**Diet composition and preferences of mountain nyala (*Tragelaphus buxtoni*) in Bale Mountains National Park, Southeastern Ethiopia**

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**ABSTRACT**

*An endemic mammal mountain nyala has declined substantially in number and range of its distribution. Thus, Ecological monitoring is essential for conservation. Past ecological studies on mountain nyala focused more on demography, dynamics and social organization of the species but less attention was paid to the diet composition and preferences. Thus, the aim of this study was to assess diet composition and preferences of mountain nyala in Bale Mountains National Park (BMNP), Ethiopia. The study was conducted from September 2017 – January 2018 during both wet and dry seasons. Direct observation scan sampling method was employed to collect behavior data in two habitat types namely; Gaysay grassland and woodland (park head quarter) of BMNP. Scan sampling of target group selected were carried out for 10 minutes in 15 minutes interval and routine follow up were carried out (early morning and late afternoon) to identify plant species consumed by the species and the frequency of consumption of each plant species consumed. Nutrient proximate analysis of representative plant species from highly, moderately and least preferred plant species were conducted to understand governing principle that determine selective grazing and browsing. A total of 32 plant species out of 85 plant species available classified under 18 families were recorded during the study period. Mountain nyala are selective mixed feeders (mostly grazers) and predominantly folivores. Moreover, a clear seasonal dietary pattern was found in this study. In general* *the findings of this study imply that preference for forage species could be explained by nutritional quality. Consequently, increasing the abundance of preferred plant species is expected to benefit mountain nyala.*

**Key words/phrases:** consumed,direct observation, endemic, plant species, proximate analysis

**1. INTRODUCTION**

The Mountain nyala *Tragelaphus buxtoni* (Lydekker, 1910) is sexually dimorphic spiral-horned ungulate endemic to south-eastern highlands of Ethiopia. Mountain nyala was described as one distinct species of antelope in 1910 by Lydekker (Lydekker, 1910, 1912). Most of the populations of mountain nyala occur in Bale Mountains and some occur in Arsi Mountains National Park (AMNP) and few occur in the Chercher/Ahmar Mountains (Atickem et al. 2011; Atickem, 2013; Brown, 1969; Evangelista et al., 2007; Girma et al., 2018; Yalden & Largen, 1992). Mountain nyala commonly occurs between the altitudes of 3,000 to 4,200 meters a.s.l, although they may infrequently be found as low as 1,800 meters a.sl. (Evangelista et al., 2007). The preferred habitat for the mountain nyala is the upper and ­lower Afro-montane vegetation zones (2,300 and 3,250 m.a.s.l.) (Evangelista et al., 2007; Girma, 2016; Girma et al., 2018; Mamo et al., 2012). However, in areas where the Afro-montane vegetation is lost such as Arsi and Chercher mountains, it is known to commonly occur in the subalpine/ ericaceous zone (3,200 to 3,700 m. a.s.l.) (Atickem, 2013; Evangelista et al., 2007; Girma, 2016).

Mountain nyala are browsers, grazers and mixed-feeders; depending on the type of the habitat they occur (Evangelista et al., 2007; Girma, 2016; Refera & Bekele, 2004). They are known to feed on a variety of trees, herbs, grasses and shrubs (Evangelista et al., 2007; Girma, 2016). Mountain nyala is classified as ruminant herbivore with four-chambered stomach that is able to digest carbohydrates and proteins with aid of microorganisms. In particular, microorganisms in the gut of the ruminant aid cellulose (up to 60% of cellulose content) digestion, which enables it to feed on a wide variety of plants (Kingdon, 1997). Mountain nyala exhibits seasonal diet selection (Girma, 2016). For example, during rainy seasons grasses are consumed when young shoots have great nutritional value; while during dry season prefer to browse on succulent leaves of trees and shrubs (Hillman and Hillman, 1987; Evangelista et al., 2007; Girma, 2016).

The mountain nyala inhabit rugged mountains areas of southeastern Ethiopia, including remote areas with poor accessibility. This has made the population estimate difficult and current global population estimate is scant and unreliable. The most comprehensive global population estimate was given by Atickem (2013) exploring populations over different ranges. Bale mountains contains comparatively the largest mountain nyala population (3756 individuals) and 115 individuals in Munessa, 62 individuals in Galama and Chilalo mountains, 80 individuals in Arbagugu and Dindin and 37 individuals in Kuni-Muktar Mountains (Atickem, 2013). Accordingly, the most recent and comprehensive global population estimate of mountain nyala is 4094 (Atickem, 2013). Due to its limited distribution and presumed decline in numbers, the species has been listed as endangered by the IUCN Red List (IUCN, 2017).

A number of factors have contributed to the mountain nyala's population decline. However, habitat quality deterioration is the most common and severe threat. Particularly, habitat degradation, fragmentation and loss derived by deforestation, anthropogenic fire, livestock encroachment, expansion of agriculture and human settlement are common threats over all its ranges including the present study area (Atickem & Loe, 2014; Girma et al., 2018; Tadesse & Kotler, 2016; Worku et al., 2021). This reduced the cover and foraging opportunity of species (Evangelista et al., 2012; Girma 2016).

On top of that, the dietary requirement of mountain nyala in its seriously threatened habitats is among the least studied ecological aspect. Previous ecological studies on mountain nyala have focused on habitat suitability (Evangelista et al., 2008), poulation estimate (Atickem et al*.*, 2013; Mamo et al*.*, 2010), habitat quality (Evangelista et al., 2012) Habitat use (Mamo et al., 2012; Tadesse and Kotler, 2013) and social organization (Mamo et al*.*, 2015). Dietary data is important for understanding the relationships between plant communities and herbivores. Diet composition and preferences are governed by factors like plant availability, palatability, nutritional composition and chemical and physical defense mechanisms (Clauss et al., 2010; Tanentzap et al., 2009; Zweifel-Schielly et al., 2012). Hence, to maintain health population growth of mountain nyala, there is a need for clear understanding of the diet composition and explains the diet preferences in terms of plant nutritional content.

However, due to the timid (true wild) nature of mountain nyala obtaining reliable dietary data has remained difficult. The study of diet analysis of elusive wild ungulates including mountain nyala has entirely been based on simple direct observations. Attempts have been to investigate the diet composition of mountain nyala at different time using direct observations (Brown, 1969; Evangelist et al., 2007; Evangelista et al., 2012; Hillman 1985; Hillman, 1987; Girma, 2016; Kindgdon, 1997; Refera and Bekele, 2004; Tadesse and Kotler, 2013). However, these studies were not independent feeding ecology studies, most related to population studies and habitat use. As a result, did not provide detail information on diet composition and preferences most only listed few plants consumed by the mountin nyala most with no or little account on food preference indexes and nutritional content analysis of the plants consumed. Thus, no complete quantification of diet for the endangered mountain nyala is available. This is due to the cryptic life style, small fragmented meta population and the inhabitant of dense habitat with limited ability to track the activity of the animals (Brown, 1969; Kindgdon, 1997). As result the present study is aimed at answering research questions such as what are the plant species consumed be mountain nyala, what are the most and least preferred plant species consumed by the species and why at Gaysay Grassland and Dinsho/northern Woodland of Bale Mountains National Park (BMNP)? Data on diet composition of mountain nyala is important for better understanding of the species habitat requirements and its influence on ecosystem functioning (Tanentzap et al., 2009). Particularly, it nutritional composition analysis is vital for understanding the species normal growth and health maintenance (Clauss et al., 2010), which all contribute for sustainable population growth and consequently sustainable conservation of the endangered mountain nyala. Thus, the aim of this study is to investigate the diet composition and preferences of mountain nyala at Gaysay Grassland and Dinsho Woodland of BMNP, Ethiopia.

**2. MATERIALS AND METHOD****S**

**2.1. Study area description**

Bale Mountains National Park is located in southeastern Ethiopia under the administrative regional of Oromia Regional National State. It is located at about 400 km southeast of Addis Ababa, the capital. It is geographically situated between 6° 29’ to 7° 10’ N latitude and 39° 28’ to 39° 57’ E longitude (Figure 2). The total area coverage of BMNP is about 2200 km2 area, out of which the present study localities namely; Northern Woodlands (Dinsho woodland) and the Gaysay Grassland cover about 1.2 km2 34.4 km2 respectively (Figure 2) (FZS, 2007).

The park exhibits wide altitudinal range (1500 to 4377 m asl), including the largest expanse of Afro-alpine habitat in Africa and the second largest moist tropical forest in Ethiopia. The area is characterized by bimodal rainfall pattern with major rain season between the months of July to October and minor rainy season from March to June. The dry season occurs from November to February. The average annual rainfall is between 1000 to 2400 mm, with average monthly minimum and maximum temperatures of 5.6°C and 21.4°C respectively (Muhammed and Elias, 2021a).

The Bale Mountains National Park is one of the world biodiversity hotspot that Ethiopia has and is also UNESCO World Heritage proposed site. It has the highest occurrences of animal endemism. The park encompasses a total of 78 species of mammals, from 23 families of mammalian groups (Asefa, 2011). Twenty (26%) of them are Ethiopia’s endemic species including mountain nyala (Asefa, 2011). In addition to a wealth of endemic, unique and endangered mammals, Bale Mountains National Park is home to a wide range of bird species (FZS, 2007).

The Gaysay grassland, which is flat terrain covered by montane grassland, covers 1.6% of the park’s area and is located in the northern part of the park at 3200 to 3500 m asl (Yalden and Largen, 1992). Gaysay Grasslands (Northern grasslands) are dominated by swamp grasses and sedges, especially of the *Cyperus* and *Scirpus* genera (FZS, 2007). Higher areas are scrubby with African or wild worm herb (*Artemesia afra*) and Cape gold (*Helichrysum splendidum*). *Hagenia abyssinica* trees and Wild fennel also grows here (Muhammed and Elias, 2021b; Yalden and Largen, 1992). The Gaysay grasslands are the best place for viewing the endemic mountain nyala. Other mammals that are commonly seen are warthog, common duiker, serval cat, and golden (common) jackal, along with the spotted hyena at night (Mamo et al., 2015; Yalden and Largen, 1992).

The Juniper Woodlands (Park Headquarters, Dinsho) cover the northern slopes of the Bale massif. *Hagenia abyssinica* and African juniper (*Juniperus procera*) dominate the woodlands. St John’s wort (*Hypericum revolutum*) is also common in the woodlands, growing as shrubs near the lower edge and reaching a height of 5m tree in the upper edge. Mountain nyala, warthog, Menelik’s bushbuck, colobus monkey and olive baboon are commonly spotted in the woodland (Muhammed and Elias, 2021b).

**2.2. Methods**

**2.2.1. Sampling design**

Reconnaissance survey was carried out during the first week of September, 2017 before the actual data collection commenced. The purpose of the reconnaissance survey was to have basic information on accessibility, infrastructure, vegetation cover, topography and population distribution of mountain nyala. Based on the reconnaissance survey two habitat types namely; Gaysay grassland and woodland (head quarter) were selected based on the availability of mountain nyala population, accessibility and ease of investigating feeding ecology. Based on the proportion of the area, 2 groups of mountain nyala in the woodland and 3 groups of mountain nyala in the Gaysay grassland at least 1 km far apart (based on group territory behavior) that are easily recognizable and approachable were purposefully selected. The focal groups for scanning were identified by their natural marking, size, coat color, and facial features of some distinctive member of each these groups (Bekele and Refera 2004; Girma, 2016).

The diet composition and preferences data of mountain nyala were collected through continuous focal animals observation of individuals (ranged from 7 to ten individuals per group). The same group was used throughout the dietary data collection period and all individuals targeted were available during the whole data collection period) (Altmann, 1974; Derebe and Girma, 2020). Dietary scan sampling was carried out following all individuals of one selected easily recognizable and approachable group at a time (Yihune & Bekele, 2012; Derebe and Girma, 2020). Scan sampling of the group selected were carried out for thirty minutes in fifteen minutes interval and routine follow up of the animals were carried out during early morning hours (7:00 a.m. to 11:00 a.m.) and late afternoon hours (3:00 p.m. to 5:00 p.m.), when the animals were actively foraging, for each recognizable group at each habitat type during both dry and wet seasons (Derebe and Girma, 2020). A total of 328 hours in 40 days (both in wet and dry seasons) were spent observing the focal animals. In each season a total of 164 hours in 20 days were spent observing the focal animals. The diet composition and preferences were recorded by approaching the individuals of mountain nyala from 30-50 meter (Hillman, 1988). All individuals in a group were observed at the same time with a help of trained field assistants; wildlife experts and scouts of the park. Field assistants were trained onsite for one day on dietary data collection and recording.

The frequency of occurrence of the plant species that were consumed by mountain nyala and those available but not consumed in the study area were estimated using 60 plots established on three transect lines with a minimum distance of 50 m between sampling plots. A plot size 4m by 4m was established on each 1 km long transects. The number of transect was distributed proportionally to the area size of each habitat type. Accordingly, two transects in gay say grassland and one in woodland was randomly established with a minimum of 1 km distances in between. Transects were established in a way it captures all the plant species consumed by the mountain nyala. In addition, previous publication on plant species list of the area was used to compare preferences of each plant species with availability.

**2.2.2. Data collection**

Data was collected by dividing the study period in to dry and wet seasons. In each season, there was two data collection sessions namely; Wet I, Wet II, Dry I and Dry II. Wet season data collection was carried out from September to October, 2017, while dry season data collection was carried out from December, 2017 to January, 2018.

Dietary data including plant species consumed, plant parts consumed (leaves, stem, bark, flowers and fruits) were collected through observations of individuals of a target groups with naked eyes and Nikon action 10 x 50 binocular. Those individuals seen within a distance of < 50 m from the nearby group were recorded as members of the same group (Hillman, 1988). Time spent feeding on a particular selected plant species was recorded using hand watch.

To minimize any effect caused by the observer camophlaging clothes were used. Furthermore, the animals were approached walking gently and quietly against the direction of wind movement to avoid being scented by the animals. Once the animals were approached to observable distance, before collecting information they were allowed to become acclimated and resume feeding for a minimum of 10 minutes following Tadesse and Kotler (2013) and Girma (2016).

Close investigation of the feeding site was carried out after the 30 minutes continuous observation ended up, during 10 minutes interval break, for verification of plant species consumed. Evident, green, moist, freshly severed tissue characteristics were considered as a confirmation of a particular plant species consumed by the ungulates (Girma, 2016; Pienaar, 2013). Plant species, growth form, foraged plant parts, location, date and sex of the animals were recorded on data sheets to investigate the diet composition and plant parts consumed by the species. The plant species that was consumed by mountain nyala were recorded through estimating their frequency of occurrence in different plots. Samples of all the plant species consumed by the mountain nyala were collected, coded, pressed and taken to Hawassa University, Wondo Genet College of Forestry and Natural Resource herbarium for identifications. A plant species specimen collected were identified to species level in comparison with archived specimens collected in the herbarium and guided by Flora of Ethiopia and Eretria.

The untouched fresh plant leaves (both young and matured) and shoots for trees and shrubs and leaves, shoots, flowers and fruits for grass species consumed by the mountain nyala from the two habitat types (grassland and woodland) were collected in a plastic bag for proximate analysis following Derebe and Girma (2020) and Girma (2016). Samples for the proximate analysis were collected only for dry season, hence only dry season proximate analysis data is available. About 40% of the plants consumed by the mountain nyala, considering the most preferred, moderately preferred and least preferred ones, were used for forage quality test analysis.

As part of proximate analysis the dry matter content, percentage of Ash, organic dry matter content and total moisture, percentage of nitrogen, neutral detergent fiber, acid detergent fiber and crude protein were analyzed. The whole proximate analysis were analysed following AOAC (1995) proximate analysis laboratory procedures.

Before proceeding to the analysis, the weight of sampled items was weighed using electronic balance. The fresh forage samples were dried for 48 hours at 60 °C in an air-circulation oven to obtain air dried samples ready for grinding. The samples were ground to 1 mm particle size with a Wiley mill (AOAC, 1995). Before preceding the analysis, the weight of sample items was recorded by electronic beam. Dried and ground samples were stored in airtight containers away from heat and light to avoid moisture intake following AOAC (1995).

The moisture content was determined by drying the samples in hot air oven for 72 hrs. Then the dried samples were measured and the weight was recorded. The weight loss was expressed in terms of percent moisture content of the sample. For the determination of Dry Matter, Ash and Organic Matter, empty porcelain crucibles were dried overnight at 105 °C and were cooled in desiccators to room temperature. Oven-dried crucibles were measured (Wt) then approximately 2 g of ground sample were added in each crucibles and recorded (Ws). Then after, it was dried overnight at 105 °C and cooled in desiccators to room temperature. Then, oven-dried crucible and sample were measured (Wo) (AOAC, 1995).

Then, the dry matter samples were ignited overnight at 550 °C in muffle furnace and cooled in desiccators to room temperature. The ignited crucibles and samples were measured (Wa) to determine ash. To determine Percent Nitrogen/Crude Protein, the selected twelve samples from most preferred, moderately preferred and least preferred were digested in sulfuric acid using K2SO4 and CuSO4 as a catalysts. The N was converted into NH3, then distilled and trapped in boric acid and titrated with H2SO4 (AOAC, 1995). Then 1g of dry sample was added in digestion tubes (250 ml). After that, half the tablet of catalysts and 13 ml of concentrated sulfuric acid (H2SO4) were added. The tubes were inserted in a rack, including blank and standard samples in digestion block heater under fume hood, and exhaust manifold connected to water aspirator was installed and kept in digester at 420 °C until liquid becomes transparent. Then, the racks with exhaust manifold from digester were removed and cooled to room temperature under fume hood. After all, exhaust manifold were removed and tubes were transferred separately to distillation unit. The condensed liquid were collected in Erlenmeyer ﬂask with 10 ml indicator solution and the liquid was titrated with 0.1142 N sulfuric acid until color turned purple (AOAC, 1995).

Determination of Neutral Detergent Fiber (NDF) was carried out by adding 1 g sample (Ws) in 600 ml Berzelius beaker. Then, 100 ml of neutral detergent solution and 0.5 g sodium sulfite (Na2SO3) were added. After boiling it for one hour in refluxing apparatus, it was poured through glass crucibles and the vacuum was admitted. Crucibles were rinsed with approximately 50 ml hot water four times until all traces are removed and rinsed with acetone repeatedly until drained liquid is cleared. After that, it was dried at 105 °C overnight and cooled to room temperature in desiccators. Then the samples and crucibles were measured (Wo). The residues were allowed to be ash for three hours at 550 °C and cooled to room temperature in desiccators then crucibles and residues were measured (Wa) (AOAC, 1995).

Acid Detergent Fibre (ADF) was determined by adding 1 g sample (Ws) in 600 ml Berzelius beaker and 100 ml of acid detergent solution were added on it. It was boiled for one hour on refluxing apparatus. Then twelve oven dried glass crucibles were measured (Wt) and Poured through glass crucibles. After admitting the vacuum, crucibles were rinsed with approximately 50 ml hot water four times until all traces are removed and also rinsed with acetone repeatedly until drained liquid is cleared. Then it was dried at 105 °C overnight and cooled to room temperature in desiccators. After all, the samples and crucible were measured (Wo) and the residues were ashed for three hours at 550 °C and cooled to room temperature in desiccators. Then the crucibles and residues were measured (Wa) (AOAC, 1995).

**2.2.3. Data analysis**

To summarize and reorganize data on plant species consumed, consumed plants parts, frequency of occurrence and habit per plant species consumed by mountain nyala in to tables and figures Microsoft Excel 2010 was used. SPSS version 16.0 and Minitab version 17 computer softwares were used for all statistical analysis. The seasonal variation in the number of plant species consumed by mountain nyala was tested using independent sample t test.

The food preference indices (FPI) for each plants consumed by the species were calculated and ranked to determine the most preferred plants by mountain nyala. The food preference index for each particular plant species consumed was calculated following Martin (1995) and Yineger (2008) using equations (1) to (3) below;

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The total bite count per plant species consumed over the total time of observation was calculated. It was calculated by adding bite rate of different individuals of plants of the same species and dividing it by the total time of feeding observation. Then the bite count per minute for each plant species consumed was calculated.

The percentage preference of mountain nyala to plant parts (%PPP) was computed using Equation (4);

Sorenson's similarity (Ss) index was also used to compare the plant species consumed by mountain nyala similarity among wet and dry season (Kent & Coker, 1992) using Equation (5) below;

Ss

where a = number of species consumed in both seasons, b = number of species unique to wet season c = number of species unique to dry season.

The percentage values of all the proximate analysis were calculated by the equations (6) to (14) following AOAC (1995) procedures;

(Method 930.04)

where %M = percentage of Moisture, Wbd = wt of sample + dish before drying, Wad = wt of sample + dish after drying, Ws = Wt of sample taken.

) (Method 2001.2)

DM= Dry matter, Wo= oven-dried crucible and sample, Wt= oven-dried crucibles, Ws=ground samples.

(Method 942.05)

Wa= ignited crucibles and samples, Wt= oven-dried crucibles, Wo= oven-dried crucible and sample.

(Method 967.05)

ODM= organic dry matter.

(Method 930.04)

N= nitrogen, Va= volume of acid used for sample titration, Vb= volume of acid used for the blank, *N*= Normality of acid, W= sample weight in grams, 1.4007= conversion factor mill equivalent weight of nitrogen and N percent.

(Method 978.04)

CP: Crude protein, F = 0.625 for all forages

(Method 2002.04)

NDF= Neutral Detergent Fiber, WO= samples and crucibles, Wt=oven-dried crucible, Ws= samples.

(Method 973.18)

ADF= Acid Detergent Fiber, WO= samples and crucibles, Wt=oven-dried crucible, Ws= samples.

Multivariate hierarchical clustering procedure was carried out to classify the plant species consumed by mountain nyala into forage quality groups based on nutritional quality from proximate analyses and percent frequency of usage of plants consumed data calculated using the formula above (Equation 2). The amalgamation steps used the Euclidean distance and complete linkage (furthest neighbor) to calculate the inter-cluster distances and the final partitioning was presented in a Dendrogram.

**3. RESULTS AND DISCUSSION**

**3.1****. Diet Composition**

**3.1.1. Plant species consumed by mountain nyala**

A total of 32 plant species out of 85 plant species avilable, from 18 families were recorded to be consumed by mountain nyala in the study period (Table 1). Evangelista et al. (2007) and Evangelista et al. (2012), recorded 40 and 51 plant species to be consumed by mountain nyala respectively in lower and upper afromontane forest and sub-alpine /Erica srub/ vegetation. The variations in the number of plant species consumed could be related to the sampling effort such as area sampled, frequency of sampling, occurrence of identification of plant species consumed, time/season of sampling and disturbance level. Evangelista et al. (2007) and Evangelista et al. (2012) covered wider altitudinal range and diverse ecosystem as compared to the present study, hence could be the reason for higher of number of plant species consumed recorded. TIn Gaysay grassland and Disho (northern) woodland mountain nyala consumed predominately herbs and few trees and shrubs. Likewise, it was reported by Evangelista et al. (2007) and Evangelista et al. (2012) mountain nyala to consume herbs and few trees and shrubs. Mountain nyala exhibit mixed feeding strategy that shift between grazers and browsers, depending on where they are. This is perhaps attributed to the ability to digest and access different array of plants species from herbs to trees (Brown, 1969; Evangelista et al., 2007). In particular, microorganisms allow of digestion cellulose (up to 60% of cellulose content) which enables both mammals to feed on a wide variety of plants (Evangelista et al., 2007; Kingdon, 1997).

Even though, both species can consume from herbs to tress, they adjust their food preference depending on what is available in the immediate habitat (Evangelista et al., 2007). In the present study area (Gay say grassland and dinsho woodland) herbaceous community dominated over other growth forms, hence could consume more herbs over other growth forms. Furthermore, herbs especially most grass species are known to be less fibrous and with higher nutrient content than most shrubs and trees (Codron et al., 2007; Kazemi et al., 2012). Likewise, previous studies in Bale and Arsi on diet composition reported dominance of herbs in the species dietary requirements (Evangelista et al., 2007; Girma, 2016; Refera and Bekele, 2004).

Thirty one plant species from 18 families and 20 plant species from 12 families were recorded during wet and dry seasons respectively (Table 1). There were statistically significant difference on the number of recorded plant species consumed by mountain nyala (df =38, p = 0.001) during wet and dry seasons. Mountain nyala feed on few evergreen and succulent plant species such as *Alchemilla abyssinica*, *Alchemilla rothii*, *Artemisia afra,* *Hypericum revolutum*, *Carduus nyassus* during the dry season. Mountain nyalaare selective feeders. They have been observed to frequently consume on few plant species despite the abundance of money other species in the study area (32/85 species). Weather affects the feeding behavior of animals (Refera and Bekele, 2004). It has been indicated that evergreen and succulent grasses, shrubs and trees are consumed mainly in the dry season when most grasses have less moisture content (Girma, 2016). Moreover, browsing and grazing ungulates shift from herbaceous diet to shrub and tree diet, because highly nutritious grasses are scare in the dry seasons (Girma, 2016; Evangelista et al., 2007). During dry season grasses loss cell turgidity as a result of excessive loss of water that makes them less attractive and palatable to wildlife species (Dankwa-Wiredu and Euler, 2002). A study in Borena rangeland, southern Ethiopia revealed grasses to contain less Crude Protein (CP) and higher Neutral Detergent Fiber (NDF) and Acid Detergent Fiber (ADF) during dry season than wet season (Keba et al., 2013). Similarly, the present study records relatively few number of plant species during dry season due to weathering of grasses and herbs. In the same way, mountain nyala has been observed to browse more frequently on some shrubs and trees in BMNP especially during the dry season as compared to wet season.

The Sorenson's similarity index calculated for dietary overlap between wet and dry season is 0.74%. According to Ratliff (1993), Sorenson's similarity index values in arrange of 0.51 to 0.75 indicates high similarly, implying high degree of mountain nyala dietary overlap among seasons. The significantly high diet overlap between dry and wet seasons could be explained by the year round availability of most consumed species in the study area. The higher number of plant species consumed recorded during wet season could be attributed to the fact that the availability of abundant rainfall consequently the availability of diverse nutritional rich grass species in the area during wet season (Muhammed and Elias, 2021a,b).

**3.1.2. Plant parts consumed by mountain nyala**

Leaves (62.5%, 20 species ) were the most consumed plant part by the mountain nyala, among this only leaves of 8 plant species were exclusively consumed (Table 2). The pre-dominance of leaves in the diet composition of mountain nyala could be attributed to simple digestibility and better nutritional content than other parts of the plant (Girma, 2016). Marvin et al. (2016), revealed that leaves are highly nutritious in protein quality, vitamin and mineral concentrations than other plant parts. Evangelista et al. (2007), in his study in BMNP observed mountain nyala feeding mostly on leaves of some plant species. However, barks and fallen leaves were the least consumed plant parts by the mountain nyala, only fallen leaves of *Hagenia abyssinica* and barks of *Hagenia abyssinica* and *Juniperus procera* were consumed (Table 2). However, attack to plant stems and barks reduced plants performance. Removal of stem and bark by herbivores had greatest impact on plant and branch survival (Taheren, 2018). Leaves have been reported to contain more CP and less NDF and ADF than stem and barks (Hao et al., 2021).

Mountain nyala also consumed leaves and petioles of *Alchemilla abyssinica, Alchemilla rothii* and *Trifolium cryptopodium*. Stem and leaves of Plant species like *Artemisia afra, Cynoglossum coeruleum, Helichrysum splendidum, Solanum giganteum* and *Thymus schimperi* were consumed by the animal (Table 2). Furthermore, the flowers of *Kniphofia foliosa, Lobelia minutula, Cyanotis polyrrhiza* and *Satureja paradoxa* were also consumed (Table 2). Evangelista et al. (2007), in his study in BMNP observed mountain nyala feeding on flowers of some plant species. The flowers are free of anti-nutrients and toxic compounds. Further, flowers have higher quantities of proteins and carbohydrates and lower NDF and ADF (Taheren, 2018).

The endemic mammal mountain nyala consumed leaves to the extent of over 40% of its diet composition during wet season. On the other hand, during the dry season it shifted more to stems and leaves combined (46%) (Table 2; Figure 2). This is probably due to the fact that leaves are less available, with less moisture content and less nutritional during dry season than wet season and, hence mountain nyala has to include stems to meet up its dietary requirements.

**3.2. Diet preferences of the mountain nyala**

Mountain nyala has been observed to have clear diet preference differences among wet and dry season. For example, *Haplocarpha rueppellii* and *Kniphofia foliosa* were clearly the most preferred species by the mountain nyala during wet season. However, later in the dry season *Haplocarpha rueppellii* and *Kniphofia foliosa* decreased or disappeared entirely from the diet of mountain nyala (Tables 3 and 4). Animals acquire preferences for foods that meet nutritional needs (Provenza, 2005). Various environmental factors like availability of species, season, disturbance, digestibility, the concentration of secondary metabolites and nutritional quality of the plants could affect the food preference of mountain nyala (Girma, 2016; Evangelista et al., 2007). However, *Trifolium cryptopodium* was the second most preferred plant species during both dry and wet seasons. This could be due to the fact that the species is evergreen, higher protein content and succulent nature of the plant that provide mountain nyala with quality juicy food year round. The proximate analysis revealed the high moisture of *Trifolium cryptopodium*. It has been reported that *Trifolium* *spp*. contain essential nutrients and considerable level of proteins. A study on five species of *Trifolium spp*. revealed 35.1 to 45.4% proteins (Gounden et al., 2018). *Haplocarpha rueppellii, Trifolium cryptopodium* and *Kniphofia foliosa* were the top most three preferred plant species by mountain nyala during the wet season **(**Tables 3 and 4). *Haplocarpha rueppellii* and *Kniphofia foliosa* could be preferred because of higher nitrogen and crude protein contents and lowest NDF content as revealed in the proximate analysis (Table 5). Despite their abundance in the habitats of mountain nyala, *Solanum giganteum, Juniperus procera* and *Satureja paradoxa* were rarely consumed during wet season. This is perhaps due to its lower dry matter content and moderate nitrogen and crude protein content of *Satureja paradoxa* as revealed by the proximate analysis (Table 5).Likewise, *Juniperus procera* might not be preferred by its lowest moisture content. *Solanum giganteum* could not be preferred probably because of secondary metabolites or structural defenses like the presence of thorns and spines. Mechanical protection on the surface of the plants such as hairs, trichomes, thorns, spines, and thicker leaves are major plant direct defense strategy against that shapes selective grazing or browsing behavior in herbivores (Hanley et al., 2007).

On the other hand, *Artemisia afra, Trifolium cryptopodium* and *Carduus nyassus* were the most preferred plant species during dry season(Tables 3 and 4). *Artemisia afra* might be favored by itshigher nitrogen and crude protein contents and least NDF and ADF contents as revealed in the proximate analysis (Table 5). Besides, various studies in BMNP and AMNP have shown that *Artemisia afra* and *Kniphofia foliosa* are most frequently consumed plants by the mountain nyala (Brown, 1969; Evangelista et al., 2007; Girma, 2016; Refera and Bekele, 2004). Similar studies elsewhere have indicated that selective grazing is highly governed by nutritional content such as CP, moisture, NDF and ADF (Chinomona et al., 2018; Kingdon & Hoffmann, 2013; Omphile et al., 2004).

**3.3. Proximate analysis of plant species**

*Satureja paradoxa* and *Juncus oxycarpus* contained the highest percent moisture 9.08% and 8.27% respectively (Tabe 5). *Artemisia afra (*38.46%) and *Kniphofia foliosa* (32.88%) had the highest crude protein content, whereas *Cynodon dactylon* (8.91%) and *Alchemilla abyssinica* (10.01%) contained the least crude protein content (Table 5). The highest neutral detergent fiber was recorded in *Cynodon dactylon* (65.91%) and *Gallium simenses* (56.17%), whereas the least was recorded in *Satureja paradoxa* (19.96%) and *Kniphofia foliosa* (29.71%). The highest acid detergent fiber was recorded in *Gallium simenses* (54.44%) and *Juncus oxycarpus* (46.31%), whereas the least acid detergent fiber was recorded in *Kniphofia foliosa* (29.03%) and *Juniperus procera* (30.14%).

The final partition of the cluster group analysis clustered all the observations with 66.7% similarity in to three clusters. Cluster 2 has the highest number of observations (6), while cluster 3 has the least number of observations (1). The five observations in cluster one are; *Trifolium cryptopodium, Haplocarpha rueppellii, Kniphofia foliosa, Artemisia afra* and *Juniperus procera* had highest crude protein content and mostly less and moderate NDF and ADF. The top most three species preferred during wet season are those with high crude protein content. This indicates the mountain nyala selectively graze these species so frequently over many other abundant in order to meet there nutritional requirements. On the other hand, during the dry season those species with high moisture or crude protein or both were preferred. *Artemisia afra* had the highest crude protein content, whereas as *Trifolium cryptopodium* contained relative higher crude protein and among highest moisture content. Girma (2016) in his study in Arsi Mountains National Park (AMNP) was also reported that *Kniphofia foliosa and Artemisia afra* contained highest crude protein content among the plants consumed by the mountain nyala and also were among the top preferred plants by the species*.* The species found to be highly preferred by the mountain nyala are among the least frequently/abundant species in the area, a fact that strength the highly selective foraging behavior of mountain nyala. This calls conservation attention to those plant species so as to insure sustainable conservation of the endangered and endemic mountain nyala.Studies have revealed that feeding preferences of herbivores is a factor of availability, food quality and dietary requirements of the animal (Chinomona et al., 2018; Provenza, 2005; Sinclair et al., 2006).Plant species observations clustered in cluster two were *Gallium simenses, Alchemilla abyssinica, Cynoglossum coeruleum, Juncus oxycarpus, Hagenia abyssinica* and *Cynodon dactylon* and mostly had moderate and least crude protein and moderately and highest NDF and ADF. Plant species grouped in cluster three was *Satureja paradoxa* and had the highest moisture content and moderate phosphorus and nitrogen content and NDF and ADF**(**Tables 6 and 7, Figure 3).

According to the optimal foraging theory animals maximize fitness through a foraging strategy that incur low cost and with maximum energy gain, maximizing the net energy gain. Species such as *Gallium simenses, Alchemilla abyssinica, Cynoglossum coeruleum, Juncus oxycarpus* that are moderately preferred by the mountain nyala those they have little crude protein content they are fairly abundant in the area (25 to 50% abundance). There abundance could make them to be preferred secondarily due to the fact foraging incur lost cost, since it reduces the time of traveling in search of food, which inurn maximize net energy gain. Furthermore, the presence of chemical (secondary metabolites such as flavonoids, tannin) and physical (the presence of spines ants etc) defenses could determines selective grazing (Clauss et al., 2010; Tanentzap et al., 2009; Zweifel-Schielly et al., 2012).

**4. CONCLUSION**

According to the findings of this study mountain nyala are selective mixed feeders (mostly grazers) and predominantly folivores. Moreover, a clear seasonal dietary pattern was found in this study. The findings also imply that most preferred plant species are those rich in nutrient content such as crude protein and contain less fibre. Therefore preference for forage species could be explained by nutritional quality. This implies the need for promoting sustainable conservation of preferred plant species in the park. This will probably benefit mountain nyala in terms of meeting its dietary requirements and promoting healthy population growth. This in turn significantly contributes for sustainable conservation of the endangered and endemic mountain nyala populations.

**List of Figures**

Figure 1 Location map of the study area.

Figure 2 Percentage contributions of plant parts during wet (A) and dry (B) seasons.

Figure 3Cluster grouping observations dendrogram of 12 foraged plants by Mountain nyala based on nutritional analysis using cluster centroids distance as proxy for clustering**.**

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**CONFLICT OF INTERESTS**

We the authors declare no conflict of interests.

**AUTHOR CONTRIBUTION**

**Melkam Getachew**: Conceptualization (supporting); Data curation (lead); Formal analysis (lead); Funding acquisition (lead); Investigation (equal); Methodology (supporting); Project administration (equal); Resources (lead); Software (supporting); Supervision (supporting); Validation (supporting); Visualization (equal); Writing-original draft (equal); Writing-review & editing (supporting). **Zerihun Girma**: Conceptualization (lead); Data curation (supporting); Formal analysis (equal); Investigation (equal); Methodology (lead); Project administration (equal); Resources (supporting); Software (lead); Supervision (lead); Validation (equal); Visualization (equal); Writing-original draft (equal); Writing-review & editing (lead).

DATA AVA I L A B I LIT Y S TATEMENT

The data supporting the findings of this study will be made available after publication of the manuscript. The data will be made available by the file name mountain nyala diet composition and preferences at the Zenodo data repository promptly after the day of publication.

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