Primates
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ORIGINAL ARTICLE

Distribution and diversity of primates and threats to their survival in the Awi Zone, northwestern Ethiopia

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Abstract

Habitat loss and fragmentation affect the diversity and distribution of primates in a human-modified landscape. Ethiopia has a high diversity of primates, but increasing human pressure has negatively impacted their distribution and abundance across the country, primarily due to deforestation. To date, the diversity and distribution of primate species are poorly known in northwestern Ethiopia. From October 2020 until September 2021, we assessed the diversity and distribution of primate species in 26 forest patches in the Awi Zone, Northwestern Ethiopia using line transect surveys, and we examined the potential conservation threats to the survival of these taxa. Across transects, we encountered 459 groups of four primate taxa: olive baboons (*Papio anubis*), grivet monkeys (*Chlorocebus aethiops*), Boutourlini's blue monkeys (*Cercopithecus mitis boutourlinii*), and black-and-white colobus monkeys (*Colobus guereza* spp. *guereza*). The latter two are endemic to Ethiopia. We observed black-and-white colobus monkeys in all surveyed forest patches, while we observed Boutourlini's blue monkeys in 18 patches. Black-and-white colobus monkeys were the most frequently observed ($n = 325$ sighting; relative encounter frequency = 70.8%), while grivet monkeys (*Chlorocebus aethiops*) were the least ($n = 34$ sighting; relative encounter frequency = 7.4%) in the region. Similarly, the relative encounter frequency of olive baboons was 9.2% ($n = 42$ sighting). The overall mean group size for each species was: Boutourlini's blue monkeys (26.1 individuals), black-and-white colobus monkeys (8.8 individuals), grivet monkeys (34.1 individuals), and olive baboons (41.4 individuals). We identified agricultural expansions, exotic tree plantations, deforestations, firewood collections, livestock grazing, and killings over their crop-feeding behaviors as the main threats to primates and their habitats in the region. This study provides crucial information on an area likely to support primate species that we know very little about. Assigning protected connecting forest patches should be an urgent priority for the conservation of the primates in this region.

Keywords Biodiversity priority area · Conservation · Deforestation · Human-modified landscape · Forest patches · Primate

Introduction

Habitat loss and fragmentation through deforestation are current threats to biodiversity in the tropics (Morris 2010; Hansen et al. 2013; Newbold et al. 2015). Since most primate species depend on forested habitats, they are particularly vulnerable to forest loss, habitat degradation, and hunting (Almeida-Rocha et al. 2017; Estrada et al. 2017, 2018). Approximately 60% of primate species (300/504) are threatened with extinction, and ~ 75% have declining populations (Estrada et al. 2017). In effect, habitat fragmentation and human disturbance can have a significant impact on primate distribution pattern, species abundance, diversity, group size, and population density, threatening their survival (Chapman and Chapman 2000; Onderdonk and Chapman 2000; Pimm and Raven 2000; Clarke et al. 2002; Haddad et al. 2015; Marsh et al. 2016).

In addition, habitat fragmentation isolates remaining forest patches and draws many primate species to inhabit human-modified landscapes (Walker et al. 2008; Galán-Acedo et al. 2019; Helenbrook and Valdez 2021; Kifle and Bekele 2021). Thus, many primate species now exist in small, isolated forest fragments surrounded by mosaic

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agriculture and human settlement landscapes (Marsh 2003; Estrada et al. 2017; Galán-Acedo et al. 2019; Kifle and Bekele 2021). Consequently, many primates in such fragments experience increased conflict with local farmers due to crop feeding (Mc Guinness and Taylor 2014; Hill 2017; Kifle and Bekele 2020a, b) and small-livestock predation (Kifle and Bekele 2020b; Kifle 2021). Crop damage caused by primates exacerbates human–primate conflicts that threaten their survival through local extirpation (Peterson et al. 2010; McLennan and Hill 2012; Priston et al. 2012; Hardwick et al. 2017; Hill 2017; Kifle and Bekele 2020a, b).

Ethiopia has a high degree of primate diversity (at least 16 species and subspecies) and at least six are endemic (Yalden 1977; Bekele and Yalden 2013; Mekonnen et al. 2020). However, most of these primate species and subspecies live outside protected areas and are steadily declining in population abundance. They are also threatened with local extinction due to deforestation, habitat degradation, conflict with humans, and other anthropogenic activities (Beehner et al. 2007; Mekonnen et al. 2017; Kifle and Bekele 2020b, 2021). Due to such continuous decline in primate populations compounded by our lack of knowledge on their distribution, species abundance, and diversity, it is paramount to establish baseline qualitative and quantitative data from an uninvestigated region. Moreover, in an area where no preliminary research has been conducted, and very few protections have been received, a primary survey can provide a vital first step for documenting the diversity and distribution of primate species and the conservation threats they face. There are no data available on the diversity, abundance, and distribution of primate species in northwestern Ethiopia (e.g., Awi Zone, Fig. 1). Yet the region could be important for primate conservation and other animal species because many parts of this region are still composed of indigenous forest coverage. Establishing these baseline data are critical for several reasons: they are crucial for determining priority areas for conservation and management (Rylands et al. 2008); they are necessary for further ecological and biogeographical studies (Ravetta and Ferrari 2009; Funk and Fa 2010; Bersacola et al. 2018); and they are important to provide data for updating IUCN assessments (Plumptre 2000; Bersacola et al. 2018). Therefore, the main objectives of the present study were to (1) investigate the diversity of primate species in this area (Awi Zone of northwestern Ethiopia), (2) determine the distribution of primates across a large number of forest patches, and (3) identify the conservation threats that may influence the future existence of primates and their habitats in the region.

Methods

Study area

The study was conducted in the Awi Zone, northwestern Ethiopia (Fig. 1). The geographical location of the Awi Zone lies between latitudes 10°40′–11° 20′ N and longitudes 36°25′–37°10′ E. The elevation of the area ranges from 1700 to 3100 m above sea level. The region experiences two main seasons: the wet season (~ May-Oct) and the dry season (~ Nov-Apr). The zone retains mosaic virgin forest patches, wetlands, grassland areas, and lakes of various sizes

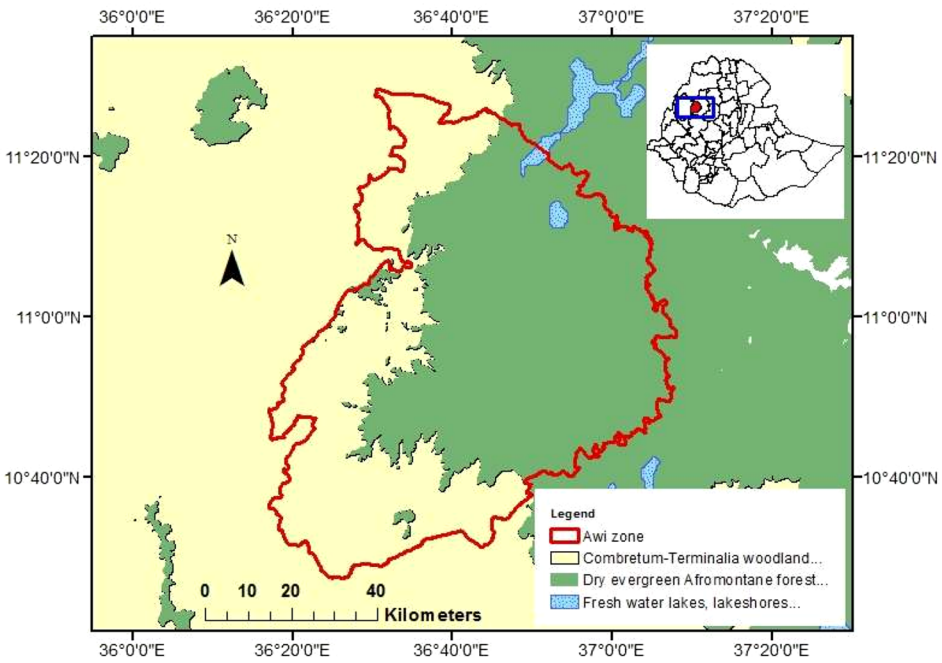

Fig. 1 Location of Awi Zone within Ethiopia

(Z. Kifle pers. obs.). The region is identified as a biodiversity hotspot site for wild animal and forest conservation in northwestern Ethiopia (EWNHS 2010). It is perhaps one of the most promising sites for developing primate and forest-oriented ecotourism strategies.

The Awi Zone is home to five primate species: Boutourlini's blue monkeys (*Cercopithecus mitis boutourlinii*), black-and-white colobus monkeys (*Colobus guereza* spp. *guereza*), grivet monkeys (*Chlorocebus aethiops*), olive baboons (*Papio anubis*), and patas monkeys (*Erythrocebus patas*). It is also home to several other mammals: leopards (*Panthera pardus*), spotted hyenas (*Crocuta crocuta*), hares (*Lepus* spp.), bushbucks (*Tragelaphus scriptus*), klipspringers (*Oreotragus oreotragus*), crested porcupines (*Hystrix cristata*), bush hyraxes (*Heterohyrax brucei*), bushpigs (*Potamochoerus larvatus*), common warthog (*Phacochoerus africanus*), golden jackals (*Canis aureus*), and Gambian sun squirrels (*Heliosciurus gambianus*). In addition, the region is the habitat for a multitude of bird, butterfly, and snail species.

The forest patches of Awi Zone comprise four vegetation types: dry evergreen Afromontane forest, *Combretum-Terminalia* woodland, riverine vegetation, and lakeshore and flood plain vegetation (Friis et al. 2010). Some of the most dominant flora in this region include *Albizia schimperiana* (Apocynaceae), *Prunus Africana* (Rosaceae), *Albizia gummifera* (Fabaceae), *Apdoytes dimidiata* (Icacinaceae), *Croton macrostachyus* (Euphorbiaceae), *Ekebergia capensis* (Meliaceae), *Carissa spinarum* (Apocynaceae), *Deinbollia kilimandscharica* (Sapindaceae), *Erythrococca trichogyne* (Euphorbiaceae), *Vepris dainellii* (Rutaceae), *Celtis Africana* (Ulmaceae), *Maytenus arbutifolia* (Celastraceae), *Maytenus obscura* (Celastraceae), *Canthium oligocarpum* (Rubiaceae), *Rytigynia neglecta* (Rubiaceae), *Discopodium penninervium* (Solanaceae), and *Combretum paniculatum* (Combretaceae) (Berhanu 2017). Many of the tree specimens of the forest patches in this area are remarkable in that they are likely primary growth stems, with notable trunk width and height (Z. Kifle pers. obs.).

Data collection

Between Oct 2020 and Sep 2021, we surveyed seven of the nine *woredas* (local districts) in the Awi Zone, northwest Ethiopia. During this period, we examined 26 forest patches within these local districts. We used a direct observation method to determine the presence of each primate species in each forest patch. We used line transect surveys following Peres (1999), a method that involves searching forest patches along transects and recording all primate groups with a count of the number of individuals within each group. The surveys followed existing trails and rivers and tried to maintain a line transect methodology by following linear (or nearly linear) directions. Transects were 100–200 m apart and the length of each transect ranged from 0.5 to 1.5 km. We conducted surveys from 07:00 to 11:00 h in the morning and 14:00–17:00 h in the afternoon, walking transects at a maximum speed of approximately 1 km/h to minimize background noise and increase detection probabilities. Upon encountering a primate group, we waited up to 20 min prior to moving on, to increase the chance that we detect all group member. During this period, we recorded the species identity, group size, location of detection along the transect using a GPS device (Garmin GPSMap 62 s), altitude, forest locality name, and habitat type. We classified the habitat types as continuous and degraded forest and bushland. We defined the continuous forest as a natural forest with an intact canopy composed of large indigenous trees with less human disturbance. We identified the degraded forest as habitats consisting of mostly indigenous trees with more open areas and high human disturbance. We defined bushland as a habitat type dominated by woody shrubs and sparsely distributed trees with high human disturbance.

Using informal surveys through unstructured interviews with the local people and personal observations, we collected information on the threats to primates and their habitats, such as deforestation, logging, livestock grazing, firewood collection, charcoal production, and human–primate conflict. If there is a human–primate conflict around each forest patch, we asked the name of the primate species that damages crops in their localities.

Data analyses

We analyzed the data using descriptive statistics through SPSS version 20 software (IBM SPSS Inc., Chicago, IL, USA). We calculated encounter frequency by dividing the number of sightings of each primate species by the total number of sightings of all primates in all forest patches. The species encounter frequency indicates the broad trends of population abundances and is useful when density estimation is not the study objective (Marshall et al. 2008). We also calculated the average group size by dividing the total number of individuals of species by the overall number of encountered groups (Anderson et al. 2007). In addition, we qualitatively described threats to primates in the region.

Results

Primate diversity and distribution

We observed 26 forest patches in the seven surveyed *woredas* (Table 1; Fig. 2). In these forest patches, we recorded four primate species of Family Cercopithecidae (Table 1). These species were Boutourlini's blue monkeys (*Cercopithecus*

Table 1 Location visited during the study and presence of primate species

ID	Forest name	Habitat type	*Woreda*	*Kebele*	Latitude UTM	Longitude UTM	Altitude	Sighting primates	Sighting frequency
1	Bradi-Illala	CF	Gungue	Ambqi	236,284	1,202,430	1946	BM, CM, OB, GM	2, 21, 2, 3
2	Kambo	CF	Gungue	Ambqi	235,569	1,193,582	1979	BM, CM, OB, GM	5, 18, 2, 2
3	Gomera Keni	CF	Gungue	Linsadegera	236,722	1,204,761	1950	BM, CM, OB, GM	3, 11, 2, 2
4	Titar-Yedr	CF	Gungue	Ambki	239,349	1,200,628	2160	BM, CM, OB, GM	3, 16, 1, 1
5	Gisayta	CF	Zigem	Gisayta	231,352	1,200,505	2069	BM, CM, OB, GM	6, 23, 3, 2
6	Gubawuha	DF	Zigem	Gohanesh	232,143	1,193,862	2100	BM, CM, OB, GM	5, 20, 2, 1
7	Jomora	CF	Zigem	Jomora	241,707	1,190,889	1805	BM, CM, OB, GM	4, 12, 2, 1
8	Ardi	CF	AnkashaGugusa	Mesela	249,809	1,209,518	2010	BM, CM, OB, GM	2, 10, 1, 1
9	Donder	CF	AnkashaGugusa	Bakona	249,111	1,201,084	2098	BM, CM, OB, GM	3, 30, 2, 1
10	Shulala	DF	Gungue	Wayikela	246,116	1,208,813	2088	BM, CM, OB, GM	1, 8, 1, 1
11	Lasi-Korate	BL	Dangla	Gayita	270,454	1,235,915	2183	CM, OB, GM	4, 1, 1
12	Kondisha	DF	Dangla	Kondisha	262,252	1,237,792	2338	CM, OB, GM	4, 2, 1
13	Urang	BL	Fagta	Kilanj	273,755	1,232,516	2235	CM, OB, GM	2, 1, 1
14	Khatasa	CF	Fagta	Ayikalta	254,753	1,219,315	2335	BM, CM, OB, GM	3, 12, 3, 2
15	Tsarqu-Dagi	CF	Fagta	Chigoli	256,142	1,223,860	2315	BM, CM, OB, GM	2, 10, 2, 2
16	Dukume	CF	Banja	Kidamaja	245,521	1,215,189	2070	BM, CM, OB, GM	5, 24, 3, 1
17	Apini-Bari	CF	Banja	Zufariya	248,119	1,220,687	2165	BM, CM, OB, GM	5, 26, 2, 1
18	Tseharkan	CF	Gungue	Wayikela	248,705	1,210,756	2341	BM, CM, OB, GM	3, 24, 2, 2
19	Kurbe	DF	Gugusashekudade	Asukuna	285,117	1,198,485	2570	CM, GM	9, 2
20	Abli	BL	Gugusashekudade	Absla	283,771	1,196,460	2340	CM, GM	2, 1
21	Cherha	CF	Banja	Askunabo	252,792	1,217,120	2187	BM, CM, OB	3, 16, 2
22	Zemet	BL	Gugusashekudade	Wenjela	280,371	1,192,140	2333	CM, OB, GM	1, 1, 1
23	Barawja	CF	Gungue	Shashena	244,537	1,213,402	1865	BM, CM, OB, GM	2, 13, 1, 1
24	Goji	CF	Banja	Goji	251,472	1,214,962	2128	BM, CM, OB, GM	1, 7, 2, 1
25	Terba	DF	AnkashaGugusa	Terba	260,086	1,198,124	2260	CM, OB, GM	1, 2, 1
26	Zengena	DF	Banja	Kessa	277,340	1,207,049	2524	CM, GM	1, 1

CF continuous forest, *DF* degraded forest, *BL* bushland

mitis boutourlinii), black-and-white colobus monkeys (*Colobus guereza* spp. *guereza*), grivet monkeys (*Chlorocebus aethiops*), and olive baboons (*Papio anubis*) – locally called "baradli," "barajagni," "zagri," and "chocha," respectively. In addition, local people reported the existence of these four primate species in two unvisited *woredas (*Jawi and Azena*)*. Local administrators also informed us that patas monkeys (*Erythrocebus patas*) are located in the Jawi *woreda*.

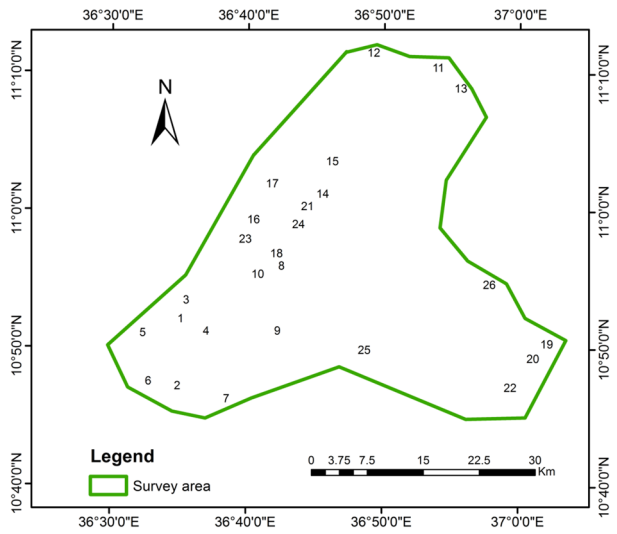

Fig. 2 The survey area and distribution of primate species at different forest patches in the Awi Zone, Ethiopia. The *numbers* represent the IDs and locations where the primate species recorded at each forest patch

However, we did not visit these two *woredas* due to political insecurity in the area.

We recorded 459 observational sightings of primate groups with different encounter rates (Table 2). Among these primate species, black-and-white colobus monkeys were the most frequently observed ($n = 325$ sightings), and grivet monkeys were the least ($n = 34$ sightings). Regarding relative encounter rate, black-and-white colobus monkeys had the highest encounter frequency (70.8%), followed by Boutourlini's blue monkeys (12.6%). We recorded Boutourlini's blue monkeys (range 14–39; mean = 26.1, SD = 5.6) in 69.2% (18/26) of forest patches (Table 2), while we recorded black-and-white colobus monkeys (range 5–16; mean = 8.8, SD = 2.5) in 100% (26/26) of forest patches. We also recorded 42 troops of olive baboons (range 4–60; mean = 41.4, SD = 8.9) in 88.5% (23/26) of forest patches. In addition, we counted a total of 1169 individuals of grivet monkeys in 96.2% (25/26) of forest patches. During our surveys, we observed grivet monkeys mostly around the forest edges. For most of our observations, Boutourlini's blue monkeys were associated sympatrically with black-and-white colobus monkeys and occasionally with olive baboons.

Threats to primates in the Awi Zone

Concerning the entire surveyed forest patches in the Awi Zone, we identified several threats to primate species and their habitats: habitat loss and fragmentation due to deforestation, exotic tree plantation (mainly *Eucalyptus* spp. and *Acacia decurrens*), and livestock grazing. Deforestation in the area results primarily from agricultural expansion. Trees are cut for firewood for personal use or sold to the local markets and for house construction (Fig. 3).

All surveyed forest patches are encircled by human settlements and farmlands and are highly fragmented. Consequently, these forests are under intense human pressure due to the high demand for farmable and grazeable land. Thus, they are intercepted by matrices of agricultural and livestock grazing areas. Subsistence agriculture is the most important means of livelihood for local farmers in the region (Z. Kifle pers. obs.). Therefore, it is perhaps the most pressing threat to biodiversity (Fig. 1).

Human–primate conflict is another threat to primates in the region. Local farmers reported that crop feeding is the most likely form of human–olive baboon conflict almost in all areas. They also claimed crop feeding by grivet monkeys in 25 sites, Boutourlini's blue monkeys in two, and black-and-white colobus monkeys in three. In one forest patch, we found an olive baboon group comprised of only four individuals due to the mass killing of their troop members. We asked residents about such mass killing of baboons, and they informed us that they stranded them in their sleeping trees, preventing them from feeding and drinking for three consecutive days until they weakened and starved to death. In addition, we observed locally made trap houses to capture and kill olive baboons due to agricultural conflicts at two sites (Fig. 4). We asked villagers how to capture primates using those traps. They informed us that they put maize inside the traps to lure the olive baboons, and when they enter these traditional traps to eat the maize, the gate of the houses shuts behind them. Then, the local people killed the trapped baboons using spears.

Table 2 Recorded sites, encounter rates, and frequencies and mean group sizes of the four primate species

Species common name	Recorded sites	Sighting number	Relative encounter frequency	Number of individuals	Group range	Mean group size
Black-and-white colobus monkeys	26	325	70.8%	2875	5–16	8.8 ± 2.5
Boutourlini's blue monkeys	18	58	12.6%	1512	14–39	26.1 ± 5.6
Olive baboons	23	42	9.2%	1738	4–60	41.4 ± 8.9
Grivet monkeys	25	34	7.4%	1169	20–46	34.1 ± 7.2
N = total	26	459	–	7294	–	–

Fig. 3 Threats to primates and their habitats in the surveyed forests, Awi Zone (Photo: Zewdu Kifle 2021)

Fig. 4 Villager making traps for crop feeding primates in the nearby surveyed forests, Awi Zone, Ethiopia (Photo: Zewdu Kifle 2021)

Discussion

Diversity and distribution survey

The distribution of most Ethiopian primates is poorly known. Only a few studies have been carried out on the diversity and distribution of primates across Ethiopia (Fufa et al. 2020; Mekonnen 2020); and this was first study to determine the composition and distribution of primate species in the Awi Zone of northwestern Ethiopia. In this field survey, we recorded four primate species in 26 forest patches at elevations ranging from 1805 to 2570 m a.s.l. (Table 1). Of these primates, Boutourlini's blue monkeys and black-and-white colobus monkeys are endemic to Ethiopia. These four primate species were not uniformly distributed across the visited forest patches of the region. For example, Boutourlini's blue monkeys were restricted to the 18 intact continuous forest patches. These may be due to the local extinction of Boutourlini's blue monkeys from the degraded forest patches we surveyed, where the other three primate species still exist. Thus, interspecific differences in tolerance to anthropogenic disturbance may affect the distribution of primate species in a region.

We are not the first study to find that Boutourlini's blue monkeys are restricted to intact forest patches. Tesfaye et al. (2013), Geleta and Bekele (2016), Fufa et al. (2020), and Mekonnen et al. (2020) also found that Boutourlini's blue monkeys occur in an intact tropical montane forest type of habitats. Similarly, Boutourlini's blue monkeys inhabit a relatively undisturbed and tree-dominated forest near Welele Mountain of Kellem Wollega Zone, Ethiopia (Fufa et al. 2020). We suspect that such dense forest type may be their preferred habitat compared to other local primate species. In addition, the feeding behavior and resource utilization may restrict them in dense forests. Therefore, we suggest that Boutourlini's blue monkeys might be incapable of living in small degraded forest patches and bushlands with sparsely growing trees.

In contrast, our findings indicate that grivet monkeys, black-and-white colobus monkeys, and olive baboons may be somewhat resilient in small degraded forest patches since we observed them in almost all surveyed forest patches. These species, therefore, appear to be much better adapted for habitat disturbance than the Boutourlini's blue monkeys. For example, Kifle (2021) reported the presence of grivet monkeys and olive baboons in Yeshum Valley, Wollo, a highly human-disturbed landscape. These two

primate species may adapt quickly to (and perhaps even thrive on) human-modified habitats due to their behavioral and ecological flexibilities. Olive baboons are omnivorous and exhibit several flexible behavioral strategies that allow them to inhabit different levels of human-modified habitat types (Fischer et al. 2019; Fufa et al 2020; Kifle 2021). Similarly, the Sulawesi Tonkean macaque (*Macaca tonkeana*), an Indonesian monkey, has shown an ability to thrive in forests converted to agricultural plantations by changing their food habits, activity patterns, and group size (Riley 2007).

In addition, we found that the encounter rate of primates was uneven in the region. For example, black-and-white colobus monkeys were the most frequently observed, and grivet monkeys were the least in the area. Black-and-white colobus monkeys are tolerant to occupying the small forest patches by forming multiple groups (Fashing 2022). The natural history traits (e.g., feeding habits, behavioral flexibility, habitat preference, and group and home range sizes) of primate species can determine their encounter rate. Studies also showed that life-history traits such as physiology, demography, ecology, and behavioral variations are factors that primates respond differently to environmental change and habitat degradation (Fleagle 2013; Rylands and Mittermeier 2014). In turn, these factors may cause some primate species to be vulnerable to local extinction (O'Grady et al. 2004; Hernández-Yáñez et al. 2022).

Threats to primates and forest patches

Although our preliminary data need to be supported by a formal survey in detail, they show a negative effect of human disturbances on the future survival of primates in the region. Grivet monkeys, olive baboons, and black-and-white colobus monkeys were recorded in disturbed habitats near human settlements: in remnant forest patches and bushlands nearby agricultural lands. Habitat fragmentation and degradation due to logging and conversion of forest habitats to agricultural lands are highly evident in the local extinction of many strictly arboreal primates (Estrada et al. 2017). Similarly, habitat fragmentation and degradation, unrestricted livestock grazing, firewood collection, and human–wildlife conflict are the major threats to primates in the Awi Zone. These factors may increase the risk of local extinction of primate species in the region. For example, at one forest patch, we found only four individuals of olive baboons due to mass killing through starvation in response to crop damage by the local people. Such retaliatory killings can affect the survival of primate species in an area. In addition, we found Boutourlini's blue monkeys in 18 of 26 surveyed forest patches. They were not recorded in any of the highly disturbed forest patches. Their distribution pattern appears restricted to continuous dense forest patches. Thus, the study shows that Boutourlini's blue monkey may be the most sensitive to human disturbance. If we use one of these species as an 'indicator' for forest health, we should focus on Boutourlini's blue monkey.

These threats not only directly lead to a decline in primate populations and a reduction in habitat size but also create a loss of habitat connectivity among populations, thus influencing their persistence in the region. Studies predicted that a small population is at high risk of extinction due to loss of genetic diversity and inbreeding depression (Salgado-Lynn et al. 2016). As for most other primates (Estrada et al. 2017), deforestation is the main threat, especially for strictly arboreal primate species (e.g., Boutourlini's blue monkeys and black-and-white colobus monkeys) in the Awi Zone. Many of our surveyed forest patches receive partial protection. These partial protections may help to stop further agriculture expansion through deforestation. Thus, upgrading these potential forest patches to national park status would help to ensure the long-term primate survival in their habitats (Pringle 2017).

In addition, human–wildlife conflict is another threat to primates in the Awi Zone. Grivet monkeys and olive baboons were consistently reported to be avid crop feeders across the entire surveyed areas of the region. Likewise, olive baboons are reported as the most destructive crop forager next to geladas (*Theropithecus gelada*) in Wollo, Ethiopia (Kifle 2021). Baboons are perceived to be worse than other crop-feeding primate species (Hill 2000; Warren 2008; Gataro and Tekalign 2021). Similarly, the crop feeding behavior of grivet monkeys is a routine source of conflict with local farmers in Ethiopia (Gebeyehu and Bekele 2009; Kifle and Bekele 2020b; Kifle 2021). Olive baboons and grivet monkeys are thought to be such successful crop pests because of their behavioral adaptability to changing habitats. Marchal and Hill (2009) also reported that the long-tailed macaque (*Macacafascicularis*) is perhaps the most destructive crop foraging species in north Sumatra, Indonesia, due to their behavioral adaptability to human-modified landscape.

Conclusions

This study provides crucial information on the diversity and distribution of four primate species and their conservation management implications inhabiting the Awi Zone, Ethiopia. We identified the region as an important areas for strictly arboreal primate species (e.g., Boutourlini's blue monkeys and black-and-white colobus monkeys) conservation. However, the forest patches of the primate habitats have experienced extensive habitat loss and degradation through anthropogenic activities. These threats are likely to be continued, threatening such strictly highly arboreal species to and their continual survival in the region. In addition, many of these primate species isolate from one another into small

meta-populations. Therefore, continuous undisturbed forests are undoubtedly inimitable and crucial for sustaining and conserving tropical biodiversity (Gibson et al. 2011) that includes these primate species. A regional landscape-level conservation plan that maintains forest patch connectivity and minimizes habitat loss and degradation should develop for primate conservation and their habitat. Thus, we recommend establishing strictly protected areas in the Awi Zone by making connections among nearby forest patches through wildlife corridors. The forest patches should also be enclosed for livestock grazing entrances to allow the regeneration of seedlings. The conservation plan should reduce the human impact on the forest patches by creating alternative job opportunities for local farmers like implementing modern bee farming to create economic benefit and promoting the use of biofuel to minimize cutting trees for firewood. In addition, the plan should include community educational awareness programs and community-based participation by coordinating local and district zone responsible offices. Thus, the concerned stakeholders should implement our solutions to conserve primates and their habitats in the Awi Zone. Finally, we suggest undertaking long-term ecological and behavioral research on the primate species and quantifying the nature of anthropogenic-related threats to primates and their habitats in more detail in the region.

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Declarations

Conflict of interest None.

Ethical approval Permission to conduct this research was granted by Amhara National Regional State Environment, Forest, Wildlife Protection, and Development Authority.

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