

RESEARCH ARTICLE

Use of cultivated foods and matrix habitat by Bale monkeys in forest fragments: Assessing local human attitudes and perceptions

Addisu Mekonnen^{1,2}  | Peter J. Fashing^{1,3}  | Afework Bekele² | Nils Chr. Stenseth^{1,2}

¹Department of Biosciences, Centre for Ecological and Evolutionary Synthesis, University of Oslo, Oslo, Norway

²Department of Zoological Sciences, Addis Ababa University, Addis Ababa, Ethiopia

³Department of Anthropology and Environmental Studies Program, California State University Fullerton, Fullerton, California

Correspondence

Addisu Mekonnen, Centre for Ecological and Evolutionary Synthesis (CEES), Department of Biosciences, University of Oslo, P.O. Box 1066, Blindern, N-0316 Oslo, Norway.
Email: addisumekonnen@gmail.com

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Abstract

Primates inhabiting human-modified landscapes often exploit matrix habitat to supplement their diet with cultivated foods, at times resulting in economic losses and conflict with local people. Understanding human-nonhuman primate interactions and the attitudes and perceptions of local people towards crop feeding species are crucial to designing effective species-based management plans. Over a 12-month period, we used scan sampling to study the consumption of cultivated foods and matrix use patterns by two habituated groups of Bale monkeys (*Chlorocebus djamdjamensis*), Ethiopian-endemic bamboo specialists, in two forest fragments (Kokosa and Afursa) set amidst human settlements and farmland in the southern Ethiopian Highlands. Further, we conducted interviews with local people to document their attitudes and perceptions towards Bale monkeys at the two sites. We found that Bale monkeys at Kokosa, a more degraded habitat by most measures, consumed significantly more cultivated foods than their counterparts at Afursa. Moreover, Bale monkeys at Kokosa spent significantly more time in the matrix than in the forest habitat, while monkeys at Afursa spent significantly less time in the matrix than in the forest habitat. Not surprisingly, local people displayed a more negative attitude towards monkeys inhabiting Kokosa than those inhabiting Afursa. The differences in Bale monkey cultivated food consumption and matrix use patterns—as well as in local people's attitudes and perceptions towards Bale monkeys—between Kokosa and Afursa are probably associated with differences in habitat structure, degree of habitat alteration, and land-use practices between the sites. We conclude that to ensure long-term coexistence between Bale monkeys and local people in human-modified landscapes, it is vital to incorporate nearby matrix habitats into management plans and to work closely with local communities to develop effective nonlethal crop protection strategies, thereby reducing the likelihood of negative interactions between Bale monkeys and humans.

KEYWORDS

behavioral flexibility, *Chlorocebus djamdjamensis*, crop feeding, Ethiopian Highlands, ethnoprimateology, habitat fragmentation

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1 | INTRODUCTION

Many nonhuman primate species face a variety of anthropogenic threats, including habitat loss and fragmentation, hunting, and climate change (Dickman, 2010; Estrada et al., 2017; Haddad et al., 2015). Habitat loss and fragmentation, in particular, have forced many primate populations to live in small forest fragments isolated from one another by human-modified landscapes (Estrada et al., 2017; Gardner et al., 2009; Marsh, 2003). Primates living adjacent to agricultural lands are known to enter matrix habitats and feed on crops there, leading to more frequent interactions with humans (Anderson, Rowcliffe, & Cowlshaw, 2007a; Campbell-Smith, Campbell-Smith, Singleton, & Linkie, 2011; Chaves & Bicca-Marques, 2017; Hockings et al., 2015; McKinney, 2011).

In areas where local people depend primarily on subsistence farming, competition between crop feeding primates and the local community can be especially severe (Webber & Hill, 2014). In these areas, local people often view crop feeding species negatively and sometimes pursue retaliatory tactics like hunting these species, further jeopardizing primates already at risk of extinction due to habitat destruction (Chapman et al., 2016; Hill, 1997; McLennan, Hyeroba, Asimwe, Reynolds, & Walls, 2012; Meijaard et al., 2011). Studying the relationship between humans and nonhuman primates in areas where they are at odds is essential for designing management plans that will ensure long-term coexistence between crop feeding species and local people (Chaves & Bicca-Marques, 2017; Hill & Webber, 2010; Lee & Priston, 2005; Spagnoletti, Cardoso, Fragaszy, & Izar, 2017).

Crop feeding has been documented in many primates (reviewed in McLennan, Spagnoletti, & Hockings, 2017), though only a handful of genera account for most of the studies in the primate crop foraging literature (Hill, 2018). These intensively-studied taxa include baboons (*Papio* spp.; Henzi, Brown, Barrett, & Marais, 2011; Hill, 2018), macaques (*Macaca* spp.; Riley, 2010; Riley & Priston, 2010), chimpanzees (*Pan troglodytes*; Hockings, Anderson, & Matsuzawa, 2009; McLennan & Hockings, 2014) and African green monkeys (*Chlorocebus* spp.; Ango, Börjeson, & Senbeta, 2017; Saj, Sicotte, & Paterson, 2001).

African green monkeys comprise six medium-sized species in the genus *Chlorocebus*, including vervets (*C. pygerythrus*), grivets (*C. aethiops*), green monkeys (*C. sabaeus*), Malbrouck monkeys (*C. cynosuros*), tantalus monkeys (*C. tantalus*), and Bale monkeys (*C. djamdjamensis*) (Groves, 2005; Haus et al., 2013), and many are known to consume crops (Cancelliere, Chapman, Twinomugisha, & Rothman, 2018; Hill, 2018; Mekonnen et al., 2012; Saj et al., 2001). All green monkeys, except Bale monkeys (*C. djamdjamensis*), are widely distributed generalists that inhabit open and wooded habitats, consume a diverse diet, and are terrestrial or semiterrestrial (Cardini, Dunn, O'Higgins, & Elton, 2013; Cardini, Jansson, & Elton, 2007; Enstam & Isbell, 2007; Isbell, Pruettz, Lewis, & Young, 1998; Kingdon, 2015).

Bale monkeys, unlike other green monkeys, are endemic to the southern Ethiopian Highlands, specialize on bamboo, and are mainly arboreal in continuous forest (Mekonnen, Bekele, Fashing, Hemson, & Atickem, 2010; Mekonnen, Bekele, Hemson, Teshome, & Atickem, 2010; Mekonnen, Fashing, Sargis, et al., 2018). Remarkably, a single species of

bamboo (*Arundinaria alpina*) accounts for up to 81% of their annual diet (mostly young leaves and shoots) in the continuous forest (Mekonnen, Bekele, Fashing, et al., 2010; Mekonnen, Fashing, Bekele, et al., 2018). However, the species is also known to persist in small and isolated forest fragments where bamboo populations have been degraded or nearly eradicated (Mekonnen et al., 2012). To persist in these fragments, the monkeys consume more diverse diets than in continuous forest (Mekonnen et al., 2012; Mekonnen, Fashing, Bekele, et al., 2018).

Our recent study found that habitat fragmentation and degradation significantly reduced food availability and habitat quality for Bale monkeys (Mekonnen et al., 2017; Mekonnen, Fashing, Bekele, et al., 2018). Such changes in habitat structure and food availability, along with associated changes in diet (Mekonnen, Fashing, Bekele, et al., 2018) and terrestrial behavior (Mekonnen, Fashing, Sargis, et al., 2018), might be expected to affect the consumption of cultivated foods and associated matrix use patterns by Bale monkeys.

Like many other crop feeding African primates (Hill, 2018; McLennan et al., 2012), Bale monkeys face conflict with local people and are sometimes hunted in response to their crop feeding behavior (Mekonnen et al., 2012; Mekonnen, Fashing, Bekele, et al., 2018). In fact, several Bale monkey populations are believed to have been extirpated in recent decades (Mekonnen et al., 2012). Despite these concerns, the interactions between humans and Bale monkeys have never been studied in detail. During a 12-month period, we assessed the crop-feeding behavior of Bale monkeys in two different forest fragments and explored how this behavior influenced the relationships between local humans and Bale monkeys at these sites. Specifically, we (a) evaluated the contribution of cultivated foods to the diets of Bale monkeys, (b) evaluated whether crop consumption by Bale monkeys is influenced by natural food availability, (c) examined the matrix use patterns of Bale monkeys, and (d) assessed the attitudes and perceptions of local people towards Bale monkeys. Because of differences in habitat structure, composition, and food availability between the two fragments in our study, Kokosa (or Patchy, the more degraded fragment) and Afursa (or Hilltop, the less degraded fragment) (Mekonnen et al., 2017; Mekonnen, Fashing, Bekele, et al., 2018), we predicted that (a) Bale monkeys in Patchy would consume a greater percentage of cultivated foods than those in Hilltop, (b) the mean monthly consumption of cultivated foods by Bale monkeys in both groups would be inversely correlated with the overall availability of natural foods in the fragments, (c) Bale monkeys in Patchy would spend a greater proportion of their time in matrix habitat than those in Hilltop and (d) the attitudes and perceptions of local people towards Bale monkeys would be more negative near the fragment where the greatest crop consumption was occurring.

2 | METHODS

2.1 | Study areas and fragments

We conducted our study on Bale monkey crop feeding and matrix use in and around two forest fragments (6°44'–06°45'N and

38°48'–38°51'E), Kokosa and Afursa, in the southern Ethiopian Highlands (Mekonnen et al., 2017). Our research on human–Bale monkey interactions was conducted in the villages adjacent to Kokosa and Afursa forest fragments.

Kokosa forest fragment (hereafter referred to as “Patchy” fragment) consists of trees, shrubs, lianas, and bamboo set amidst a larger matrix of cultivated land, shrubland, human settlement, and grazing land. In total, Patchy covers 162 ha at elevations ranging from 2,534 to 2,780 m asl. Most of the fragment is owned privately by local individuals, though a smaller portion is collectively owned by the local community (Mekonnen et al., 2017). Cutting of bamboo by local people is common in the fragment and remaining stands are dwindling, though the site was dominated by bamboo forest just three decades ago (Mekonnen et al., 2012). The bamboo in the fragment today is a mix of naturally occurring stands and stands planted more recently by local people in their yards.

Located only 9 km from Kokosa, Afursa forest fragment (hereafter referred to as “Hilltop” fragment) is centered on a hilltop and consists of a mix of trees, shrubs, lianas, and a *Eucalyptus* plantation with graminoid and forb cover underneath. Though abundant at Hilltop 30 years ago, bamboo has been nearly eradicated through intensive harvesting. Hilltop covers 34 ha at elevations ranging from 2,582 to 2,790 m asl and is surrounded by an anthropogenic matrix of cultivated lands, pastures, and human settlements. Currently, cutting trees and using the fragment for grazing are prohibited. However, the edge of the fragment, especially the ground cover underneath the *Eucalyptus* plantation, is used for grazing (Mekonnen et al., 2017).

The main source of income for most people living near Patchy and Hilltop is agriculture, consisting of both planted crops and livestock farming. The rainfall and temperature patterns are also similar between the two fragments due to their geographic proximity, an occurrence at similar elevations, and orientation in the same north–south and east–west directions (Mekonnen, Fashing, Bekele, et al., 2018). Annual rainfall averages 1676 mm and follows a bimodal pattern with a long wet season and a short dry season (Mekonnen, Fashing, Bekele, et al., 2018). Mean annual temperature averages 16.7°C (Mekonnen, Fashing, Bekele, et al., 2018). The only primates sympatric with Bale monkeys in each fragment are black-and-white colobus monkeys (*Colobus guereza*; Mekonnen et al., 2012), though other large mammals present include porcupines (*Hystrix cristata*), bushbuck (*Tragelaphus scriptus meneliki*), dik-diks (*Madoqua saltiana*), and mole rats (*Tachyoryctes splendens*).

There are several notable differences between the two fragments. First, Hilltop is surrounded by a busy road and denser human settlement than Patchy (A. Mekonnen, pers. obs.). Second, Hilltop is nearly five times smaller and contains fewer different habitat types, including much less cultivated land than Patchy (Mekonnen et al., 2017). Third, the vegetation composition and abundance of the forested habitat at the sites differ substantially. Hilltop is more species-rich (47 vs. 35 species of plants ≥ 2 m tall) and has a much higher canopy (mean height: 22.2 vs. 11.1 m), mean DBH of all large trees (≥ 10 cm DBH; 38.3 vs. 23.7 cm), large tree basal area (1080 vs. 481 cm²/ha), mean DBH of food trees (41.4 vs. 22.6 cm), and basal

area of food trees (1264 vs. 434 cm²/ha) than Patchy (Mekonnen et al., 2017). On the other hand, though bamboo density in both fragments is far lower than in intact continuous bamboo forest, the density of bamboo is 35× higher at Patchy than at Hilltop (Mekonnen et al., 2017). Further details about the characteristics of the two fragments can be found in Table 1 of Mekonnen et al. (2017).

2.2 | Study groups

We studied one Bale monkey group at Patchy (28 individuals) and another group at Hilltop (23 individuals) (Mekonnen et al., 2017). The home range size of Patchy group was more than twice that of Hilltop (40 vs. 16 ha) (Mekonnen et al., 2017). The home ranges of these groups consisted of variable habitat types. The home range of Patchy group consisted of five habitat classes: grazing land (37.9%), shrubland (29.5%), mixed bamboo forest (17.1%), tree-dominated forest (8.0%), and cultivated land (7.5%) while the range of Hilltop group consisted of four habitat classes: shrubland (50.4%), tree-dominated forest (22.7%), *Eucalyptus* plantation (24.3%), and grazing land (2.7%) (Mekonnen et al., 2017). Specifically, the available cultivated land was much greater for Patchy group, accounting for 7.5% of its home range (95% kernel density estimate), whereas Hilltop group had no cultivated land in its range (95% kernel density estimate) (Mekonnen et al., 2017). The study groups were habituated to human observers from March–June 2013 (Mekonnen et al., 2017). Further details about the study areas, study groups, and home range characteristics can be found in Table 1 of Mekonnen et al. (2017).

2.3 | Behavioral observation

We collected data on the consumption of cultivated foods and matrix use patterns from July 2013 to June 2014 via instantaneous scan sampling at 15 min intervals for up to 5 min duration on up to 5 visible individuals excluding infants, from 0630 to 1830 (Mekonnen et al., 2017; Mekonnen, Fashing, Bekele, et al., 2018). During scan sampling, when a monkey was observed feeding, we recorded the type of food item and the species to which it belonged as well as whether it was from a natural or cultivated food source. In instances where Bale monkeys consumed bamboo, we distinguished between wild bamboo (natural) and bamboo obtained from the backyards of farmers (cultivated).

To evaluate temporal changes in the availability of potential natural food resources, we carried out monthly phenological assessments over an annual cycle for eight plant food species selected based on an earlier 8-month study of the species' diet in continuous forest (Mekonnen, Bekele, Fashing, et al., 2010). We monitored 10–15 individuals of each plant species on a monthly basis, including trees (≥ 10 cm DBH), bamboo (*Arundinaria alpina*) and shrubs. For each plant, we recorded the relative abundance score (ranging from 0 [item absent] to 8 [fully laden with the item]) for each of its potential food items (young leaves, mature leaves, flowers, ripe

fruits, and shoots) via visual inspection as well as using binoculars where necessary (Mekonnen et al., 2017; Mekonnen, Fashing, Bekele, et al., 2018). We analyzed phenological data from eight food species that cumulatively accounted for 50.9% and 44.5% of the annual diets of the study groups at Patchy and Hilltop, respectively (Mekonnen et al., 2017; Mekonnen, Fashing, Bekele, et al., 2018). The somewhat low contribution of monitored plants to the diets of the study groups resulted from these groups consuming much less bamboo as well as a greater variety of food species—including insects, graminoids and forbs, which are difficult to monitor (Fashing, Nguyen, Venkataraman, & Kerby, 2014)—than our original study group in continuous forest, which ate primarily bamboo plus several other plant species (Mekonnen, Fashing, Bekele, et al., 2018). We calculated the monthly food availability index (FAI) for each plant part by multiplying the mean phenology scores of species *i* with the mean basal area of species *i* and density of the corresponding species *i* per ha (Mekonnen et al., 2017; Mekonnen, Fashing, Bekele, et al., 2018).

At the same 15 min intervals when scan sampling for diet was conducted, we also recorded the GPS location (Garmin GPSMap 62 s with a precision of ± 3 m) representing the “center of mass” (Fashing, 2001) of most of the group members and the corresponding habitat occupied: “forest” or “matrix” (Mekonnen et al., 2017). Matrix habitat was defined as a habitat that predominantly served as a human use area either for grazing land, human settlement, tree plantation or cultivated land. Forest habitat was defined as a habitat dominated by natural forest habitat with little human use including habitats other than grazing land, human settlement, tree plantation, or cultivated land (Mekonnen et al., 2017).

2.4 | Ethnoprimateological methods

We conducted semistructured interviews with local people in the communities near our two study sites. We interviewed 40 people near Hilltop and 65 people near Patchy (Table S1). In each community, we randomly sampled households and carried out an interview with one adult per household (Gavin & Anderson, 2007; Gollin, McMillen, & Wilcox, 2004). We completed the interviews in the local languages of the interviewees (Sidamigna or Oromifa).

The interviews were designed to evaluate a) the demographic and socioeconomic profiles of respondents, b) their general knowledge about Bale monkeys, and c) their attitudes and perceptions towards Bale monkeys and their crop feeding behavior. First, we gathered data on the demographic and socioeconomic variables of the interviewees, including their age, sex, ethnicity, highest level of formal education, and occupation (Campbell-Smith, Simanjorang, Leader-Williams, & Linkie, 2010; Meijaard et al., 2011). Second, we showed each interviewee a photo of a Bale monkey and a sympatric black and white colobus monkey which are phenotypically very different, minimizing the risk of potential confusion. Local people also differentiate between them by their local names, a distinction that exists in both local languages. Next, we assessed the attitudes and perceptions of local people towards Bale monkeys, including whether

they (a) knew Bale monkeys are endemic to Ethiopia, (b) were aware that Bale monkeys are legally protected, (c) considered it necessary to conserve Bale monkeys, (d) had ever reported crop feeding by Bale monkeys to government authorities, and (e) had one of the following attitudes toward Bale monkeys: “like,” “dislike” or “indifferent.” Finally, the participants were asked: (a) the types of crops they grow on their farms, (b) to list, based on their experience, the top three crop feeding wildlife species in decreasing order of crop consumption, (c) whether Bale monkeys consume cultivated species and, if so, (d) which species, (e) the protection measures employed by local people to prevent crop loss by Bale monkeys and their perceived effectiveness (“highly effective,” “less effective,” or “not effective”), and (f) their reactions (“agree,” “disagree,” or “indifferent”) to seven possible protection measures to mitigate adverse human-Bale monkey interactions, and if they had any additional measures to recommend.

The mean time taken to complete an interview was 20.5 min \pm standard deviation (SD) 8.83 (range 8–33). The mean age of interviewees was 37.6 years \pm SD 12.23 (range 20–75). Most of the participants were males (84.8%; Table S1). After checking that responses by males and females followed similar patterns, we combined the data for both sexes in our analyses. Most participants were farmers that engage in both agriculture and livestock farming (Table S1). The two sites, however, differ in both ethnicity and religion: Afursa is inhabited mostly by Christian Sidama people and Kokosa is inhabited mostly by Muslim Oromo people (Table S1).

2.5 | Ethical statement

We obtained informed voluntary consent from all participants before their inclusion in the interview survey. Permission to carry out this project was granted by the Ethiopian Wildlife Conservation Authority. This project also adhered to the legal requirements of Ethiopia and complied with the American Society of Primatologists Principles for the Ethical Treatment of Primates.

2.6 | Data analysis

We tested all data for normality and homogeneity of variances using Shapiro–Wilk and Levene tests, respectively ($p > .05$). To normalize the data, we carried out logit transformations of proportion data and log transformation of food availability data before conducting statistical analysis (Warton & Hui, 2011).

We assessed cultivated food consumption for each group by determining the proportion of feeding scans accounted for by cultivated food species. We compared the consumption of cultivated food species between groups using an independent Student's *t*-test. We used linear regressions to evaluate whether monthly values for overall food availability were a good predictor of the monthly proportion of cultivated food species consumption.

To assess the matrix use patterns, we classified the home range (95% Kernel Density Estimation, KDE) of Bale monkeys (Mekonnen et al., 2017) into matrix and forest using the corresponding GPS locations collected during group follows in ArcGIS 10.3 (ESRI, 2016). We then calculated the areas of both matrix and forest habitats in ArcGIS. To determine whether Bale monkeys avoid matrix habitat or not, we calculated matrix use ratios by dividing the frequency of observed use (% of range scans in matrix vs. forest) by the frequency of expected use (% of home range area accounted for by matrix vs. forest) (Krebs, 1999; Manly, McDonald, Thomas, McDonald, & Erickson, 2002). We calculated the observed use of matrix and forest by dividing the total number of GPS points recorded in each category with the total number of GPS points recorded in the home range. To calculate the expected use of matrix and forest habitats, we multiplied the percentage representation of matrix and forest areas with the total number of range points recorded within the home range. A selection ratio close to 1 indicates no selectivity for that habitat, <1 indicates a habitat is avoided and >1 indicates a habitat is selected (Krebs, 1999). We also used χ^2 goodness-of-fit tests to compare the observed versus the expected frequencies of matrix and forest utilized by each group in their home range.

Finally, we used descriptive statistics to examine differences between the human communities near Patchy and Hilltop in demographic and socioeconomic variables as well as their attitudes and perceptions towards Bale monkeys. We conducted all statistical tests using R version 3.5.2 (R Development Core Team, 2018) with significance set at $p \leq .05$.

3 | RESULTS

3.1 | Consumption of cultivated food species by Bale monkeys

Bale monkeys in forest fragments cumulatively exploited five cultivated food species including bamboo planted on farms near

the fragments (Table 1; Figure 1). Patchy group consumed all five of these species whereas Hilltop group consumed only two of them (Table 1). The percentage of the overall annual diet accounted for by cultivated species was also much greater in Patchy group (10.3%) than in Hilltop group (0.2%). Further, the percentage of the overall diet accounted for by cultivated food species each month was significantly higher for Patchy group than for Hilltop group (Student's t -test: $p < .001$; $n = 12$ months). Monthly percentage consumption of cultivated foods varied widely in Patchy group (1.7–19.8%) but never exceeded 1.1% in Hilltop group. Barley (*Hordeum vulgare*) was the most exploited cultivated species (0.0–15.5% of monthly feeding records), and planted bamboo (*A. alpina*) was the second most frequently consumed cultivated species (1.0–8.2% of monthly feeding records) by Patchy group (Figure S1). In contrast, cultivated food species were rarely consumed (planted bamboo: 0.0–0.3% and maize: 0.0–1.1%) by Hilltop group (Figure S1). We found no correlation between percentage monthly consumption of cultivated species and overall monthly food availability for Patchy group (R^2 adj = 0.05; $df = 1$; $F = 1.53$; $p = .244$). For Hilltop group, cultivated species made up too little of the diet to warrant running such an analysis.

3.2 | Matrix effect

The available matrix habitat was much greater for Patchy group, accounting for 73.5% of its home range, than for Hilltop group, whose range included only 26.9% matrix habitat (Table 2; Figure S2). Bale monkeys in Hilltop group also used the matrix habitat less frequently than expected by chance based on its availability in their home range ($\chi^2 = 63.79$; $df = 1$; $p < .001$; Table 2). In contrast, Bale monkeys in Patchy group used matrix habitat more frequently than expected by chance based on its availability in their home range ($\chi^2 = 24.45$; $df = 1$; $p < .001$; Table 2).

TABLE 1 The proportion of annual feeding records (Patchy, $n = 5239$ records; Hilltop, $n = 3950$ records) devoted to each cultivated food item by Bale monkey study groups at Patchy (Kokosa) and Hilltop (Afursa) fragments

Group	Family	Percentage of feeding records for each cultivated food item								
		Species consumed	Common name	YL	SH	FR	ST	SE	OT	Total
Patchy	Poaceae	<i>Hordeum vulgare</i>	Barley	0.17	–	–	–	3.44	–	3.61
	Poaceae	<i>Arundinaria alpina</i>	Bamboo	2.14	1.05	–	–	–	0.11	3.30
	Musaceae	<i>Ensete ventricosum</i>	Ensete	0.09	1.00	–	0.87	–	–	1.96
	Poaceae	<i>Zea mays</i>	Maize	–	–	1.05	0.05	–	–	1.09
	Solanaceae	<i>Solanum tuberosum</i>	Potato	0.20	–	0.02	–	–	–	0.22
	Total			2.60	2.05	1.07	0.92	3.44	0.11	10.18
Hilltop	Poaceae	<i>Zea mays</i>	Maize	–	–	0.11	–	–	–	0.11
	Poaceae	<i>Arundinaria alpina</i>	Bamboo	–	0.05	–	–	–	–	0.05
	Total			–	0.05	0.11	–	–	–	0.16

Abbreviations: FR, fruits; OT, others; SE, seeds; SH, shoots; ST, stems; YL, young leaves.



FIGURE 1 Bale monkeys feeding on cultivated food species at Patchy fragment (Kokosa), Ethiopia. (a) Adult male Bale monkey feeding on a young shoot of bamboo collected from a nearby local farmer's bamboo garden. (b) Adult male Bale monkey feeding on maize collected from nearby cultivated land. (c) Bale monkey feeding on a young ensete stem near a farm. (d) Bale monkeys feeding on barley despite the presence of a scarecrow meant to deter crop consumption by the monkeys. Photos by Addisu Mekonnen

3.3 | Local people's attitudes and perceptions towards Bale monkeys

Based on the results of our interviews, ensete (*Ensete ventricosum*) or false banana was the most cultivated food species at both sites and was grown by 95% of farmers near Hilltop and 83% of farmers near Patchy. Other crops grown by at least 50% of farmers include barley (93%), onions (78%), maize (75%), and cabbage (65%) near Hilltop and maize (80%) and barley (68%) near Patchy. The cultivated species reported as being most often damaged by Bale monkeys was cabbage (*Brassica carinata*; 85% of farmers)—a species we never observed them consuming—near Hilltop, and maize (*Zea mays*; 86% of farmers) near Patchy (Table S2). Other crops reported as often damaged by Bale monkeys include maize (80%), barley (73%) and bamboo (55%) near Hilltop, and ensete (72%), cabbage (71%),

potatoes (71%), and wheat (66%) near Patchy (Table S2). Most of the cultivated species reportedly damaged by Bale monkeys were those that we observed to be eaten by monkeys in Patchy. However, Bale monkeys in Hilltop may have been blamed for crop damage that was caused by other species.

All respondents regarded Bale monkeys as crop feeders. Local people near Patchy (45%) were more likely to report disliking Bale monkeys than those near Hilltop (20%) (Table 3). Sixty-eight percent of respondents incorrectly believed Bale monkeys are not legally protected, and 58% believed it is necessary to conserve Bale monkeys. Nearly two-thirds (60.0%) of the respondents perceived Bale monkeys as the species causing the most damage to crops near Patchy, whereas only 18% of respondents considered them to be the species causing the most damage to crops near Hilltop (Table S3).

TABLE 2 Differences in the forest and matrix habitat use patterns of the Bale monkey study groups at Patchy (Kokosa) and Afursa (Hilltop) fragments

Group	Habitat type	95% KDE Area (ha)	Area (%)	Observed use 95% KDE (%)	Expected use 95% KDE (%)	Selection ratio	Selection status
Patchy	Matrix	29.3	73.5	1743 (78.1)	1640 (73.5)	1.06	Selected
	Forest	10.6	26.5	489 (21.9)	592 (26.5)	0.83	Avoided
Hilltop	Matrix	4.2	26.9	422 (19.3)	587 (26.9)	0.72	Avoided
	Forest	11.6	73.1	1762 (80.7)	1595 (73.1)	1.11	Selected

Note: Bale monkey group habitat use records (matrix vs. forest), 95% KDE utilization in hectares (ha) and percentage (%), observed use of Bale monkey group scans (observed number of habitat use records), expected use (expected number of habitat use records) and habitat use selection ratio (observed over expected use) calculated within the 95% KDE home ranges of each study group.

Abbreviation: KDE, kernel density estimation.

TABLE 3 Attitudes and perceptions of members of the local community towards Bale monkeys at Hilltop (Afursa) and Patchy (Kokosa) study sites

	% of responses		
	Hilltop (n = 40)	Patchy (n = 65)	Combined (n = 105)
Do Bale monkeys feed on crops?			
Yes	100.0	100.0	100.0
No	0.0	0.0	0.0
Are Bale monkeys legally protected?			
Yes	27.5	35.4	32.4
No	72.5	64.6	67.6
Is it necessary to conserve Bale monkeys?			
Yes	72.5	49.2	58.1
No	27.5	50.8	41.9
Do you have experience reporting crop feeding by Bale monkeys to local authorities?			
Yes	2.5	10.8	7.6
No	85.0	86.2	85.7
No response	12.5	3.1	6.7
Are Bale monkeys endemic to Ethiopia?			
Yes	17.5	18.5	18.1
No	82.5	78.5	80.0
No response	0.0	3.1	1.9
Attitude towards Bale monkeys			
Like	27.5	15.4	20.0
Dislike	20.0	44.6	35.2
Neutral	45.0	40.0	41.9
No response	7.5	0.0	2.9

3.4 | Human–Bale monkey interaction management practices and strategies

Local people reported using several strategies to try to reduce the consumption of cultivated foods by Bale monkeys at both study sites (Table 4a). They reported that guarding crops was the most effective strategy for preventing the loss of cultivated species at both sites. No other strategy was regarded as “highly effective” at Hilltop, the site where crop feeding by Bale monkeys was rare. In contrast, at Patchy where crop feeding by Bale monkeys was a much more common occurrence, shouting and patrolling by dogs were also considered “highly effective” by more than half of all interviewees. Further, while shooting monkeys (80%) and setting traps or snares (87.5%) were widely reported to be “not effective” at Hilltop where there was little need for such draconian strategies, 66.2% of interviewees at Patchy considered shooting monkeys at least somewhat effective and 73.8% considered setting traps or snares to be at least somewhat effective.

Of the seven possible protection measures mentioned to local people (some of them already in use) for their feedback, guarding, public education campaigns, creating buffer zones, and planting crops not eaten by monkeys all received >80% support at Hilltop (Table 4b). Conversely, at Patchy, only guarding and shouting received such high support, and all other measures were supported by <25% of respondents there.

4 | DISCUSSION

Habitat loss, land use change, and reduction in habitat quality all affect the survival of primates in forest fragments (Almeida-Rocha, Peres, & Oliveira, 2017; Arroyo-Rodríguez & Mandujano, 2006; Estrada et al., 2017). The results of our research suggest that to persist in fragments, Bale monkeys have the flexibility to pursue variable coping strategies depending on the ecological context at a particular site. While Bale monkeys in both our study fragments broadened their diet beyond primarily bamboo (Mekonnen, Fashing, Bekele, et al., 2018), only those at Kokosa (or Patchy) fragment intensively exploited cultivated foods and relied much more heavily on matrix habitats than those at Afursa (or Hilltop) fragment. Correspondingly, local human attitudes and perceptions toward Bale monkeys were much more negative near Patchy than near Hilltop. Here, we discuss the patterns revealed by our study in greater detail and place them within the context of the literature on primate crop feeding behavior and human–nonhuman primate interactions.

Crop feeding behavior is a common response by some primates to the reduction of their preferred wild food resources, often resulting from human disturbances. For instance, populations of several primates have been found to spend more time feeding on crops when wild food availability is low (for example, chimpanzees [*Pan troglodytes*; Hockings et al., 2009; McLennan, 2013], tufted capuchin monkeys [*Sapajus nigritus*; Mikich & Liebsch, 2014], bearded capuchin monkeys [*Sapajus libidinosus*; de Freitas, Setz, Araujo, & Gobbi, 2008], and ring-tailed lemurs [*Lemur catta*; LaFleur & Gould, 2009]). Furthermore, primates in severely degraded fragments where food availability and habitat quality are lower are more likely to supplement their diets with cultivated species than conspecifics in fragments that are less degraded (for example, chimpanzees [*Pan troglodytes*; McLennan, 2013] and bonnet macaques [*Macaca radiata radiata*; Singh, Erinjery, Kavana, Roy, & Singh, 2011]). In our study, most measures of forest structure and food availability—aside from bamboo abundance—were poorer in Patchy fragment (Mekonnen et al., 2017) and it was in this fragment that the diet of Bale monkeys consisted of a much greater percentage of crops (10.3% vs. 0.2% of the annual diet at Hilltop). Species richness, DBH of large trees, height of large trees, basal area of large trees, DBH of food tree species, and overall basal area of food tree species were all approximately two or more times greater at Hilltop than at Patchy (Mekonnen et al., 2017). Further, although bamboo—the preferred food species of Bale monkeys in continuous forest (Mekonnen, Bekele, Fashing, et al., 2010)—was more abundant at Patchy, it was

TABLE 4 Local people's responses to interviewer questions on current and possible protection measures to deter the consumption of cultivated foods by Bale monkeys at two fragmented forest study sites, Hilltop (Afursa) and Patchy (Kokosa)

a) Current protection measures used and people's perceptions of their effectiveness	Type	Hilltop (n = 40) Percentage of total interviewees				Patchy (n = 65) Percentage of total interviewees			
		Highly effective	Less effective	Not effective	No response	Highly effective	Less effective	Not effective	No response
Guarding	Nonlethal	92.5	7.50	0.0	0.00	81.5	13.8	4.6	0.0
Scarecrow	Nonlethal	0.0	7.5	92.5	0.00	46.2	49.2	3.1	1.5
Shouting	Nonlethal	7.3	73.2	19.5	0.00	61.5	36.9	0.0	1.5
Suspending cans	Nonlethal	0.0	55.0	45.0	0.00	9.2	75.4	10.8	4.6
Patrolling by dogs	Lethal	30.0	55.0	12.5	2.50	58.5	36.9	4.6	0.0
Throwing stones/wood	Lethal	0.0	87.2	10.3	2.56	20.0	72.3	6.2	1.5
Shooting with gun	Lethal	0.0	20.0	80.0	0.00	10.8	55.4	30.8	3.1
Traps/local snare (e.g., wooden "house," rope, wire)	Lethal	0.0	10.0	87.5	2.50	1.5	72.3	23.1	3.1
b) People's reactions to 7 possible protection measures	Type	Agree	Disagree	Indifferent	No response	Agree	Disagree	Indifferent	No response
Guarding	Nonlethal	97.5	0.0	0.0	2.5	92.3	7.7	0.0	0.0
Planting crops not eaten by monkeys	Nonlethal	82.5	12.5	0.0	5.0	18.5	55.4	24.6	1.5
Public education on coexistence	Nonlethal	97.5	2.5	0.0	0.0	23.1	43.1	32.3	1.5
Compensation for losses	Nonlethal	35.0	65.0	0.0	0.0	10.8	70.8	18.5	0.0
Shouting	Nonlethal	5.0	90.0	0.0	5.0	83.1	16.9	0.0	0.0
Creating buffer zones	Nonlethal	92.5	5.0	0.0	2.5	9.2	63.1	26.2	1.5
Translocation	Nonlethal	7.5	92.5	0.0	0.0	23.1	61.5	13.8	1.5
Selective killing of nuisance animals	Lethal	7.5	90.0	2.5	0.0	16.9	69.2	13.8	0.0
Throwing stones	Lethal	25.0	72.5	0.0	2.5	84.6	12.3	1.5	1.5
Patrolling with dogs	Lethal	27.5	70.0	0.0	2.5	72.3	23.1	4.6	0.0

still quite scarce, especially when compared with its typical abundance in continuous forest (Mekonnen et al., 2017). As a result, we contend that Bale monkeys in Patchy are consuming a much greater (53-fold difference) proportion of cultivated foods than those at Hilltop, at least partly because of the lower overall food availability and habitat quality in Patchy.

Several studies have found that it is not reduced natural food availability but rather the spatiotemporal availability of crops that predicts crop feeding by primates (Cancelliere et al., 2018; Hill, 2017). For instance, crop feeding has been found to be related to the spatiotemporal accessibility and availability of cultivated foods in vervet monkeys (*Chlorocebus pygerythrus*; Cancelliere et al., 2018), brown howlers (*Alouatta guariba clamitans*; Chaves & Bicca-Marques, 2017), and mountain gorillas (*Gorilla beringei beringei*; Seiler & Robbins, 2016). In our study of Patchy group, we also found no relationship between the monthly percentage of the diet accounted for by crops and the monthly availability of natural foods, leading us to posit that crop feeding by members of this group of Bale monkeys

may also be mostly opportunistic and tied to variation in the availability of crop foods. Further research should examine the relationship between temporal changes in crop availability and consumption among Bale monkeys in fragments. In addition, nutritional and other ecological studies have revealed that some primates may prefer crop foods when available because they can contain less fiber, tend to contain higher levels of digestible carbohydrates, and tend to be more spatially and temporally clumped than wild foods (McLennan & Ganzhorn, 2017; Strum, 1994). Hence, comparing the nutritional value of crops and wild foods at fragments inhabited by Bale monkeys may help to unravel the factors behind crop feeding behavior in this species.

To facilitate their greater crop consumption, Bale monkeys in Patchy more frequently used matrix habitat than those in Hilltop. While 74% of Patchy group's home range consisted of matrix habitat, only 27% of Hilltop group's range was accounted for by matrix. Notably, Patchy group included far more cultivated land in their home range than Hilltop group which entered cultivated land so

rarely that none even ended up making it into their 95% KDE home range estimate. Studies have shown that primates with greater access to cultivated foods tend to occupy more matrix habitat than those with little or no access to cultivated foods (*Lemur catta* [Gabriel, 2013; Kelley, 2013], *Colobus vellerosus* [Wong & Sicotte, 2007] and *Cebus capucinus* [McKinney, 2011]). Furthermore, highly fragmented and irregular shaped home ranges often contain more edge than forest interior habitat, thus forcing species to use matrix habitats more frequently (Fahrig, 2003). Indeed, in our study, the group that used matrix habitat most (Patchy) occupied a more irregularly shaped home range with lots of edge habitat.

Given the much greater crop feeding by Bale monkeys at Patchy, it is unsurprising we found that local people had more negative attitudes and perceptions towards Bale monkeys living near Patchy than those living near Hilltop. Local people near Patchy were much more likely to regard Bale monkeys as the wildlife species most responsible for crop feeding in the area than locals near Hilltop where Bale monkeys were viewed more benignly. Not only did Bale monkeys consume crops much more often at Patchy, but they also had much greater range overlap with human use areas there. Sharing a landscape with wildlife often adversely influences the attitudes and perceptions of local people and consequently has the potential to obstruct conservation activities (Campbell-Smith et al., 2010; Hockings et al., 2015). Still, local people do not always consider wildlife that shares the human matrix to be problematic. Attitudes depend on the culture of local humans as well as the behavior of the matrix-using primate species. For example, Anderson and colleagues found that Angolan colobus (*Colobus angolensis*) in fragmented forests in SE Kenya rarely consumed crops and were tolerated in matrix habitats by local people (Anderson et al., 2007a; Anderson, Rowcliffe, and Cowlshaw, 2007b). In some circumstances, local people are even tolerant of some crop foraging and/or damage by primates (e.g., Chaves & Bicca-Marques, 2017; Siex & Struhsaker, 1999; Spagnoletti et al., 2017).

The differences in the attitudes and perceptions of local people towards Bale monkeys at Patchy versus Hilltop can almost certainly be attributed to the unequal crop losses caused by Bale monkeys at these sites. Similarly, local people display more negative attitudes towards chimpanzees that cause more crop damage than those that cause less, resulting in instances of retaliatory killing of chimpanzees by humans (McLennan et al., 2012). Although crop feeding by Bale monkeys is very infrequent at Hilltop, accounting for only 0.2% of their annual diet, local people still perceived the monkeys there as crop feeders. The discrepancies between the actual crop consumption and the perceived crop feeding risks by Bale monkeys—including 85% of farmers reporting cabbage being the crop most often damaged by the monkeys—at Hilltop are difficult to explain. Given the intensity of our observational study of Bale monkeys at Hilltop, we suggest that other more nocturnal large mammal species are the more likely culprits for cabbage and most other crop feeding at Hilltop. Still, we cannot rule out the possibility that Bale monkeys are entering farmlands and consuming cabbage and other crops near Hilltop after dark when we were not observing them. We also

acknowledge that people's individual experiences, societal values, and cultural norms can contribute to their perception of crop feeding by primates and other animals (Hill, 2018).

Local people near both our study sites reported that guarding was the most commonly used and effective strategy to protect their farmland (Table 4a). Though guarding can be an effective crop protection strategy, it requires human power and this task is primarily carried out by children in many countries (including Ethiopia), coming at the expense of their time at school (e.g., Mackenzie, Sengupta, & Kaoser, 2015; A. Mekonnen, pers. obs.). In general, our finding that most people at both study sites are recommending and implementing nonlethal crop protection strategies is a good sign for Bale monkeys in these forest fragments. However, some individuals near Patchy stated that lethal or potentially lethal strategies such as culling problematic animals (11%), throwing stones (20%), and patrolling with dogs (59%) are "highly effective." Because Bale monkeys are protected by Ethiopian law as a Threatened species (Butynski, Gippoliti, Kingdon, & De Jong, 2008; Mekonnen, Bekele, Hemson, et al., 2010), all of these strategies are illegal.

If all other possible nonlethal protection methods do not succeed, translocation from fragments where Bale monkeys are engaging in problematic levels of crop feeding to less disturbed habitats was supported by some locals, especially near Patchy fragment. However, in practice, translocation is expensive and it would be a tremendous challenge to find remaining suitable but unoccupied habitats for Bale monkeys to move to (Mekonnen et al., 2012). Similar constraints have limited the utility of translocation for conserving other crop feeding primates as well (Osborn & Hill, 2005).

We suggest that to ensure the long-term survival of Bale monkeys in forest fragments, it will be necessary to incorporate nearby matrix habitats into Bale monkey management plans, and to work closely with local communities to help improve their livelihoods, reduce crop losses to Bale monkeys and other crop feeding species, and reduce logging of natural habitats (Garriga, Marco, Casas-Díaz, Amarasekaran, & Humle, 2018). Any restoration projects in degraded forest fragments must focus on mitigating adverse human-Bale monkey interactions, planting appropriate indigenous food plant species, protecting natural habitats, minimizing edge effects, increasing fragment sizes, and enhancing forest fragment connectivity (Anderson et al., 2007a; Estrada, Raboy, & Oliveira, 2012; Hill, 2017). We hope that this study documenting the variability in Bale monkey crop feeding behavior in and around forest fragments, as well as the variation in human attitudes and perceptions towards Bale monkeys near these fragments, will contribute to future such conservation initiatives in the fragmented forests of southern Ethiopia.

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ORCID

Addisu Mekonnen  <http://orcid.org/0000-0001-8403-1071>

Peter J. Fashing  <http://orcid.org/0000-0003-3854-1999>

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section.

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