Reporting period from December 2019 to 1st January 2021

Distribution pattern and population estimate of Colobus guereza gallarum from the eastern Ethiopian highland, Ethiopia

BY

Chala Adugna Kufa

Department of Zoological Sciences

Addis Ababa University

Email: chalaadugna@wldu.edu.et; kchalaadugna@gmail.com

1. Introduction

Colobus is an African genus belonging to the Colobinae subfamily of the Cercopithecidae family. It is a black-and-white colobus monkey, comprised of five species such as *Colobus angolensis*, *Colobus guereza*, *Colobus polykomos*, *Colobus satanas*, and *Colobus vellerosus* (Kingdon, 2015). They have been recognized since the early days of systematic mammalogy (Schwarz, 1929) with three pairs of characters appear to be of exceptional importance in the systematic arrangement of these monkeys: (1) the distribution of the white body-marking and the growth of a beard and elongated hairs on the flanks and shoulders, (2) the extension of white on the tail and the development of the tail-brush, and (3) the structure and direction of the hairs on the crown of the head.

The black-and-white colobus monkeys (*Colobus guereza*, Ruppel 1835) are diurnal and arboreal Old World Monkeys found in the sub-Saharan African countries (Zinner et al., 2019). They are large, robustly built, with striking, glossy, black-and-white pelage and produce a 'roar' loud-call (Fashing, 2001; Butynski et al., 2013). They are slightly sexually dimorphic, where males are larger and heavier than females. As it was described by some scholars, the Colobus Guerezas average body weight for males falls between 6.4 and 14.4 kg while for females between 5.4 and 10.9 kg, with tail lengths ranging from 520–900mm (Kingdon, 2015). They are usually live in one-male multi-female groups, though multimale multifemale groups are not uncommon (Fashing, 2001).

There are eight subspecies of *Colobus guereza*: *C. g. guereza*, *C. g. gallarum*, *C. g. caudatus, C. g. percivali, C. g. kikuyuensis, C. g. occidentalis, C. g. dodingae, and C. g. matschiei.* Among the eight subspecies, two of which are endemic to Ethiopia: *C. g. guereza* and *C. g. gallarum* (Zinner et al., 2019). Ethiopian guereza has a unique set of features. The distinction between *C. g. guereza* and *C. g. gallarum* is based on craniometric variations and tail base color differences (Fashing and Oates, 2013). Omo River Guereza (*C. g. guereza*) has mantle fur that is comparatively long, covering about 20% of the tail, and a tail that is much longer than HB: proximal portion of tail grey; distal ca. 53 percent silvery white. On the other hand, Djaffa Mountains Guereza (*C. g. gallarum)* has a black proximal tail with scattered grey hairs increasing distally, a white and bushy distal tail approximately 55 percent (Butynski et al., 2013).

Because of a lack of field surveys and uncertainty regarding the taxonomy of Colobus guereza in Ethiopia, where two endemic subspecies occur, the distribution and population status of *C. g. gallarum* is unknown. Previously the *C. g. gallarum* was thought to be found in the entire parts of the Eastern side of the Rift Valley, particularly in Bale Mountains, Sidamo Provenance, Arsi Mountains and Ahmar Mountains (Yalden et al., 1977; Gippolliti and Butynski, 2008), while *C. g. guereza* was thought to be widespread from the Omo River valley to the Ethiopian highlands west of the rift valley (Gippolliti and Butynski, 2008). The Rift Valley was assumed to constitute a barrier to gene flow between *C. g. guereza* and *C. g. gallarum*, keeping the gene pools of the two subspecies of Ethiopia apart. However, a study done by Zinner et al. (2019) based on molecular taxonomy reveals more concrete evidence for the taxonomy of the *C. g. guereza* and *C. g. gallarum* which support the detailed study based on craniometric differences. In their study, Zinner and his colleagues confirmed that the populations which were previously thought to be *C. g. gallarum* in the Bale and Arsi mountains were found to be rather *C. g. guereza*. The best current estimate where *C. g. gallarum* occupies is forested highland areas northeast of the Rift Valley (in the Harrar and eastern Arsi Mountains) and possibly parts of the Rift Valley itself (Carpaneto and Gippoliti 1994). It may be sympatric with *C. g. guereza* in the Arsi region (Yalden et al. 1977). Despite these uncertainties, the geographic range of *C. g. gallarum* is certainly much smaller than that of *C. g. guereza* (Yalden et al. 1977, Carpaneto and Gippoliti, 1994).

As this study is rather new to science and conservation managers in terms of the range of the *C. g. gallarum* in the present study area, with increasing habitat loss and extinction risk of mammals, understanding the phylogenetic relationships of different populations of a species is an important component for determining conservation priorities. The only population which was found to be unique and clustered with the gallarum taxon is confined to the Ahmar Mountains, the mountains east of the Arsi Mountain. Unfortunately, Ahmar Mountains is found in the Eastern escarpment and South-eastern slope Centre and is the most degraded mountain with little coverage of forest. The *C. g. gallarum* is obviously in great danger of extinction which is clear from its restricted range of less than 26,000 km^2 area of the Ahmar Mountains which is already lost much of its forest area. The current real *C. g. gallarum* populations restricted in the Ahmar Mountains however not get any protection, and in fact, remain unknown to the recent period. A new management plan is needed once the exact distribution range and its current population status were investigated. Thus the study aimed to determine the distribution and population estimate of Djafa Mountains Guereza (*Colobus guereza gallarum*) from Eastern Ethiopian Highlands, Ahmar Mountains, Ethiopia.

2. Study area

This research was conducted in the eastern Ethiopian highland, coincides with Eastern Afromontane Biodiversity hotspots, particularly in the Ahmar Mountains, in the Eastern Oromia region (Figure 1). The Eastern highlands of Ethiopia slope gently towards the Southern and South-eastern lowlands that continue into Somalia and extend to the Indian Ocean (Friis et al., 2010). The 26,000 km^2 of the study area part of the eastern Ethiopia elevates over 1,500 masl is used during the present study. The study sites include Dindin Controlled hunting area, Sorroro Torgam forest, Kuni-muktar wildlife sanctuary, Haddes forest and Gara Mulleta.

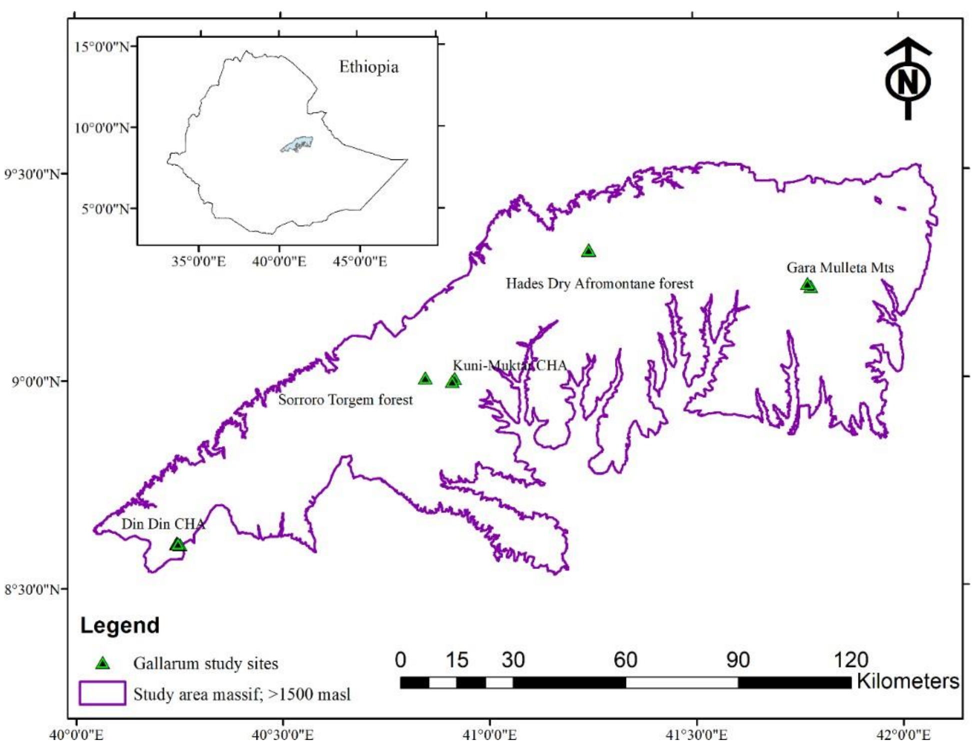

Figure 1. Distribution of Djaffa Mountains Guereza (*Colobus guereza gallarum*) in Ahmar Mountains, Ethiopia.

3. Methods

3.1. Distribution and population status of Djaffa Mountains Guereza (*Colobus guereza gallarum*) in Ahmar Mountains, Ethiopia

During the present study, a line transect distance sampling technique was employed (Thomas et al., 2010). Because, this method has been widely used to quantify the animal population abundance in the forests (Peres, 1999). A systematic random sampling design was used (Buckland et al., 2010), in which the line transects were placed randomly (Plumptre et al., 2013).

A freshly prepared transects were laid to rest at for one whole day, which will allow the disruption created by the trial preparation personnel to normalize, and the gallarum populations to redistribute themselves in space along the transect area in the total absence of observer disturbance. During surveys, we walked slowly along the laid line transect paths (for instance, 1km/hour according to Plumptre *et al.* (2013)); from 0630-0645 h to 1030-1045 h in the morning, and 1400 to 1800h in the afternoon (Peres, 1999), during sunrise and sunset. We ascertained the presence of the gallarum groups by direct observation with the aid of Binoculars and by hearing adult male loud calls (roaring). Since guereza are known to 'sunbathe' at the beginning of the day, they may stay in the sun for up to 3 hours before starting to move about and forage. This period is compatible with the peak activity periods of most diurnal animals. About 10 min observation efforts were spent to see and obtain the required information when *C. g. gallarum* group is encountered (Altman *et al.*, 1981).

At the beginning of each census walk, we recorded the survey site name, area, date, weather conditions, transect number and transect length, name of surveyors/personnel, the start and end time of each walk, total distance walked as well as the start and end location of the transects on prepared field protocol. Upon detecting the groups, the time of sighting, species identity, number of groups, group size, group spread, sighting location along the transect, perpendicular transect to animal distance, observer to animal distance as well as the time encounter ended and initial detection cue (auditory or visual) were recorded, preferably in the same sequence onto a standardized datasheet which facilitates their entry into an electronic data file (Peres, 1999). Such detailed study of a specific group was made to collect the reliable data used to assess the status, demography, and ecological aspects of the target subspecies following methods of Altman *et al.* (1981) and Fashing (2001). For the survey, we defined those groups that are spread at least greater than 20 m as a separate group (Buckland et al., 2010). Also, other information such as activity when first detected, the height of the first individual sighted, age, and sex of animals sighted, mixed-species associations, and vegetation features were recorded.

3.2. Habitat suitability models of Djaffa Mountains Guereza (*Colobus guereza gallarum*) in Ahmar Mountains, Ethiopia

To predict the habitat suitability of *C. g. gallarum*, which is currently widely used, we used the presence only algorithm Maxent (Phillips et al., 2006). Maxent software requires the occurrence data and the environmental predictor's variables. The data required during this study were obtained from different sources. We used the personal collection method, literatures and online resources (e.g., Global Biodiversity Information Facility (www.gbif.org) to extract the occurrence localities of the *C. g. gallarum*. Accordingly, a total of 42 occurrence localities were obtained from the personal collection and some of the previous localities of the gallarum in the Ahmar Mountains were obtained from both literatures and GBIF. The personal occurrence data were collected along the population survey of the *C. g. gallarum* during the study period. Field surveys were carried out in forest fragments, identified from high resolution Landsat Images obtained from Google Earth, to collect the presence-only data systematically using the line-transect distance sampling technique. These occurrence data were collected during the dry season from January 2020 to April 2021 and dry seasonal habitat suitability for the target subject will be modelled soon.

On the other hand, a set of environmental variables used for modeling habitat suitability were defined and formatted with a great care. We used the most commonly available variables and affecting the distribution and ecology of animals such as climate (e.g., temperature, precipitation, and 19 bioclimatic), topography (e.g., slope, elevation, and aspect), vegetation types, land cover, ecoregion, and human disturbances as an environmental predictors. All analyses were undertaken at a resolution of 1 km^2. The bioclimatic environmental variables derived from temperature and precipitation were obtained from Worldclim version 2.1 (http://www.worldclim.org/), at a spatial resolution of 1 km/30 arc-seconds. We then clipped the climatic variables to the study area of interest and considered them for modeling.

Topographical attributes for the globe at 1km resolution were generated from the USGS (http://edc.usgs.gov/products/elevation/gtopo30). This is very useful for deriving altitude, slope, and aspect (northenss) of the study area. The vegetation metric including land cover land use, ecoregion and vegetation type were used to model the distribution of the gallarum in the study area. We used different land cover datasets from the sources of Global Landcover Facility (http://glcf.umiacs.umd.edu/data/) (Pearson, 2010) and the Global Forest Watch database (Global Forest Watch, 2014). The human disturbance variables included distance to roads, settlements, human influence index (HII) and human population. These variables were calculated using the Euclidean Distance Tool of ArcGIS ver. 10.4.1.

4. Preliminary results of the project

4.1. Distribution and population status of Colobus guereza gallarum

The whole data on this project is in the processes of data entry and comprehensive analysis will be carried out soon. The final manuscripts will be submitted to Jana Robeyst Trust Fund with in short period of time. I presented here only the preliminary results. To date, I've been collected data on the dry season population census, occurrence localities, floristic composition, and structures in the Ahmar Mountains of Eastern Ethiopia's forest fragments. The number, length, and orientation of transects, as well as the metric of both effort, design unit, and stratum area, and were presented (Table 1).

As a preliminary result indicated a total of 30 groups of *C. g. gallarum* were recorded across the Ahmar Mountains of the study area. Within each forest fragment, the number of groups and their group sizes were varies. For instance, 15 groups in Dindin forest, 7 groups in Haddes forest, 2 groups in Kuni-Muktar, 1 in Jallo-Sorroro Torgam and 5 groups in Gara Mulleta were recorded. The group size was ranges from 3 individuals to 15 individuals with an average size of 5.09 per group.

Table 1. The study sites and survey design attributes generated during this study

Study site name	Area (km^2)	Coordinate systems (DD, N/E)	Alt. Range (masl)	# Lines generated	SW (m)	Lines spacing (km)	Name of each transect	Total lines length (km)	Lines angle (degrees)
Din Din CHA	101.0	8.62769N, 40.26627 E	2000 - 3070	16	100	1	T1/T2...T16	138.182	180
Haddes DAF	6.0	9.31772N, 41.24332E	2517- 2743	4	100	1	T1/T2/T3/T4	9.08	90
Kuni-Muktar	15.7	8.98885N, 40.92519E	1900 - 3310	5	100	1	T1/T2/T3/T4 /T5	21.655	90
Jallo-Sorroro	19.2	9.01547N, 40.85807E	2000 - 3000	3	100	1	T1/T2/T3	20.722	90
Gara Mulleta		9.25486N, 41.75294E	2400-3400	4	100	1	T1/T2/T3/T4	16	90/180

4.2. Habitat suitability models of Colobus guereza gallarum

A total of 42 occurrence localities were obtained from the personal collection during the field surveys. Environmental variables were defined and gathered to forecast a taxon's habitat suitability and distribution models (Table 2).

JANA ROBEYST TRUST FUND

Table 2. A list of environmental variables used for predicting the habitat suitability and distribution models of *C. g. gallarum* in this study

Category	Variables	Code	Units	Data sources
Bioclimatic	Annual Mean Temperature	BIO1	Degree Celsius	http://www.worldclim.org
	Mean Diurnal Range (Mean of monthly)	BIO2	Degree Celsius	
	Isothermality (BIO2/BIO7) (×100)	BIO3	Degree Celsius	
	Temperature Seasonality (standard deviation ×100)	BIO4	Degree Celsius	
	Max Temperature of Warmest Month	BIO5	Degree Celsius	
	Min Temperature of Coldest Month	BIO6	Degree Celsius	
	Temperature Annual Range (BIO5-BIO6)	BIO7	Degree Celsius	
	Mean Temperature of Wettest Quarter	BIO8	Degree Celsius	
	Mean Temperature of Driest Quarter	BIO9	Degree Celsius	
	Mean Temperature of Warmest Quarter	BIO10	Degree Celsius	
	Mean Temperature of Coldest Quarter	BIO11	Degree Celsius	
	Annual Precipitation	BIO12	Millimeters	
	Precipitation of Wettest Month	BIO13	Millimeters	
	Precipitation of Driest Month	BIO14	Millimeters	
	Precipitation Seasonality (Coefficient of Variation)	BIO15	Millimeters	
	Precipitation of Wettest Quarter	BIO16	Millimeters	
	Precipitation of Driest Quarter	BIO17	Millimeters	
	Precipitation of Warmest Quarter	BIO18	Millimeters	
	Precipitation of Coldest Quarter	BIO19	Millimeters	
Disturbance	Distance to roads	DTRO	Meters	
	Distance to settlements	DTS	Meters	
Topographic attribute	Elevation	Alt	Meters	https://earthexplorer.usgs.gov
	Slope	Slop	Degrees	
	Aspect/Northness	Asp	Degrees	
	Distance to rivers	DTR	Meters	
Landscape attribute	Land cover class	LCC	Unitless	https://cds.climate.copernicus.eu/
	Terrestrial ecoregions of the World	Ecoreg	Unitless	Olson et al. 2001
Resource	Vegetation type	VegT	Unitless	

4.3. Fecal samples collection and DNA Extraction

Using a non-invasively techniques, fresh fecal samples were collected in the ratio: 1 g of fecal to 4-5 ml of ethanol. A sterile applicator sticks were used to collect 4-6 pellets of fecal sample and were immersed into a sterile 50 ml falcon tube with 97% ethanol while wearing latex gloves (Plate I). Falcon tube containing the samples were labeled using a permanent marker including forest fragment name, group code, number of the sample taken, and date. The samples of pellet collected were deposited at -20 °C in the Lab of Insect Science (AAU) to extract DNA for sequencing the population genetic structure of the gallarum. The name of forest fragments, their landscape metrics and number of faeceal samples collected from the Eastern Ethiopian highlands during the survey period (December 2020 to April 2021) were presented (Table 3).

Plate I. Illustration of how pellet samples were collected

Table **3**. The name of forest fragments, their landscape metrics and number of faeceal samples collected from the Eastern Ethiopian highlands during the survey period (January 2020 to April 2021).

Field site	Group code	# of individual seen	GPS Location		Sampling time	# of sample taken	Age of the sample	Alt.
			Lat.	Long.				
Assela (Ardu)	G1S1	07	0513297	0876708	8:30	05	Fresh	2432
Warganbula	G1S1	04	0586516	0899987	8:00	05	>>	1983
Angada (Husa)	G1S1	05	0591020	0925424	8:05	05	24 hrs old	2197
Angada (Husa)	G2S2	05	0590976	0925420	8:15	05	Fresh	2197
Din Din (Toma Heto)	G1S1	12	0636925	0951912	2:30	05	Fresh	2527
Din Din (Defo)	G2S2	05	0636911	0951568	3:45	05	>>	2612
Din Din (Defo Oli)	G3S3	04	0637838	0951396	4:15	05	1 fresh + 4 old	2697
Din Din (Defo Gadi)	G4S4	12	0637210	0951705	6:30	05	Fresh	2572
Kuni-muktar	G1S1	03	0710989	0995728	4:00	05	>>	2682
Kuni-muktar	G2S2	05	0710290	0994965	6:20	02	>>	2641
Sorroro Torgem	G1S1	08	0703172	0995944	5:00	07	5 fresh + 2 24 hr old	2878
Hadas	G1S1	05	0746631	1029806	4:25	04	Fresh	2559
Hadas	G2S2	04	0746731	1029947	5:20	01	Fresh	2565
Hadas	G3S3	?	0746687	1029977	5:30	04	Fresh	2542
Hadas	G4S4	08	-	-	6:10	03	Fresh	2501
Hadas	G5S5	?	-	-	6:30	04	Fresh	2494
Gara Mullata	G1S1	06	0805892	1020245	5:00	05	>>	2586
Gara Mullata	G2S2	?	0804964	1021070	7:00	05	Dry	2753

Photos that are taken during population's census and spatial distribution investigations

Plate I. Pictures of *Colobus guereza gallarum* taken during the survey period

Some pictures showing habitat characterstics of the study sites

Plate II. Dindin forest

Plate III. Jallo-Sorroro Torgam CHA

Plate IV. Kuni-Muktar Mountain forest

Plate V. Haddes forest

Plate VI. Gara Mulleta Mountains

Plate VII. Werganbula_Arba Gugu gorge

Conservation challenges

Plate VIII. Deforestation and livestock grazing

Plate IX. Saw-Mill for timber production at Dindin forest

Plate XI: Pictures of Researcher Team

PlateXII: Habitat characterization and trees DBH measurments

5. The next steps

The previous summer (June-September 2020) was a nationwide lockdown due to the Covid-19 pandemic, so the wet season population survey was not completed. So, from June to August 2021, I'll collect data for the wet season by conducting surveys, and the population status of *Colobus guereza gallarum* will then be evaluated. The habitat suitability and distribution models will be created and mapped in a short period of time using the Maxent program. Between August and September 2021, DNA will be extracted in the Genetic Lab of the Zoological Sciences, Addis Ababa University, and sequencing will be done in Germany with a colleague from the Primate Genetics Laboratory, German Primate Center (DPZ), and in Norway, in the University of Oslo. After finishing the data analysis, the final manuscript will be submitted to the Jana Robeyst Trust Fund, and their funding will be acknowledged in all relevant publications of this project's outputs.

Acknowledgment

We appreciate the financial assistance provided by The JANA ROBEYST TRUST FUND. During the field surveys, the funds were used as Per Diem payment for research assistance, principal investigator and local guiders. Thank you very much for supporting this project.

Reference

Altman, J., Bracketi, B., Goy, R., Marrioti, B., New, A. and Senner, J. (1981).Techniques for the Study of Primate Population Ecology.National Academy Press Washington, D.C.

Buckland, S. T., Plumptre, A. J., Thomas, L., & Rexstad, E. A. (2010). Design and Analysis of Line Transect Surveys for Primates. *International Journal of Primatology*, *31*(5), 833–847. https://doi.org/10.1007/s10764-010-9431-5.

Butynski T. M. Kingdon J. Kalina J. (eds.). 2013. Mammals of Africa. Volume II: Primates. Bloomsbury Publishing, London, United Kingdom, 556 pp.

Carpaneto, G.M. and Gippoliti, S. 1994. Primates of the Harenna Forest, Ethiopia. *Primate Conservation* 11: 12-15.

Fashing, P. and Oates, J. (2013).*Colobus guerezaguereza*. In: *Mammals of Africa*, Volume II: Primates, edited by: Butynski, T. M., Kingdon, J., and Kalina, J., Bloomsbury, London, pp.111–119.

Fashing, P. J. (2001). Male and female strategies during intergroup encounters in guerezas (Colobus guereza): evidence for resource defense mediated through males and a comparison with other primates. *Behav Ecol Sociobiol*, 219–230.

https://doi.org/10.1007/s002650100358.

Fashing, P.J. & Oates, J.F. 2019. *Colobus guereza ssp. gallarum*. The IUCN Red List of Threatened Species 2019: e.T5150A17983175. http://dx.doi.org/10.2305/IUCN.UK.2019-3.RLTS.T5150A17983175.en.

Friis, I., Sebsebe, D., Breugel, P., 2010. Atlas of the Potential Vegetation of Ethiopia Atlas of the Potential Vegetation of Ethiopia.

Gippolliti, S. and Butynski, T. (2008).*Colobus guereza ssp. gallarum.* The IUCN Red List of Threatened Species 2008: e.T5150A11118023.

Kingdon, J. (2015). The Kingdon Field Guide to African Mammals: Second Edition.

Bloomsbury Publishing Plc, London, United Kingdom, 623 pp.

Pearson, R. G. (2010). Species ' Distribution Modeling for Conservation Educators and Practitioners. *Lessons in Conservation*, *3*, 54–89.

Peres, C. A. (1999). General Guidelines for standardizing line-transect surveys of tropical forest primates. *NEOTROPICAL PRIMATES*, *7*(1), 11–16.

Phillips, S. J., Anderson, R. P., & Schapire, R. E. (2006). Maximum entropy modeling of species geographic distributions. *Ecological Modelling*, *190*, 231–259.

Plumptre, Sterling, and B. (2013). Primate census and survey techniques. *Primate Ecology and Conservation: A Handbook OfTechniques. First Edition. Edited by Eleanor J. Sterling, Nora Bynum, and Mary E. Blair. © Oxford University Pres*, *1*(1), 10–26. https://doi.org/10.1093/acprof.

Thomas, L., S.T. Buckland, E.A. Rexstad, J. L. Laake, S. Strindberg, S. L. Hedley, J. R.B. Bishop, T. A. Marques, and K. P. Burnham. 2010. Distance software: design and analysis of distance sampling surveys for estimating population size. Journal of Applied Ecology 47: 5-14. DOI: 10.1111/j.1365-2664.2009.01737.

Yalden, D. W., Largen, M. J. and Kock, D. 1977. Catalogue of the mammals of Ethiopia.

3. Primates. *Monitore zoologico italiano/Italian Journal of Zoology, N.S. Supplemento* 9(1): 1-52.

Zinner, D., Dereje Tesfaye, Stenseth, N., Afework Bekele, Aemro Mekonnen, Doeschner, S., Anagaw Atickem and Roos, C. (2019). Is Colobus guereza gallarum a valid endemic Ethiopian taxon? *Primate Biol.* **6**: 7–16.