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Human and livestock encroachments into the habitat of Mountain Nyala (*Tragelaphus buxtoni*) in the Bale Mountains National Park, Ethiopia

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Abstract: A study to assess the impacts of livestock grazing and human encroachments on the habitat of Mountain Nyala (*Tragelaphus buxtoni*) was carried out in the Bale Mountains National Park, Ethiopia during 2003-2005. Parameters such as the presence or absence of both livestock and Mountain Nyala dung, extent of browsing, vegetation height and evidence of wood extraction by the local communities were assessed from 171 randomly laid plots (each covering 100 m^2). Additional 25 plots were used to measure spatial changes of vegetation structure and cover across Gaysay grassland area. Presence of livestock and other human activities in the area negatively affected habitat availability and quality for Nyala.

Resumen: Se llevó a cabo un estudio para evaluar los impactos del ramoneo del ganado y la invasión humana en el hábitat del nyala de montaña (Tragelaphus buxtoni) en el Parque Nacional de las Mountains Bale, Etiopía, durante 2003-2005. Se evaluaron parámetros como la presencia o ausencia de estiércol tanto de ganado como del nyala de montaña, la magnitud del ramoneo, la altura de la vegetación y evidencia de extracción de madera por las comunidades locales, en 171 parcelas establecidas al azar (cada una de 100 m^2). Se usaron 25 parcelas más para medir los cambios espaciales de la estructura y la cobertura de la vegetación a través del área de pastizales de Gaysay. La presencia de ganado y otras actividades humanas en el área afectaron negativamente la disponibilidad y la calidad del hábitat del nyala.

Resumo: Um estudo do impacte de pastagem de gado e humanos no habitat do Nyala de montanha (Tragelaphus buxtoni) foi levado a efeito no Parque Nacional das Montanhas Nyala, Etiópia durante 2003-2005. Parâmetros como a presença ou ausência de gado ou de excrementos de Nyala de montanha, extensão da zona pastada, altura da vegetação e evidência de extracção de madeira pelas comunidades locais foram avaliadas em 171 parcelas (cada uma de 100 m^2), casualmente distribuídas. Umas 25 parcelas adicionais foram utilizadas para medir as mudanças espaciais na estrutura da vegetação e no coberto através da área de pasto de Gaysay. A presença de gado e de outras actividades humanas na área afectou negativamente a disponibilidade e qualidade do habitat para o Nyala.

Key words: Browsing, encroachment, habitat, livestock, Mountain Nyala, vegetation.

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Introduction

Land use systems and human actions strongly influence the natural ecosystems and wildlife habitats despite the best efforts to conserve them in several localities (Norgard 1994; Redman 1999). Human population growth and development lead to the appropriation of extensive areas of land for settlement, agriculture, resource extraction and the infrastructure to support these activities, which in turn are responsible for wildlife habitat loss and fragmentation (Foley *et al.* 2005; Hundessa 1992; Kidane 1982; Mace *et al.* 2001). In many instances, the rate of habitat destruction and degradation has reached the point where the damage and losses are probably irreversible (Chris & Stuart 1996). Habitat loss and fragmentation due to human encroachment are probably the most common cause for the extinction of species (Brooks & Balmford 1996; Mace & Balmford 2000). Effects of habitat fragmentation on limiting a species' potential for dispersal and colonization by creating barriers to normal dispersal and colonization processes are widely reported (Debinski & Holt 2000; Rochelle *et al.* 1999; Trombulak & Frisell 2000). Presently, extinction of species as a result of human activities is more than 100 times faster than the natural rate of extinction and far more rapidly than new species can evolve (Primack 2002).

The Ethiopian highlands, which are densely populated by humans, support several species of threatened and endangered mammals (Baillie *et al.* 2004; Fjeldsa *et al.* 2004). The threat posed by human pressures on endangered species through habitat loss is widely documented (Forman 1996; Hundessa 1997; Kidane 1982; Wiegand *et al.* 2005). However, understanding about specific threats to species like Mountain Nyala (*Tragelaphus buxtoni*) is crucially lacking. Most parts of the historical range of Mountain Nyala in Ethiopia have been occupied by human settlements and cultivation (Brown 1969 a & b; Evangelista *et al.* 2007; Hillman 1986a, 1988). In such areas, its populations have shown considerable decline (Brown 1969 a & b; Hillman 1986 a & b, 1988). Relatively high number of individuals of this species occur in Dinsho, Gaysay/Adelay area (Gebrekidan 1996), and limited numbers in the Web Valley and high-lands in the central part of the Bale Mountains National Park. The Web Valley and highlands support a relic population due to extensive grazing and settlements in the areas. Naturally, small populations become increasingly vulnerable to extinction as human disturbances increase (Pullin 2002; Primack 2002). In some parts of its range, the population decline has been attributed to hunting (Brown 1969a). Widespread hunting of Nyala was noted during the change of government in 1991 (Gebrekidan 1994; Malcolm & Evangelista 2002; Tedla 1995). Currently, adult males are specifically hunted by license about 2 - 3 km from the Park boundary.

Similar to other anthropogenic pressures, livestock grazing can have strong impacts on native wildlife, their habitat and overall ecosystem function and structure. Hence, it is globally considered an important conservation concern (Aagesen 2000; Bagchi *et al.* 2004; Floyd *et al.* 2003; Hobbs 2001; Mishra & Rawat 1998; McIntyre *et al.* 2003; Prins 2000; Saberwal 1998; Smith *et al.* 2000; Yates *et al.* 2000). Recent reviews indicate that there is a world-wide scarcity of studies addressing the issue (Aagesen 2000; Prins 2000). This is especially true in Ethiopia, which supports the largest livestock population in Africa (FAO 1998). Livestock grazing in the Park area has become a common practice (Stephens *et al.* 2001; Tedla 1995). Often wild herbivores are out-competed by livestock from preferred resources and end up utilizing the less suitable forage. Similar scenarios are assumed to be the case for the wild herbivores in the Bale Mountains National Park, which supports high density of livestock as well as wild herbivores.

Although the effects of anthropogenic factors on Mountain Nyala were briefly stated by different researchers, information on how local people and livestock affect the Mountain Nyala population was lacking. The current conservation status of Mountain Nyala, as designated by IUCN (2002) is 'Endangered' due to its reduced population and continued decline. A better understanding of the effects of anthropogenic activities including livestock grazing on natural habitat can help decision makers implement conservation plans so that conflict of interests between humans and conservation of threatened species can be minimized (Baillie *et al.* 2004). Thus, the general aim of this study was to investigate the effects of encroachment by the local people and livestock on the Nyala and their habitat in the northern part of the Bale Mountains National Park (BMNP), where the surrounding farmers are predominantly dependent on subsistence farming and livestock rearing.

Study area

The study area is located in the northern parts of BMNP, between 6º 20' to 7º 40' N latitudes and

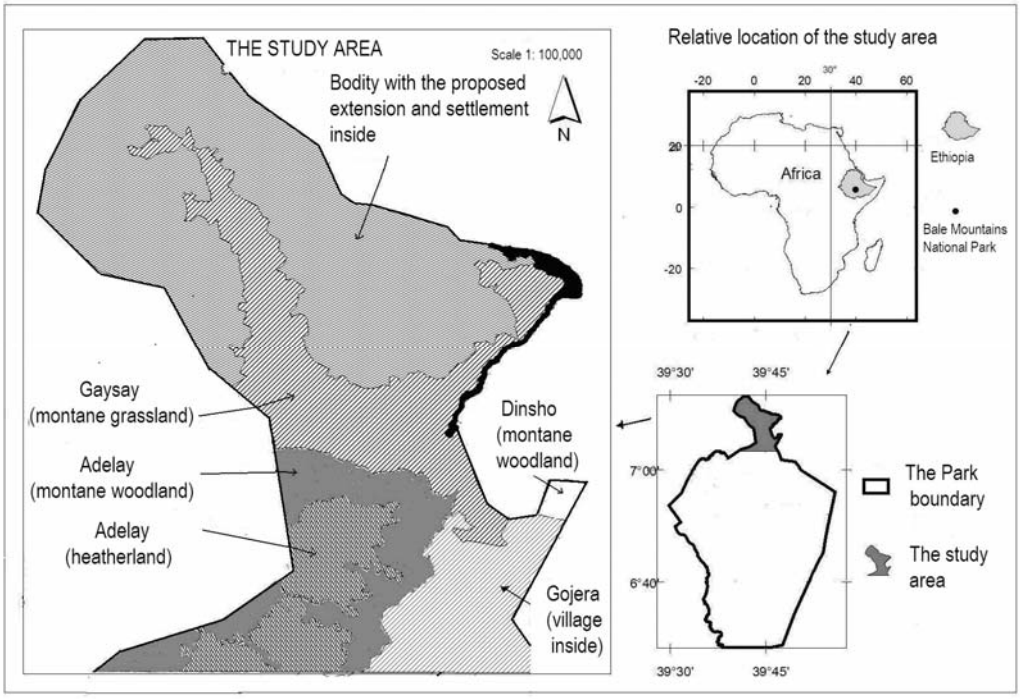

Fig. 1. Location map of the study area showing villages.

39º 30' to 39º 58' E longitudes in the southeastern highlands of Ethiopia (Fig. 1). There are seven village settlements in and around the study area. The northern boundary of the Park has not been finalized so far.

The northern montane grassland habitat (3000 - 3100 m asl) in the study area is a flat terrain located on the extreme north of the Park which supports large herds of Mountain Nyala. The area is subdivided into three vegetation zones: open grassland; marshy grassland and *Artemesia/ helichrysum* bushland (Hillman 1986b). The northern montane woodland habitat (3000 - 3400 m asl) and adjacent *Erica* heatherland (3400 - 3800 m asl) are subdivided into five zones mainly based on the major vegetation types they support. These are: *Hagenia/Juniperus* woodland, *Hypericum* bush, montane grassland, *Hypericum* woodland and *Erica* heatherland. The boundary of the Park, particularly in the northern part, has been changed at least three times with changes in governments. The Park is not yet gazetted, and hence the exact location of the boundary between the Park and villages outside will remain an issue of dispute.

Methods

Seven parallel transects were randomly laid in Gaysay grassland area in north-south direction with 20º bearing with a minimum distance of 950 m in between two transect lines. Additional two transect lines were randomly located at the edges of Gaysay grassland of the Park area. A total of 94 (10 x 10 m) sample plots were laid randomly with a minimum distance of 150 m between them. For ease of data collection, each of the 10 x 10 m plots was sub-divided into 400 equal squares of 0.25 m^2. Vegetation height, signs of use, dominant plant species and extent of browsing were measured in each plot.

In Adelay woodland area, three transect lines totaling 6.7 km running in northwesterly direction were established with minimum distance of 1,500 m in between. Seventy one circular plots of 100 m^2 (r = 5.64 m) were laid randomly along the transect lines with a minimum distance of 75 m. In Dinsho, three transect lines were laid randomly along a north-south direction at 20º, starting from the southern baseline of the sanctuary. A total of 31 circular plots (100 m^2 each) were randomly placed along the transect lines with a minimum distance of 200 m between plots. Each of the circular plots was established with two smaller plots nested within. The bigger plot was labelled as "tree plot" with an area of 100 m^2 (r = 5.64 m), the medium as "shrub plot" with an area of 10 m^2 (r = 1.78 m) and the smallest as "herb plot" with an area of 1 m^2 (r = 0.56 m). The total survey line covered in the

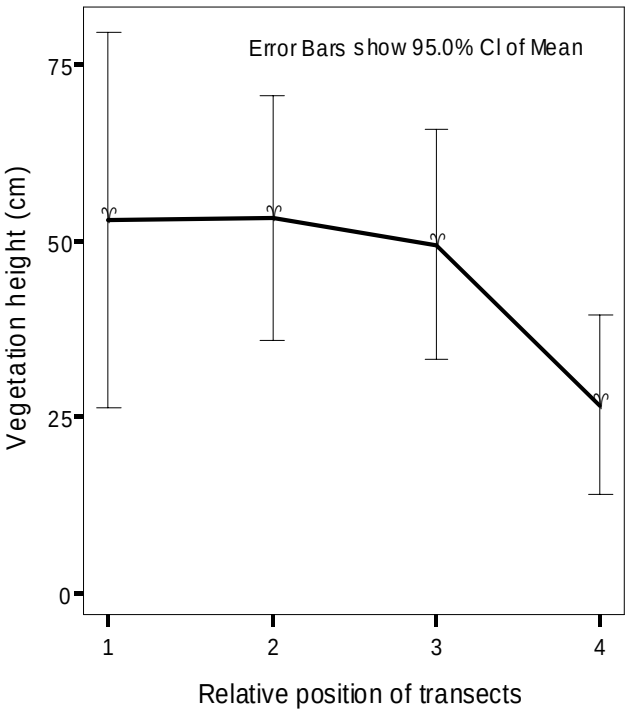

Fig. 2. Vegetation height and relative position of transects from the centre of Gaysay grassland towards either edges of the Park boundary in 20° N-S direction. (relative position 1 represents the centre, while 2, 3 & 4 represent areas away from the centre of the grassland towards the edges, respectively).

sampling was 19.5 km. The geographic location, elevation and slope of each plot were recorded using GPS, altimeter and clinometer devices, respectively. Levels of browsing, ground cover, sign of plot use by Nyala, vegetation height, dominant tree regeneration, stem damage, crown cut and stump number were recorded within each plot.

Livestock densities were calculated and converted into Adult Cattle Unit (ACU), as an indicator of grazing pressure. ACU conversion unit followed Silori & Mishra (2001), where 1 adult cow or bull =1 ACU; 1 cow calf = 0.5 ACU; 1 adult horse =1.5 ACU and 1 sheep/goat = 0.5 ACU.

Dissimilarity of vegetation cover inside the Park and at the edge was calculated following Czekanowski (1913): $S_C = 2\sum_{i=1}^{m}\min(x_i, y_i) \Big/ \sum_{i=1}^{m} x_i + \sum_{i=1}^{m} y_i$, where, X_i and Y_i denotes the abundance of species i, $\sum_{i}^{m}\min(x_i, y_i)$ denotes the sum of lesser scores of species i, where it occurs in both areas (plots or quadrats), m denotes number of species.

Data were summarized and analyzed using SPSS version 14 statistical software. Changes in Nyala habitat range in the Park area under different administrative regimes (1970-74; 1975-91 and from 1992 to 2005) were assessed using ArcView GIS 3.2 software. Moreover, points measured by GPS to demarcate the northern part of the Park were obtained from the office of Park management. In addition, information obtained particularly from Hillman's (1986b) management plan and Hillman (1993) boundary demarcation documents were used to draw maps using ArcView GIS 3.2 software. These maps were compared against the map developed based on the suggestions made by Hillman (1986b) to extend the northern part of the Park.

Results

Differences were observed in vegetation height inside the Park (mean = 49 cm; 41 - 58 cm at 95 % CI) and that of the edge areas (mean = 26 cm; 18 - 35 cm at 95 % CI) (df = 1, 40, F = 3.264, P = 0.002) (Fig. 2). The vegetation height was 47 % shorter at the edges of the Park area than the inside. The extent of open grassland area was larger by 26 % at the edge (84 % covered by grass) than inside the Park (58 % covered by grass). As one moves away from the centre of Gaysay grassland area in east-west direction, the vegetation structure gets shorter, more uniform and less diverse (Table 1). When all vegetation types were pooled together, level of browsing was higher at the edges (mean level = 3.3) than inside the Park area (mean level = 2.4) and the difference was significant (F = 15.228, df = 1, 36, P = 0.000).

The species dominant within the Park, viz., *Artemesia afra*, *Helichrysum splendidum,* grasses and sedges in the marshy areas were virtually absent around the border and outside the Park area. On the contrary, species such as *Ferula communis* and *Kniphofia foliosa,* which were relatively absent inside the Park area of Gaysay, were dominant towards the edges of the Park and outside. Such vegetation types were often abundant in areas settled by people and grazed by livestock. The dissimilarity between the vegetation cover along the edges and inside the Park (Gaysay area) was 29 % (Table 1). In Dinsho Sanctuary, plant species such as *Euphorbia dumalis* and *Solanum giganteum* were more common.

On an average, 134 ACU km^{-2} and 36 ACU km^{-2} of livestock were recorded in Gaysay grassland and Adelay woodland, respectively (Table 2). These values were well above the average numbers of Mountain Nyala found in the area. Cattle accoun-

Table 1. Dissimilarity between cover towards the edge and inside the Park of Gaysay grassland.

Vegetation type	% cover from plots inside the Gaysay grassland	% cover from plots towards edges of the Gaysay grassland
Artemisia bush	14	4[a]
Helichrysum bush	6	2[a]
Hypericum bush	3	0
Marshy grassland	10	0
Open grassland	58[a]	84
Mixed	9	6[a]
Total cover	100	96*

[a] Sum of the lesser scores of species common to both sites = 71 %. *The remaining 4 % is open ground without vegetation cover.

Table 2. Domestic animals as Adult Cattle Units (ACU) in Gaysay grassland and Adelay woodland areas ($df_{1,164}$).

Type of domestic animals	Sites	Mean ACU km^{-2}	*P* value
Cattle	Adelay Woodland	7	0.084
	Gaysay grassland	52	
	Mean	30	
Horse	Adelay Woodland	5	0.002*
	Gaysay grassland	38	
	Mean	21	
Sheep	Adelay Woodland	15	0.083
	Gaysay grassland	38	
	Mean	27	
Goat	Adelay Woodland	9	0.366
	Gaysay grassland	6	
	Mean	8	

*Significantly different at 0.01 level.

ted for the highest value of ACU per km^2 (30), followed by sheep (27), horses (21) and goats (8). Livestock were the common feature of Gaysay grassland area. A total of 160 ACU km^{-2} was recorded in Gaysay/Adelay areas. Hence, the average dry forage that would be required by livestock in the area per day is about 1,200 kg (7.5 kg × 160 ACU).

There was a significant correlation between incidence of browsing and livestock densities ($r = 0.3$, $P < 0.001$); while the correlation between vegetation height and livestock densities was negative ($r = -0.2$) but not significant ($P > 0.05$) (Table 3). The relationship between high incidence of browsing and frequency of livestock droppings was also positively correlated at 0.01 level ($r = 0.6$). Livestock presence in the area considerably affected the vegetation structure and eventually the vegetation availability to Mountain Nyala.

Incidence of browsing was positively correlated with livestock density while negatively correlated with Nyala density. There was a negative correlation ($r = -0.5$) between livestock and Nyala densities. Similarly, the presence of livestock with the presence of Mountain Nyala droppings was negatively correlated ($r = -0.2$).

A significant block of the area that was supposed to be the major habitat of Nyala was taken over by the local community for settlement and agriculture. The area, once dominated by *Hagenia* and *Juniperus* woodland, was converted to open agricultural field with few remnant trees scattered across the field. The main village in the area (Gojera), occupies 14 km^2 inside the Park. The following projection, based on the carrying capacity of the nearest area (Adelay woodland) was made to estimate the number of Mountain Nyala that could be supported by the area. The Park could have supported 266 more Nyala (14 km^2 × 19 Nyala km^{-2}) had the Gojera area not been converted into settlement and agricultural fields by the local settlers. This number is equivalent to 29 % of the Nyala population estimated to have existed in the study site of the Park area.

Evidence of wood use was not significantly different between Dinsho Sanctuary and Adelay woodland, which was relatively exposed to human and livestock interferences (Table 4). Out of the 102 plots surveyed, regeneration of *Juniperus procera* was observed in 13, while no sign of *Hagenia abyssinica* saplings was recorded in any of the other plots.

Discussion

The results suggest that the presence of livestock and their browsing pressure negatively

Table 3. Correlations (Pearson) between parameters related to mountain nyala and livestock.

Parameters	Browsing	Vegetation height	Presence of mountain nyala droppings	Presence of livestock droppings	Livestock density
Vegetation height	R = - 0.669 P = 0.000**				
Presence of mountain nyala droppings	R = - 0.100 P = 0.339	R = -0.045 P = 0.668			
Presence of livestock droppings	R = 0.098 P = 0.348	R = -0.006 P = 0.958	R = -0.227 P = 0.028*		
Livestock density	R = 0.311 P = 0.002*	R = -0.126 P = 0.226	R = -0.052 P = 0.620	R = 0.103 P = 0.326	
Mountain nyala Density	R = - 0.083 P = 0.073	R = 0.302 P = 0.003*	R = 0.203 P = 0.049*	R = -0.046 P = 0.657	R = -0.508 P = 0.000**

Correlation is significant at the 0.001 level & at 0.05 level*.

Table 4. Incidence of wood use by local communities per plot (N = 102 plots, each with 100 m^2 area size, $df_{1,70}$).

Variables	Sites	Mean ±SE	P value
Stumps cut	Adelay Woodland	2 ± 0.3	0.549
	Dinsho Woodland	2 ± 0.4	
Crown damage	Adelay Woodland	1 ± 0.0	0.777
	Dinsho Woodland	1 ± 0.1	
Stem damage	Adelay Woodland	1 ± 0.0	0.485
	Dinsho Woodland	1 ± 0.0	
Evidence of wood use or collection	Adelay Woodland	1 ± 0.0	0.572
	Dinsho Woodland	1 ± 0.0	

affected the structure and composition of the vegetation in the Park. In sites where human and livestock interferences are more prevalent, the vegetation types and composition showed considerable changes from more diverse and suitable to less diverse and unpalatable types. The important food sources for Nyala such as *Hypericum revolutum* and *Artemesia afra* have almost been eradicated around the edges of Gaysay area. Instead, less palatable species often avoided by Nyala were found in high abundance. Changes in vegetation structure and composition caused by the overgrazing of cattle were also documented by Morrison *et al.* (1998), Brown (1969a) and Malcom & Evangelista (2002). The vegetation cover and height tend to decrease away from the centre of the Gaysay area of the Park towards the edges suggesting that the latter areas are heavily grazed by livestock. People and livestock related encroachments were causes of concern to the whole Gaysay grassland habitat as there were no physical barriers and/or law enforcement to prevent the spread of such unwanted changes in vegetation structure towards the middle of the Gaysay grassland area. Marshy grasslands were almost absent towards the edges of the Park and outside, presumably because of observed heavy livestock grazing and trampling pressures. Thus, it is evident that unregulated exploitation of wood and forest resources from the Park area by the local communities could put the Nyala at risk. Brown (1969a) has estimated the potential reduction of habitat range of Nyala from 2,910 to 1,670 km^2 in the Bale Mountains. However, the current range of the species is estimated to be less than 100 km^2 in the Bale Mountains National Park. In addition to habitat loss, Mountain Nyala faces the danger of habitat fragmentation. When patches of habitat become smaller and more isolated due to fragmentation, the species living within them are more likely to go extinct and individuals from neighbouring patches are unable to immigrate or repopulate the patch (Brooks & Balmford 1996; Primack

2002; Pullin 2002; Rochelle *et al.* 1999). At present, Nyala faces a similar scenario. Few individuals of this species occur in relatively isolated areas of Dinsho, Gaysay, Adelay, Web Valley and highlands in the central part of the Park. The Web Valley and adjacent highlands support only a relic population due to extensive grazing and settlements in the areas. If the current state of land appropriation for settlement and agriculture continues in the area, it is unlikely that Nyala population would continue to thrive in this area.

The movement of Mountain Nyala within their home ranges was not without problems. The barbed wire fence and the local communities around put the lives of many animals at risk. Farmers frequently encounter Mountain Nyala during the night time in their farmlands and at times poached. Another potential negative impacts of livestock on the Nyala population include heavy infestation by ticks as observed in a dead Nyala during field survey. Stephens *et al.* (2001) noted that high number of livestock has negative impact on the Park in terms of tourist attraction.

Given the fact that free range grazing was a major source of food for livestock in the area and that local communities do not practice fodder cultivation, direct competition for food between livestock and mountain Nyala is inevitable. Mishra & Rawat (1998) have noted that when there is a high overlap in the habitat and forage requirements of livestock and wild herbivores, overstocking can cause competitive exclusion of the latter. The negative correlation between livestock and Nyala (density and droppings) also supports the hypothesis that Mountain Nyala avoids areas dominated by livestock. Expansion of agricultural land and settlements by clearing the vegetation which otherwise could have been used by Nyala directly reduces habitat ranges and availability. For example, the mineral spring locally known as 'Hora', which was used as salt licks by Mountain Nyala, was encroached by expanding settlements. This area, which is the only one in this part of the Park, is now out of the reaches of mountain Nyala. Kemp-McCarthy (1990) made important recommendations regarding the use of 'Horas' (salt soil) within and around BMNP.

Widespread growth of plants such as *Euphorbia dumalis, Ferula communis* and *Solanum giganteum* in and around Dinsho is an evidence of negative effects of human and livestock encroachments on the habitat quality. These species were largely avoided by Nyala as feed. These species are known to be associated with human presence or interferences and often occur in abandoned farmlands (Gebrekidan 1994; Watkinson & Ormerod 2001). It was observed that several grasslands in the area have been invaded by alien species such as red-hot Poker *(Kinphofia foliosa)* and *Cupressus luistanica* affecting the browse availability for native herbivores. The spread of *Solanum giganteum* in Dinsho and its adverse effects on habitats of Mountain Nyala has also been documented by Assefa (2003). There was little evidence of regeneration of the dominant tree species particularly *Hagenia abyssinica* in this area. Regeneration of *Juniperus procera* was observed, although not significant. Lack of regeneration of dominant tree species in the woodlands might be due to excessive grazing and/or browsing, and trampling pressure on young seedlings and saplings by herbivores (wild and domestic) in the area. Unless this is controlled, canopy trees that are potential cover and food sources for Mountain Nyala could be lost.

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