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SHORT COMMUNICATION

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Living on the edge: Rapid assessment of the mammal community in a coffee forest in south-western Ethiopia

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1 | INTRODUCTION

The highlands of Ethiopia are within the Eastern Afromontane biodiversity hotspot and contain some of the largest remaining patches of nearly undisturbed moist forest (Mittermeier et al., 2004). This region of Ethiopia is known as the evolutionary origin of coffee (*Coffea arabica*), and the production of the crop remains important to this day. Coffee is traditionally grown in forests, in the shade of native trees (Senbeta & Denish, 2006), and is managed mostly using traditional practices that maintain a diverse and complex forest structure (Aerts et al., 2011). Traditionally managed coffee forests have the potential to benefit biodiversity by creating buffer areas, providing forest habitat for wildlife and plant species, and by slowing down deforestation rates for agricultural production (Caudill, DeClerck, & Husband, 2014; Hylander, Neomissa, Delrue, & Enkosa, 2013). However, in recent decades, intensification of coffee production has been encouraged by national policies through the use of improved varieties, increasing coffee density, and reducing the diversity of shade trees, leading to simplification of forest structure and diversity (Tadesse, Zavaleta, & Shennan, 2014a). In addition, despite the presence of coffee, ongoing expansion of agricultural land in the region increases deforestation rates, leading to forest fragmentation and increasing forest edge density (Tadesse, Zavaleta, Shennan, & FitzSimmons, 2014b). Thus, while Ethiopia's coffee forests could potentially benefit biodiversity conservation, the combined threats of forest simplification and forest fragmentation can have severe impacts on species diversity (Hundera et al., 2013; Hylander et al., 2013).

To date, the conservation potential of Ethiopia's coffee forests has been assessed mostly for birds (Buechley et al., 2015; Rodrigues et al., 2018) and plants (Senbeta, Schmitt, Woldemariam, Boehmer, & Denich, 2014), including in the context of intensified coffee production (Aerts et al., 2011; Gove, Hylander, Nemomisa, & Shimelis, 2008). Yet, very little information is available for mammals or other taxa. Mammals, however, are particularly sensitive to changes in forest extent and quality because many require large areas of near-natural forest habitat. At the same time, mammals can cause serious damage to people's livelihoods in terms of crop loss, livestock predation and human injury, which may intensify as a consequence of changes to their habitat. Given the current threats facing coffee forest landscapes, there is a critical need to assess which mammal species are still present in the region to inform future research and conservation priorities. Here, we present the first results of a rapid assessment of the mammal community present at the edge of coffee forests in south-western Ethiopia. Rapid assessments of biodiversity are a useful approach to collect biodiversity data in poorly studied regions, when time and financial resources are limited (Silveira, Jácomo, & Diniz-filho, 2003). Camera trapping is a widely used method to perform rapid assessments of the diversity of medium-sized and large mammals (Tobler, Carrillo-Percastegui, Pitman, Mares, & Powell, 2008; Yasuda, 2004). It is noninvasive and cost-effective, especially for cryptic species with elusive behaviour and nocturnal habits (Munari, Keller, & Venticinque, 2011). We recognise that a more comprehensive assessment, over longer periods of time, and including locations deep within the forest, would be desirable. Hence, we offer our findings as a starting point that can help inform future management and research priorities.

2 | METHODS

2.1 | Study area

The study area encompasses an area of 3,800 km^2 and is located in a coffee growing area in the Oromia Region, south-western Ethiopia (Figure 1). Mammal communities were assessed in four

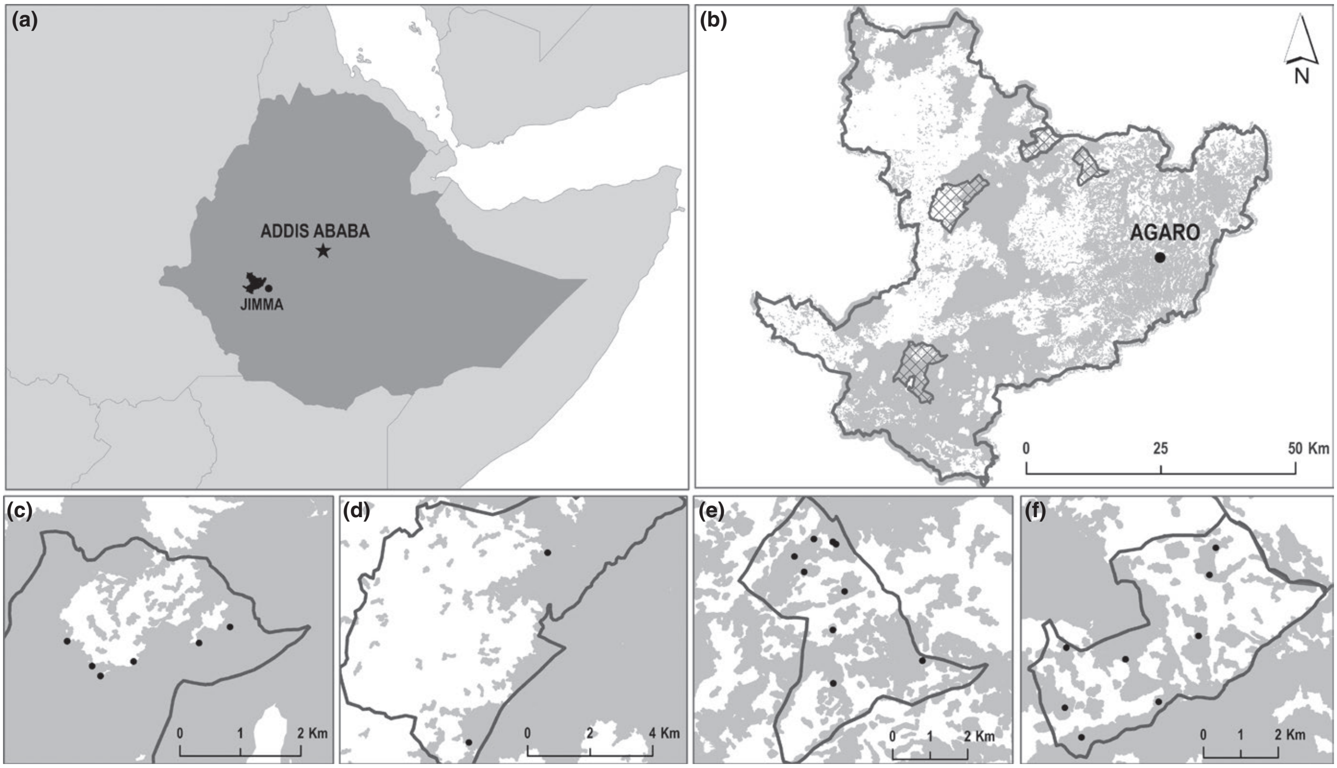

FIGURE 1 Study area and camera sites location: (a) study area in south-west Ethiopia; (b) selected *kebeles* (hatched) within the study area; and (c, d, e, and f) camera sites in the different *kebeles*. Grey colour in (b–f) depicts area of woody vegetation. Woody vegetation includes undisturbed natural forest and shade coffee forests, the latter being widespread near the forest edges in particular

kebeles (smallest administrative unit in Ethiopia) across three districts (*woredas*): Gera, Gumay and Setema. The region is undulating, with steep slopes and flat plateaus, and elevation ranging from 1,900 to 3,000 m above sea level. Wild coffee is usually found at elevations ranging between 1,000 and 2,000 m above sea level (Senbeta et al., 2014), although cultivated plants can be found between 900 and 2,800 m (Hundera et al., 2013).

2.2 | Data collection and data analysis

We randomly set up 25 motion-triggered Bushnell Trophy Cam HD Max cameras, within forest near the forest edge, in the dry season from 8 November 2015 to 2 February 2016. Although all of the kebeles have extensive coffee areas, and most of the cameras were placed within wild coffee altitude, seven cameras were placed in forest above wild coffee altitude. Cameras were placed along animal trails and in few cases on human trails. Cameras were tied to trees at knee height, and no bait was used. The area in front of the camera was cleared of herbs and small shrubs to increase the potential for capture success and to prevent empty frame pictures triggered by wind. The clearance of vegetation can affect the detectability of species since some species can avoid open areas. Nonetheless, since the area cleared was relatively small (approximately 9 m^2) and the same procedure was applied to all of the cameras (n = 25), we assume that its effect was minimal. Cameras were placed on average 40 m (SD ± 26.95) from the forest edge and were on average 1,382 m apart from each other (minimum distance: 140 m; maximum distance: 6,540 m). We focused on the forest edge because for this rapid assessment, it provided a logistically feasible entry point to learning about the regional mammal fauna, and because the forest edge is of major economic importance through the widespread production of coffee in this area. Technically, we defined the edge as the "interface between forested and nonforested ecosystems," which "appears as a belt of variable width" (Harper et al., 2015). Cameras were programmed to take photographs 24 hr/day, with sequences of three photographs at a time. Date and time of day were tagged in each photograph. Cameras were active between 13 and 60 days (average: 43 days), depending on logistical conditions beyond the control of the research team. No cameras were stolen, but two cameras stopped recording before the pickup date, due to an unidentified equipment fault.

The pictures were manually classified using ExifPRO™ software. Empty frames and pictures with birds were excluded, and all pictures of humans were counted and then deleted from the database to comply with the ethics protocol approved by Leuphana University. All pictures triggered within a one-hour period and for the same species were considered to be the same event (Rovero & Marshall, 2009). Species belonging to the families *Procaviidae*, *Leporidae* and *Canidae* and some species from *Herpestidae* and *Viverridae* could only be identified to genus level because of low image quality.

Given the scope of this research and the relatively small data set, we opted for analyses that were suitable for a preliminary (rather than authoritative) assessment of the data. We therefore opted to use nonmetric multidimensional scaling (NMDS), with Bray–Curtis distance measure, to investigate patterns in the mammal community. NMDS is a robust unconstrained ordination method commonly used in community ecology studies (Minchin, 1987). It runs on a distance matrix (or a matrix of dissimilarities) and attempts to represent the pairwise dissimilarity between objects (given by their rank order) in a low-dimensional space defined beforehand (Borcard, Gillet, & Legendre, 2011). In an NMDS diagram, sites that are similar in species composition are located close to each other, while sites that are less similar are placed further apart. The fit of the data is assessed by the stress value (low stress values indicate a good fit, whereas stress

TABLE 1 Mammal species recorded by camera traps at the forest edge in south-western Ethiopia, during a total of 1,075 camera trap days

Order Family	Species	Common name	Species code	NS	NE
Hyracoidea					
Procaviidae	*Heterohyrax brucei* (Gray, 1868) and *Procavia capensis* (Pallas, 1766)	Hyrax	Hyraxes	12	27
Tubulidentata					
Orycteropodidae	*Orycteropus afer* (Pallas, 1766)	Aardvark	Oryc_afer	3	3
Primates					
Galagidae	*Galago senegalensis* (Saint-Hilaire, 1796)	Northern lesser galago	Gala_sene	2	3
Cercopithecidae	*Cercopithecus neglectus* (Schlegel, 1876)	De Brazza's monkey	Cerc_negl	1	1
Cercopithecidae	*Cercopithecus mitis* (Wolf, 1822)	Blue monkey	Cerc_miti	5	16
Cercopithecidae	*Chlorocebus aethiops* (Linnaeus, 1758)	Grivet monkey	Chlo_aeth	11	37
Cercopithecidae	*Papio anubis* (Lesson, 1827)	Olive baboon	Papi_anub	20	204
Cercopithecidae	*Colobus guereza* (Rüppell, 1835)	Guereza	Colo_guer	9	13
Rodentia					
Sciuridae	*Heliosciurus gambianus* (Ogilby, 1835)	Gambian sun squirrel	Heli_gamb	1	1
Hystricidae	*Hystrix cristata* (Linnaeus, 1758)	Crested porcupine	Hyst_cris	14	42
Muridae	*Lophiomys imhausi* (Milne-Edwards, 1867)	Crested rat	Loph_imha	1	1
Lagomorpha					
Leporidae	*Lepus saxatilis* (Cuvier, 1823) and *L. fagani (Hoffmann and Smith 2005)*	Hare	Lepu_sp	5	64
Carnivora					
Felidae	*Panthera pardus* (Linnaeus, 1758)	Leopard	Pant_pard	2	3
Viverridae	*Civettictis civetta* (Schreber, 1776)	African civet	Cive_cive	14	67
Viverridae	*Genetta maculata* (Gray, 1830) and *G. genetta* (Linnaeus, 1758)	Genets	Gene_sp	21	305
Herpestidae	*Atilax paludinosus* (Cuvier, 1829)	Marsh mongoose	Atil_palu	3	3
Herpestidae	*Herpestes sanguinea* (Rüppell, 1835) and *H. ichneumon* (Linnaeus, 1758)	Mongoose	Herp_sp	5	7
Herpestidae	*Ichneumia albicauda* (Cuvier 1829)	White-tailed mongoose	Ichn_albi	9	41
Hyaenidae	*Crocuta crocuta* (Erxleben, 1777)	Spotted hyaena	Croc_croc	6	39
Canidae	*Canis mesomelas* (Schreber, 1775), *C. adustus* (Sundevall, 1847) and C. aureus (Linnaeus, 1758)	Jackals	Cani_sp	4	6
Mustelidae	*Mellivora capensis* (Schreber, 1776)	Ratel/honey badger	Mell_cape	3	4
Artiodactyla					
Suidae	*Phacochoerus africanus* (Gmelin, 1788)	Common warthog	Phac_afri	13	42
Suidae	*Hylochoerus meinertzhageni* (Thomas, 1904)	Giant forest hog	Hylo_mein	2	3
Suidae	*Potamochoerus larvatus* (Cuvier, 1822)	Bush pig	Pota_larv	17	45
Bovidae	*Tragelaphus scriptus* (Pallas, 1766)	Bushbuck	Trag_scri	18	128
Bovidae	*Sylvicapra grimmia* (Linnaeus, 1758)	Bushduiker	Sylv_grim	19	187

Notes. Nomenclature follows Wilson and Reeder (2005).
NE: number of independent events; NS: number of sites.

values larger than 0.3 indicate a poor fit) (Zuur, Ieno, & Smith, 2007). For this analysis, we excluded the records of the Gambian squirrel and the crested rat because camera trapping is not the most appropriate method to survey these small-bodied species (for all scientific names, see Table 1). The NMDS was performed on the encounter rate matrix (number of independent events divided by sampling effort) and square-root-transformed to decrease the influence of a small number of highly abundant species. NMDS was performed in R (version 3.3.1; R Core Team, 2016) using package vegan and function metaMDS (Oksanen et al., 2013).

FIGURE 2 Some of the mammal species detected in the study area: (a) De Brazza's monkey; (b) warthog; (c) bush pig; (d) African civet; (e) blotched genet; (f) aardvark; (g) Grivet monkey; (h) bushduiker; (i) spotted hyaena; (j) colobus guereza; (k) blue monkey; (l) baboons; (m) porcupine; (n) leopard (melanistic form); (o) honey badger; (p) white-tail mongoose; and (q) bushbuck [Colour figure can be viewed at wileyonlinelibrary.com]

3 | RESULTS AND DISCUSSION

Our sampling effort corresponded to 1,075 camera trap days, retrieving a total of 101,435 pictures, of which 14% corresponded to wild mammal species (with 1,292 independent events), 58% to people (59,325 pictures) and 28% to empty frames.

A total of 26 mammal species (including five congenerics) corresponding to 16 families were recorded (Table 1 and Figure 2). The order Carnivora was represented by eight species, Primates by six species and Artiodactyla by five species. The number of species detected per site varied between 3 and 14. Genets, baboons, bushduiker and bushbuck were the most common species (with more than 100 independent events and recorded at least in 15 sites; Table 1).

Importantly, the leopard was observed at the forest edge. This is a species of conservation concern (vulnerable status on IUCN Red List, Stein et al., 2016), and one of the leopard records corresponded to a melanistic form of the species (Figure 2n) (da Silva et al., 2017). Mantled guereza and blue monkeys were documented together on the ground in a mixed-species group in two independent events, a behaviour also observed elsewhere in Africa (Chapman & Chapman, 1996). Baboons were recorded feeding on coffee shrubs, which are in agreement with observations of local people who mentioned losses in coffee production due to baboons (I. Dorresteijn, personal communication). The crested rat was detected at one site, in a highly fragmented coffee forest (in Kuda Kufi *kebele*, Figure 1e). This record complements findings by De Beenhouver, Mertens, and Habtamu (2016), who published a first observation of the crested rat in the Afromontane rainforest in the nearby Belete-Gera forest. Our new record now expands the known distribution of this species to the north. Interestingly, while De Beenhouver et al. (2016) observed the species in natural forest, and stipulated that low anthropogenic disturbance might have contributed positively to its survival, our record indicates that the species can also use more disturbed edge forest.

The NMDS resulted in a two-axis optimal solution (stress value: 0.194). In the ordination plot, the distribution of species across the sites indicated some clustering of species by ecological guild: carnivores clustered together at the right end of the first axis, horned ungulates at the left side of the diagram, and primates and wild pigs at the centre (Figure 3). This result may indicate that regardless of site location, some species associated with human–wildlife conflicts, such as baboons, warthogs, bush pigs, grivet monkeys, hyaenas, genets and civets, are always present at the forest edge. These species are commonly reported by locals to damage crops or attack domestic animals with major negative consequences for peoples' livelihoods (Ango, Börjeson, Senbeta, & Hylander, 2014; Dorresteijn et al., 2017; Lemessa, Hylander, & Hambäck, 2013). Because there appears to be no escape from potentially problematic mammals, there is a crucial societal need to understand the factors driving their distribution.

Forest edges in the region are intensively used by local people for different purposes, including the collection of timber and firewood, as forage area for cattle, or to place beehives (Dorresteijn et al., 2017; Hylander et al., 2013). Furthermore, due to greater accessibility, the more intensively managed plots for coffee are also usually found at the forest edge. Perhaps surprisingly, despite this level of anthropogenic disturbance, many mammal species used the edges, including some typical forest interior species, such as the leopard

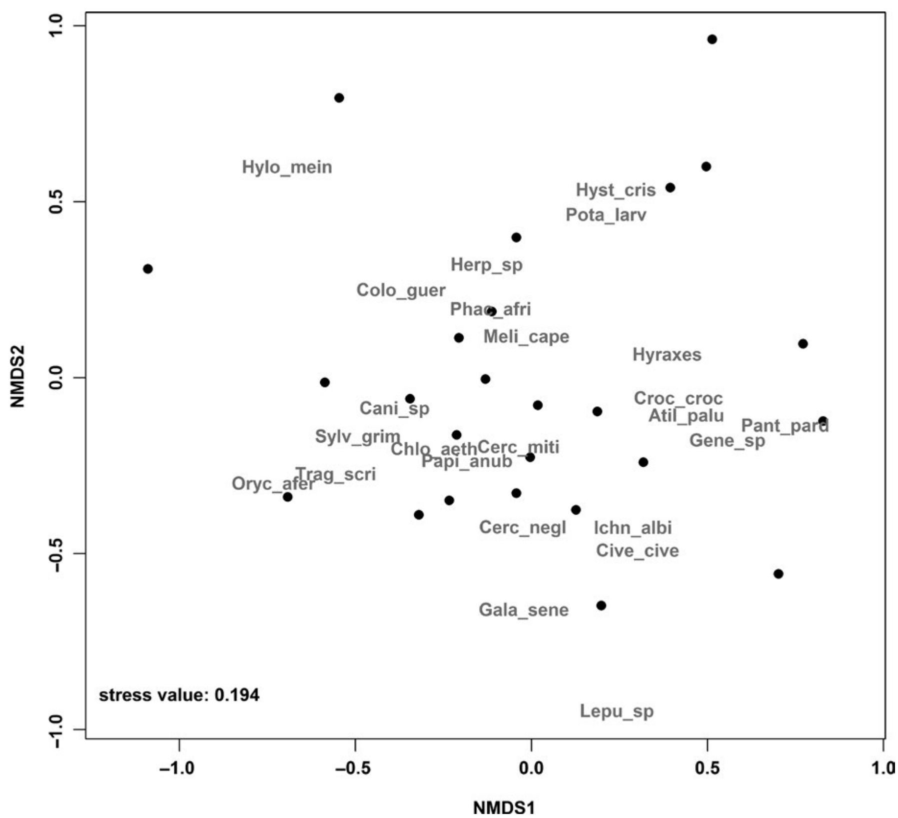

FIGURE 3 Ordination diagram using nonmetric multidimensional scaling, showing some clustering of species by ecological guild: carnivores (Pant_pard; Gene_sp; Atil_palu; Croc_croc; Ichn_albi; Cive_cive) clustered together at the right end of the first axis, horned ungulates (Trag_scri and Sylv_grim) at the left side of the diagram and primates (Chlo_aeth; Cerc_miti; Papi_anub) and wild pigs (Phac_afri; Pota_larv) at the centre. Black dots represent camera sites. Species codes are provided in Table 1. Only medium to large species were included

and giant forest hog. Further research could compare the encounter rates of these species at forest edges with encounter rates in the forest interior, to better understand this finding. Key questions are whether forest edges are in fact sought out by these species because they offer access to useful resources (crops and livestock) or whether they represent spillover or "sink" areas from core populations in the forest interior. Noting the potential of coffee forests for mammal conservation, we highlight the need to further understand how these forests support mammal diversity. More research is especially needed to shed light on (a) the implications of coffee management intensification on the mammal community; and (b) the role of fragmentation on different mammal groups.

Central to answering these key priorities is to extend mammal research beyond the forest edge and into the poorly explored forest interior. Understanding mammal communities in the forest interior is needed as a baseline to assess the effect of different coffee management intensities on mammal communities. The possibility exists that different mammal groups respond differently to changes in forest structure and quality. For example, generalist species or species that draw on resources in the agricultural landscape may persist at the forest edge (Pfeifer et al., 2017), whereas more specialised species may be limited to interior areas with high forest cover and low fragmentation. Moreover, differential impacts of forest fragmentation on different mammal groups could potentially disrupt natural top-down trophic control of crop-raiding species (warthogs or baboons at the edge) by large predators (Estes et al., 2011), thereby further aggravating the problem of crop-raiding mammals for local people.

To summarise, coffee forests in south-western Ethiopia hold promise for mammal conservation. However, a deeper understanding of mammal communities is needed to provide more complete insights for how to best manage the landscape for mammal conservation and for the mitigation of human–wildlife conflicts. In this context, gaining a better understanding of the dynamics between mammal distributions in the forest interior versus the forest edge should be prioritised.

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