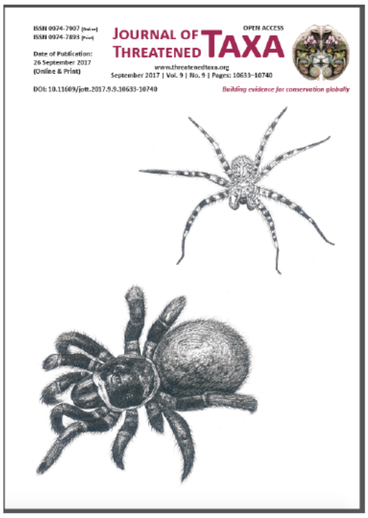

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ARTICLE

THE ECOLOGY OF HARWOOD'S FRANCOLIN *PTERNISTIS HARWOODI* (AVES: GALLIFORMES: PHASIANIDAE) AT MERHABETE DISTRICT, CENTRAL HIGHLANDS OF ETHIOPIA: IMPLICATIONS FOR CONSERVATION

Abadi Mehari Abrha & Habtu Kiros Nigus

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The ecology of Harwood's Francolin *Pternistis harwoodi* (Aves: Galliformes: Phasianidae) at Merhabete District, central highlands of Ethiopia: implications for conservation

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Abadi Mehari Abrha [1] & **Habtu Kiros Nigus** [2]

[1] Department of Wildlife and Ecotourism Management, Mekelle University, P.O.Box: 231, Tigray, Ethiopia
[2] Department of Statistics, Mekelle University, P.O.Box: 231, Tigray, Ethiopia
[1] abmehari23@gmail.com (corresponding author), [2] habturaya@gmail.com

Abstract: This paper investigates the abundance, density and habitat preference of Harwood's Francolin, and considers threats posed to this species at Merhabete District, Ethiopia. A total of 20 line transects ranging from 0.5–1.2 km, each 150–400 m apart, were placed in four study blocks. Habitat preferences were evaluated by digital elevation model (DEM) analysis and slope. Human pressures were also quantified based on circular plot placements along each line transect. Hence, distance sampling survey was used to count population data. The estimated population size and density were 184±26.46 birds and 43.48±6.25 birds/km2, respectively, with an overall encounter rate of 8.52 birds/km in Jema and Jara valleys. This species mainly preferred dry evergreen scrublands mixed with grassy, rock areas and dispersed acacia woodlands. However, based on stepwise regression model, the main threats to this species were burning, cutting, firewood collection and grazing. Generally, only cutting and firewood collection were the most important predictors that affected the focal species. This finding could be used to plan conservation of the species with the joint contribution of scientists, government and local communities.

Keywords: Abundance, digital elevation model, habitat preference, Harwood's Francolin, Merhabete, threats.

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Author Details: Abadi Mehari Abrha holds triple MSc degrees in tropical biodiversity and ecosystems from ERASMUS MUNDUS Scholarship. Habtu Kiros Nigus holds MSc in Biometry from Haramaya University, Ethiopia. He has been giving different wide-ranging software training in some universities and other governmental organizations of the country. Currently, both authors are active employees of Mekelle University, Tigary, Ethiopia.

Author Contribution: AMA did the whole manuscript preparation and data analyses mainly using distance software and R software. HKN contributed a lot on the manuscript draft. More importantly, he handled and treated the other statistical analyses (i.e., anthropogenic disturbance data and habitat utilization).

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INTRODUCTION

The study of population size and density of bird species is fundamental to successful conservation, management and monitoring purposes (Conroy & Noon 1996; Bibby et al. 1998; Braun 2005; Ramesh et al. 2011; Şekercioğlu 2011). It is also used for management decisions on the loss of tropical biodiversity decisive to quantify the loss of tropical biodiversity (Şekercioğlu 2011). Bird species are key indicators of the environment (Getachew et al. 2012), biological diversity (BirdLife International 2008, 2013) as well as conditions of habitats (Bhattacharya et al. 2009).

Avifauna is currently categorized into 36 orders, with the majority of species recorded in order Passeriformes (BirdLife International 2014). A total of 16 bird species are endemic to Ethiopia, and 14 are near endemic to Ethiopia and Eritrea (EWNHS 1996; Pol 2004). In Ethiopia, there are approximately 10 species of francolins identified to date (Ash & Atkins 2009; Redman et al. 2009). The Phasianidae family commonly referred to as "pheasants" includes bird species such as francolins, quails and stone partridge in the region (Ash & Atkins 2009; Redman et al. 2009). Of these Harwood's Francolin, *Pternistis harwoodi* (BirdLife International 2014; del Hoyo et al. 2014; IUCN 2015) is the only endemic francolin species. This species was formerly categorized in *Fracolinus,* which was recently replaced by *Pternistis* (BirdLife International 2014; del Hoyo et al. 2014), hence the older designation *Francolinus harwoodi* (Blundell & Lovett 1899).

Harwood's Francolin (Image 1) is a poorly-known pheasant restricted to dryland ecosystems of the Central Highlands of Ethiopia (Ash 1978; Wondafrash unpubl. report. 2005). There are 73 important bird areas (IBAs) identified so far, of which Jema and Jara valleys are recognized as IBA and endemic bird areas (EBAs; EWNHS 1996) in the Central Highlands. Harwood's Francolin displays gregarious behavior intermittently and has a polygamous mating system in the area (Robertson et al. 1999). It shows habitat overlapping with other pheasant species. For instance, it is reported that the species shares similar habitat with Helmeted Guineafowl *Numida meleagris* in lowlands and highlands of Jema and Jara Valleys and forages on seeds and invertebrates (Robertson et al. 1999). There is little information available concerning the abundance, distribution, habitat preferences and human-induced threats to Harwood's Francolin in its natural habitats. The aims of this study were to: (a) investigate population abundance and density in various habitat types; (b) establish habitat preference and identify human pressures on this species in the Jema and Jara valleys.

MATERIALS AND METHODS

Study area

The study area is located c. 180km away from Addis Ababa in Merhabete District at 9.91527778–10.13444444 N & 38.94416667–39.07333333 E. The most important rivers in the area are the Jema and Jara rivers, associated with their respective valleys. The larger Jema is fed by the Jara and empties into the Blue Nile River (Abbay River). The study area included the entire Jema Valley and the western Jara Valley at Werkamba tabia. These valleys have been identified as the most important sites for this species over the past four decades (Ash 1978; Ash & Gullick 1989; Collar et al. 1994; Robertson et al. 1997; EWNHS 1996; BirdLife International 2008).

The study area was divided into four blocks A-D of 25km^2, 40km^2, 30km^2 and 5km^2, respectively (Fig. 1) making a total sampled area of 100km^2. The blocks had a variety of vegetation assemblages and elevation levels, and study sites were classified into four strata based on habitat types (e.g., vegetation patterns) and land usage. The first three blocks had the same strata

Image 1. Harwood's Francolin *Pternistis harwoodi*

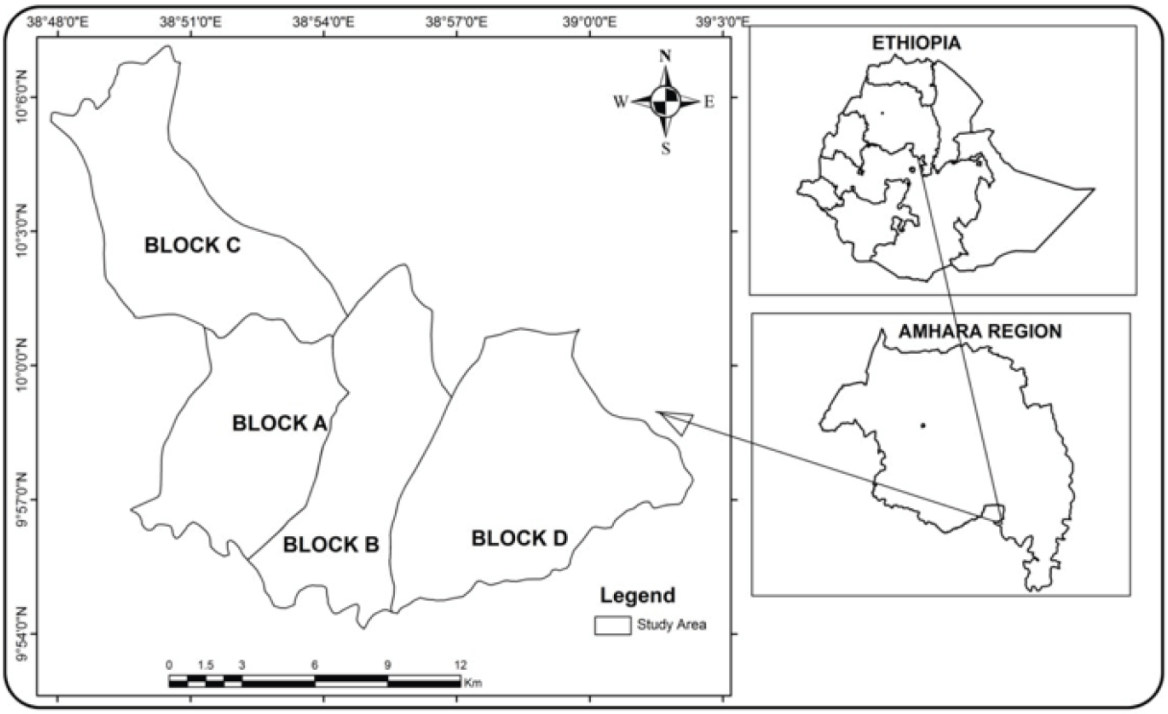

Figure 1. Map of the study area and blocks.

including scrubland, forestland and farmland, while Block D had mainly wetland strata and only two patches of forest. Wetland stratum possessed mainly wetland plant communities (commonly Broadleaf Cattail *Typha latifolia*).

Field methods

There are many techniques for studying pheasants. The combinations of line transect, circular plots and digital elevation modeling (hereafter DEM) were conducted to meet the aforementioned objectives. All surveys were conducted within four months (February–May) in 2015. Initial identification of key habitats in study areas was done via rapid assessment survey. Line transect (e.g., Bibby et al. 1998, 2000; Buckland et al. 2004; Thomas et al. 2010) was then used for bird surveys and subsequently sampling was conducted within four study blocks over four months.

A total of 20 line transects ranging in length from 0.5–1.2 km (150 –400 m spaced) were laid in the four strata using Universal Transverse Mercator (UTM) gridlines on 10×10 km^2 areas. Distance sampling was marked with flagging tape or sheared vegetation. Surveys were conducted three times per month during early morning (06:00–09:00 hr) and evening (15:00–18:00 hr) time blocks, and each study site had five line transects. Data collection was not carried out during heavy rainfall, low cloud and windy conditions due to low visibility and difficult terrain.

Anthropogenic disturbances were assessed via 10m radius circular plots spaced along each line transect at 100m intervals, within which potential threats were measured once per month (i.e., 152 plots/month; 608 plots during the whole study period). The main threats identified as affecting the target species habitat directly or indirectly were burning, cutting, debarking, firewood collection, grazing, hunting, mining, mowing and thatching. The intensity of impacts was classified as: no disturbance (0), low disturbance (less than 0.25), moderate disturbance (0.25–0.5), high disturbance (0.5–0.75) and very high disturbance (>0.75).

The distribution and habitat preference of the species was recorded along the elevation gradient and slope. A 30m spatial resolution of DEM was downloaded from USGS to compare habitat association of the species in relation to elevation. Bird counting along the elevation gradient and slope were conducted during ground truthing. The slope of study areas along the line transects was gauged using clinometers.

Data analyses

Distance 7.0 alpha 1 release was used to analyze detection function; encounter rate and cluster (i.e., group) size (Thomas et al. 2010). The conventional distance sampling (CDS) was chosen as an analysis engine (Buckland et al. 2004; Thomas et al. 2010). Sightings were recorded only in 146 line transects, and were truncated at a constant width of 210m prior to analysis. Thus, only 5.5% of detected birds were not considered for additional analysis. The cluster size estimation method used size bias regression method followed by regression of ln (cluster size) against estimated g (x). This technique was applied to eliminate any effect of size bias and to correct underestimation of cluster sizes (Thomas et al. 2010). The g(x) refers to probability of detection of a group of birds at perpendicular distance *x* from the line transect (Buckland et al. 2004; Thomas et al. 2014). Observations were also untruncated to choose and compare the fittest model. Akaike's information criterion (hereafter AIC) values were used to determine the best model by using four key function models (Buckland et al. 1993) (Table 1). All data were pooled for better estimation of detection function, overall abundance and density (Buckland et al. 2004).

Data collected via distance sampling were used to calculate encounter rate (ER), abundance (N), density of the species (D) (Thomas et al. 2010) and human induced impacts in relation to encounter rate of the species.

1. Encounter Rate, $ER = \frac{n}{L}$ .... Equation 1

where, n = number of observed birds and; L = total distance walked.

2. Abundance, $N = \frac{nE(s)}{P}$ .... Equation 2

where, E(s) = expected value of cluster size; p = probability of observing a bird in a defined area.

3. Density $(D) = \frac{nE(s)}{2WLP}$ .... Equation 3

where, W = width of line transect.

The data from all habitat types were combined and nonparametric factorial ANOVA was performed on the response variable (i.e., cluster size), considering habitat type and time as independent variables. Wald type statistic (WTS) and ANOVA type statistic (ATS) (Pauly et al. 1995) was obtained to see the interaction effect of time blocks and habitat types on cluster sizes of the focal species. Pairwise multiple comparisons were conducted using Dunn's-test for cluster sizes recorded in habitat types with bonferroni p value adjustment method. In addition, Mann-Whitney test (U) was used to establish comparisons of cluster size between morning and evening time blocks.

Using linear regression various disturbance indices were analyzed. The regression analyses were used to weigh the encounter rate against various important anthropogenic factors. Forward stepwise regression model was applied to select better predictors that affected the species. In addition, we conducted bivariate regression model to check the correlation of the species against each disturbance factor. Unlike, stepwise regression, only two predictors were selected using Benjamini & Hochberg (1995) adjustment method. This method was used to control the overall rate of false positives without inflating the rate of false negatives in bivariate regression model. The statistical significance level was checked at $\alpha = 0.05$. The analyses were done by R Core Team 2017.

The application of GIS techniques with the help of Arcinfo and Arcview software (version 10.1) was used for spatial analysis. DEM was applied for the distribution of the species and comparison of habitat preference in relation to elevational level, sightings and slopes. Seven slope classes were considered and identified using clinometers in the study area. These classes included flat (0–2 %), gentle sloping (2–5 %), sloping (5–8 %), moderately steep (8–15 %), steep (15–30 %), very steep (30–60 %) and extremely steep (>60%).

RESULTS

Abundance and density of Harwood's Francolin

Four key functions such as uniform, half normal, hazard rate and negative exponentials were run with untruncated and truncated data adjusted with cosine, simple polynomial and hermite polynomial. As depicted in Table 1, the minimum exploratory covariate is 1 whereas the maximum is 3. Some models were disregarded because the analysis engine showed unsuccessful results. In addition, only negative exponential failed during the entire analysis and it was ignored for further statistical model selection (Table 1). Thus, the AIC evaluates relative measure of fit among models and the best fit is to be the lowest AIC. As a result, based on AIC, the best-fitted model was half-normal with cosine adjustment. Following the selected model (half normal + cos), the results of density, abundance and detection function was calculated (Table 2).

The entire length of line transects (L) were 16.2km within which 138 flocks of birds were detected (excluding the truncated observations). So, the encounter rate (eq. 1) was 8.52 birds/km with percent of CV 11.85 (95% CI of 6.65 and 10.91).

Table 1. Statistical model selection by CDS engine analysis in DISTANCE SOFTWARE. The P value was based on goodness of fit chi-square test.

Model (Key function + Adjustment)	Parameter	AIC	ΔAIC	D	N	GOF Chi-P values
Uniform + Cos	1	1450.72	0.29	44.4	188	0.886
Half Normal + Cos	1	1450.43	0	43.48	184	0.906
Uniform + Simple Poly	1	1451.7	1.27	39.25	166	0.798
Untrun Hazard rate + Cos	3	1588.5	138.1	44.81	190	0.708
Hazard rate + Cos	2	1453.31	2.88	46.59	197	0.792
Untrun Hazard rate + Herm Poly	2	1591.75	141.3	37.76	160	0.32
Untrun Half Normal+ Simple Poly	1	1585.65	135.2	43.83	185	0.787

Untrun - Untruncated; D - estimated density; N - estimated number of birds; GoF - Goodness of Fit.

Table 2. Population abundance, density and mean cluster size of Harwood's Francolin in the study area.

Parameter	Point estimate	Standard error	% CV	95% of confidence interval	
				Lower	Upper
DS	32.05	4.48	13.97	24.18	42.50
E(S)	1.36	0.05	3.39	1.27	1.45
D	43.48	6.25	14.38	32.56	58.05
N	184.00	26.46	14.38	138.00	246.00

DS - Estimate of density of clusters; E(S) - Estimate of expected value of cluster size; D - Estimate of density of Harwood's Francolin; N - Estimate of number of Harwood's Francolin in specified area.

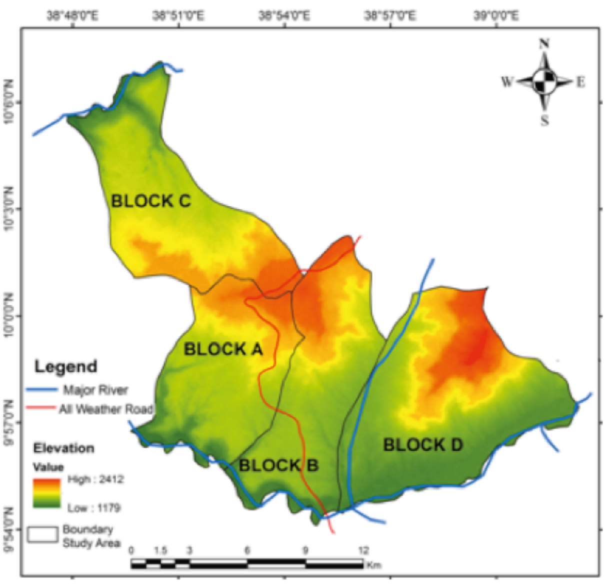

Figure 2. The elevation, major road and rivers (Jema and Jara) of the study area.

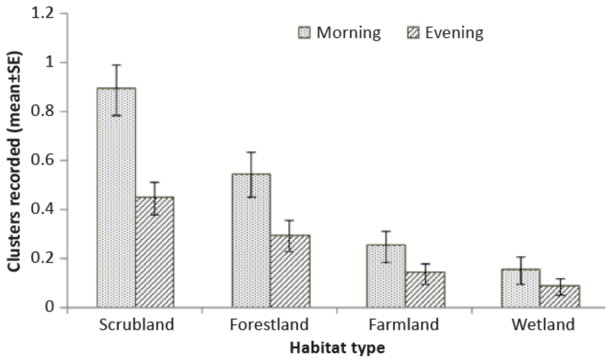

Figure 3. The total cluster sizes observed for each habitat type during morning and evening sessions (mean ±SE).

The mean number of the species counted during ground truth estimation is tabulated below (Table 3) and DEM analysis confirmed that the species was recorded highly and distributed in the intermediate altitudinal level (Fig. 2) and Small numbers of the target species were also detected along the riverine vegetation (green color) and at the steep slope elevations (red color). In addition, the mean population decreased from higher altitude to low altitude (Table 3).

The table showed that both time and habitat type had a significant effect on the cluster sizes of the species independently. The interaction, however, revealed no significant difference on the detected groups (cluster sizes) of Harwood's Francolin in the area (Table 4).

The pairwise comparison showed mean significant differences between habitat types except Wetland vs Farmland (Table 5).

In all habitat types, the encounter rate of Harwood's Francolin was higher in the morning than in the evening, however, it was not statistically significant different

Table 3. The average number of Harwood's Francolin counted (mean ± SE) in association with elevation and slope.

Surveyed sites	Block A			Block B			Block C			Block D	
	S	F	Fa	S	F	Fa	S	F	Fa	W	F
ME (m)	2053.9 ± 3.1	2023 ± 3.3	1913.4 ± 78.5	2112.3 ± 16.3	2103 ± 2.2	1778.2 ± 49.7	2103 ± 2.2	2120 ±16.8	1969.7 ± 44.1	1371.8 ± 77.9	1257.2 ± 58.8
MP	2.88 ± 0.4	1.83 ± 0.3	1.08 ± 0.4	2.96 ± 0.2	1.08 ± 0.4	1.21 ± 0.3	2.25 ± 0.2	2.25 ± 0.4	0.96 ± 0.3	0.77 ± 0.2	1.42 ± 0.5
MS (degree)	20.3 ± 1.7	6.7 ± 0.9	4.3 ± 0.8	24.8 ± 2.3	15.6 ± 0.9	2.4 ± 0.7	15.6 ± 0.9	18 ± 1.1	1.6 ± 0.5	0.3 ± 0.2	7.5 ± 1.3

ME - mean elevation; MP - mean population; MS - mean slope; S - scrubland; F - forestland; Fa - farmland; W - wetland

Table 4. Nonparametric statistical test for the habitat type, time and their interaction

	Wald Type Statistic (WTS)		ANOVA type Statistic(ATS)	
	statistic	p-Value	statistic	p-Value
Habitat Type	89.923	<0.001	30.133	<0.001
Time	13.375	<0.001	13.374	<0.001
Time * Habitat Type	5.828	0.120	1.972	0.123

Table 5. Pairwise comparisons of cluster sizes based on habitat types. Values in parenthesis describe p values

Habitat types	Pairwise comparisons		
	Farmland	Forestland	Scrubland
Forestland	0.078 (0.021)	-	-
Scrubland	0.181 (<0.001)	0.103 (0.001)	-
Wetland	-0.033 (1.000)	-0.111 (0.001)	-0.214 (0.001)

Table 6. Estimation of total area coverage of various types of ecosystems in four study sites based on GIS and remote sensing techniques (http://earthpoint.us).

Type of ecosystems	Block A		Block B		Block C		Block D	
	Area/ha	%	Area/ha	%	Area/ha	%	Area/ha	%
Agriculture	2097.9	83.9	3355.35	83.88	2205	73.5	436.5	87.3
Forest	47.94	1.91	132.4	3.31	116.7	3.89	18.5	3.7
RV	4.4	0.2	10.1	0.25	26.5	0.88	0.175	0.04
Wetland	-	-	-	-	-	-	44.8	8.96
SA	200	8	135.5	3.39	253.2	8.44	-	-
Scrubland	149.77	5.99	366.7	9.17	398.6	13.29	-	-
Total	2500	100	4000	100	3000	100	500	100

RV - riparian vegetation; SA - settlements and agriculture

between time blocks (Mann-Whitney test, U= 4; d.f = 1; p = 0.343). Mean cluster size computation showed that habitat association of the species was strongly associated with scrubland dominated vegetation (Fig. 3).

Measuring human disturbances within line transects

The habitat of the species was dominated by agricultural lands and settlements (Table 6). The coefficient of determination of the entire multiple linear regression identified threats against to the encounter rate of the species was R^2=0.83 ($F_{9, 10}$ = 5.59, P = 0.006). After conducting, stepwise regression model, the best explanatory variables were burning, cutting, firewood collection and grazing ($F_{4, 15}$ = 15.46, p < 0.001), explaining 80 % of the variance for the encounter rate variable (R^2 = 0.80).

Therefore, the equation of the model is:

$\widehat{ER}$ = 42.43 – 20.98b – 37.02c – 8.95fc + 10.54g ....Equation 4

Where, ER represents encounter rate and b= burning, c= cutting, fc= firewood collection and g=grazing.

However, based on bivariate regression model, Harwood's Francolin was highly disturbed by cutting and firewood collection during the study period (P<0.05). Although the target species was negatively associated with burning, grazing and mining, there was not statistical justification for the correlations in the multiple tests.

The species was positively associated with debarking, hunting, mowing and thatching in the area. However, there were no significant differences between the bivariate regression models (P>0.05) (Fig. 4).

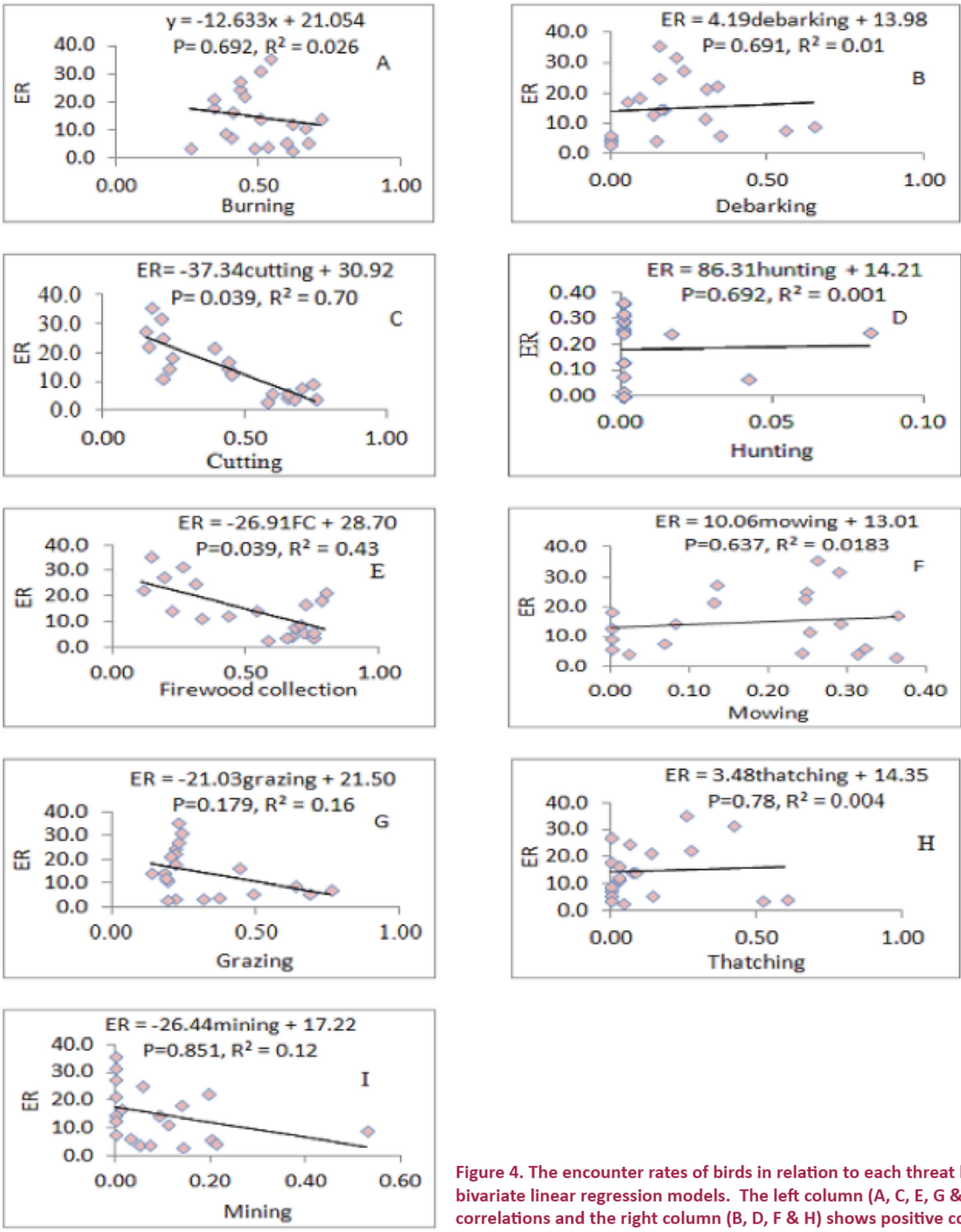

Figure 4. The encounter rates of birds in relation to each threat based on bivariate linear regression models. The left column (A, C, E, G & I) shows negative correlations and the right column (B, D, F & H) shows positive correlations.

DISCUSSION

Population size and distribution of Harwood's Francolin

The abundance and population density of Harwood's Francolin in the Jema Valley and its vicinities were determined from cluster sizes and pooled data. The observed abundance and density during the study period were 184±26.46 and 43.48±6.25, respectively. The highest detection of the species was recorded in scrubland habitat types. These comparisons with past published work (Robertson et al. 1997) indicates a decrease for this species, although differences in population estimates may also be influenced by differences in replications, sampled sites, habitat loss and time of study.

In most sites where birds were observed, shrubs and acacia provided a thorny, thick canopy for roosting, hiding and nesting, while utilized herbaceous vegetation was used for foraging, sheltering and laying eggs. The largest mean cluster sizes were observed in scrubland, followed by forestland and farmland habitats, indicating a preference for areas allowing birds to avoid predators and human disturbance. Elsewhere in Asia, francolin species also favour trees, shrubs and herbs for nesting, foraging and hiding (Mahmood et al. 2010), and Estades (1997) also reported that various neotropical bird species are dependent on vegetation gradients.

Bird habitats are located mainly in gently sloping to steep areas, while most settlements in the study sites are on flat areas. Thus the impact of human pressure tends to decrease with increasing slope and elevation. Findings in other areas indicate a similar relationship between species richness and potential anthropogenic disturbance (Nogues-Bravo et al. 2008). High elevation is not necessarily a decisive factor for the distribution of the target species. Because there are flat, less vegetation diversity and settlements at the plateau of the areas in which any sightings were not recorded. But based on DEM analysis, the species showed a marked preference at mid elevation level, such as Block A, Block B and Block C. This finding agrees with Acharya et al. (2011) and Pan et al. (2016) that bird richness in the eastern and central Himalaya region was higher at middle elevation gradients.

Anthropogenic disturbances

The area is gradually degraded by multiple factors, which are frequently attributed by the people. For example, the Typha coverage of the wetlands of the Jema River was 1.2km^2 (Robertson et al. 1997) and this study reported that the area coverage is remained with 0.45km^2. This indicates that the conversion of wetland habitat to cultivable lands may have a certain influence to the species as well as to the habitats at large. It was observed that highland villagers were partitioning the land and encroaching by introducing fire to the aquatic vegetations and scattered riverine fig trees. The species was severely affected by cutting and firewood collection during the study period. Most of the local communities have no other alternative income and complete dependence on forest, shrub and wetland ecosystems for various needs were observed (Abrha & Gebremikael unpubl. report. 2017). Cutting trees for fuel wood collection, settlement, agricultural expansion, fence construction, charcoal extraction and so forth affected the detectability of the species mainly at the bottom and plateau of the mountains. On the other hand, hunting is exceptionally positively correlated with the species in the whole study site. This is because hunting and egg collection is practiced during wet season but it is identified as a possible threat. In the earlier study, however, hunting time was limited from June to September in the area (Robertson et al. 1997). This suggests that the environmental factors like habitat components and other climatic factors may be changing the breeding season of the species.

All threats identified within line transects were categorized under habitat destruction, deforestation and hunting. Agricultural expansions, settlements and other connected human needs are undergoing in expense of vegetations, fishes, birds, mammals (mainly antelope species) and other biological resources. For instance, mining activity affects several birds (Smith et al. 2005). Moreover, mining is currently undergoing along the river and hillsides of the study area. This activity is also expected in aggravation of the current situation in the areas.

Implications for conservation

Central highlands of Ethiopia harbors diverse flora and fauna species along different environmental gradients (Ash & Atkins 2009). Important and endemic bird areas like Jema and Jara valleys (EWNHS 1996) are the key biodiversity indicator in tropics (Stattersfield et al. 2000). There is an ongoing human disturbance (mining activity, overexploitation, firewood collection, etc.,), however, in the habitats of the focal species (Abrha et al. in press). The government, the NGOs in association with the local communities can establish critical legislation to minimize the steadily increasing threats in Jema and Jara valleys. If not, the values of the grass root destination will be plummeted and gradually terminated. The conservation of scrubland ecosystems along the gorges of the area may help the survival of the species. Therefore, this study pays particular attention towards conservation of Harwood's Francolin which in return may foster the management and conservation of the habitats of the species. The current poor land use practices, however, must be given special emphasis to dissolve the problems that affects the species directly and indirectly.

CONCLUSIONS

The result of the study showed that that population abundance and density of Harwood's Francolin is decreasing in the area. The main causes for the reduction of the species are habitat loss in virtue of burning, cutting, firewood collection and grazing. The encounter rates of the species were higher in scrublands and forestlands. So, the species prefers grassy steep slope and rocky slopes at the intermediate elevation of dry evergreen scrub and dry evergreen montane forest ecosystems. In these sites human encroachments are limited because of the inaccessibility of the habitats.

Since most of the biological importance ecosystems of the country are in danger, a special conservation action should be formulated (Pol 2004). Responsible organizations such as EWCA, EWNHS and other stakeholders should work in cooperation to conserve and mange the habitat of this species in the country, in particular the existing and potential habitats of the species.

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