Population structure and distribution of geladas (Theropithicus gelada, Ruppell1835) in Kotu Forest, Northern Ethiopia

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Abstract

The populations of the endemic gelada outside protected areas are less studied and population estimates are not available. As a result, a study was conducted to investigate population structure and distribution of geladas in Kotu forest and associated grasslands, in Northern Ethiopia. The study area was stratified into five habitats namely; grassland, wooded grassland, plantation forest, natural forest and bushland based on dominant vegetation type. Each habitat type was further divided into blocks and total counting technique was employed to count the individuals of geladas. The total mean number of gelada in the Kotu forest was 229 ± 6.11. The mean ratio of male to female was 1:1.178. Age composition of geladas comprised: 113 (49.34%) adults, 77 (33.62%) sub adults and 39 (17.03%) juveniles. The mean group size of gelada was 18± 2.0, out of which 2.5± 0.5 (13.89%) was all- male unit (AMU) and 15.5± 1.5 (86.11%) was one male unit (OMU) social system. The average band size was 45.0± 2.53. The highest number of geladas was recorded from grassland habitat 68 (29.87%) and the lowest from plantation forest habitat 34 (14.74%). Even though, the sex ratio was female biased, the proportion of juveniles to other age classes was very low, indicating negative consequences for the future viability of the gelada populations in the area. Geladas were widely distributed over open grassland habitat. For sustainable conservation of the geladas in the area there is a need for integrated management of the area with special attention on the conservation of the grassland habitat.

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ABSTRACT

The populations of the endemic gelada outside protected areas are less studied and population estimates are not available. As a result, a study was conducted to investigate population structure and distribution of geladas in Kotu forest and associated grasslands, in Northern Ethiopia. The study area was stratified into five habitats namely; grassland, wooded grassland, plantation forest, natural forest and bushland based on dominant vegetation type. Each habitat type was further divided into blocks and total counting technique was employed to count the individuals of geladas. The total mean number of gelada in the Kotu forest was 229 ± 6.11. The mean ratio of male to female was 1:1.178. Age composition of geladas comprised: 113 (49.34%) adults, 77 (33.62%) sub adults and 39 (17.03%) juveniles. The mean group size of gelada was 18± 2.0, out of which 2.5± 0.5 (13.89%) was all- male unit (AMU) and 15.5± 1.5 (86.11%) was one male unit (OMU) *social system. The average band size was 45.0± 2.53. The highest number of geladas was recorded from grassland habitat 68 (29.87%) and the lowest from plantation forest habitat 34 (14.74%). Even though, the sex ratio was female biased, the proportion of juveniles to other age classes was very low, indicating negative consequences for the future viability of the gelada populations in the area. Geladas were widely distributed over open grassland habitat. For sustainable conservation of the geladas in the area there is a need for integrated management of the area with special attention on the conservation of the grassland habitat.*

Key words: Age sturcutre, habitat, group size, band size, sex ratio

Introduction

Geladas are large primates with dark brown to buff coarse pelage with dark brown faces and lighter, pale eyelids (Ankel- Simons, 2007). Females have a shorter pelage than males (Puff & Nemomissa, 2005). Adult males are larger than adult females and marked sexual dimorphism is the characteristics of the species, with adult females around two-third the size of adult males. Adult females weigh on average around 11 kg, while adult males weigh 18.5 kg (Jolly, 1972). The unique, distinct characteristics of gelada are the hairless hourglass-shaped pink or red area of the skin located on the chest (Yalden and Largen, 1992).

There are two sub-species of geladas that occur in Ethiopia. These are: *Theropithecus gelada gelada* and *Theropithecus gelada obscure.* The former occur in the northern highlands and the latter occur in the centralhighlands of Ethiopia (Yalden, 1983; Gippoliti, 2010). The differences between in *T.g. gelada* and *T.g. obscure* are minimal; there are a few visible differences. *Theropithecus gelada obscure* has darker coloured dorsal fur and flesh coloured face (Belay and Shotake, 1998). This sub species inhabits the north-western area of the Great Rift Valley in Showa (Menz, Debrelebanos and Muger areas), and in the Wollo and Gojjam Provinces (Yalden, Largen, & Hilman, 1996); Moges, 2015; Abie and Bekele, 2017). However, *Theropithecus gelada gelada* (Gippoliti, 2010), has a lighter fur appearance. This subspecies inhabits the northern highlands particularly in Simen Mountains National Park (SMNP) and associated highlands (Yalden et al., 1996; Boehner, Bergman & McCann, 2008; Ejigu and Bekele, 2014) and few populations recently reported from in the highalnds of Tigray (Girmay and Dati, 2020). According to Mori and Belay (1990) and Moges (2019), there is also sub population of gelada distributed in the southeastern part of the rift valley in the Arsi province near to Bale Mountains National Park. Some pilot survey showed that the Arsi gelada populations can be regarded as yet another distinct subspecies, *T. gelada arsi* (Belay and Mori, 2006; Gippoliti, 2010; Shotake, Aijunth, Agatsuma & Kawamoton, 2016; Zinner et al., 2018). Arsi gelada population lives in a lower- elevation habitat ranging from 1,800 to 2, 300 m asl (Belay and Mori, 2006; Moges, 2019). *Theropithecus gelada obscure* located in Wolo province is the current study species.

According to Mori and Belay (1990), the distribution of gelada population on the Ethiopian plateau is associated with the availability of easily digested montane grasses. Geladas occur between an altitude of 1800 and 4400 m asl. The Blue Nile gorge and the upper Shebelle rift valley (east of the Bale massif) mark the western and southeastern borders and the range correspondingly (Gippoliti and Hunter, 2008). The highest population of gelada occurs in SMNP (Beehner et al., 2008; Asfaw and Subramanaian, 2013; Woldegeoriges, 2015). The second largest population of gelada is found in GCCA) (Moges, 2015). More recently, , populations of gelada are reported from Wof-Washa Forest (Gosh-Meda Area), central Ethiopia (Goshme and Yihune, 2018) and from eastern escapments of Tigray (Girmay and Dati, 2020). Gelada population is limited to the highly grassland cliff in the deep gorges in the central plateau, of the south wollo in Azwa and Arego patches of valley forest and associated grasslands (Ayalew, 2009), north wollo specifically, in Mount Abune Yosef community conservation area (Eshete et al. , 2015), in Gondar area (Yalden et al., 1996), Borena Sayint National Park (Denknore forest) (Adem, 2009; Kifle, 2018) and population of gelada also occurs in the Wonchit valley in Amhara regional state between north shoa and south wollo (Kifle, Belay & Bekele, 2013). The southern isolated population of gelada is distributed over valley and forest escarpments of Robe, Amigna and Bele districts (woreda) in Arsi zone (Abu, 2011; Moges, 2019).

The population size of gelada in different parts of Ethiopia is surveyed with the help of direct counting method and population estimate is available for its well known ranges. According to Beehner et al.(2008), in the SMNP, the population size of gelada estimated to be about 4620 individuals. The GCCA population estimate is 1502 individuals of gelada (Moges, 2015). The population in and around Borena Sayint National Park (Kifle, 2018), Azwa and Arego forest patch (Ayalew, 2009), Wof-Washa forest (Gosh Meda area) (Goshme and Yihune, 2018), Debrelibanos highlands (Abie and Bekele, 2017) and Arsi (Robe, Amigna and Bele districts) (Moges, 2019) were estimated to be 2786, 914, 435,1608 and 1315 individuals respectively. A recenty survey in estern escarpments of Tigray estimated the poulation of gelada around Hawzien and Ganta-Afeshum to be 105 individuals (Girmay and Dati, 2020). According to the gelada population estimate above in its different ranges, the current gobal poulation estimate is about ten thousand individuals. However, Beehner et al. (2008), estimated the global population estimate of gelada over all its potential ranges from 50,000 to 60,000 individuals indicating wide gap in population estimate that imply poulations in most of its ranges remain unexplored.

Geladas that live in protected area received high conservation attention and have been studied very well at different time by different researchers (Hunter, 2001; Beehner et al., 2008 and WoldeGeorgis, 2015). However, populations of gelada have been known to face habitat degradation, fragmentation and loss throughout its range (Yihune, Bekele & Tefera, 2009; Andarge, 2010; Moges, 2015; Abi and Bekele, 2017). Particularly, populations of gelada that lived outside protected area receive little conservation attention (Kifle et al., 2013) and there is no sufficient study on such small fragmented forest habitat of the endemic primates that serve as population stock source with significant economical, ecological, social and cultural values. The gap between the total population estimate (50,000 to 60,000 individuals, Beehneret al. 2008) and the population clearly estimated so far is wide, indicating to explore all possible ranges of the species to come to sound global population estimate.

In the present study area (Kotu forest) anthropogenic activities such as livestock encroachments, logging and firewood collection are causing habitat degradation and fragmentation of the habitats of gelada in particular and wildlife in general (DelantaWoreda Agricultural and Natural Resource Development Office (DWANRDO), 2016). Furthermore, there is an active mineral (Opal) extraction activities going on in the area that degrades the habitat of the gelada. This mineral naturally occurs embedded within a rock in the cliffs (Rondeau et al., 2010), which are ideal habitat for gelada in providing cover against extreme temperatures, predator and serve as breeding sites. As a result, the active extraction of the mineral is severely reducing the cover requirement of the species. At the mean time , there is no exact population estimate of the geladas and information on population distribution of gelada among dominant habitat types.

In the field of population ecology accurate population estimates of wild animal populations are essential for a number of reasons. Primarily, population estimate across a time will help to determine whether the numbers of particular species in the given habitat are being maintained, in decline or in recovery (Beehner et al., 2008). Secondly, establishing accurate numbers for each species is a first step in conservation and to draft effective wildlife policy. Thirdly, it is also important to estimate the wildlife population and describe its distribution for managing human-wildlife conflict in and around protected areas and outside protected areas. Therefore, the present study is aimed at determining the population size and population distribution of geladas among dominant habitat types of Kotu Forest nexus for sustainable population conservation.

Methods

Study area

Kotu forest is located in Delanta district, South Wollo Zonal Administration of the Amhara National Regional State of Ethiopia (Fig. 1). It is located at a distance of 499 km north of Addis Ababa. Kotu forest geographically lies between 11*30'45 " N to 11*35'45"N latitude and 39*11' 50" E to 39* 14'10" E longitude (Fig. 1). The total area of the forest is 1374 ha (Table 1) with an altitude ranging from 2771- 2987 m asl. The study area is geologically characterized by extensive escarpment plateaus, hills with small mountainous ridges and gorges. Cambisols, vertiosols and leptosoils are the dominant soil types in the area (DWANRDO, 2016). The mean average temperature of the study area is 13^{0}C with maximum temperatureof 19.8^{0}C and with annual mean minimum temperature of 6.8^{0}c (Ethiopian National Meterological Agency (ENMA), 2017). The study area is characterized by bimodal rainfall distribution patterns; with a long rainy season from June to October and a minor rainy season from March to May. It receives the highest rainfall (75-80%) during the long rainy season (ENMA, 2017) and 20-25% rainfall during the short rain season. The area comprises five dominant habitat types namely; grassland, wooded grassland, natural forest (dry evergreen Afromontane forest), plantation forest and bushland. *Acacia abysinica, Acacia salingna* , *Acacia decurrens* , *Olea europaea* , and *Juniperous procera* are among the dominate tree species in the study area (DWANRDO, 2016).

Grassland

This habitat is locally named "Ambanat". This habitat is dominated by grass species. The grass species often cosumed by the geladas such as*Cynodon aethiopicus* , *Andropogone abyssinicus* ,*Pennisetum clandestinum* , *Digitaria abyssinica* are predominatly cover in this habitat type. Its altitude ranges from 2900 to 2987m asl. In this habitat type there are permanent water sources and sufficient food resources better than any other habitat type. However, illegal livestock grazing and grass cutting are widely practiced especially during the wet season (DWANRDO, 2016).

Wooded grassland

This habitat type is dominated by grass species with scattered*Acacia spp* . The dominat grass species in this habitat type that are consumed by geladas are *Cynodon aethiopicus, Pennisetum clandestinum, Sporobolus pyramidalis etc.* The habitat type is locally called "Minch" (local mean spring, due to its your round source of water). Its altitude is within the ranges of 2872 to 2901 m asl. In this site cutting of *Acacia spp* . for charcoal production was frequently observed (DWANRDO, 2016).

Plantation forest

This habitat type is dominated by plantations of *Juniperus procera* with intermixed grass and shrub species in understory vegetation. In this habitat type grass species consumed by the galdas such as *Andropogone abyssinicus* and *Sporobolus pyramidalis*are found sparsely. Its altitude ranges from 2902 to 2969 m asl. The habitat is locally called "Chichet". In this habitat, human disturbance is intense due to increased availability of logging trees such as *Juniperus procera* and availability of the mineral Opal (Rondeau et al. 2010). There was an illegal cutting of trees such as*Juniperus procera* by the local communities for household consumption and for sell in the local market. The local community also constantly destructs the rocky cliff refugees of the gelada in search of the mineral Opal in the rock cracks (DWANRDO, 2016).

Natural forest (dry evergreen Afromontane forest)

This habitat type is situated within an attitudinal range of 2771 to 2810 m asl. It is locally named "Embsareh" (locally mean*Allophylus abyssinicus, Allophylus abyssinicus* is fairly abundant in this habitat type). Herb species consumed by the geladas such as*Trifolium temnense* , *Thymus schimperi* and*Plantago lanceolate* intermixed with scatter grass species such as*Andropogone abyssinicus* spersely cover the understory vegatation. The habitat is dominated by tree species such as*Acacia spp, Olea europaea, Juniperous procera* and*Allophylus abyssinicus* with some bushes and grasses forming the understory vegetation (DWANRDO, 2016).

Bushland habitat

Bushland is locally named "Berwsirt". Its altitude ranges from 2825 to 2891 m asl. This habitat type comprises deciduous and evergreen shrubs mainly *Dedonaea viscose* intermixed with grasses and other herbaceous vegetation forming the understory. Herb species consumed by the geladas such as *Trifolium temnense* and *Plantago lanceolate* are rarely found (DWANRDO, 2016).

Sampling design and data collection

The study area was stratified into five dominant habitat types based on the dominant vegetation types (Figure 2). The area coverage of each habitat type was as follows; grassland (336 ha, 24.45%), wooded grassland (226 ha, 16.45%), natural forest (dry evergreen Afromontane forest) (243 ha, 17.69%), plantation forest (251 ha, 18.27%) and bushland (318 ha, 23.14%). Proportional to the area coverage of each habitat type, each habitat was further subdivided in to counting blocks. Grassland and bushland habitats were sub divided in to 6 and 5 blocks respectively, whereas plantation forest, natural forest and wooded grassland were subdivided into 4, 4 and 3 blocks respectively. Each habitat type was subdivided into counting blocks using natural boundaries and marks such as mountains, cliffs, springs, valleys, etc.

Data collection was carried out from August 2017 to February 2018 covering both dry and wet seasons. The wet season data collection was carried out from August 2017 to October 2017 and the dry season data collection was carried out from December 2017 to February 2018.

Total count method was employed to census the population of gelada in the study area. Total count method has been widely practiced to census the population of geladas over its ranges (Beehner et al. , 2008; Adem, 2009; Ayalew, 2009; Abu, 2011; Kifle et al., 2013; Moges, 2015; Goshme and Yihune, 2018; Girmay & Dati, 2020), due to their behaviour to live in open habitat that increases visibility and due to their highly mobile nature. The total census was carried out in each habitat type on foot simultaneously from a suitable vantage points or by moving along the habitat through involving well trained people in each habitat types to avoid double counting problems (Fashing and Cords, 2000; Mekonen, Bekele, Hemson & Alemu 2010). Since the simultaneous counting of the individuals geladas demands the involvement of groups of people, in each of the five habitats and counting sub blocks; people from the locality were selected and trained. A total of 40 people were involved in the data collection. One day theoretical and two days practical (on site) training was given to the trainees on the methodology of counting geladas, age and sex identification techniques as per following Beehner et al. (2008). All trainees' received a secondary school education and had prior experience about the species identification and its behavior. A census was conducted only when gelada start moving to the cliff edge and no individual remained on the cliff-edges following Hunter (2001). All gelada population counting was conducted on the same day and at the same time during early morning (7:00 to 11:00 a.m.) following Beehner et al. (2008) and Mekonen et al. (2010).

Determination of age and sex structure was carried out according to the procedures of Beehner et al. (2008). The sex and age of individuals of gelada were identified based on body size and developmental characteristics of individual gelada in the troop, this was done using 7x40 Binocular and with the naked eye through direct observation of individuals of geladas. Adult gelada males were identified by their visible manes and their size about twice bigger than that of adult gelada females. Sub adult males were defined as males equal in size to adult females gelada, but with partially developed mane. Sub adult female geladas were distinguished from adult females due to the smaller body size (Beehner et al., 2008). Young geladas sex identification was found difficult, so were recorded as juvenile with no sex discrimination. In addition, the group composition and size of the group were recorded before treating the group in to respective age and sex categories and recorded on a separate date sheet as: adult males, adult females, sub-adult males, sub-adult females and juvenile (young). A group of gelada is a multilevel social order that consists of individuals of gelada usually composed of a leader male, several adult females, and their offspring (Gippoloti and Hunter, 2017). Those individuals seen within a distance of < 50 m from the nearby group was recorded as members of the same group. One-male units (OMUs) group is defined as a group of gelada that consist of a leader male, several adult females, and their offspring. Whereas, all-male units (AMUs) group is defend as group of gelada that composed of 2–15 males (Gippoloti and Hunter, 2017). A band of gelada is defined as group of geladas that is made up of two to 27 reproductive units and several all-male units (Gippoloti and Hunter, 2017).

To determine the distribution pattern of gelada intensive ground inspection was conducted in each habitat type and in each block during the continuous daily counting time periods following Groves (2005). The GPS location (coordinate points), group size, altitude and habitat type were recorded. During the survey 6 to 8 coordinates points of all non-over lapping range groups of geladas were recorded.

Data analysis

Statistical Package for Social Science (SPSS) version 16 computer software program was used for all statistical analysis. All statistical tests were two tailed with 95% of confidence intervals and the rejection level were (P [?] 0.05). Mann- Whitney- U test was used to test the population count among wet and dry seasons. Chi square test was used to test the association of population density with season (among dry and wet seasons). One way ANOVA was used to test the variations in population structure (age and sex structure) among seasons. During the total count identifying the group of gelada and counting the number of individual that form the group was a base for estimating the population density of gelada in the study area (Bocian, 1997).

$$\text{Population Density} = \frac{Number\ of\ individuals\ that\ were\ counted\ in\ the\ area \ldots\ldots\ldots Eq\ 1}{\text{Total area}}$$

The population density of each habitat type in both wet and dry season was calculated and expressed as the number of individuals per km^2.

Non overlapping ranges of groups of baboons were mapped using coordinates collected using GPS and using the help of Arc GIS software. In addition, the population count at each dominant habitat type was used to describe the distribution pattern. To determine the distribution pattern of wild animal populations, different researcher used the relative frequencies of observation of the animal in each habitat type (Yazezew, Mamo & Bekele, 2011; Abie and Bekele 2017; Goshme and Yihune 2018).

RESULTS

Population size and density

The total mean number of gelada in the Kotu forest was 229 ± 6.11. They were 259 ± 6.77 and 198 ± 5.44 individuals of gelada during the dry and wet seasons, respectively. There was significant variation in population size between wet and dry seasons (U= 1330.0, P= 0.001). The mean population density of gelada in the study area was 16.63 ± 2.21 individuals per km^2 (Table 1). The population density of gelada was 14.41 and 18.85 per km^2 during the wet and dry seasons, respectively.

Age and sex structure

Out of the total mean number of 229 ±6.11 individuals of the gelada encountered in the study area, females comprised 121± 18.8 (52.84 %) individuals and males 69± 5.0 (30.13%) individuals, whereas 39 individuals were juveniles with undetermined sex (Table 2). The number of females was significantly higher than males (χ^2= 14.23, df= 1, P= 0.000). There was higher number of female individuals during dry (140 ± 16.10) season than the wet season (102.0± 13.10). Out of the total mean individuals of geladas recorded in the study area adult, sub adult and juvenile constituted 113 (49.34%), 77 (33.62%) and 39 (17.03%) respectively. The adult: subadult: suvenile ratio is 2.8:1.9:1.

There was a significant difference in age/ sex classes in the population of geladas ($F_{4\ 20}$ =7.279, P= 0.001). The population was dominated by adult females (75 ±10.90), while sub adult males (31 ± 1.75) were least represented (Table 2). Adult females comprised the highest proportion of geladas during both dry (86 ± 2.67, 33.20%) and wet (64 ± 1.88, 32.32%) seasons (Table 2). On the other hand, sub adult males comprised the least proportion of geladas during both dry (32 ± 1.02, 12.36%) and wet (29± 0.86, 14.64%) seasons (Table 2). There was a significant difference of age/ sex classes during both wet ($F_{4\ 20}$ = 4.948, P= 0.006) and dry ($F_{4\ 20}$= 4.948, P= 0.000) seasons. The mean male to female sex ratio was 1:1.78. The average ratio of adult male to adult female was 1:1.96 (Table 3).

Group size and composition

The mean group size of gelada was 18± 2.0, out of which 2.5± 0.5 (13.89%) was all- male unit (AMU) and 15.5± 1.5 (86.11%) was one male unit (OMU) social system. During the wet season, 16 groups were encountered, out of this 2 (12.5%) was AMU (bachelor and sub adult male) and 14 (87.5%) was OMU social system. During the dry season, 20 groups were recorded, out of which 3 (15%) was AMU and 17 (85%) was OMU social system.

The average maximum group size of AMU was 11.5± 0.5 and the average minimum group size was 3.5± 0.5. During the wet season, the maximum group size of AMU was 11 and the minimum was 4. Whereas, during the dry season, the maximum group size of AMU was 12 and the minimum was 3. On the other hand, during the dry season, the maximum group size of OMU was 17 and the minimum was 6. Whereas, during the wet season, the maximum group size of OMU was 13 and the minimum was 7. The average band size was 45.0± 2.53. The band size during the wet season was 2-4 adult male geladas with their follower up to 60 individuals aggregated together. On the otherhand, during dry season, the band size and compostion comprised, most of a time 2- 8 adult males with its follower maximum up to 110 individuals of geladas.

Population distribution pattern

Populations of gelada were not uniformly distributed over the study area among doimant habitat types. The highest number of gelada was observed in grassland habitat 68± 8.0 (29.87 %), while the least were recorded in plantation forest habitat 34 ± 4.5 (14.74%) (Table 4). Simlarly, the highest density of geladas was recorded in grassland habitat (4.96 ± 0.56), while the least was in plantation forest (2.45 ± 0.29) (Table 1). There was significant difference in the number of geladas among habitat types (χ^2= 15.913, df= 4, P= 0.003). Significant variation in the number of geladas was observed among habitat types during both wet (χ^2=14.980, df= 4, P= 0.005) and dry (χ^2=17.699, df=4, P=0.001) seasons. During the wet season, 16 groups of geladas comprising 198 individuals' were recorded in Kotu forest (Fig. 3). Out of these, the highest number of groups 5 (31.25% were recorded from grassland habitat and the lowest groups 2 (12.50%) in the plantation forest (Fig. 3). During the dry season, 20 groups comprising 259 individuals were recorded. During the dry season, the maximum numbers of group 6 (30.0%) were recorded from grassland habitat and the minimum group number 2 (10.0%) from natural forest.

Discussion

The study has revealed that the study area supports a viable population of geladas, though isolated from other sub populations in south and north wollo administrative zones. However, the area supports fewer sub population of gelada (mean population size 229) as compared to other ranges of gelada (Beehneret al. 2008, 4620 individuals SMNP; Adem 2009, 529 individuals ; Ayalew 2009, 914 individuals; Abu 2011, 338 individuals; Moges 2015, 1502 individuals, Abie and Bekele, 2017, 1608 individuals and Goshme and Yihune 2018, 435 individuals). This could be attributed to the fact that the area is the smallest area as compared to its other ranges and the habitat is characterized by ravine topography, which opens in to farm lands in all directions and more drier and with less habitat quality as compared to other ranges in comparison. Furthermore, threats such as habitat destruction in search of the mineral opal and deforestation, retaliatory kill against crop damage, which are intense in the present area (DWANRDO, 2016) as compared to its other ranges, could reduce the population size. However, the population size is larger than the recent report from estern escarpments of Tigray (Hawzien and Ganta-Afeshum districts) 105 individuals (Girmay and Dati, 2020). This could be due the fact that the range of species in Tigrai are more drier and with poorer habitat quality.

Significantly higher population of gelada was recorded during the dry season that the wet season unlike the populations of the species over its some other ranges. For example, there was no significant seasonal variations in populations of gelada in Gich, SMNP (Woldegeorgis, 2015), Debrelibanos, central Ethiopia (Abie and Bekele, 2017), Wof washa, central Ethiopia (Goshme and Yihune, 2018), eastern escarpments of Tigray (Girmay and Dati, 2020). This is mainly attributed to the reproductive and crop raiding behavior of the species and the weather condition at the particular study area. Normally, geladas give birth after wet seasons, during early dry season (Ejigu and Bekele, 2014). This could increase the number of youngs in the following dry season ultimately increasing the total population during the dry season. The most plausible explanation comes from the fact that there is intense agricultural encroachment in the surrounding habitat of the species in the present study area and wet season is a crop growing season, geladas were observed to widely involve in crop raiding behaviour during the wet season. Gelada is identified as one of a crop raider primate over most of its ranges (Yihune et al., 2009; Moges, 2015). The diet of geladas is predominantly composed of grasses and rhizomes (Moges, 2015). However, cereal crops may be taken as an alternative food source where agriculture encroaches onto the habitat of the gelada (Yihune et al., 2009). Due to crop raiding behavior during the wet season, farmers chase away geladas from their habitats bordering farmlands in to nearby cliffs using guard animal like dogs and stone at geladas to protect crop damage, which could reduce the sighting of the animals during wet season. During the dry season, crops are harvested and this enables geladas to roam freely among all habitat types. Similarly, Kifle et al. (2013), recorded fewer individuals of geladas during the wet season than dry season in Wonchit valley and discussed that this could be attributed to the fact that wet season is a cultivation season and hence, farmers have to chase away geladas far away from cropland and most of their open habitat types. Furthermore, the foggy weather conditions during wet season as compared to a bright sunny day during the dry season could reduce the sighting of the animals during the wet season. The study area receives 75- 80% rainfall during the wet season (ENMA, 2017). This high amount of rainfall and fog could affect the probability of detection of individuals' gelada in the study area. Hunter (2001), reported that excessive rainfall causes stress among geladas population and geladas to overcome this heavy rainfall they aggregate themselves in their cliff.

In addition, human disturbances like firewood collection, opal mining, grass cutting and livestock encroachments were higher during the wet season than the dry season in the study area. When farmlands were covered by crops during wet season, livestock moved into the habitats of geladas for the sake of better foraging opportunities. This introduces disturbances and competition for forage sources that could reduce the probability of detection of gelada individuals during wet season. During the wet season, human disturbance and livestock encroachments are higher than the dry season over most highlands of Ethiopia (Hassain, Asghar, Frid & Nurberdief, 2008; Girma, Bekele & Graham, 2012). Furthermore, other disturbances such as firewood collection, grass cutting and opal extraction (Rondeau et al., 2010) are more frequent during the wet season than the dry season. During the wet seasons, farmers are relatively free from their routine farm activities and have time to get engage in activities such as firewood collection, grass cutting and opal extraction, which is peculiar only to the range of gelada under study. Moreover, during the wet season there are no incomes from crops and hence, they have to engage in any other economic activities to meet household economic demand (DWANRDO, 2016). All these increase disturbances during the wet season that reduce the sighting of the animals during the wet season.

Understanding of sex and age composition of wild animal populations is important for evaluating the viability of the species as these variables reflect the structure and the dynamics of wild animal population (Wilson et al., 1996). The male to female gelada sex ratio in the study area revealed female biased ratio (the adult male to female ratio is 1:1.96). The result is consistent with other studies (e.g. Woldegeoriges (2015) (the adult male to female ratio is 1:3) at Gich area of the Simen Mountain National Park, Abie and Bekele 2017 (the adult male to female ratio is 1:3.57) at Deberelibanos highlands, central Ethiopia and Moges, 2019 (the adult male to female ratio is 1:4.1 in Arsi). The female biased ratio is a characteristic of naturally growing population under normal circumstances (Beehner et al., 2008). Secondly, the reduced number of male geladas could be attributed to retaliatory killings induced by the species involvement in intense crop raiding behavior and presence of predators. Kifle et al. (2013), reported that the numbers of males in Wonchit valley were small due to similar crop raiding behavior and retaliatory killing. In addition, the natural predator caracal*(Files carcal*) has been observed to be frequent over most of the habitats of gelada. Caracal could potentially prey on adult and sub adult males that usually behaviorally isolate them from the main groups of gelada and roam freely. Similarly, Roberts and Dunbar (1991) reported that the male, especially bachelors and sub adult male geladas are always vulnerable to predators. However, the reduced number of females as compared to above studies carried out elsewhere over the ranges of geladas could indicate predicts reduced population growth and signal for immediate conservation attention.

Unequal mean ratio of juveniles to other age class in the study area was observed. The possible reason of the small proportion of juveniles in the study area could be less availability of food resource (due to anthropogenic activities) that limits reproduction in the study area as discussed above. Dunbar (1987), discussed that food resource availability negatively correlates with the birth rate of gelada population. Furthermore, the presence of natural predators such as common jackal in the study area could reduce the juvenile population. Common jackals were seen frequently moving between habitat patches looking for prays. Juveniles at this stage are vulnerable towards predators. Furthermore, unproductive female geladas may exist in the population that could reduce the population of juveniles. Dunbar (2002), revealed that the existence of unproductive female gelada attributes to the existence of the small number of juveniles in gelada populations.

The mean group size (11.5) of gelada at Kotu forest was higher than Chenek, Simien Mountains National Park (10.5) (Ejigu and Bekele, 2014), Wof Washa Forest (Goshme and Yihune, 2018), Borena Saynit National Park (Kifle, 2018), and Guassa Community Conservation Area (8.9) (Mamo and Wube, 2019). However, fewer average group size than Gich, SMNP (15.4) (Woldegeorgis, 2015) and Arsi (14.9) (Moges, 2019). According to Ohsawa and Dunbar (1984), mean group size in geladas is mainly dependent on the social factors that are related to group congregation. Variations in group size are the results of cost and benefits of group congregation mainly associated food and predators availability (Majolo, Vizioli and Schino, 2008; Ejigu and Bekele, 2014). Generally, larger groups benefit from defending predators and smaller groups benefit from less competion for food. The relatively higher mean group size of geladas in the present study area is probably attributed to the risk of predation from carnivores such as caracal that were observed to frequently prey on geladas during the study period. On the other hand the higher group size and band size during dry season than wet season could be due to crop raiding behaviour during dry season. During dry season crop are harvested and could congregate to feed on crops and crops residue, specially during early dry season (Kifle et al., 2013). During the dry season predation risk could be minimized due to absence of foggy weather, presence of open habitat that increase vigilance. It has been reported that group size increases during dy season as there will not be partial restrictions (Beehner et al., 2008). However, the findings of the study contradict with findings of other similar studies elsewhere over the ranges of geladas that stated that the higher mean group size occurred during wet season than dry season (e.g. Abie and Bekele 2017; Goshme and Yihune 2018). This could be explained due to variations in food availability, climatic conditions and level of threats among the study areas and the above cited literatures.

The distribution pattern of Gelada in the study area was not uniform, varied depending on the food and water availability. The highest number of Gelada was recorded in the open grassland habitat while the least was in plantation forest habitat. It is known that the diet of geladas predominantly comprises grass species (Moges, 2019). As indicated in the study area description grass species highly preferred by the geladas such as *Cynodon aethiopicus, Andropogone abyssinicus, Pennisetum clandestinum* (Moges, 2015) are commonly abundant in the grassland habitat, while they are very scarce in plantation forest. Furthermore, the grassland habitat also offers permeant source of water for the geladas. The result is in line with other studies such as Dunbar (1992), Abi and Bekele (2017) and Goshme and Yihune (2018). The grassland habitat preference is attributed to the better availability food and water sources and increased vigilance effect. The open nature of the habitat enables gelada to take a measure to avoid predators by visual communication. Studies over different ranges of geladas concluded that open grassland is the most preferred habitat of geladas. This is attributed to the fact that grasses and rhizomes comprise the predominant diet of geladas (e.g. Dunbar 1987, 92; Moges, 2015)

Conclusion and recommendations

The study revealed the presence of isolated populations of endemic geladas at Kotu forest and associated grasslands. The population sex ratio was female biased, indicating potential of population growth, through adding new individuals in to the population. However, the proportion of juveniles to other age class was very low. Such a small number of juveniles will have negative consequences for the future viability of the gelada population in the study area. Geladas distribution is highly governed by water, food and cover availability and quality and presence of threats. As a result, open grassland habitat is the most preferable habitat in the study area. For sustainable conservation of the geladas in the study area there is a need for integrated management of the area with special attention on the conservation of the grassland habitats and rocky cliffs. Disturbances such as livestock grazing, firewood collection and opal extraction should be halted if possible or managed well. There is also a need for declaring the area as a protected area interconnecting with other ranges of geladas in the surroundings.

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Conflict of interests

We the authors declare no competing interests.

Author contribution

Degu Abate : Data curation (lead); Investigation (equal); Methodology (supporting); Writing-original draft (supporting).**Zerihun Girma** : Conceptualization (lead); Formal analysis (equal); Methodology (equal); Project administration (lead); Supervision (lead); Writing-original draft (lead); Writing-review & editing (lead).

Data Availability Statement

I will here confirm that I will avail the data that support the findings of this study up on request after publication of the manuscript. Particularly, the data that support the findings will be available by the file name Endemic gelada at Zenodo data repository after publication.

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List of Figures

Table 1 . The population density of Gelada in each habitat type during wet and dry seasons at Kotu forest (Mean± SE)

Local names	Habitat type	Population density per Seasons	Population density per Seasons	Mean population de
		Wet	Dry	Mean ± (SE)
Ambanat	Grassland	4.38	5.53	4.96 ± 0.56
Minch	Wooded grassland	2.88	3.78	3.33 ± 0.45
Chichet	Plantation forest	2.16	2.74	2.45 ± 0.29
Embsareh	Natural forest	2.33	2.91	2.62 ± 0.29
Berwsirt	Bushland	2.66	3.89	3.27 ± 0.62
Total		14.41	18.85	16.63 ± 2.21

Table 2 Age and sex structure of Gelada population during wet and dry seasons (Mean ± SE) in Kotu forest.

Age and sex categories	Wet season Population abundance	Dry season Population abundance	Total Mean
Adult male	34 ± 0.78	42 ± 0.74	38 ± 4.10
Adult female	64 ± 1.88	86 ± 2.67	75 ± 10.90
Sub adult male	29 ± 0.86	32 ± 1.02	31 ± 1.75
Sub adult female	38 ± 1.40	54 ± 1.39	46 ± 7.90
Juveniles	33 ± 0.97	45 ± 1.14	39 ± 5.85
Male	63 ± 2.50	74 ± 5.10	69 ± 5.00
Female	102±13.10	140 ± 16.10	121± 18.8

Table 3. Age and sex ratio of gelada baboon during the wet and dry seasons at Kotu forest

Age and sex ratio

Season	AM :AF	SAM:SAF	SAM:AM	SAF:AF	JUV:AF	M:F
Wet	1:1.88	1:1.31	1:1.17	1:1.69	1:1.94	1:1.64
Dry	1:2.04	1:1.69	1:1.24	1:1.59	1:1.91	1:1.89
Mean	1:1.96	1:1.50	1:1.21	1:1.64	1:1.91	1:1.78

Notes : AM: Adult males, AF: Adult females, SAM: Sub-adult males, SAF: Sub- adult females, JUV: Juveniles, M: Males and F: Females.

Table 4 Population abundance of geladas among different habitat types during wet and dry seasons in Kotu forest.

Habitat type	Abundance per season		Total (mean± SE)
	Wet (mean± SE)	Dry (mean± SE)	
Grassland	60 ± 1.89 (30.40%)	76 ±2.88 (29.34%)	68 ± 8.0(29.87%)
Wooded grassland	40 ± 1.58 (20.00%)	52 ± 1.63 (20.00%)	46 ± 6.0 (20.00%)
Plantation forest	29 ± 0.66 (14.95%)	38 ± 0.97 (14.52)	34 ± 4.5 (14.74%)
Natural forest	32 ± 1.62(16.16%)	40 ± 1.48 (15.44%)	36 ±4.0 (15.80%)
Bushland	37 ±1.44 (18.48%)	53 ± 2.40 (20.54%)	45 ± 8.0 (19.51%)

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`Figure 2. Eco and Evo. docx.pdf` available at https://authorea.com/users/397521/articles/510372-population-structure-and-distribution-of-geladas-theropithicus-gelada-ruppell1835-in-kotu-forest-northern-ethiopia