 0.001$] and the dry season [$F_{(2,\ 106)}$ = 10.28; $p < 0.001$], where it was greatest in the plantation habitat (Figure 4 and Table S1). The intensity of wood use by humans differed among habitats in the wet [$F_{(2,\ 106)}$ = 22.08; $p < 0.001$] and the dry season [$F_{(2,\ 106)}$ = 5.54; $p = 0.005$], with highest values in the natural forest (Figure 5 and Table S1). Similarly, the number of stumps cut by humans differed among habitats in the wet [$F_{(2,\ 106)}$ = 23.17; $p < 0.001$] and the dry season [$F_{(2,\ 106)}$ = 24.31; $p < 0.001$], with greatest numbers in the natural forest habitat (Figure 6 and Table S1). Signs of livestock presence did not differ among habitats in either the wet [$F_{(2,\ 106)}$ = 1.76; $p = 0.177$] or the dry season [$F_{(2,\ 106)}$ = 0.17; $p = 0.846$]; instead they were dispersed throughout all habitats (Figure 7 and Table S1). For overall comparison,

Table 3. A summary of the density of livestock type (that is, cattle, horse, donkey, sheep and goat) in different habitats in the wet and the dry season field surveys: minimum, mean and maximum densities were shown as the number of times each livestock type were seen in each habitat type and as a percent of total number of times that habitat was sampled.

Season	Habitat type	N	Livestock type	Minimum density/ha	Mean density/ha	Maximum density/ha	St. Dev.	Number of livestock type sightings	Sightings per transect walk (%)
Wet	Cleared vegetation	16	Cattle	0.63	1.40	2.55	0.60	16	100.00
			Horse	0.00	0.09	0.30	0.10	9	56.25
			Donkey	0.00	0.53	1.30	0.38	15	93.75
			Sheep	0.00	0.46	1.02	0.30	14	87.50
			Goat	0.00	0.19	0.65	0.22	9	56.25
	Plantation	16	Cattle	0.56	1.39	4.43	0.96	16	100.00
			Horse	0.00	0.05	0.32	0.08	7	43.75
			Donkey	0.00	0.47	1.01	0.31	15	93.75
			Sheep	0.34	0.71	1.43	0.28	16	100.00
			Goat	0.00	0.23	0.69	0.18	14	87.50
	Natural forest	16	Cattle	0.46	2.93	7.23	1.90	16	100.00
			Horse	0.00	0.03	0.24	0.06	6	37.50
			Donkey	0.00	0.56	1.64	0.48	13	81.25
			Sheep	0.26	1.46	2.82	0.71	16	100.00
			Goat	0.35	0.81	1.51	0.36	16	100.00
Dry	Cleared vegetation	24	Cattle	0.00	0.86	3.52	0.77	22	91.67
			Horse	0.00	0.17	0.79	0.21	15	62.50
			Donkey	0.00	0.46	1.20	0.33	23	95.83
			Sheep	0.00	0.38	1.58	0.45	15	62.50
			Goat	0.00	0.16	0.93	0.24	13	54.17
	Plantation	24	Cattle	0.00	1.06	2.68	0.76	23	95.83
			Horse	0.00	0.07	0.51	0.12	12	50.00
			Donkey	0.00	0.21	1.01	0.20	22	91.67
			Sheep	0.00	0.26	0.66	0.23	17	70.83
			Goat	0.00	0.11	0.40	0.11	15	62.50
	Natural forest	24	Cattle	0.31	1.51	5.25	1.01	24	100.00
			Horse	0.00	0.02	0.39	0.08	2	8.33
			Donkey	0.00	0.23	1.18	0.25	21	87.50
			Sheep	0.00	0.37	1.33	0.46	12	50.00
			Goat	0.00	0.24	0.87	0.30	12	50.00

The standard deviation for each livestock type in all habitats in the wet and the dry seasons were also included. N = total number of transects sampled in that habitat type.

sign of livestock presence was higher in the wet than the dry season [$F_{(1, 212)}$ = 48.85; $p < 0.001$] (Figure 7 and Table S1). In the wet season, the level of grazing / browsing by livestock differed among habitats [$F_{(2, 106)}$ = 10.99; $p < 0.001$], with heaviest foraging occurring in the natural forest (Figure 8 and Table S1). In contrast, the level of grazing / browsing by livestock did not differ among habitats [$F_{(2, 106)}$ = 0.33; p = 0.724] during the dry season. Overall, the intensity of livestock grazing / browsing was higher in the wet than the dry season [$F_{(1, 212)}$ = 63.78; $p < 0.001$] (Figure 8 and Table S1).

DISCUSSION

Livestock foraging differed in Munessa across habitats and seasons. In the wet season, livestock activity density was greater in the natural forest habitat where there is more diverse palatable forage. During the dry season,

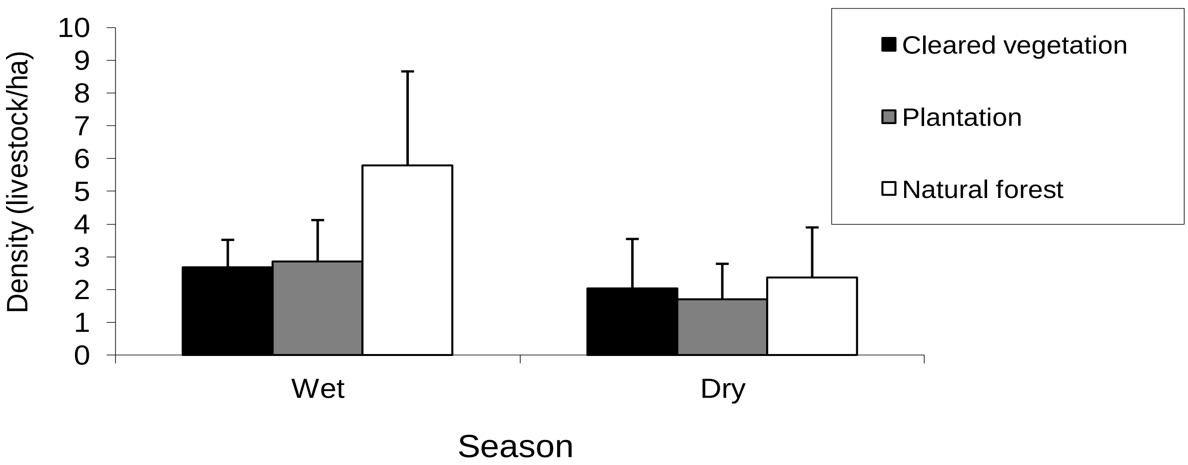

Figure 3. Seasonal activity densities of livestock across habitats. The error bars represent +1 SD.

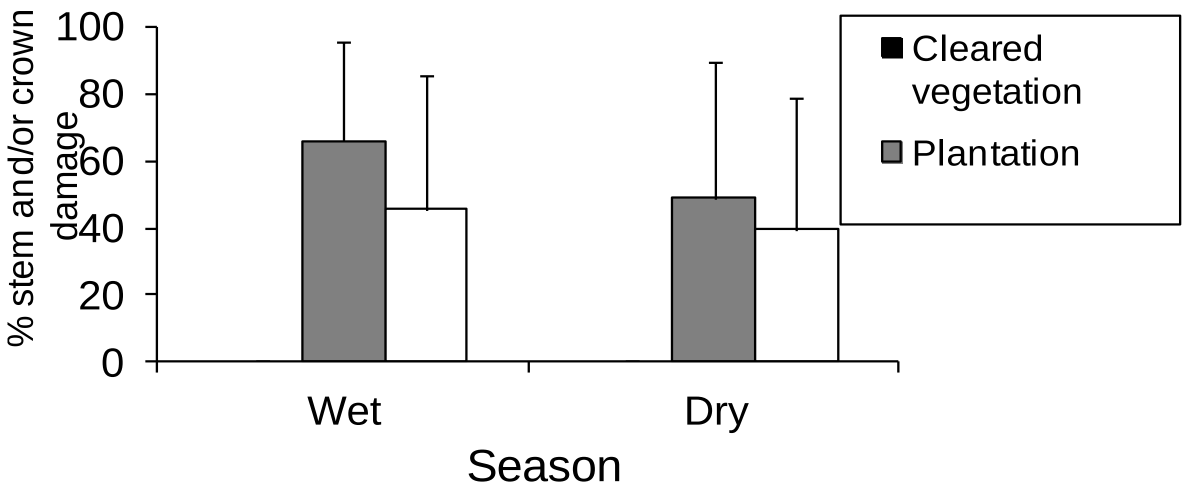

Figure 4. Seasonal stem and /or crown damages by humans across habitats. The error bars represent +1 SD. Presence or absence of peeled and /or damaged barks and removed and / or broken branches were assessed to quantify human caused stem and /or crown damages in each plot. No tree was observed in plots laid in the cleared vegetation so that stem and crown damages were not recorded in this habitat.

livestock did not show significant differences in their habitat use, but their mean activity density was still nominally greatest in the natural forest. The prevalence of cattle in the livestock was highest both in the wet and the dry season, but horses had the lowest activity densities during both seasons in all habitat type (Table 3). Overall, livestock activity densities in all habitat type were higher in the wet than in the dry season (Table 3). One possible explanation is as follows: In the wet season, much of the lands of the local people were occupied by crop cultivation so that the local people had few options, but to drive their livestock into the Munessa Forest for free-range grazing. However, in the dry season, the crops were harvested and crop residues were available for livestock feeding, and thus, there would be little need to take them to the forest. The extent and the level of grazing / browsing by livestock in Munessa were most intensive in the natural forest especially in the wet season (Figures 7, 8 and Table S1). Teketay (1992) and Abebe (2008) suggested that lack of regeneration of dominant tree species such as *Prunus africana*, *Syzygium guineense*, and *Hagenia abyssinica* in the Munessa Forest may be due to excessive grazing / browsing and trampling pressure on young seedlings and saplings by domestic herbivores. Evangelista et al. (2007) noted that *P. africana*, *S. guineense* and *H. abyssinica* are good sources of forage for mountain nyala in Munessa. In this way, livestock grazing / browsing may affect the availability and quality of habitats for mountain nyala over the study area.

Most importantly, during free-range grazing, all livestock in Munessa were observed being followed by their

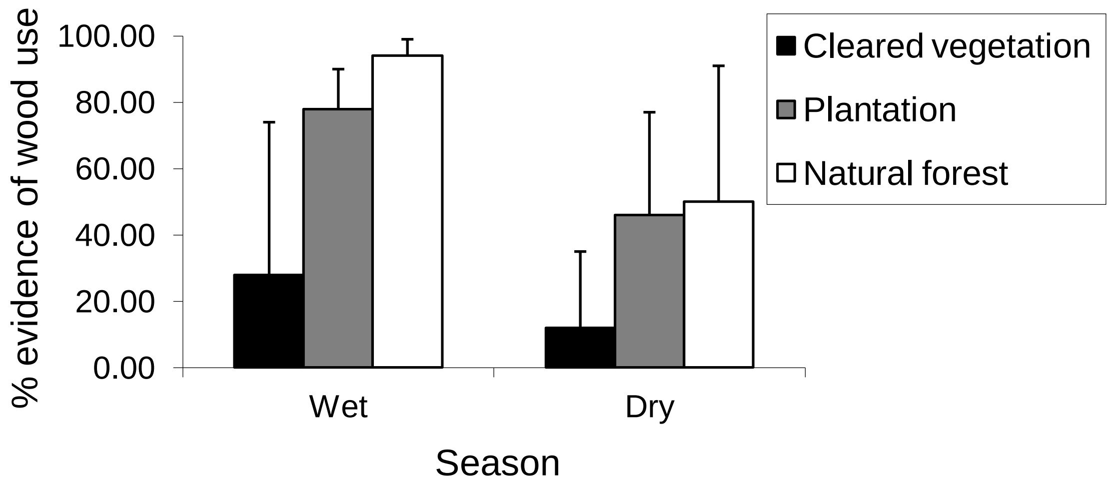

Figure 5. Seasonal wood use by humans across habitats. The error bars represent +1 SD. Presence or absence of any leftover materials after wood collection was assessed to quantify evidence of wood use by humans.

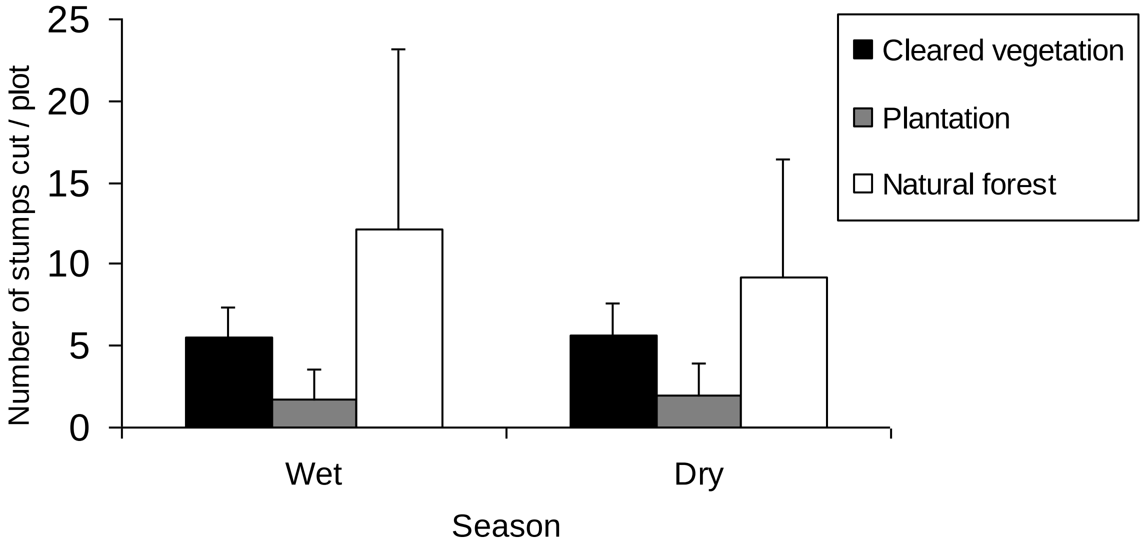

Figure 6. Stumps cut by humans in different season and habitats. The error bars represent +1 SD. The number of stumps cut was quantified in each plot.

shepherds. This reduces the risk of predation to livestock (Shrader et al., 2008) so that livestock often leave the foraging patch with very low giving-up densities which ultimately results in overgrazing of the best habitats for mountain nyala. In addition, perennial palatable grasses cannot tolerate the repeated impacts of livestock grazing / browsing and trampling, which eventually lead them to be replaced by unpalatable grass, forbs and shrub species (Mamo, 2007; Kebede, 2009).

Therefore, unless the interference of livestock is controlled in Munessa, canopy trees and shrubs that are potential cover and food sources for mountain nyala could become rare or locally extinct. Human encroachments differed across habitats and seasons in Munessa. For example, commercial fuel wood collection, tree cutting for construction materials, and logging are common threats to mountain nyala and their habitats.

This study suggests that those problems are more prevalent and chronic in the wet season of the year. For example, it was frequently observed that many of the local people go to the Munessa Forest to cut trees and collect wood for commercial sale during the crop growing season, thus, intensifying disturbance and decreasing habitat quality for mountain nyala. In this manner, the

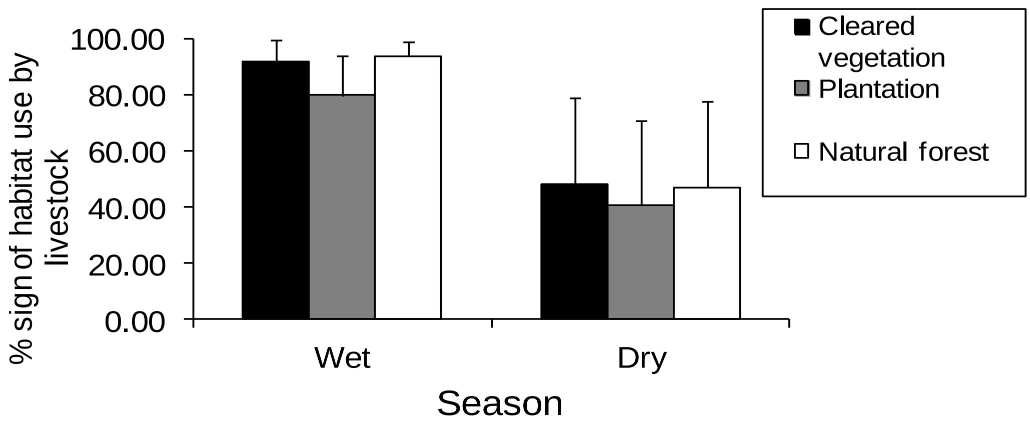

Figure 7. Seasonal habitat use by livestock. The error bars represent +1 SD. Each plot was assessed for the presence or absence of sign of habitat use by livestock (for example, presence or absence of foot prints and droppings).

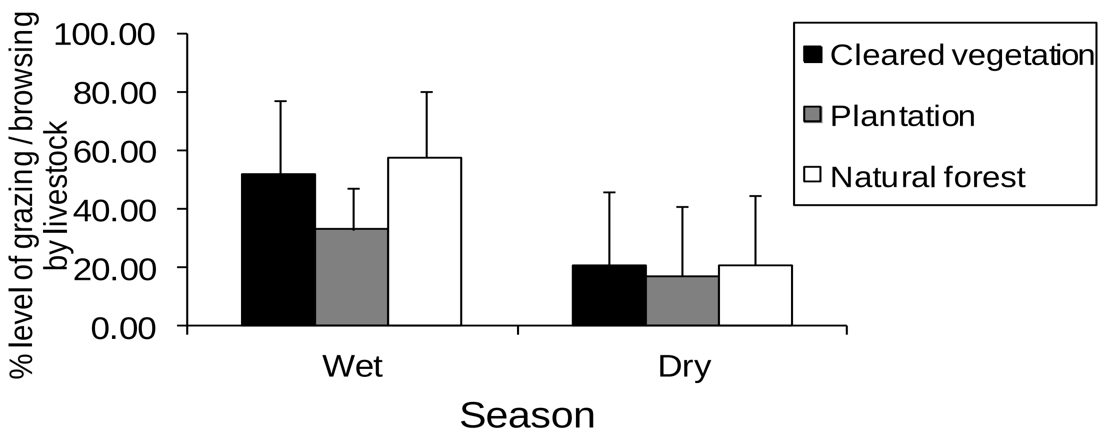

Figure 8. Seasonal level of grazing / browsing by livestock across habitats. The error bars represent +1 SD. Each nested circular plot was assessed to quantify the level of grazing / browsing by livestock.

ever-increasing demand for forest products coupled with the rapid increase in human population is putting pressure on the remaining forest fragments and wildlife habitats in Munessa (Teketay, 1992; Evangelista et al., 2007; Abebe, 2008).

Stem damage and crown removal by humans were the most prevalent problems in the plantation habitat (Figure 4 and Table S1). We observed that the local people frequently de-bark standing trees in the plantation to get materials for traditional beehive building. In addition, we frequently noted that the local people removed the crowns of the standing trees in the plantation to get wood to sell. We also saw that the local people often cut the branches of palatable shrubs and trees in the natural forest to feed their livestock on site. In the wet and dry season, the presence of leftover materials after wood collection suggested that human disturbance is a common problem in all habitats of mountain nyala in Munessa, but is most prevalent in the natural forest (Figure 5 and Table S1). The number of stumps cut also illustrates that illegal tree cutting activity is a common problem in all habitats, but the problem is most severe in the natural forest both in the wet and dry season (Figure 6 and Table S1). In another study, Teketay (1992) noted that the clearing of natural vegetation for the expansion of agricultural land and settlements has directly reduced the ranges, availabilities and qualities of habitats for wild animals including the mountain nyala in Munessa. The distribution and habitat use of wild animals are often negatively affected by the presence and proximity of people and livestock (Austin and Urness, 1986; Wallace and Krausman, 1987; Young et al., 2005; Kebede, 2009). For example, during our field observations, habitats which are adjacent to human settlement were less used by mountain nyala in Munessa, largely due to high human nuisance and livestock disturbances.

In a recent study, Mamo (2007) noted that the mineral spring locally known as 'Hora', which was once used as salt licks by mountain nyala, was largely encroached by expanding human settlements in the Bale Mountains National Park (BMNP). As a result, mountain nyala avoided human settlement areas in the BMNP. Atickem et al. (2011) also found that the presence, distribution and habitat use of mountain nyala in the Bale Mountains was negatively affected by human developments such as agriculture and settlements. The temporal partitioning in habitat use between livestock and mountain nyala in Munessa should be a direct indicator of the exclusion of the latter by the former. In our field observations, livestock used all the three habitat types in both seasons, but mountain nyala always avoided at least one habitat, usually that with heavy livestock use. In addition, we never saw mountain nyala in any of the three habitat types while livestock were there in either season. Similarly, Hansen and Reid (1975) and Mishra and Rawat (1998) noted that when there is high overlap in habitat and forage requirements by livestock and wild herbivores, overstocking can cause competitive exclusion of the latter.

Malcolm and Evangelista (2005) also reported that mountain nyala are confined in the steep woodland areas which are unsuitable for human settlement and crop cultivation in the Arsi and the Bale Mountains. All these support the notion that mountain nyala avoid areas dominated or over-utilized by humans and livestock. Thus, the impact of livestock and human activity is manifold, affecting range quality for mountain nyala and reducing the potential for ecotourism by reducing the quality of wildlife viewing. Stephens et al. (2001) also noted that the high number of livestock has negative impact on the Bale Mountains National Park in terms of tourist attraction. In summary, the negative impacts of human and livestock encroachments on mountain nyala can be understood in terms of shifts in their habitat use. Even though mountain nyala are known to persist in areas heavily affected by human activities (Evangelista et al., 2008), we found that in Munessa, the presence of people and livestock often excludes mountain nyala from using their optimum habitats.

As selective feeders, mountain nyala usually browse on new leaves, twigs, flowers and fruits (Refera and Bekele, 2004; Evangelista et al., 2007). As a result, mountain nyala never graze an area which is overgrazed by livestock (Stephens et al., 2001; Mamo, 2007). Unless urgent and consistent conservation measure and management action is taken against the negative impacts of human and livestock encroachments, the anthropogenically pressured small population of the unique mountain nyala in Munessa may locally go extinct in the foreseeable future.

Implications for conservation and management

Based on the results of our study, we would like to recommend the followings. The Munessa Forest District should give due emphasis to control illegal tree cutting activities for fuel wood and construction materials, as well as restrict free-range livestock grazing in the area. The proper maintenance and management of the forests enhances the availability and quality of habitats for mountain nyala. Close contact between livestock and mountain nyala inevitably results in various problems such as increased predation of juvenile and calf mountain nyala by guard dogs (Woldegebriel, 1996), loss of genetic viability through hybridization (Evangelista et al., 2007), competition for limited forage resources (Mamo, 2007) and risk of disease transmission (Jessup et al., 1995; Sillero-Zubiri et al., 1996; Stephens et al., 2001). Moreover, complex interactions involving humans, livestock and wild animals create environments favorable to the emergence of new diseases (Palmer, 2007). So, zonation of the core habitats may reduce the negative impacts of humans and livestock encroachments on mountain nyala in Munessa.

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Table S1. Seasonal humans and livestock encroachments across habitats. Mean and standard deviation values are included. N = number of plots assessed to quantify that parameter. The field data were collected once in a month (that is, three times during each season).

Season	Habitat type	N	Parameter	Mean	Std. Dev.
Wet	Cleared vegetation	31	Stem and / or crown damage / plot	0.00	0.00
		31	Evidence of wood use / plot	0.28	0.46
		31	Number of stumps cut / plot	5.48	1.91
		31	Sign of habitat use by livestock / plot	0.92	0.28
		31	Level of grazing / browsing by livestock / plot	2.08	1.00
	Plantation	41	Stem and / or crown damage / plot	0.66	0.30
		41	Evidence of wood use / plot	0.78	0.42
		41	Number of stumps cut / plot	1.73	1.84
		41	Sign of habitat use by livestock / plot	0.80	0.40
		41	Level of grazing / browsing by livestock / plot	1.32	0.96
	Natural forest	37	Stem and / or crown damage / plot	0.45	0.41
		37	Evidence of wood use / plot	0.94	0.25
		37	Number of stumps cut / plot	12.16	11.05
		37	Sign of habitat use by livestock / plot	0.94	0.25
		37	Level of grazing / browsing by livestock / plot	2.31	0.90
Dry	Cleared vegetation	31	Stem and / or crown damage / plot	0.00	0.00
		31	Evidence of wood use / plot	0.12	0.33
		31	Number of stumps cut / plot	5.48	1.91
		31	Sign of habitat use by livestock / plot	0.48	0.51
		31	Level of grazing / browsing by livestock / plot	0.84	0.99
	Plantation	41	Stem and / or crown damage / plot	0.49	0.51
		41	Evidence of wood use / plot	0.46	0.50
		41	Number of stumps cut / plot	2.00	1.94
		41	Sign of habitat use by livestock / plot	0.41	0.50
		41	Level of grazing / browsing by livestock / plot	0.68	0.96
	Natural forest	37	Stem and / or crown damage / plot	0.40	0.39
		37	Evidence of wood use / plot	0.50	0.51
		37	Number of stumps cut / plot	9.25	7.22
		37	Sign of habitat use by livestock / plot	0.47	0.51
		37	Level of grazing / browsing by livestock / plot	0.84	0.95

Notability:
i) Stem and / or crown damage (0 = absent; 1 = present).
ii) Evidence of wood use (0 = absent; 1 = present).
iii) Sign of habitat use by livestock (0 = absent; 1 = present).

Level of browsing / grazing by livestock:
i) 0 = No evidence (0% browsed /grazed);
ii) 1 = lightly browsed /grazed (1-25% browsed /grazed);
iii) 2 = moderately browsed /grazed (26-50% browsed /grazed); and
iv) 3 = heavily browsed /grazed (>50% browsed).