Home Range and Habitat Selection of Female Mountain Nyalas (Tragelaphus Buxtoni) in the Human-Dominated Landscape of the Ethiopian Highlands

Anagaw Atickem (anagawam@gmail.com)
Addis Ababa University
Matthias Klapproth
Deutsches Primatenzentrum GmbH - Leibniz-Institut fur Primatenforschung
Martha Fischer
Saint Louis Zoo
Dietmar Zinner
Deutsches Primatenzentrum GmbH - Leibniz-Institut fur Primatenforschung
Leif Egil Loe
Norwegian University of Life science

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Abstract

Background: Human settlement and agricultural activities restrict increasingly the range of large mammals in many cases contributing to declining numbers of ungulates. Here, we studied home range size and habitat selection of female mountain nyalas in the northern end of the Bale Mountains National Park (BMNP) (31 km^2) surrounded by human settlement. We collected data on space use of seven adult female mountain nyalas equipped with Global Positioning System (GPS) collars. Home range size was estimated using fixed kernel density and habitat selection was determined by resource selection functions.

Results: We found that female mountain nyalas have much smaller (5.7 km^2) home ranges than the 19 km^2 home range size predicted for a 170 kg, group-living species living in mixed habitats. Home ranges were 30% larger in night time than daytime. We suggest that the night time extension beyond the park boundaries were caused by both push and pull effects. The presumably high livestock and other ungulates grazing pressure within the protected area may cause forage-driven excursions out of the park, in particular during agricultural crop seasons. In addition, mountain nyalas are probably attracted by humans as shields against hyena predation. Resource selection index indicates bush land and forest habitat are the most preferred habitat types while agriculture and human settlements are least preferred habitats.

Conclusions: Given that mountain nyalas are found in high density (24 individuals/km^2) and the size of the northern part of the Bale Mountain National Park, which is currently under protection by the park authorities for the mountain nyala conservation, is too small for the predicted home range size of large ungulates, we suggest protecting additional area may be needed for the long-term conservation of the endangered mountain nyala.

Background

Home ranges and activity pattern of animals can be affected by the availability and quality of food and other resources, population densities of the respective species, the presence of competitors, risk of predation and climate [1–4]. Increasingly, human activities and human caused landscape alteration and fragmentation affect animal home range size, habitat use, activity and movement patterns [1, 5, 6].

As a rule of thumb, the size of a home range is expected to increase with the body size of the respective species, mediated also by habitat type and quality (e.g., open, mixed, closed) and the species' social organization (e.g., solitary or group living) [7–9]. The influence of humans is expected to be higher for large mammals because of their higher space requirements [10, 11]. Furthermore, since humans are mainly diurnal they interfere with wildlife more during daytime than during night time, pushing many mammal species towards a more nocturnal activity [12].

A greater understanding of the human impact on activity and movement patterns, home ranges and habitat use constitute important baseline data for conservation management [13, 14, 5]. This is of particular importance for endangered species whose populations and ranges have already been reduced [15]. Ecological information on home range size, activity pattern and habitat use are essential for wildlife management and design of protected areas.

Mountain nyalas, *Tragelaphus buxtoni*, are endangered antelopes endemic to the south-eastern highlands of Ethiopia [16]. The largest mountain nyala population (n = 1100) exists in a forest-dominated landscape of the Bale Mountains National Park (BMNP) [17]. The park was established during the 1970s primarily to protect mountain nyalas and another endemic species, the Ethiopian wolf, *Canis simensis* [18]. Currently, about 90% of the mountain nyala population of the park is confined to its northern part, the Gaysay Area [17]. Human settlement and livestock grazing, however, is increasing outside and inside the park, resulting in competition for space and food with wild large herbivores, such as the mountain nyala [19].

In this study we equipped seven female mountain nyalas with GPS collars to investigate their activity and movement pattern, home range size and habitat use. Given the strong human encroachment in the area surrounding the Gasay Area, we predict that the home ranges of mountain nyala are smaller than expected from theory [20] and that diurnal habitat selection and movement patterns are influenced by human infrastructure. Based on our findings, we discuss whether the current size of the protected area and conservation measures are sufficient for long-term conservation of mountain nyala.

Materials And Methods

Study area

The study was carried out in the Gaysay Area (31 km^2) of the BMNP and its surroundings outside of the national park. Unlike large parts of the BMNP, which are dominated by human settlements and herds of livestock, the Gaysay Area is patrolled by rangers as protection from livestock grazing but the extent of illegal grazing is still extensive [19]. The climate of the Bale Mountains is characterized by a 4-month dry season (November to February) and 8-month rainy season (March to October).

We defined our study area as the 100% minimum convex polygon containing the all locations (fixes) of all collared female mountain nyalas (number fixes = 31,649) which corresponds to an area of about 133 km^2 (Fig. 1).

Mountain nyala GPS-data

We equipped seven female mountain nyalas with Global Positioning System (GPS) collars (Followit Holding AB, Sweden) between 25/05/2008 and 29/05/2008[21]. The females were immobilized using a remote injection system and collared. The GPS units were programmed to take fixes every other hour, i.e. 12 fixes per day. We downloaded data from the GPS collars remotely by an external telemetry receiver, and transferred respective location data onto a computer with a Tellus Project Manager. The collars lasted on average 402 days before failure (SD = 215, range 212–681 days). The immobilization and animal handling was carried out with the permit and Ethical guidelines of Ethiopian Wildlife Conservation Authority [21].

Habitat classification

We defined habitats as grassland, forest, heath (dominated by *Erica* sp.), bushland, agriculture and human settlement. The habitat map was classified from SPOT images (2 m resolution) by using a supervised classification (ERDAS Imagine) based on 220 ground truthing locations [22, 23]. Elevation and slope values were derived from 90 m Digital Elevation Model (DEM). Geographic positions of households (settlements) adjacent to the Gaysay Area were recorded by using handheld GPS (24, for more details on habitat classification).

Statistical analyses

Home range estimation

We conducted home range analyses using fixed kernel density estimation. The bandwidth *h* was determined with the rule-based *ad hoc* approach [25]. Home range contours were calculated at the 95% isopleth level. The most intensively used portion of a home range is defined as the core area, i.e. areas where individuals are found with greater probability within the home ranges, and was determined at the 50% isopleth level [26, 27]. In addition, we calculated the extent of total area using the minimum convex polygon (MCP) method (determined at the 100% isopleth level) for habitat utilization analysis. Home ranges and core areas were estimated with the R package "rhr" [28].

Home range and body size

To predict the home range size of a species of body size 170 kg [20, 29], living in mixed habitat and with a mean group size of seven we followed Ofstad et al. [9, Eq. 1].

Eqn 1: $HR = \exp(-10.28 + 1.44*\log(BM) + 0.3*\log(\text{group size}))/100$

where HR refers to home-range, BM to body mass (measured in grams), group size in number of individuals. Note that the constant (-10.28) is specific for species living in mixed habitats.

Habitat selection analysis

The habit preference within our study area was carried out by using Generalized Linear Models (GLMs) with a use-availability design in R [30–32]. We used animal location as the sample unit in all analyses.

Each used location was paired with one random location in the following way: the random location copied all the non-spatial variables from the used point (ID, season, day time/night time) before adding new spatial covariates (distance to humans, habitat class) from the random location [33]. The response variable is binomially distributed and consists of used points (GPS points of respective mountain nyalas, coded 1) and randomly sampled available points (coded 0).

To account for temporal autocorrelation among observations we estimated robust standard errors using the approach of Forester et al. [34], i.e. we clustered the data based on the lag of the temporal autocorrelation and placed every other cluster in a second data set. The robust standard errors were calculated by averaging the covariance matrices for both subsets of data, while the parameter estimates represent fitted values from the full-data set.

The sample size differed among individuals. To prevent individuals with larger samples from influencing the results more than individuals with smaller samples, we weighted the contribution of each data point by a vector W = the lowest sample size across all individuals / sample size of focal animal in the GLM using the weights argument. Parameter estimates of this analysis are log odds of use relative to reference categories of categorical variables and zero values of continuous variables.

Results

Home range size

A total of 31,649 GPS fixes were obtained from the seven females with an average of 4,521 GPS fixes [SD = 2368] per female. The GPS collars recorded fixes with an overall success rate, successful records of GPS record in 2 hrs interval, of 92.1% (range between 82.8–96.3%). The mean home range size of a female was 5.7 ± 4.4 km^2 and mean core area size was 1.1 ± 0.79 km^2 (Table 1). This is only about 1/3 of the 19 km^2 home range size expected from Eq. 1.

Table 1
Size (km²) of home ranges (HR) and core areas (core) of female mountain nyalas (fixed kernel estimate home range 95%; core area 50%).

ID	size					
	annual		wet		dry	
	core	HR	core	HR	core	HR
F1	0.8	4.2	1.0	4.7	1.3	5.7
F2	0.6	3.6	0.6	3.7	0.6	3.4
F4	1.2	7.1	1.2	7.5	0.7	3.5
F5	1.1	6.5	1.0	6.1	0.9	4.3
F7	2.8	14.4	2.5	13.9	1.7	9.9
F8	0.5	2.6	0.4	2.0	0.4	2.7
F9	0.7	5.2	0.7	5.9	0.9	4.9
mean ± SD	1.1 ± 0.8	5.7 ± 4.4	1.1 ± 0.7	6.3 ± 3.8	0.9 ± 0.4	4.9 ± 2.4

During night time females were significantly more often located outside the protected area (30% ± 33%) than during daytime (13% ± 18%, $V = 2$, $n = 7$, $p = 0.021$). However, females showed large inter-individual difference on the proportion of GPS fixes outside the protected area during the night which varied from 2.26 to 99.39% of the total GPS fixes of the night time (Table 2, see also 24). On average, 70% (SE = 30%, range: 22–100%, Table 3, Fig. 1) of the home range of the females was located inside the protected area, but there were large individual differences.

Table 2
Proportion (%) of GPS fixes outside and inside the protected Gaysay Area during day and night.

ID	total fixes	day/night fixes		out/in	day	night
F1	7561	day	4454	out	28.0	76.7
		night	3107	in	72.1	23.3
F2	7650	day	4417	out	1.8	2.3
		night	3233	in	98.2	97.7
F4	5574	day	3187	out	2.4	18.3
		night	2387	in	97.6	81.7
F5	2631	day	1546	out	2.6	22.9
		night	1085	in	97.4	77.1
F7	2917	day	1638	out	9.7	9.5
		night	1279	in	90.4	90.5
F8	3114	day	1796	out	0.5	0.6
		night	1318	in	99.6	99.4
F9	2202	day	1273	out	48. 8	77.6
		night	929	in	51.2	22.4
total	31649	day	18311	out	13.4 ± 18.3	29.7 ± 33.4
mean ± SD		night	13338	in	86.6 ± 18.3	70.3 ± 33.4

Table 3
The proportion (%) of the 95% home range estimate within the Gaysay Area.

ID	proportion
F1	38.1
F2	100.0
F4	83.5
F5	66.4
F7	77.7
F8	100.0
F9	22.0
mean (± SD)	69.7 ± 30.0

Habitat use and habitat selection

The Gaysay Area consists of grassland (45.5%), forest (22.9%), bush land (19.4%), heath (5.5%) and others including water bodies, roads, and settlements (6.8%). The buffer zone of the Gaysay Area is dominated by human settlement and agricultural fields.

Habitat selection of the female mountain nyalas differed between seasons and between night and day for some, but not all, habitat types. Heath was avoided both day and night in both seasons. Bushland and grassland were preferred daytime habitats, but avoided during night (with the exception of bushland in wet season). Forest is the strongly selected daytime habitat and moderately preferred night time during dry season, while preference of forest is neutral both in day and night in wet season (Fig. 2, Table 4). All seven females tend to avoid human settlements and agriculture.

Table 4

A Generalized Linear Model for habitat selection of female mountain nyalas. Parameter estimates are log odds of use relative to reference categories of categorical variables and zero values of continuous variables. Spatial autocorrelation and different sample size is accounted for (see material and methods).

	Estimate	robust SE	z	p
Intercept	-176.5900	11.1220	-15.88	< 0.001
Vegetation (Heath-Forest)	-1.4953	0.2958	-5.06	< 0.0000
Vegetation (Grassland-Forest)	-0.4430	0.1188	-3.73	0.0002
Vegetation (Bushland-Forest)	-0.4442	0.1454	-3.06	0.0022
Vegetation (Settlement-Forest)	-3.9325	0.6202	-6.34	< 0.0001
Vegetation (Agriculture-Forest)	-4.5864	0.6839	-6.71	< 0.0001
Slope (steep-flat)	-0.4618	0.2604	-1.77	0.0762
Elevation	0.1087	0.0070	15.57	< 0.001
Elevation2	0.0000	0.0000	-15.21	< 0.001
Distance to house	-0.0003	0.0003	-1.00	0.3197
Distance to house2	0.0000	0.0000	2.15	0.0312
Season (Wet-Dry)	-1.2041	0.1861	-6.47	0.0000
Light (Night-Day)	1.3873	0.1983	7.00	< 0.0000
Distance to house x Season	0.0009	0.0004	2.41	0.0160
Distance to house2 x Season	0.0000	0.0000	-1.35	0.1784
Vegetation (Heath-Forest) x Season	0.0729	0.2934	0.25	0.8037
Vegetation (Grassland-Forest) x Season	0.6888	0.1242	5.55	< 0.0001
Vegetation (Bushland-Forest) x Season	0.8109	0.1509	5.37	< 0.0001
Vegetation (Settlement-Forest) x Season	-0.0834	0.3057	-0.27	0.7850
Vegetation (Agriculture-Forest) x Season	0.6875	0.2438	2.82	0,0048
Vegetation (Heath-Forest) x Light	0.4053	0.2843	1.43	0.1539
Vegetation (Grassland-Forest) x Light	-0.4619	0.1146	-4.03	0.0001
Vegetation (Bushland-Forest) x Light	-0.1751	0.1358	-1.29	0.1971
Vegetation (Settlement-Forest) x Light	2.5837	0.6112	4.23	< 0.0001
Vegetation (Agriculture-Forest) x Light	3.6086	0.6735	5.36	< 0.0001

Discussion

The Gaysay Area at the northern end of the BMNP has been the stronghold of mountain nyalas for over four decades and is home for 90% the mountain nyala population in the park. The Gaysay Area is, however, small in size [31 km^2] with many herbivore wildlife species and is under livestock grazing pressure [19]. With this study, we demonstrated the home range size of the female mountain nyalas is by far less than the home range size predicted for group living species living in mixed habitat. Bush land and forest are the most preferred habitat types by female mountain nyalas and these habitats combined are much smaller (13 km^2) suggesting the need for additional protected area free from human and livestock grazing impact. Hence, we recommend extending the protection of the Gaysay Area habitat against human settlement and livestock grazing beyond the current 31 km^2 area towards southern range of the mountains. During 1986, this area was used intensively by mountain nyalas and used as corridor to the eastern escarpments of the Bale Mountains [35].

The mean 95% of the home range estimate (5.3 km^2) was only 28% of the home range expected for a 170 kg, group-living species living in mixed habitat. The comparatively small and largely overlapping home ranges of female mountain nyalas may be due to the dense human population surrounding the park. It is reported that human-dominated landscapes surrounded by a matrix exploited by agriculture or human settlement limits the ranging pattern and adversely affects the fitness of wildlife [1, 5, 34]. There is reason to expect a large cumulate impact on the suite of large herbivores in the Gaysay Area. In addition to the mountain nyala population which is estimated to be about 840 individuals [17], the Gaysay Area is home for many other herbivores including about 400 Bohor reedbucks *Redunca redunca* [35], ca 600 common warthogs *Phacochoerus africanus* [36] and an unknown number of Menelik's bushbucks *Tragelaphus scriptus* and grey duikers *Sylvicapra grimmia*. In addition, there is extensive illegal grazing of domestic cattle [19]. The carrying capacity of the Gaysay Area may limit further population growth of the herbivore community including mountain nyalas.

Protected areas are the primary biodiversity conservation strategy used across the globe to avert biodiversity loss [37]. Effectiveness of the protected areas however becomes controversial as wildlife population decline from several protected areas [11, 38 – 44]. The decline is in particular severe for large mammals where Craigie et al. [45] reported a 59% decline in large mammal population abundance in Africa's Protected Areas in less than 40 years. Understanding the ecological requirement of large mammals and available resources in the protected area is key for reversing the currently observed decline of wildlife species [46, 47]. During the night time, mountain nyalas spend a relatively higher proportion of their time outside the park than during the daytime. During the wet season, mountain nyalas may move out of the park for foraging on the barley crop, but they also move toward human settlements to avoid hyena predation [24], known as the human shield strategy [48]. While mountain nyalas are very shy in much of their range in the eastern escarpments of the Bale Mountains where legal and illegal hunting may occur, they are more tolerant for human presence in the protected Gaysay Area [24]. Therefore range contraction due to human infrastructure may be expected to be stronger than in other areas inhabited by mountain nyalas.

For large herbivores, habitat selection is often a trade-off between foraging and avoidance of predators [49]. Many prey species resolve this by selecting predator-safe habitat during the time the predator is active and foraging habitat while the predator is inactive [50]. The mountain nyalas moved out of the park, in particular during the dry season when no crop for forage is available, to avoid hyena predation [24].

Resource selection index indicates bush land and forest habitat are the most preferred habitat types for mountain nyalas while agriculture and human settlements are least preferred habitats. Heath bushland, one of the most important habitats for mountain nyalas [51], is part of the Gaysay Area and was found to be among least used and least preferred habitats during this study. From the geographic scale resource selection of mountain nyalas [17], forest areas were found to be the most preferred habitat with largest mountain nyala population while mountain nyalas avoid human influenced area (agriculture and human settlement). The mountain nyala population of the Gaysay Area may be established due to its protected status rather than its habitat quality for forage in the first place. Mountain nyalas were not reported in the Gaysay Area during Brown survey in 1969 [51]. Following the establishment of the park in 1970, the mountain nyala population dramatically increased from few individuals [52] to 1,100 in 1986 [35]. While the population may have increased through births, the rate of increase likely represents high emigration from the surrounding mountains due to pressure from the human population and attraction to the protected status of the area. Since 1991, humans and their livestock have encroached upon BMNP leaving the Gaysay Area as last stand refuge for the mountain nyala population [53].

Conclusion

Our study suggests, the currently protected area of the northern end of the Bale Mountains National Park, Gaysay area, is too small for the mountain nyala conservation. Given with large number of other herbivores and continued livestock grazing, the future long term conservation of the endangered mountain nyala need additional protected area free from human and livestock grazing impact.

Abbreviations

GPS: Global Positioning System; CEES: Centre for Ecological and Evolutionary Synthesis.

Declarations

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Authors' Contributions

AA and LEL designed the study. AA and LEL collected the data, LEL amd MK analyzed the data. AA drafted a first manuscript which was improved by MF and DZ. All authors read, comment and approved the final manuscript.

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Availability of data and materials

Data is available at Dryad, Dataset, https://doi.org/10.5061/dryad.fttdz08pv.

Ethics approval and consent to participate

Immobilization of mountain nyala was carried out with the guideline and permit of the Ethiopian wildlife conservation authority

Consent to publish

Not applicable. Here we confirm that the data is collected with the ownership of the authors and have no any restriction to publish the resutls.

Competing interests

The authors declare that they have no competing interests.

Author details

[1]Department of Zoological Sciences, Addis Ababa University, PO Box 1176, Addis Ababa, Ethiopia. [2]Cognitive Ethology Laboratory, German Primate Center (DPZ), Leibniz Institute for Primate Research, Kellnerweg 4, 37077 Göttingen, Germany. [3]WildCare Institute Center for Conservation in the Horn of Africa, Saint Louis Zoo, St. Louis, Missouri, USA. [4]Leibniz Science Campus Primate Cognition, Göttingen, Germany; [4]Department of Primate Cognition, Georg-August-University of Göttingen, Göttingen, Germany. [6]Departments of Ecology and Natural Resource Management, Norwegian University of Life Sciences, Aas, Norway.

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Figures

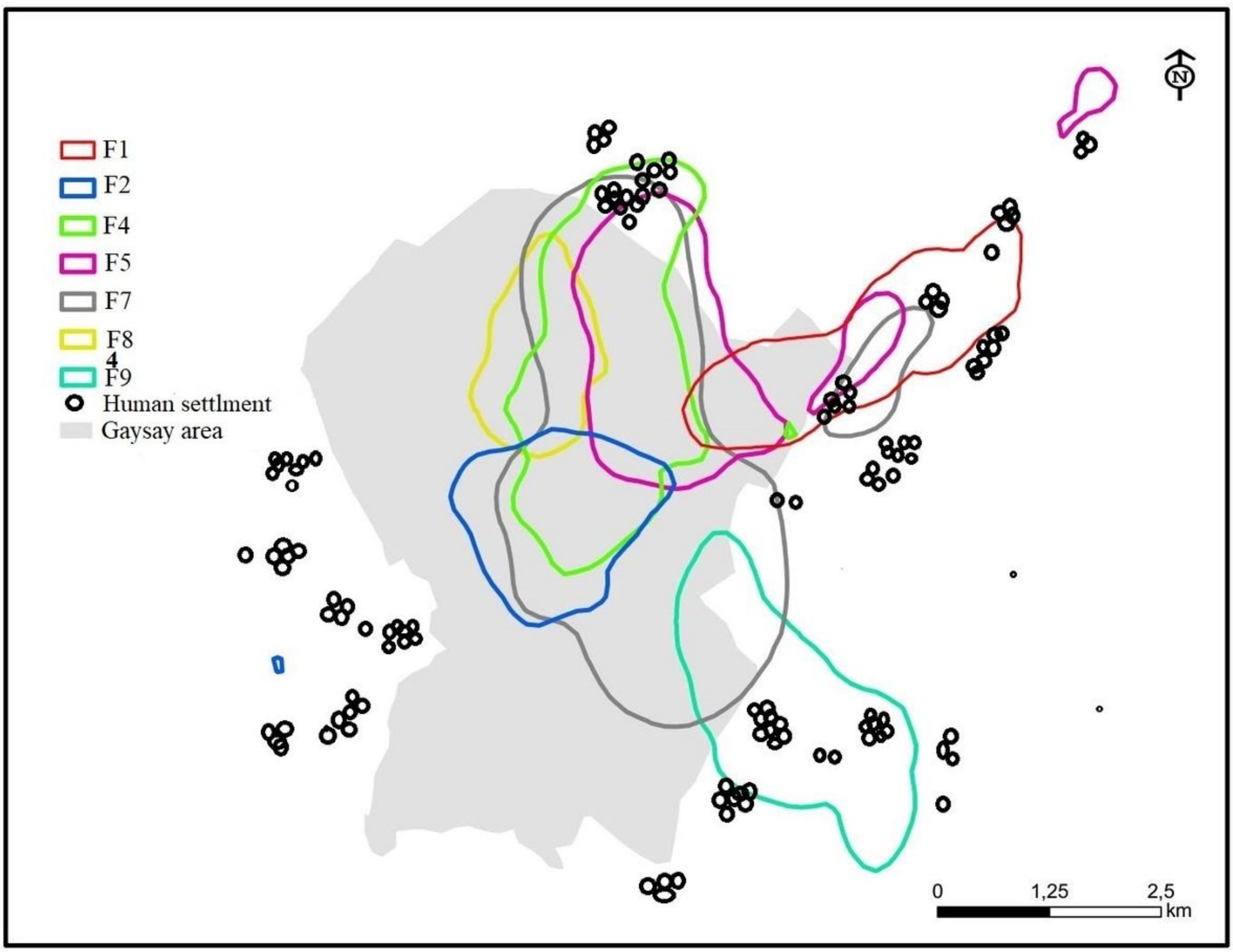

Figure 1

Study area in the northern part of the Bale Mountain National Park, Gaysay Area, and 95% kernel home ranges of the seven female mountain nyalas.

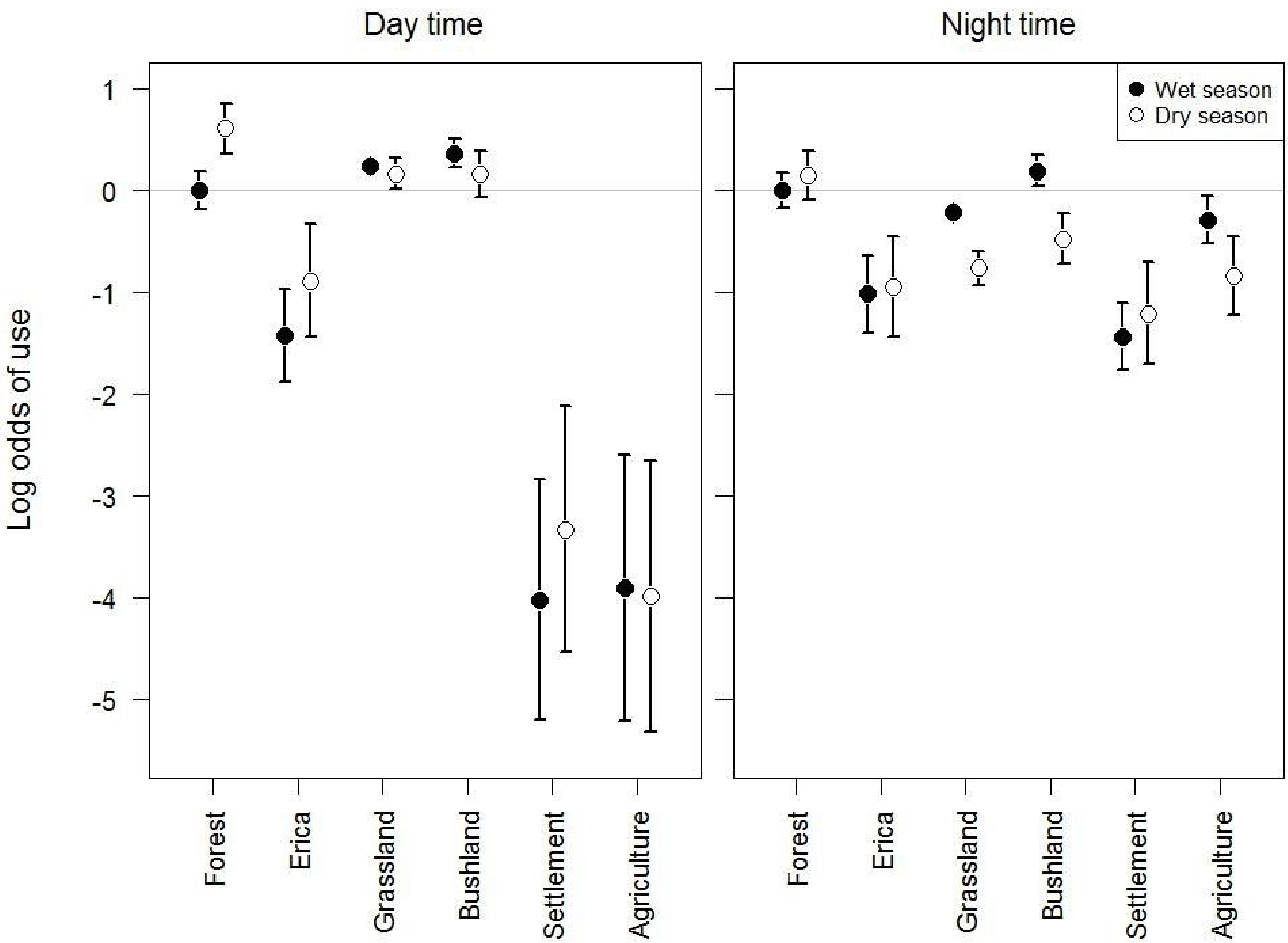

Figure 2

Predicted log odds of use with increasing elevation. Predicted values are for flat slopes (0-20 degrees), 2000 m from human households, vegetation type grassland and for daytime in the wet season. Elevation is modelled as a second order polynomial with no interactions with light (day and night) or season.