Research Article

Contribution of the guassa community eco-lodge to the conservation of wild mammals, birds and woody plants in menz-gera midir district, north shewa administrative zone, Ethiopia

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Abstract

In recent decades, several eco-lodges have been established in biodiversity areas of Ethiopia, but quantitative scientific information that helps guide the sustainable management of eco-lodges is lacking. This study was the first attempt that examined the role of the GCEL for the conservation of wild mammals, birds, and woody plants. The objective of the study was to characterize and quantify species diversities and densities of wild mammals, birds, and woody plants in the compound of the eco-lodge and in the adjacent field. Following a total of six randomly aligned transects, field data on the species richness and abundance of wild mammals and birds across the landscape were collected in the compound of the GCEL (here after the EHH) versus in the adjacent field (here after the FGH).

Moreover, a systematic sampling design was employed to lay a total of 39 circular plots (i.e, each with a radius of 10m) and collect data on the species richness and abundance of woody plants. The results revealed that species richness, diversity, and evenness of wild mammals were 11, 1.6 and 0.67, respectively, in the EHH and 11, 1.4 and 0.6, respectively, in the FGH. Similarly, species richness, diversity and evenness of birds were 33, 3.3 and 0.96, respectively, in the EHH, and 29, 3 and 0.88, respectively, in the FGH. The woody species were represented by 16, 2.7 and 0.97 species richness, diversity, and evenness, respectively, in the EHH, and 16, 2.6 and 0.94 species richness, diversity, and evenness, respectively, in the FGH. The total mean densities of wild mammals recorded in the EHH and FGH were 16.0 and 7.5 individuals, respectively. Similarly, the total mean densities of birds computed in the EHH and FGH were 668.5 and 158.3 individuals, respectively. Moreover, the total mean densities of woody species estimated in the EHH and FGH were 37,665.2 and 16,845.6 individuals, respectively. The findings of this study generated quantitative scientific information for policy-makers and planners that guides them toward better and more informed decision-making for eco-lodge establishment and management that is geared toward biodiversity conservation.

Keywords: densities, eco lodge, guassa, species diversities

Abbreviations: EHH, erica heather habitat; FGH, festuca grassland habitat; GCCA, guassa community conservation area; GCEL, guassa community eco lodge; GGR, guassa grassland reserve
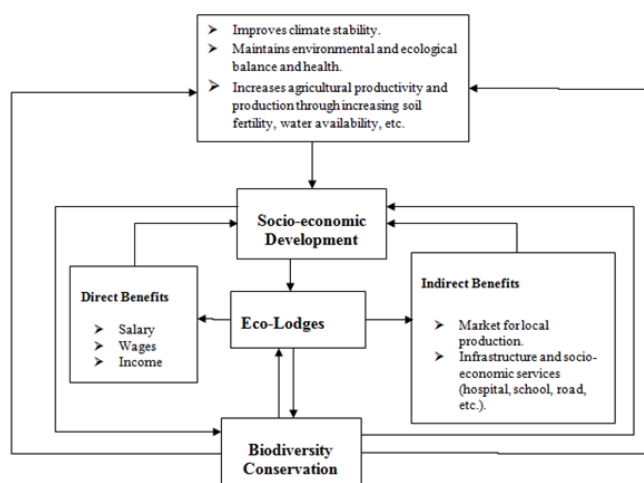
Introduction

In recent decades, several eco-lodges have been established in biodiversity areas of Ethiopia. For example, plenty of eco-lodges are found in Amhara, Oromia and Southern Nation, Nationalities and People's National Regional States. Most of the times, as eco-lodges are established from environmentally friendly, economically feasible and socially acceptable local materials, we argue that eco-lodges contribute much to the conservation of the local biodiversity. As biodiversity is one of the topmost attractions to tourists, eco-lodges conserve the local biodiversity from human and livestock induced disturbances. For example, when natural plants existing in the compounds of eco-lodges are protected from illegal human and livestock induced encroachments, they attract plenty of wild mammal and bird species from the adjacent open fields. This is because they

provide the incoming wild mammal and bird species with quality food,[1,2] suitable cover from environmental extremes,[3] breeding sites[4] and concealment from risk of predation.[5] Therefore, to maintain the long term survival of our natural ecosystems, eco-lodges play a central role in local biodiversity conservation in Figure 1. Despite the tremendous contributions of eco-lodges to local biodiversity conservation, there is a lack of scientifically tested quantitative information that addresses this issue in Ethiopia. In an attempt to bridge the gap of scientific knowledge, this study focused on assessing the role of the GCEL in the conservation of wild mammals, birds and woody plants in Menz-Gera Midir District, North Shewa Administrative Zone, Ethiopia. The reason why this site was selected as area of the study is that no study was done so far on the role of eco-lodge in biodiversity conservation.

The objective of the study was, therefore, to determine the diversity (species richness, diversity and evenness) and densities of wild mammals, birds, and woody plants in the compound of the GCEL (here after the EHH) and the adjacent field (here after the FGH). The following research question was addressed: are there

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significant differences in the species diversities and densities of wild mammals, birds, and woody plants in the EHH and the FGH? We hypothesized that species diversities and densities of wild mammals, birds, and woody plants in the EHH will be higher than in the FGH.

Figure 1 Conceptual framework illustrating the linkage of eco-lodges with biodiversity conservation and socio-economic development.

Materials and methods

Study area

The study was carried out in GCEL. GCEL is found in the GGR, also known as the GCCA. The GGR lies between 10°15′-10°27′ N and 39°45′-39°49′ E (Figure 2). The annual rainfall for the area averages between 1,200 and 1,600mm. The area ranges in altitude from 3,200 to 3,700m. The area is part of the Menz-Gera Midir District in North Shewa Administrative Zone, Ethiopia.[6] The GGR covers an area of 98km², and it is one of the oldest known common property resource management in Sub-Saharan Africa. It has been the focus of an indigenous natural resource management institution, known as "Qero," system for over 400 years.[7] The area is home to numerous endemic wild mammal species, including the iconic Ethiopian wolf, gelada and Ethiopian highland hare.[8] Other wild mammal species living in the area include klipspringer, jackal, leopard, spotted hyena, African civets and serval cat. In addition, the endemic bird species that are found in the area include Ankober serin (*Serinus ankoberensis*), abyssinian catbird (*Parophasma galinieri*), abyssinian long-claw (*Macronyx flavicollis*), Ethiopian siskin (*Serinus nigriceps*), spot-breasted lapwing (*Vanellus melanocephalus*), and wattled ibis (*Bostrychia carunculata*). The reserve also supports important and endemic plant species including Guassa grass, giant lobelia, erica moorlands and species of *Helichrysum* and *Alchemilla*. Other common plant species that are found in the area include Carex monostachya A Rich, Carex fischeri K Schum and Kniphofia foliosa Hochst. The Afro-montane vegetation of the area varies with altitude, and is a key attraction to tourists visiting the area. The GGR is one of the key biodiversity areas in the central highlands of Ethiopia.[6,7]

Data collection

To collect data on species richness and abundance of wild mammals, birds, and woody plants across the landscape, transects were randomly set with the aid of a GARMIN 75 GPS device and each transect sampling a major existing habitat type within the EHH

and in FGH. Accordingly, a total of six transects were aligned, i.e, three transects within the EHH and other three transects within the FGH. Along each transect, the viewable area of each habitat patch was quantified by walking perpendicularly from a given line transect until the unevenness of the topography or the thickness of the vegetation cover no longer allowed viewing that transect.[9,10] The GPS locations on both sides of all the viewable parts of each habitat type were then taken. This activity was important in determining the sample area of each habitat type along each transect. 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, and overlaid on the map of the study site. We, then, digitized the GPS coordinates of all the visible points for each transect using lines to make a polygon along all transects. This gave us the areas of all the habitats sampled in each transect. Transects varied in length from 0.5 to 0.8km i.e, the length of each transect varied with the size of each habitat patch. We took transect samples whose total area was about 53.18ha.

Figure 2 Map showing the location of the GCCA in the central highlands of Ethiopia.

Population census of wild mammals and birds

To measure the densities of wild mammals along each transect, we conducted regular population censusing by walking along each transect within the EHH and the FGH. During each field census, the observed wild mammal species were identified and recorded along with their sex-age class, group size and occurrence of habitat type. For bird species, a point counting method was applied. Along each transect, with the help of binoculars and field guide, each encountered bird species was identified and its group size was estimated in the two habitats. Since identifying the sex-age class of each observed bird species in the field was difficult, only their numbers were estimated when encountered during the census. The radius of the point counting depended on the visibility of the habitat patch, i.e., more visible habitat patches have longer radius than patches with dense vegetation cover. For both wild mammals and birds, counts were carried out early in the morning from 06:00 to 09:00 and late in the afternoon from 16:00 to 18:30 local time, when wild mammals and birds were most active. To increase the reliability of the field data, each transect was assessed four times. The data were collected from May 2014 to March 2015.

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Estimating species richness and abundance of woody plants

A systematic sampling design was employed to lay circular plots and collect data on abundance and species richness of woody plants. Following each transect aligned for wild mammal population censusing, the first plot within each habitat patch on each transect was randomly located. Then, successive plots were systematically added at 100m intervals along each transect. Accordingly, a total of 39 plots i.e, 18 plots within the EHH and other 21 plots within the FGH were laid down. This suggests that the number of plots laid along each transect depended on the total length of the sample transect. A circular sample plot with a radius of 10m was demarcated on each line transect. Within the circular plots, the identity and number of stems of all tree species (woody individuals with a height of ≥3m) were determined and recorded. Then, a circular nested plot of 3m radius was laid down within the larger circular plot and identity and numbers of stems of all shrubs (woody individuals with a height of <3m and 0.5m) were determined and recorded. Similarly, for seedlings of all tree species (woody individuals with a height of <0.5m), their identity and number of individuals were determined in circular nested sub-plot of 1m radius within the larger circular plot. The data were collected from May 2014 to March 2015.

Data analyses

Species richness, evenness and diversity

Species richness is a measure of the number of different species represented in an ecological community, landscape or region. Species richness is simply a count of species, but it does not take into account the abundances of the species or their relative distributions. However, species evenness is a measure of the relative abundance of the different species making up the richness of an area. Thus, species evenness quantifies how equal the abundances of the species are. Evenness compares the similarity of the population size of each of the species present.[11] A diversity index is a quantitative measure that reflects how many different types (such as species) there are in a dataset, and simultaneously takes into account how evenly the basic entities (such as individuals) are distributed among those types. The value of a diversity index increases both when the number of types (i.e. species richness) increases and when species evenness (i.e. how equal the abundances of the species are) increases. For a given number of types, the value of a diversity index is maximized when all types are equally abundant. Accordingly, Shannon diversity indices[11] for wild mammals, birds, and woody species recorded in the EHH and FGH were computed. Shannon diversity index is expressed by the formula.

$$H = -\sum_{i=1}^{S} (P_i * InP_i)$$

Where H= Shannon diversity index, P_i= fraction of the entire population made up of species i and S = numbers of species encountered.

$$p_i = \frac{n_i}{N}$$

Where n_i= number of individuals of species "i", N=total number of individuals of all species and p_i= relative abundance of species "i".

Shannon's equitability *(J)*[11] was also computed for wild mammals, birds, and woody species recorded in the EHH and FGH. Shannon's equitability (*J*) measures the evenness of a taxon and can be easily calculated by dividing the value of H with H_{max}, which equals to lnS (S=number of species encountered). Its value ranges between 0 and 1. If abundance is concentrated to one type, and the other types are very rare (even if there are many of them), Shannon equitability approaches zero. When there is only one type in the dataset, Shannon equitability exactly equals zero. The less variation in taxon between the species, the higher *J'* is.[11]

$$J' = \frac{H'}{H'_{max}}$$

where H' is the number derived from Shannon diversity index and H'_{max} is the maximum value of H', equal to

$$H'_{max} = -\sum_{i=1}^{S} In\frac{1}{S} = InS$$

where *S* is the total number of species.

Densities

The sample area information was incorporated with population census data obtained through transect counting of wild mammal species. Then, the numbers of individuals of each wild mammal species counted along each transect during each census was divided by the visible area of the respective transect for each habitat type. That enabled us to estimate the densities of each wild mammal species in each habitat type (Tables 1). As density is one of the objective measures of abundance, this helped us to estimate and compare the abundance of each wild mammal species inside the EHH and the FGH. Densities of each bird species inside the EHH and the FGH were computed by dividing the numbers of individuals of each bird species to the area of the respective point transects where that particular bird species was observed and counted. The results of these analyses were presented in Table 2. Moreover, the inventory data for each woody plant species were divided by the sample area of each circular plot to estimate the densities of each woody species i.e., densities of trees, shrubs, and seedlings in the EHH, and FGH. To make comparisons of the densities of each woody species to be more comprehensive, densities of trees, shrubs, and seedlings of individuals of each woody species were summed for that particular plot and habitat type (Table 2). A two-way ANOVA was used to check whether wild mammals, birds, and woody species exhibit differences in their densities in different habitat types.[12] To do so, we included habitat type and species as predictors, with densities of wild mammals, birds, and woody species as the dependent variables. For mean comparisons, an independent t-test was used to check if each species of wild mammals, birds, and woody species differs in its respective densities in the EHH and FGH. The overall densities of each taxon (i.e. wild mammals, birds, and woody plant species) in the EHH versus in the FGH were calculated by dividing the total numbers of individuals of each species counted in each habitat by the area of each habitat. As the area was expressed in hectares, thus, the overall densities of each taxon for that particular habitat was expressed in terms of total number of individuals per hectare as shown in Figure 3–5. The alpha value was defined as being 0.05. All the analyses were undertaken by using SPSS version 16.

Results

Species richness, diversity and evenness

The species richness (Table 3), diversity, and evenness of wild mammals were 11, 1.6, and 0.67, respectively, in the EHH, and 11,

1.4, and 0.6, respectively, in the FGH. Similarly, the species richness (Table 4), diversity, and evenness of birds were 33, 3.3, and 0.96, respectively, in the EHH, and 29, 3, and 0.88, respectively, in the FGH. The woody species were represented by 16, 2.7, and 0.97 species richness (Table 5), diversity, and evenness, respectively, in the EHH, and 16, 2.6, and 0.94 species richness (Table 5), diversity and evenness, respectively, in the FGH.

Densities of wild mammals

The total mean densities of wild mammals recorded in the EHH and FGH were 16.0 and 7.5 individuals, respectively. The maximum densities of wild mammals varied between about 0.1 individual of honey badger ha^{-1} in the FGH and 8 individuals of gelada ha^{-1} in the EHH. The highest (mean=5.6±2.1ha^{-1}) and lowest (mean=0.01±0.2ha^{-1}) mean densities of wild mammals were recorded in EHH and FGH, respectively. However, the highest percentage of sightings (91.7%) of wild mammals per transect was recorded in both habitats. The mean comparisons for the densities of six wild mammal species significantly differed between the two habitats where the mean densities of each wild mammal species were greater in the EHH than in the FGH (Table 1). Overall, densities of wild mammals showed significant difference between the EHH and the FGH (F=58.36; df=1; P<0.001) (Figure 3). Species also significantly affected densities of wild mammals between the EHH and the FGH (F=88.65; df=10; P<0.001). Furthermore, habitat type and species interacted and significantly affected densities of wild mammals between the two habitats (F=11.94; df=10; P<0.001).

Table 1 Mean densities, standard error of the mean (i.e. SE), maximum densities, number of sightings of the species and sightings per transect walk of wild mammals recorded in the two study habitats

Wild mammal species	Mean density Ha^{-1}		Maximum density Ha^{-1}		Number of sightings of the species		Sightings per transect walk (%)	
	FGH(±SE)	FGH(±SE)	EHH	FGH	EHH	FGH	EHH	FGH
African civet*	0.2(±0.10)	0.01(±0.300)	0.3	0.1	11	1	91.7	8.3
Common mol-rat	5.3(±2.20)	2.7(±7.40)	7.4	3.8	11	11	91.7	91.7
Ethiopian highland hare	0.3(±0.10)	0.1(±0.10)	0.5	0.2	11	10	91.7	83.3
Ethiopian wolf	0.4(±0.20)	0.2(±0.10)	0.8	0.3	10	11	83.3	91.7
Gelada*	5.6(±2.10)	2.1(±0.80)	7.9	3.4	11	11	91.6	91.7
Honey badger*	0.2(±0.10)	0.01(±0.020)	0.3	0.1	9	1	75	8.3
Golden jackal*	0.3(±0.10)	0.1(±0.04)	0.3	0.1	11	8	91.7	66.7
Klipspringer*	0.4(±0.20)	0.1(±0.10)	1	0.2	11	3	91.7	25
Rodent spp	2.9(±1.40)	2.0(±0.80)	5.5	3	11	11	91.7	91.7
Serval cat*	0.2(±0.10)	0.04(±0.040)	0.3	0.1	11	5	91.7	41.7
Spotted hyena	0.2(±0.10)	0.1(±0.04)	0.3	0.1	9	9	75	75
Total	16.0(±6.70)	7.46(±9.740)						

Table 2 Mean densities, standard error of the mean (i.e. SE), maximum densities, number of sightings of the species and sightings per transect walk of birds recorded in the two study habitats

Bird species	Mean density Ha^{-1}		Maximum density Ha^{-1}		Number of sightings of the species		Sightings per transect walk (%)	
	EHH(± SE)	FGH(± SE)	EHH	FGH	EHH	FGH	EHH	FGH
Black-winged lovebird*	29.1(±1.70)	0.0(±0.00)	62.2	0.0	66.0	0.0	91.7	0.0
Wattled ibis*	20.0(±1.90)	2.7(±0.60)	62.2	22.7	54.0	43.0	75.0	51.2
Wattled crane*	6.4(±1.30)	1.8(±0.40)	39.3	17.5	20.0	15.0	27.8	17.9
Augur buzzard*	5.4(±1.20)	1.2(±0.40)	58.9	26.2	22.0	13.0	30.6	15.5
Cisticola spp*	28.6(±2.20)	3.4(± 0.60)	62.2	21.8	55.0	48.0	76.4	57.1
White-collard pigeon*	52.3(±2.80)	20.8(±1.40)	111.9	53.0	70.0	61.0	97.2	72.6
Speckled pigeon*	36.8(±3.30)	2.5(±0.60)	99.5	26.2	56.0	18.0	77.8	21.4
Pied crow*	27.4(±2.10)	3.3(±0.70)	66.1	21.8	57.0	22.0	79.2	26.2
Thick-billed raven*	21.0(±2.50)	2.4(±2.20)	74.6	24.4	49.0	19.0	68.1	22.6
Fan-tailed raven*	22.7(±0.50)	3.2(±2.20)	62.2	21.8	49.0	23.0	68.1	27.4
Blue-winged goose*	18.8(±0.60)	3.3(±2.00)	74.6	17.5	46.0	25.0	63.9	29.8

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Table Continued....

Bird species	Mean density Ha⁻¹		Maximum density Ha⁻¹		Number of sightings of the species		Sightings per transect walk (%)	
	EHH(± SE)	FGH(± SE)	EHH	FGH	EHH	FGH	EHH	FGH
Little egret*	36.2(±0.60)	25.3(±2.40)	88.5	42.4	68.0	69.0	94.4	82.1
Grey kestrel*	3.7(±1.10)	0.9(±1.50)	24.9	8.7	18.0	13.0	25	15.5
Yellow-necked spurfowl*	8.0(±1.10)	2.0(±0.40)	37.3	9.4	28.0	21.0	38.9	25.0
White-backed vulture **	10.8(±1.30)	1.6(±0.40)	37.3	13.1	38.0	14.0	52.8	16.7
Hadada ibis*	17.9(±2.10)	2.9(±0.60)	74.6	21.2	45.0	22.0	62.5	26.2
Ethiopian swallow*	11.7(±1.60)	2.8(±0.50)	49.8	18.8	35.0	25.0	48.6	29.8
Blue-eared glossy starling*	38.8(±3.30)	15.9(±1.30)	111.9	48.7	59.0	69.0	81.9	82.1
Abyssinian long claw*	8.3(±1.40)	1.7(±0.40)	66.1	24.4	29.0	16.0	40.3	10.1
Black kite*	11.3(±1.50)	2.3(± 0.40)	49.8	16.3	38.0	22.0	52.8	26.2
Hooded vulture*	11.1(±1.70)	2.7(±0.60)	49.8	18.8	31.0	20.0	43.1	23.8
Sunbird spp*	22.7(±2.10)	0.0(±0.00)	62.2	0	53.0	0.0	73.6	0.0
Helmeted guineafowl*	47.5(±3.20)	15.5(±1.30)	99.5	60.9	65.0	67.0	90.3	79.8
Abyssinian catbird*	22.9(±1.70)	0.0 (±0.00)	49.8	0	58.0	0.0	80. 6	0.0
Black-headed weaver*	36.0(±3.20)	7.4(±1.00)	99.2	39.3	55.0	41.0	76.4	48.8
Yellow-vented bulbul*	11.4(±1.50)	3.6(±0.60)	71.7	42.4	39.0	34.0	54.2	40.5
Rouget's rail*	7.4(± 1.00)	2.3(±0.30)	37.3	10.6	37.0	34.0	51.4	40.5
White-rumped seed eater*	19.3(±2.30)	6.3(±0.80)	55.1	23.6	41.0	39.0	56.9	46.4
Ankober serin*	12.6(±1.20)	0.0(±0.00)	33.1	0	51.0	0.0	70.8	0.0
Ethiopian siskin*	19.9(±2.10)	6.9(±0.80)	58.9	26.2	46.0	46.0	63.9	54.8
Dusky turtle dove*	13.4(±1.20)	4.3(±0.50)	44.1	16.3	47.0	44.0	65.3	52.4
Sacred ibis*	17.8(±2.20)	5.2(±0.80)	62.2	22.7	41.0	35.0	56.9	41.7
Spot-breasted lapwing*	11.3(±1.40)	4.1(±0.50)	39.3	16.3	38.0	40.0	52.8	47.6
Total	668.5(±58.90)	158.3(±26.20)						

Table 3 List of species of wild mammals recorded during the study periods. All the 11 wild mammal species were seen in both study habitats (i.e., EHH and FGH)

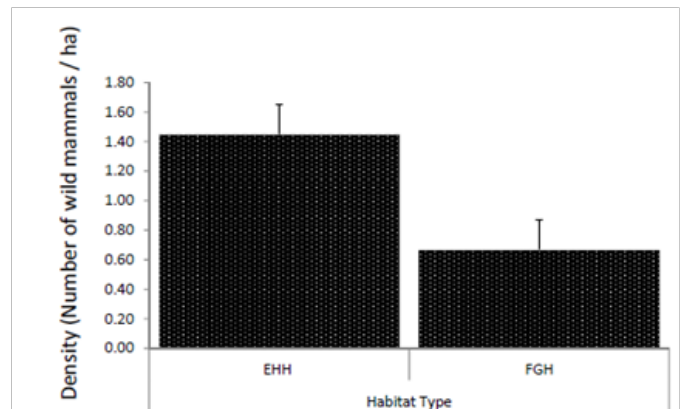| Family names	Scientific names	Common names
Viverridae	*Civettictis civetta*	African civet
Bathyergidae	*Cryptomys hottentotus*	Common mol-rat
Leporidae	*Lepus starcki*	Ethiopian highland hare
Canidae	*Canis simensis*	Ethiopian wolf
Cercopithecidae	*Theropithecus gelada*	Gelada
Mustelidae	*Mellivora capensis*	Honey badger
Canidae	*Canis aureus*	Golden jackal
Bovidae	*Oreotragus oreotragus*	Klipspringer
Muridae	*Rodent spp*	Rodent spp
Felidae	*Leptailurus serval*	Serval cat
Hyaenidae	*Crocuta crocuta*	Spotted hyena

Densities of birds

The total mean densities of birds recorded in the EHH and FGH were 668.5 and 158.3 individuals, respectively. The maximum densities of birds varied between no individuals in the FGH (black-winged lovebird, sunbird spp, abyssinian catbird and Ankober serin) and about 112 individuals ha⁻¹ (white-collard pigeon and blue-eared glossy starling) in the EHH. The highest (mean=52.3±2.8ha⁻¹, white-collared pigeon) and lowest (no individual, black-winged lovebird, sunbird spp, abyssinian catbird and Ankober serin) mean densities of birds were recorded in EHH and FGH, respectively. However, the highest percentage of sightings (97.2%) of birds per transect was recorded in the EHH. The mean comparisons for the densities of the 33 bird species significantly differed between the two habitats where the mean densities of each bird species were greater in the EHH than in the FGH (Table 5). Overall, densities of birds showed significant difference between the EHH and the FGH (F=1.93; df=1; P<0.001) (Figure 4). Species also significantly affected densities of birds between the EHH and FGH (F=71.43; df=32; P<0.001). Furthermore, habitat type and species interacted and significantly affected densities of birds between the two habitats (F=20.58; df= 32; P<0.001).

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Table 4 Mean densities, standard error of the mean (i.e. SE), maximum densities, number of sightings of the species and sightings per transect walk of wild mammals recorded in the two study habitats

Family names	Scientific names	Common names
Psittaculidae	*Agapornis taranta*	Black-winged lovebird
Threskiornithidae	*Bostrychia carunculata*	Wattled ibis
Gruidae	*Bugeranus carunculatus*	Wattled crane
Accipitridae	*Buteo rufofuscus*	Augur buzzard
Cisticolidae	*Cisticola spp*	Cisticola spp
Columbidae	*Columba albitorques*	White-collard pigeon
Columbidae	*Columba gunea*	Speckled pigeon
Corvidae	*Corvus albus*	Pied crow
Corvidae	*Corvus crassirostris*	Thick-billed raven
Corvidae	*Corvus rhipidurus*	Fan-tailed raven
Anatidae	*Cyanochen cyanoptera*	Blue-winged goose
Ardeidae	*Egretta garzetta*	Little egret
Falconidae	*Falco ardosiaceus*	Grey kestrel
Phasianidae	*Francolinus leucoscepus*	Yellow-necked spurfowl
Accipitridae	*Gyps bengalensis*	White-backed vulture
Threskiornithidae	*Hagedasha hegedash*	Hadada ibis
Hirundinidae	*Hirundo aethiopica*	Ethiopian swallow
Sturnidae	*Lamprotornis chalybaeus*	Blue-eared glossy starling
Motacillidae	*Macronyx flavicollis*	Abyssinian long claw
Accipitridae	*Milvus migrans*	Black kite
Accipitridae	*Necrosyrtes monachus*	Hooded vulture
Nectariniidae	*Nectarinia spp*	Sunbird spp
Numididae	*Numida meleagris*	Helmeted guineafowl
Timaliidae	*Parophasma galinieri*	Abyssinian catbird
Ploceidae	*Ploceus cucullatus*	Black-headed weaver
Pycnonotidae	*Pycnonotus barbatus*	Yellow-vented bulbul
Rallidae	*Rougetius rougetii*	Rouget's rail
Fringillidae	*Serinus albitorques*	White-rumped seed eater
Fringillidae	*Serinus ankoberensis*	Ankober serin
Fringillidae	*Serinus nigriceps*	Ethiopian siskin
Columbidae	*Streptopelia lugens*	Dusky turtle dove
Threskiornithidae	*Threskiornis aethiopicus*	Sacred ibis
Charadriidae	*Vanellus melanocephallus*	Spot-breasted lapwing

Table 5 List of woody plant species recorded during the study periods. All the 16 woody plant species were found in both study habitats

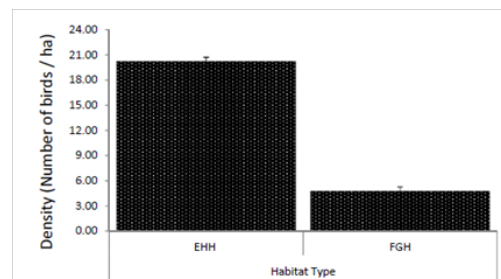| Family names	Scientific names	Growth form
Rosaceae	*Alchemilla abyssinica*	Shrub & seedling
Rosaceae	*Alchemilla rothii*	Shrub & seedling
Rosaceae	*Alchemilla cyclophylla*	Shrub & seedling
Asteraceae	*Artemisia afra*	Shrub & seedling
Asteraceae	*Carduus nyassanus*	Shrub & seedling
Cyperaceae	*Carex fischeri*	Shrub & seedling
Cyperaceae	*Carex monostachya*	Shrub & seedling
Ericaceae	*Erica arborea*	Trees, shrub & seedling
Asteraceae	*Euryops pinifolius*	Shrub & seedling
Asteraceae	*Helichrysum citrispinum*	Shrub & seedling
Asteraceae	*Helichrysum cyosum*	Shrub & seedling
Asteraceae	*Helichrysum gofense*	Shrub & seedling
Asteraceae	*Helichrysum splendidum*	Shrub & seedling
Hypericaceae	*Hypericum revolutum*	Trees, shrub & seedling
Asphodelaceae	*Kniphofia foliosa*	Shrub & seedling
Lobeliaceae	*Lobelia rhynchopetalum*	Trees, shrub & seedling

Figure 3 Densities of wild mammals in the two study habitats. The number of individuals of all wild mammals for that particular habitat type is pooled together. The error bars represent +1 *SE*. +1 SE is to mean that it is plus 1 standard error on the mean value. The range of the densities of wild mammals in the EHH was 7.9 individuals per hectare while it was 3.8 individuals per hectare in the FGH.

Densities of woody species

The total mean densities of woody species recorded in the EHH and FGH were 37,665.2 and 16,845.6 individuals, respectively. The maximum densities of woody species varied between about 3,185 individuals ha^{-1} in the FGH (about 6 species) and 16,631.3 individuals ha^{-1} of Erica arborea L in the EHH (Table 6). Moreover, the minimum densities of woody species varied between no individuals in the FGH (about 15 species) and about 6,723 individuals of E. arborea ha^{-1} in the EHH. The highest (mean=9,355±627ha^{-1}, *E arborea*) and lowest (mean=267±197ha^{-1}, *Lobelia rhynchopetalum Hochst ex A Rich.*) mean densities of woody species were recorded in EHH and

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FGH, respectively. The highest percentage of sightings (100%) of woody species per transect was recorded in the EHH (E arborea, Helichrysum splendidum Thunb and Kniphofia foliosa H*ochst*). The mean comparisons for the densities of 11 woody species significantly differed between the two habitats where the mean densities of 10 woody species were significantly greater in the EHH than in the FGH. However, the mean density of Alchemilla rothii Oliv was significantly greater in the FGH than in the EHH (Table 6). Overall, densities of woody species showed significant difference between the EHH and FGH (F=43.38; df=1; P<0.001) (Figure 5). The species also significantly affected densities of woody species between the EHH and the FGH (F=21.92; df=15; P<0.001). Furthermore, habitat type and species interacted and significantly affected densities of woody species between the two habitats (F=12.62; df=15; P<0.001).
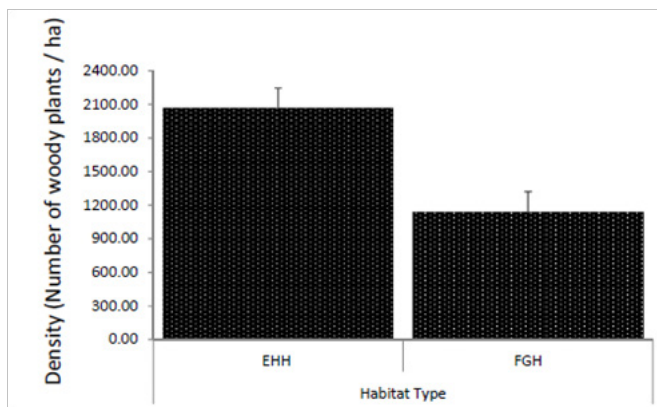

Figure 4 Densities of birds in the two study habitats. The number of individuals of each bird species for that particular habitat type is pooled together. The error bars represent +1 *SE*. +1 SE is to mean that it is plus 1 standard error on the mean value. The range of the densities of birds in the EHH was 111.9 individuals per hectare while it was 60.9 individuals per hectare in the FGH.

Table 6 Mean densities, standard error of the mean (i.e. SE), maximum densities, number of sightings of the species and sightings per transect walk of woody plants recorded in the two study habitats

Bird species	Mean density ha⁻¹		Maximum density ha⁻¹		Number of sightings of the species		Sightings per transect walk (%)	
	EHH(±SE)	FGH(±SE)	EHH	FGH	EHH	FGH	EHH	FGH
Black-winged lovebird*	29.1(±1.70)	0.0(±0.00)	62.2	0.0	66.0	0.0	91.7	0.0
Wattled ibis*	20.0(±1.90)	2.7(±0.60)	62.2	22.7	54.0	43.0	75.0	51.2
Wattled crane*	6.4(±1.30)	1.8(±0.40)	39.3	17.5	20.0	15.0	27.8	17.9
Augur buzzard*	5.4(±1.20)	1.2(±0.40)	58.9	26.2	22.0	13.0	30.6	15.5
Cisticola spp*	28.6(±2.20)	3.4(±0.60)	62.2	21.8	55.0	48.0	76.4	57.1
White-collard pigeon*	52.3(±2.80)	20.8(±1.40)	111.9	53	70.0	61.0	97.2	72.6
Speckled pigeon*	36.8(±3.30)	2.5(±0.60)	99.5	26.2	56.0	18.0	77.8	21.4
Pied crow*	27.4(±2.10)	3.3(±0.70)	66.1	21.8	57.0	22.0	79.2	26.2
Thick-billed raven*	21.0(±2.50)	2.4(±2.20)	74.6	24.4	49.0	19.0	68.1	22.6
Fan-tailed raven*	22.7(±0.50)	3.2(±2.20)	62.2	21.8	49.0	23.0	68.1	27.4
Blue-winged goose*	18.8(±0.60)	3.3(±2.00)	74.6	17.5	46.0	25.0	63.9	29.8
Little egret*	36.2(±0.60)	25.3(±2.40)	88.5	42.4	68.0	69.0	94.4	82.1
Grey kestrel*	3.7(±1.10)	0.9(±1.50)	24.9	8.7	18.0	13.0	25.0	15.5
Yellow-necked spurfowl* White-backed vulture *	8.0(±1.10)	2.0(±0.40)	37.3	9.4	28.0	21.0	38.9	25.0
White-backed vulture **	10.8(±1.30)	1.6(±0.40)	37.3	13.1	38.0	14.0	52.8	16. 7
Hadada ibis*	17.9(±2.10)	2.9(±0.60)	74.6	21.2	45.0	22.0	62.5	26.2
Ethiopian swallow*	11.7(±1.60)	2.8(±0.50)	49.8	18.8	35.0	25.0	48.6	29.8
Blue-eared glossy starling*	38.8(±3.30)	15.9(±1.30)	111.9	48.7	59.0	69.0	81.9	82.1
Abyssinian long claw*	8.3(±1.40)	1.7(±0.40)	66.1	24.4	29.0	16.0	40.3	10.1
Black kite*	11.3(±1.50)	2.3(±0.40)	49.8	16.3	38.0	22.0	52.8	26.2
Hooded vulture*	11.1(±1.70)	2.7(±0.60)	49.8	18.8	31.0	20.0	43.1	23.8
Sunbird spp*	22.7(±2.10)	0.0(± 0.00)	62.2	0.0	53.0	0.0	73.6	0.0
Helmeted guineafowl*	47.5(±3.20)	15.5(±1.30)	99.5	60.9	65.0	67.0	90.3	79.8
Abyssinian catbird*	22.9(±1.70)	0.0 (±0.00)	49.8	0.0	58.0	0.0	80. 6	0.0
Black-headed weaver*	36.0(±3.20)	7.4(±1.00)	99.2	39.3	55.0	41.0	76.4	48.8
Yellow-vented bulbul*	11.4(±1.50)	3.6(±0.60)	71.7	42.4	39.0	34.0	54.2	40.5
Rouget's rail*	7.4(± 1.00)	2.3(± 0.30)	37.3	10.6	37.0	34.0	51.4	40.5

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Table Continued....

Bird species	Mean density ha⁻¹		Maximum density ha⁻¹		Number of sightings of the species		Sightings per transect walk (%)	
	EHH(±SE)	FGH(±SE)	EHH	FGH	EHH	FGH	EHH	FGH
White-rumped seed eater*	19.3(±2.30)	6.3(±0.80)	55.1	23.6	41.0	39.0	56.9	46.4
Ankober serin*	12.6(±1.20)	0.0(± 0.00)	33.1	0.0	51.0	0.0	70.8	0.0
Ethiopian siskin*	19.9(±2.10)	6.9(±0.80)	58.9	26.2	46.0	46.0	63.9	54.8
Dusky turtle dove*	13.4(±1.20)	4.3(±0.50)	44.1	16.3	47.0	44.0	65.3	52.4
Sacred ibis*	17.8(±2.20)	5.2(±0.80)	62.2	22.7	41.0	35.0	56.9	41.7
Spot-breasted lapwing*	11.3(±1.40)	4.1(±0.50)	39.3	16.3	38.0	40.0	52.8	47.6
Total	668.5(±58.90)	158.3(±26.20)						

Figure 5 Densities of woody species in the two study habitats. The number of individuals of each woody species for that particular habitat type is pooled together. The error bars represent +1 *SE*. +1 SE is to mean that it is plus 1 standard error on the mean value. The range of the densities of woody plants in the EHH was 16,631.3 individuals per hectare while it was 6,755.1 individuals per hectare in the FGH.

Discussion

Species diversities of wild mammals, birds and woody species

As hypothesized, Shannon diversity index revealed that species diversity of wild mammals, birds, and woody species in the EHH were relatively greater than in the FGH. Moreover, as compared to the FGH, Shannon's equitabilities also suggested that wild mammal bird and woody plant communities in the EHH are of higher species evenness. There are a number of studies that suggested higher species diversity, i.e, species richness and evenness, in areas that relatively receive better conservation from human and livestock induced encroachments.[13–15] Moreover, compared with open areas, there are a number of studies that documented higher species diversity of wild mammals, birds, and woody species inside area exclosures and protected areas.[16–19] Unlike wild mammals and woody species richness, the species richness of birds was higher in the EHH than in the FGH. Some of the possible reasons for unequal distribution of the bird species in the two adjacent habitats could be attributed by the difference in habitat resource gradient and densities[9,10,20] and the presence of human- and livestock-induced disturbances.[3,4,21,22] In addition, the behavior of some bird species (e.g. shyness to human- and livestock-induced disturbances and attack by predators) may also prevent long distance movements and dispersal,[3,23–25] which,

in turn, determines the number of bird species found in a particular community.

Densities of wild mammals, birds and woody species

As hypothesized, the study revealed that the overall densities of wild mammals, birds, and woody species in the EHH were all significantly higher than in the FGH. One of the possible explanations is that when natural vegetation existing in the GCEL is reasonably protected from illegal human- and livestock-induced encroachments, they will attract plenty of wild mammal and bird species from the adjacent open fields. This is because they provide the incoming wild mammals and birds with quality food,[1,2] suitable cover from environmental extremes,[3] breeding sites[4] and concealment from risk of predation.[5] It was also noted that natural vegetation inside exclosures and restoration sites is sanctuaries for several wild mammal and bird species that have almost disappeared in most parts of encroached and degraded areas.[26] Similarly, in other parts of Africa where human-induced disturbance is low, it has been shown that the abundance of animals increases.[27,28] In addition, several endemic and endangered wild mammal and bird species have been documented inside exclosed areas such as sacred groves[29] and protected areas that are relatively free from human- and livestock-induced disturbances.[30] For example, sacred groves, which form in situ conservation sites and act as a refuge for several wild mammal and bird species, are becoming ecologically important.[26] The role played by exclosures and protected areas, including eco-lodges, in enhancing woody species regeneration that will emerge from the soil seed banks have also been well documented.[13–18,31,32] Moreover, the exclosures can buffer against the depletion of genetically adapted local variants and overall biodiversity in a given region. They can also serve as important recruitment areas to surrounding ecosystems.[26] It was also noted that the EHH in the GCCA supports rare and endemic plant species, including giant lobelia, species of *Alchemilla, Helichrysum, Carex* and *Artemisia afra* Jacq. ex Willd and other moorland vegetation.[7]

Conclusion

The study examined the contribution of the GCEL in the conservation of wild mammals, birds, and woody species. In line with our predictions, the results revealed that densities and species diversity of wild mammals, birds, and woody plants in the EHH were all relatively greater than in the FGH. Other than academic purpose, we believe that the findings of this study generated quantitative scientific information for policy-makers and planners that can be instrumental toward better and more informed decision-making for eco-lodge establishment and management that is geared toward local

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biodiversity conservation. The biodiversity data on the diversities and densities of wild mammals, birds, and woody species in the EHH and FGH were collected in a single year. This suggests that the data do not capture possible changes over time in abundance, species richness and evenness of wild mammals, birds, and woody species in the EHH and FGH. Thus, future research can add a time dimension as another factor to investigate if densities and diversity of wild mammals, birds, and woody species in the two study habitats change over time.

Acknowledgements

Conflicts of interest

Authors declare that there are no conflicts of interest.

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