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Review

Population Dynamics and Feeding Behavior of Gelada (*Theropithecus gelada*) in Ethiopia.

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Abstract: Gelada (*Theropithecus gelada*), endemic to Ethiopia, is unique among old-world monkeys, specifically adapted to Afroalpine and sub-Afroalpine grasslands and rocky gorges. Although different studies have investigated its population dynamics and feeding ecologies, the species global population status and behavioral ecology remain understudied. This review synthesizes findings from 13 peer-reviewed studies published between 2009 and 2024 to analyze gelada population dynamics and feeding behaviour. The estimated total population of gelada in Ethiopia is approximately 29,969 individuals, with 62.90% residing in the Simien Mountains National Park. Gelada predominantly inhabits sub-Afroalpine ecosystems (68.1%), followed by forests (28.8%) and Afroalpine ecosystems (3.1%). Most gelada populations (76.32%) are found in protected areas, whereas 23.68% inhabit unprotected regions. It exhibits complex social structures, forming groups from one male units to large communities, with group sizes varying from 7 to 154 individuals on average. Its diet is diverse, consisting of grasses, sedges, forbs, shrubs, roots, tubers, fruits, cereal crops, and invertebrates, which varies based on habitat type. The global gelada population is declining due to multiple threats, highlighting the urgent need for conservation strategies that integrate both protected and unprotected habitats. Strengthening conservation efforts is crucial to ensuring the long-term survival of this endemic primate species.

Keywords: Abundances; Distribution; Feeding Behavior; Gelada population; Social Organization.

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1. Introduction

Ethiopia endowed with around 39 endemic mammal species, including two unique primates: the gelada (*Theropithecus gelada*) and the Bale Mountains vervet monkey (*Chlorocebus djamdjamensis*) (Yalden, 1977; Gippoliti, 2010; Bekele and Yalden, 2013). Gelada, the only surviving *Theropithecus species*, has three subspecies: northern, southern, and Arsi gelada (Hughes et al., 2008; Zinner et al., 2018). The Northern Gelada (*Theropithecus gelada gelada*) and Southern Gelada (*Theropithecus gelada obscurus*) both exhibit white eyelids and a grey pectoral area (Gippoliti, 2010). However, the Southern Gelada is distinguished by a nearly black mane, a pure white patch around the chest area, and white fur extending along the upper inner arms, unlike the Northern Gelada's iron-grey chest fur (Ankel-Simons, 2007). The Arsi Gelada (*Theropithecus gelada arsi*), is identified later, has a slightly less vibrant color, particularly in the long hairs on its nape and tail, along with chocolate-colored fur on its back and underside (Mori and Belay, 1990; Gippoliti, 2010).

The gelada, initially discovered in 1835 by German naturalist Rüpell, was named after the local name used by inhabitants of the Gonder region where it was first observed (Last, 1982). The gelada is

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an old-world monkey (Fleagle, 2013), looking comparable to true baboons in morphology and size (Dunbar, 1983a; Page and Goodman, 2001), but differ from other baboon species by having shorter jaws, a longer face, a snub snout, and bulging cheek pouches (Crook,1966; Yalden, et al., 1984; Ankel-Simons, 2007). The red area of skin located on the chest is the most distinctive morphological feature of gelada (Ankel-Simons, 2007), giving the name of bleeding-heart monkey (Dunbar and Dunbar, 1975; Krentz, 1993; Jolly, 2007). Male gelada are larger than females (Appendix 1) and marked sexual dimorphism is the characteristic feature of the species with females averaging around two–thirds the size of males (Jolly, 2007).

Gelada prefers mostly afro-alpine grasslands, adjacent rocky gorges and cliffs (Jolly, 2007) at altitudes between 1,500 and 4,400m above sea level (Bergman and Beehner, 2013; Gippoliti *et al*., 2020). Gelada is among the most land-dwelling non-human primates, displaying distinct morphological adaptations tailored for their diet primarily consisting of grasses (Hunter, 2001; Beyene, 2010; Fashing et al., 2014; Jarvey et al., 2018; Moges, 2019; Kifle and Bekele, 2021; Kifle, 2023). They are nutrition experts, primarily feeding on graminoid leaves, which include grass and sedge (Hunter, 2001; Fashing et al., 2014; Jarvey et al., 2018; Kifle and Bekele, 2021; Ahmed et al., 2022; Kifle, 2023). Their diet comprises a variety of plant parts such as seeds, rhizomes, corms, herb leaves, flowers, bulbs, and roots (Hunter, 2001; Fashing et al., 2014; Abu et al., 2017; Kifle, 2023). During the transition from the wet to the dry season, geladas change their diet from primarily eating graminoid leaves to consuming graminoid seeds when they become available (Hunter, 2001; Fashing et al., 2014; Kifle, 2023).

Scholars roughly estimated the gelada population is probably less than 25,000 individuals (Gippoliti *et al*., 2020). Gelada population studies have been conducted in several parts of Ethiopia (Beehner *et al*., 2007; Kiflie *et al*., 2013; Haileselasie et al., 2023). However, the spatial distribution, social grouping, and dietary patterns information of geladas remain fragmented. Furthermore, comprehensive information on their population dynamics and behavior is largely unexplored. Taken these in to consideration, this study aimed to explore abundance, distribution, social organization and feeding behavior of gelada from 2009 to 2024. Therefore, a systematic review bridging 2009 to 2024 is essential to assess and consolidate existing knowledge, aiming to support future conservation planning and research efforts targeting gelada species.

2. Material and Methods

This review employed a systematic approach to identify relevant peer-reviewed studies through a structured search of selected databases. Initially, articles were searched on Google Scholar using a combination of keywords related to the study topic: [(Population* OR abundance* OR distribution* OR habitat) AND (behavior* OR feeding OR habit OR ecology) AND (Gelada)]. This search generated a total of 39 research articles relevant to the study objectives. The titles and abstracts of these articles were reviewed, and those meeting the following predetermined criteria were selected for detailed synthesis: 1) peer-reviewed research articles written in English; and 2) studies focused on population size, abundance, distribution, or behavior of Geladas. Articles that did not meet these criteria were excluded.

Ultimately, 13 research articles published between 2009 and 2024 were selected for final data analysis, which was conducted using Microsoft Excel. The population data of gelada subspecies, including abundance, social organization, and feeding behavior, were systematically compiled and presented in tables. Distribution patterns were illustrated using figures, while conservation status and habitat types were represented through graphs, accompanied by detailed explanatory notes to enhance clarity.

3. Results

3.1. Population Abundance and Distribution of Gelada

The table (Table 1) presents a comprehensive overview of gelada population estimates across different regions and sub-species in Ethiopia, based on habitat, elevation, and conservation status.

Table 1. Summary on population estimation of gelada.

Sub-species	Location	Abundance	Relative Abundance (%)	Conservation Area (Protected Area)	Average Elevation (m)	Habitat Type	Author
Arsi Gelada	Eastern Arsi	1,315	4.39	Outside	2,100	Forest	Moges (2019)
Northern Gelada	GMCCA	56	0.19	Inside	3,500	Sub-afroalpine	Teressa et al. (2021)
	SMNP	18,851	62.90	Inside	3,217	Sub-afroalpine	EWCA (2019).
	AYZCCA	929	3.10	Inside	3,892	Afroalpine	Ewnetu and Girma (2024).
	Kotu Forest	229	0.76	Outside	2,880	Forest	Abate and Girma (2023)
Southern Gelada	Yegof Forest	153	0.51	Outside	2,507	Forest	Ahmed et al. (2022)
	BSNP	1,535	5.12	Inside	2,999	Forest	Kifle (2018).
	Kosheme (around BSNP)	1,251	4.17	Outside	2,030	Forest	Kifle (2018).
	Wof Washa Forest	453	1.51	Outside	2,865	Forest	Goshme and Yihune (2018).
	Debre Libanos	1,609	5.37	Outside	2,400	Forest	Abie and Bekele (2017).
	GCCA	1,502	5.01	Inside	3,450	Sub -afroalpine	Moges (2015).
	Wonchit Valley	1,525	5.09	Outside	1,600	Forest	Kflie et al. (2013).
	Azewa and Arego	338	1.13	Outside	2,583	Forest	Ayalew (2009).
Unknown gelada sub-spp.	Tigray Region	223	0.74	Outside	2,327	Forest	Haileselasie et al., (2023)
	Total	29,969	100%		2,739 (average elevation)		

AYZCCA = Abune Yosef Zigit Community Conservation, BSNP= Borena Sayint National Park, GCCA = Guassa Community Conservation Area, GMCCA= Guna Mountain Community Conservation Area, SMNP= Siemen Mountains National Park.

Note: The Unknown gelada sub-spp. refers to unclassified population that may belong to one of the three recognized subspecies (*T. g. gelada*, *T. g. obscurus*, *T. g. arusi*) or could potentially represent a distinct subspecies.

Thus, the total estimated population of gelada (*Theropithecus gelada*) is about 29,969 individuals across various regions in Ethiopia. Currently, the gelada species has three distinct subspecies found in different regions of Ethiopia: the Arsi gelada (Appendix 2), the Northern gelada (Appendix 3), and the Southern gelada (Appendix 4). The northern gelada represents the largest proportion, with 18,907 individuals (63.09%), followed by the southern gelada, comprising 9,524 individuals (31.78%). The Arsi gelada accounts for 1,315 individuals (4.39%), while the unidentified gelada (possibly a member of one of the three known subspecies or potentially a new subspecies) is the least represented, with just 223 individuals (0.74%) (Table 1).

The Northern gelada population is predominantly concentrated in Simien Mountains National Park in northern Ethiopia, with 18,851 individuals, representing approximately 99.7% of the northern subspecies and 62.9% of the total gelada population in the country. This emphasizes the park's role as the principal stronghold for the species. In central Ethiopia, Debre Libanos supports the largest southern gelada population, with 1,609 individuals. This accounts for 16.89% of the southern subspecies and 5.37% of the total gelada population. The Arsi gelada are located in eastern Arsi, with the highest numbers in Arsi Robe (912 individuals, 69.35%), followed by Amigna (280 individuals, 21.29%) and Bele (123 individuals, 9.35%). An unclassified gelada population, which may represent one of the three known subspecies or potentially a new one, has been identified in the Tigray region. A total of 51 individuals are found in Wolkait, while 172 individuals are located in Ganta Afeshum in eastern Tigray (Fig. 1; Table 1).

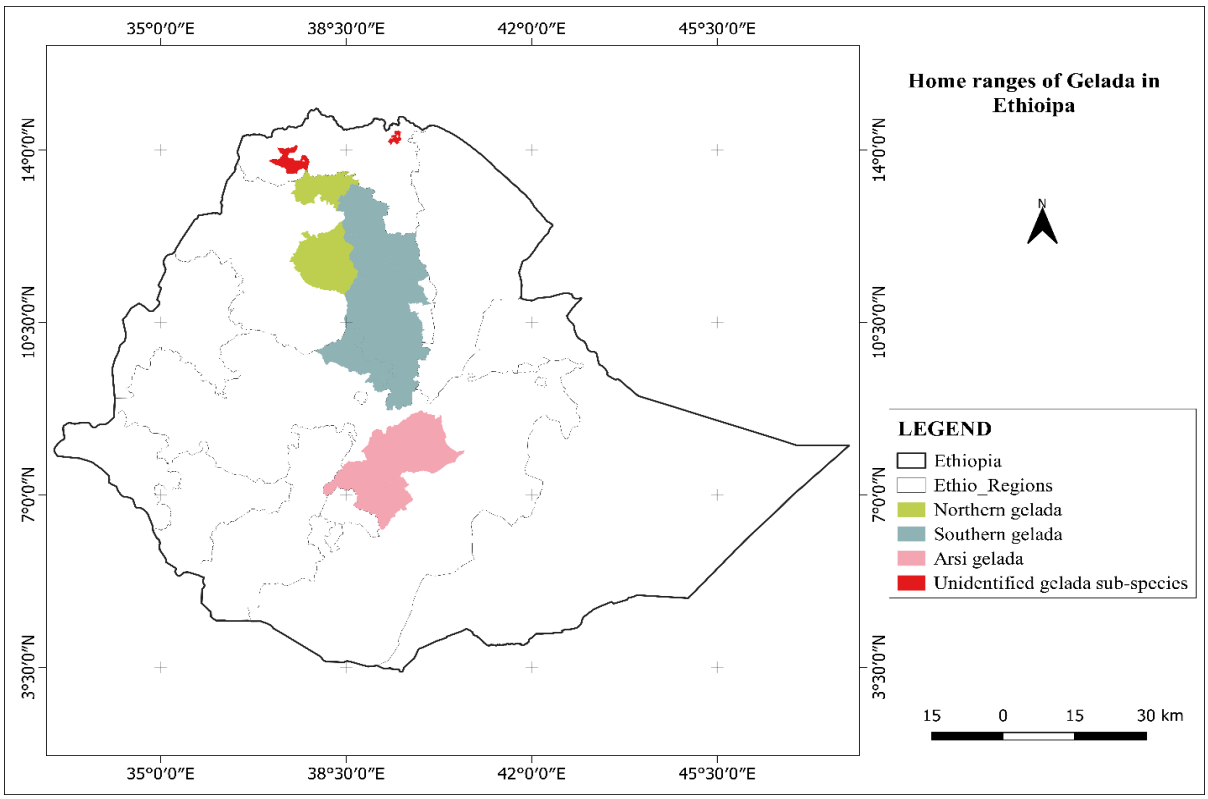

Figure 1. Distribution map of Gelada subspecies.

Protected areas are crucial for supporting large gelada populations, unprotected habitats also support a significant number of individuals. The largest gelada population, totaling 22,873 (76.32%) individuals, was recorded within protected areas, including two national parks and three community conservation areas. In contrast, 7,096 (23.68%) individuals were found across nine unprotected habitats (Figure 2; Table 1).

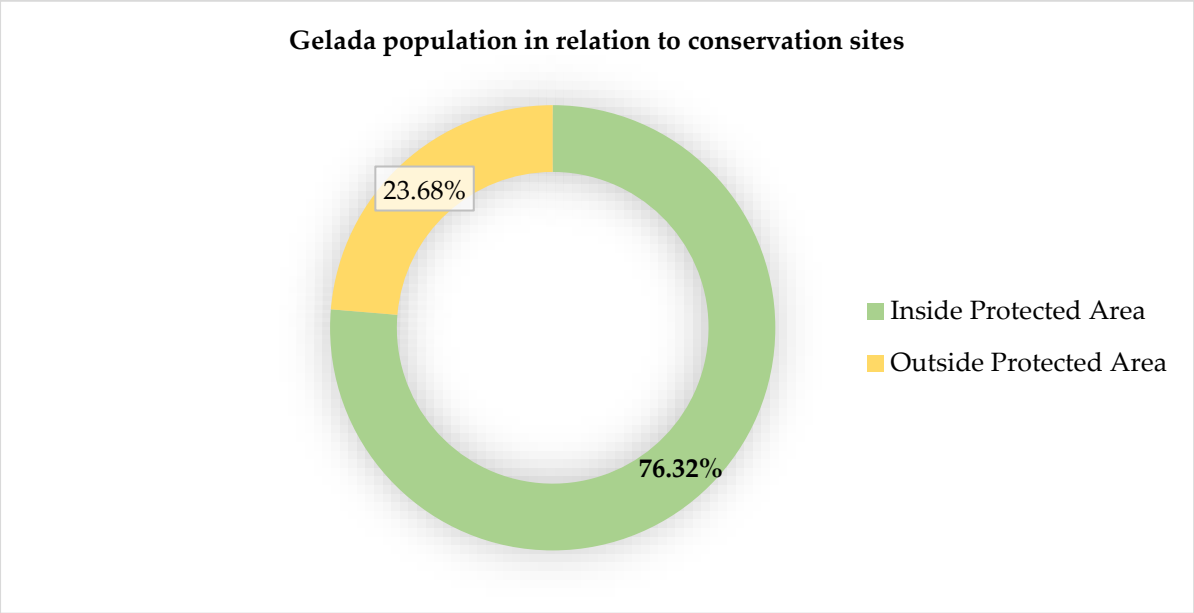

Figure 2. The proportion of gelada population between in and outside protected area

Gelada exhibits remarkable ecological flexibility, inhabiting an average elevational range from 1,600 m (Wonchit Valley) to nearly 3,900 m (AYZCCA) above sea level. Their habitat use is closely tied to elevation, which directly shapes their diet and behavior. Most geladas (10 out of 14 study sites) inhabit forested areas (below 3,000 meters), where they benefit from a diverse diet including grasses, herbs, fruits, flowers, tubers, and even invertebrates. In the sub-afroalpine zone (3,000–3,500 m), used by at least three populations, geladas have adapted to more open, rugged environments, feeding mainly on grasses, forbs, and shrubs. The afroalpine zone (above 3,500 m) is home to just one known population,

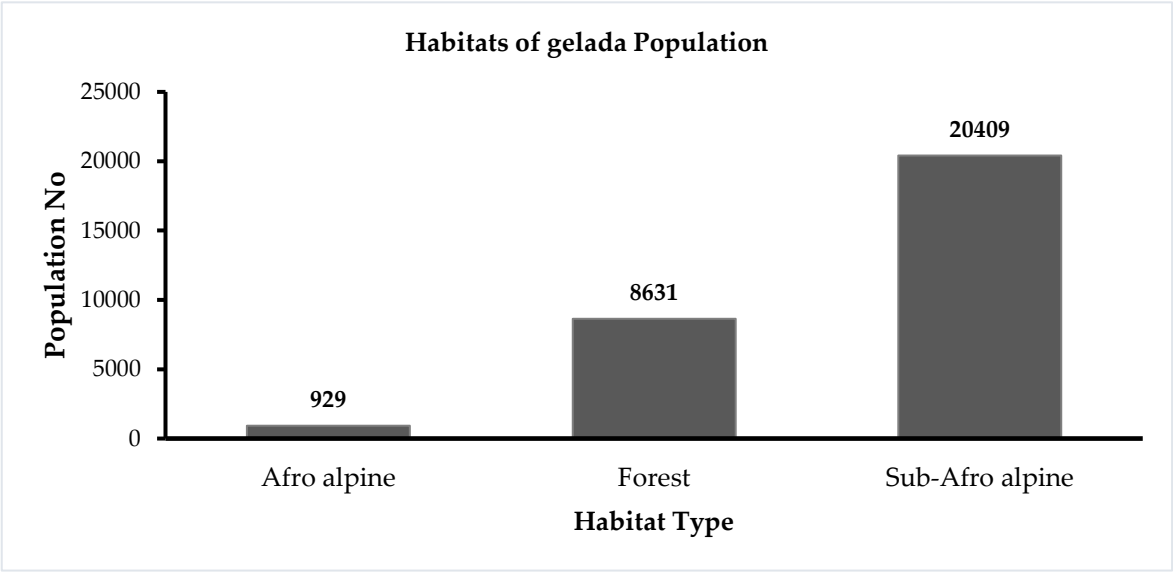

Figure 3. Habitats of gelada

surviving in harsh, high-altitude conditions on a diet of resilient plants like grasses and forbs. The highest gelada habitat reaches an average of 3,892 meters, placing them among the highest-living primates globally. On average, geladas inhabit areas around 2,739 meters, showing a preference for montane ecosystems but with the capacity to thrive across diverse altitudes. In terms of population distribution, the majority (68.1%, or about 20,409 individuals) are found in sub-afroalpine habitats,

followed by forests (28.8%, or 8,631 individuals), while only a small fraction (3.1%, or 929 individuals) occupy true afroalpine environments. These patterns underscore the gelada's ecological flexibility and ability to adapt to varying environmental conditions (**Chyba! Nenalezen zdroj odkazů.**).

3.2. Social organizations of gelada

Geladas display an intricate and multi-layered social organization, structured into hierarchical groups known as bands or communities. These social units consist of three distinct formations. One-Male Units (OMUs) are the basic social unit, typically including a single adult male, around 20 females, and their offspring. Northern populations (e.g., Simien Mountains National Park) show larger and more complete social structures, with high OMU and community sizes, indicating stable habitats and strong social cohesion.

All-Male Units (AMUs) are the second, composed exclusively of male individuals, usually averaging about eight members. Southern populations demonstrate more variability, with some areas supporting small, fragmented groups (e.g., Wof Washa) and others (e.g., AYZCCA and BSNP) maintaining exceptionally large communities. While, Eastern Arsi data is limited, but OMU size suggests moderate group structure.The third level, Multi-Male Units (MMUs), consists of multiple males alongside females and their young, with an average group size of 94 individuals.

At the highest level, gelada units merge to form bands or communities, large social groups typically formed near resting sites, averaging 123 individuals. This multi-tiered structure reflects the species' remarkable social complexity (**Chyba! Nenalezen zdroj odkazů.**).

Table 2. Social organization size in gelada subspecies.

Gelada sub-spp.	Locations	Social organization types				Authors
		AMU	OMU	AMU	OMU	
Arsi	Eastern Arsi	__	28.62	__	__	Moges (2019)
Northern	SMNP	__	34.00	__	160.00	Haileselasie et al., (2023)
Southern	AYZCCA	10.37	24.02	53.45	157.58	Ewnetu and Girma (2024)
	Wof Washa	3.88	18.40	__	75.25	Goshme and Yihune (2018).
	BSNP	11.4	10	__	81.56	Kifle (2018).
	Kosheme (around BSNP)	6.67	14.5	__	40.07	Kifle (2018).
	GCCA	__	__	133.05	219.70	Moges (2015).
	Wonchit Valley	6.32	16.00	__	__	Kifle et al. (2013)
Average		7.73	20.79	93.25	122.36	

AYZCCA= Abune Yosef Zigit Community Conservation Area, BSNP= Borena Sayint National Park, GCCA= Guassa Community Conservation Area, SMNP= Siemen Mountains National Park.

3.3. Feeding Behavior of Gelada

Geladas (*Theropithecus gelada*) exhibit remarkable dietary flexibility, adapting their foraging strategies to the ecological conditions of their habitats. Their diet primarily consists of grasses and herbs across all regions, but they also consume fruits, tubers, flowers, animal prey, and invertebrates, depending on local availability. The number of forage species they exploit varies widely, ranging from 19 (Debre Libanos) to 74 (BSNP), reflecting their ability to thrive in diverse environments. On average, geladas consume around 45 forage species across the different regions, underscoring their ecological flexibility (Table 3).

Their dietary patterns are influenced by the agro-ecological zones they inhabit, such as the afroalpine, Sub-afroalpine, and forest ecosystems. In the afroalpine regions (above 3,500 m a.s.l.), geladas primarily feed on grasses, sedges, and forbs. In sub-afroalpine areas (3,000–3,500 m a.s.l.), their diet expands to include shrubs, subterranean plant parts like roots, corms, and tubers, as well as cereal

crops and invertebrates. In lower-altitude forest habitats (below 3,000 m a.s.l.), their diet becomes even more diverse, incorporating bushes, creepers, small plants, fruits, and flowers from shrubs and trees.

Regional differences in dietary composition are further highlighted in studies across Ethiopia. Arsi geladas in Eastern Arsi have the most diverse diet, feeding on 61 species, including graminoids, forbs, fruits, shrubs, trees, and cereals. Northern geladas in the Simien Mountains National Park consume fewer species (27), primarily grasses, herbs, corms, bulbs, flowers, and seeds. Southern geladas across several locations (AYZCCA, Debre Birhan, BSNP, Debre Libanos, GCCA, and Wonchit) show the greatest variation in diet and forage diversity, with species counts ranging from 19 to 74. Their diet generally consists of grasses and herbs, with additional items like tubers, fruits, flowers, shrubs, trees, cereals, and even animal prey (Table 3).

Table 3. Dietary variation of geladas across different localities

Subspecies	Location	No of forage spp.	Major Diet Items	Author
Arsi	Eastern Arsi	61	Graminoids, forbs, fruits, shrubs, trees, and cereals	Moges (2019)
Northern	SMNP	27	Grass, Herbs, corms/bulbs, Flowers, Seeds	Woldegeorgis and Bekele (2015).
Southern	AYZCCA	25	Grasses and hebs	Ewnetu and Girma (2024)
	Debre Birhan	41	Grass, Tuber, Herbs, Animal preys	Yazezew et al. (2020)
	BSNP	74	Grasses, herbs, trees, shrubs, cereals, invertebrates	Kifle (2018).
	Debre Libanos	19	Grasses, herbs	Abie et al. (2017).
	GCCA	56	Grasses, herbs, bushes, flowers	Fashing (2014), Moges (2015)
	Wonchit	60	Grasses, forbs, fruit, flowers of trees	Kflie et al. (2013).
Average		45.38 ~ 45		

Note: AYZCCA= Abune Yosef Zigit Community Conservation Area, BSNP= Borena Sayint National Park, GCCA= Guassa Community Conservation Area, SMNP= Siemen Mountains National Park

4. Discussions

4.1. Population of Gelada

The result indicates that the estimated gelada population in Ethiopia is 29,969 individuals across 14 different sites. (Table 1). According to Lovejoy (1986), the wild gelada population was estimated at 50,000–60,000 individuals, with a noted decline over time. Gippoliti and Hunter (2008) later estimated the population at around 200,000 individuals, classifying *Theropithecus gelada* as Least Concern under the UN conservation category. This study aligns with Beehner et al. (2007), who reported that the Simien Mountains National Park, especially the Sankaber and Gich regions, provides the largest gelada population. Contrary, more recent estimates suggest the current gelada population across Ethiopia may be fewer than 25,000 individuals (Gippoliti et al., 2020). Therefore, the global population of geladas are declining significantly and require a synergy to conserve the existing population.

The Simien Mountains National Park (SMNP) provides the majority of the gelada population (18,851 individuals). This high abundance might be due to the park's status as a UNESCO World Heritage Site and its high conservation priority. Additionally, the park's diverse habitats (1,900-4,533m a.s.l), providing ample food and cover, also contribute to the large gelada population. The gelada population in the park, initially estimated at 4,300 individuals (Beehner et al., 2007), has since grown significantly to 18,851 individuals (EWCA, 2019). However, significant populations of geladas are also

found in other regions, including Wollo (Gippoliti, 2010), Guassa (Fashing et al., 2014), Debre-Libanos (Abie and Bekele, 2017), Wof-Washa Forest (Goshme and Yihune, 2018), and south of the Rift Valley in the Arsi Province (Moges, 2019). The Arsi gelada population, estimated at about 600 individuals four decades ago (Mori and Belay, 1990), has grown significantly, surpassing 1,000 individuals (Abu et al., 2017) and reaching 1,315 individuals (Moges, 2019).

A significant portion of the gelada population (68.1%) resides in sub-afroalpine habitats across various sites in Ethiopia. This preference could be rise from: first, sub-afroalpine habitats, with their open grasslands and rugged terrain, provide abundant grasses and sedges, ideal for the geladas' grazing diet. Most of the sub-afroalpine ecosystems are protected and designated as national parks and community conservation areas that might be the second reason for the large gelada population. Third, the open environment might enhances visibility, which supports the large and complex social groups of geladas by improving communication and fostering group cohesion. Similar findings were reported that geladas prefer open grasslands for foraging and cliffs for sleeping Kifle (2018), adjacent rocky gorges and cliffs (Jolly, 2007) at altitudes between 1,500 and 4,400m above sea level (Bergman and Beehner, 2013; Gippoliti *et al*., 2020).

4.2. Social Organization

Geladas form multi-level societies characterized by nested reproductive units within larger groups (Dunbar, 1983b; Dunbar, 2014). Geladas exhibit a multilevel social organization characterized by hierarchical levels one-male units (OMUs), multi-male units (MMUs), all-male units (AMUs), bands, and larger community associations (Kawai, 1979; le Roux et al., 2011; Snyder-Mackler et al., 2012; Ewnetu and Girma, 2024). This finding shows that the average one-male unit (OMU) consists of approximately 6.86 individuals (Table 2). OMU sizes varies from 16 in Wonchit Valley (Kflie et al., 2013) to 34 in SMNP (Bergman and Beehner, 2013). The average All- Male Unit (AMU) of gelada consists of approximately 7 individuals (Table 2). It was maximum at Afroalpine ecosystem of AYZCCA, 10.37 (Ewnetu and Girma, 2024) and minimum at Wof-Washa forest, 3.88 (Goshme and Yihune, 2018). This finding estimated that the average Male-Male Unit (MMU) size is approximately 94, with specific values of 53.45 in AYZCCA (Ewnetu and Girma, 2024) and 133.05 in Guassa (Moges, 2015). MMU/Team consists of 2–4 OMUs that spend at least 90% of their lifetime together, with a size ranging from 18–50 individuals (Bergman and Beehner, 2013). Bands/Community, sometimes known as herd (Dunbar, 1993), is the highest level of organization which consists of any units that come together for sleeping or foraging, with herd sizes reaching up to 1,200 individuals (Gustison et al., 2012; Bergman and Beehner, 2013). This study showed that the average band/community size is approximately 154, with specific sizes ranges from 75.25 in Wof-Washa (Goshme and Yihune, 2018) and 219.70 in GCCA (Beyene, 2010).

4.3. Feeding Ecology

Our review confirmed gelada have a diverse diet shaped by the agro-ecology of their habitats, which include Afroalpine, Sub-Afroalpine, and forest ecosystems. In Afro-alpine ecosystems (> 3,500m a.s.l.), they primarily consume grasses, sedges, and forbs. In sub-afroalpine habitat (3,000 to 3,500m a.s.l.), they primary feed on grasses and shrubs, and also includes foods like roots, insects, eggs of birds, algae, reptiles, cereal crops and invertebrates. In forest habitat (< 3,000m a.s.l.), they additionally consume bushes, creepers, small plants, fruits, shrub flowers, and tree fruits (Table 3). This result confirms that geladas are highly terrestrial primates with specialized adaptations for feeding on graminoids (Hunter, 2001; Mau et al., 2009; Beyene, 2010; Fashing et al., 2014; Jarvey et al., 2018; Moges, 2019; Kifle and Bekele, 2021; Kifle, 2023). They consume subterranean foods like roots, corms, tubers, rhizomes, cereal crops, and invertebrates (Fashing, 2014). Insects are also another food source for gelada when they are accessible (Hunter, 2001; Fashing *et al*., 2014). The diet of geladas also occasionally includes eggs from birds, mollusks, earthworms, locusts, and reptiles (Fashing *et al*., 2014). Animal prey, specifically invertebrates, constituted a minor portion of geladas' diet (Iwamoto and Dunbar, 1983; Hunter, 2001; Fashing et al., 2010). This could be attributed to either the limited abundance of

such prey or the lower efficiency of geladas in locating or capturing those (Woldegeorgis, 2015). Iwamoto and Dunbar (1983) indicated that feeding increases in response to the decrease in the protein content of the dry season forage, and hence feeding activity would increase with respect to the nutritional requirements.

Despite their predominant graminivore, gelada dietary variability is associated with the seasonal decline in preferred food with the diet consisting of less proportion of green graminoids during the dry season and the highest proportion during the wet season (Hunter, 2001). In more seasonal environments, food shortage is likely to occur at certain times of the year (Jarvey *et al*., 2018). Geladas switch to underground food items, forb seeds, shrub leaves and tree fruits when green graminoids are desiccated during the dry season (Hunter, 2001; Fashing *et al*., 2014). Geladas consume more than 90% of green graminoids during the wet seasons. However, they switch diets as green graminoids desiccate during the dry season (Fashing *et al*., 2014).

Geladas demonstrate a pronounced preference for specific plant species primarily due to their nutritional composition (Richard, 1985; Milton, 1993). Since most plant species do not provide adequate concentrations of all necessary nutrients, primates are compelled to consume a diverse array of plants (Richard, 1985; Milton, 1993; Woldegeorgis and Bekele, 2015). Apart from nutritional factors, the geladas' food preferences could also be influenced by the accessibility, availability, and utilization of forage species across different seasons (Moges, 2015; Woldegeorgis and Bekele, 2015; Moges, 2019). Grass contributed to the highest percentage of utilization in the foraging of geladas (Woldegeorgis and Bekele, 2015; Moges, 2015). This indicates a high nutritional quality of food plants as good quality forage is generally supposed to have protein content (Woldegeorgis and Bekele, 2015). The protein-to-fiber ratio of leaves significantly influences leaf selection among primates. Leaves with higher protein and lower fiber ratios makes it favored by primates (Milton, 1993), are more easily digestible compared to mature leaves, and also has low crude fat than stem and pollen (Moges, 2015).

Most preferred plants are generally poor in fat content (Moges 2015; Woldegeorgis and Bekele, 2015; Moges 2019), with the exception of some fruits and seeds (Rothman *et al*., 2012). The most preferred diet of geladas includes *D. abyssinica* at Arsi (Moges, 2019), *F. richardii* at Abune Yosef (Ewnetu and Girma, 2024), *Festuca grass spp*. (Fashing et al., 2014), *A. caffrum* and *M. verticillata* at Guassa (Moges, 2015).

5. Conclusion and Recommendations

This systematic review represents the first comprehensive assessment of gelada (*Theropithecus gelada*) population dynamics and feeding ecology from 2009 to 2024, encompassing all three known subspecies and identifying a potential unidentified subspecies in Tigray region. This finding reveals a total estimated population of 29,969 individuals, with the highest proportion (62.90%) occupies in the Simien Mountains National Park, highlighting significant geographic imbalance in distribution. Alarmingly, substantial portions of the population inhabit in unprotected areas, have been exposed them to heightened conservation risks, particularly in Wollo and central Ethiopia, and Arsi regions where urgent protective measures are needed.

The species demonstrates remarkable ecological adaptability through its habitat preferences (68.1% sub-afroalpine, 28.8% forest ecosystems, and 3.1% pure afro-alpine) and complex social organization ranging from small All-Male Units (7 individuals) to large Communities (154 members). As specialized graminivores with seasonal dietary flexibility (consuming 19-74 forage species), geladas shift to underground foods during dry periods while maintaining the capacity to utilize diverse food sources, including invertebrates and fruits. This behavioral plasticity enables their survival across Ethiopia's altitudinal gradients but also makes them vulnerable to habitat alterations. Evidence suggests that the global gelada population is declining, but no comprehensive census has been conducted. This makes it difficult to determine the exact number of geladas remaining and to measure the rate of decline. Therefore, the following suggestions have been provided:

- Implement systematic monitoring of gelada populations, their habitats, and seasonal dietary patterns to inform adaptive conservation management.
- Strengthen and expand the network of protected areas, designating additional conservation zones and enhancing management for existing parks and community areas to safeguard the gelada population.
- Conduct further studies on the dynamics of gelada social units (OMUs, AMUs, MMU, and Band/Communities) to better understand their influence on population stability and inform targeted conservation interventions.
- Given the wide variety of diets (grasses, shrubs, fruits, etc.) consumed by geladas across different habitats, future research should focus on understanding the impacts of habitat changes on their feeding ecology.
- Almost one-fourth of the gelada population is found in unprotected areas. Promote ecotourism initiatives and conservation education programs within local communities to enhance protection efforts, especially in unprotected regions.

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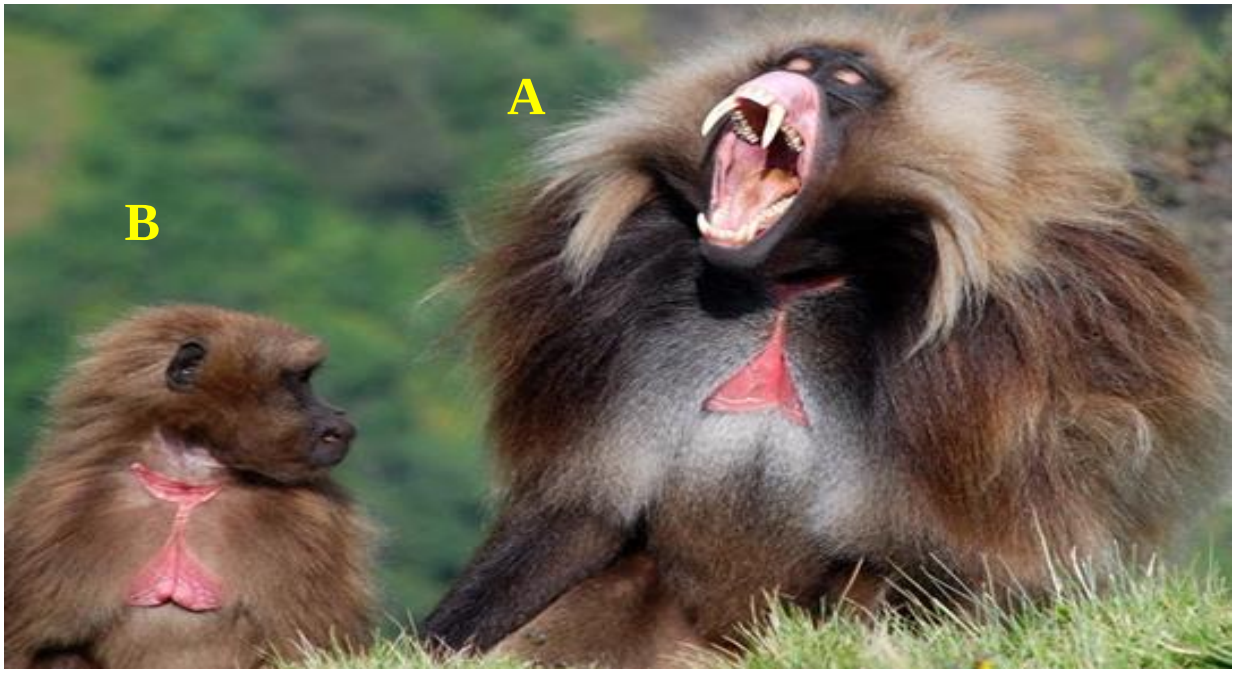
7. Appendices



Appendix 1. Male (A) and Female (B) gelada

(Source: https://i.pinimg.com/originals/f6/38/2a/f6382a55926b59e4b78b298e88add763.jpg)

Appendix 2. Arsi gelada (*T.g. arsi*) (Source: Moges A, 2019)

Appendix 3. Northern gelada (T.g. gelada) (Source: https://ethiopia-e-visa.com/instagrammable-places-in-ethiopia/)

Appendix 4. Southern gelada (*T.g. obscurus*) (Source: https://www.flickr.com/photos/timmelling/6913661206)