Activity Budget and Foraging Patterns of Nubian Giraffes (*Giraffa camelopardalis camelopardalis*) in Lake Nakuru National Park, Kenya

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Abstract. How animals decide to spend their time has a key impact on their survival and reproduction. These behavioral decisions are shaped by ecological and environmental factors, such as seasonal changes. Foraging patterns show how an animal chooses to forage in its environment as influenced by resource availability, competition, and predation risk. Giraffe activity budget has been investigated in populations across Africa and found to be influenced by body size, diet composition, and sex. The activity budget and foraging patterns of Nubian giraffes vary considerably between ecosystems. The Nubian giraffe, a subspecies of the Northern giraffe species (*Giraffa Camelopardalis*) is a critically endangered population and occurs only within Kenya, Uganda, Ethiopia, and Southern Sudan. We performed 3 months of behavioral observation on a population of Nubian giraffes in Lake Nakuru National Park, Kenya, to assess seasonal activity budgets and foraging patterns. We found that in the wet and dry seasons giraffe spent approximately the same amount of time (53% and 57%, respectively) foraging. Movement and resting duration decreased slightly from dry to wet seasons 22% to 20% and 25% to 22% respectively. Across both seasons, *Vachellia xanthophloea* (67%), *Maytenus senegalensis* (19%), and *Solanum incanum* (9%) made up the bulk of giraffe's diet. In the dry season, giraffes additionally foraged on *Maerua triphylla* (2%), *Vachellia gerrardi* (2%), and *Grewia similis* (1%); in the wet season, they added *Vachellia abyssinica* (2%) and *Rhus natalensis* (2%) to their diet. The most utilized browsing height was 3.5 meters (level 5), below their average height. Giraffes browse at lower heights after they consume the young shoots from the top of the bushes. Overall, seasonality did not appear to influence the Nubian giraffe's activity budget or foraging patterns in LNNP. Planting perennial plants encourage uniform park resource use, boosts forage diversity, and minimizes *Vachellia* browsing pressure.

Introduction

Animals have an activity time budget that reflects physiological traits and ecological interactions (Norris et al., 2010; Blake et al., 2012). These behavioral decisions (i.e., what activities to perform and how much time to dedicate to them) can affect survival and reproduction (Gaillard et al., 2010). For example, an animal whose behavior (foraging success) reduces its predation risk has a higher likelihood of survival and breeding (Lind and Cresswell, 2005; Sansom et al., 2009). Understanding how animals allocate their time across various activities is valuable for informing management actions (Burger et al., 2021).

The Critically Endangered Nubian giraffe is the most at-risk subspecies in Kenya, with only ~700 individuals in the country (Wube et al., 2018). Of these, 120 reside in LNNP (Brown et al., 2021). Most of the Nubian giraffe populations are isolated in a fenced park (Dagg, 1962; Ciofolo, 1995; Brenneman et al., 2009). Factors like habitat degradation, have reduced the Nubian giraffe's habitats by 37% in Sub-Saharan Africa and 75% in Kenya (O'Connor et al., 2019). Despite the population status and habitat loss, factors influencing Nubian giraffe activity time budget and forage patterns are not well known (O'Connor et al., 2019).

Declining numbers and increased tannin levels of *Vachelia* trees (a defense mechanism against the high browsing pressure) are some reported issues by Brenneman, 2009 in Lake Nakuru National Park, an enclosed park in Kenya (Brenneman et al., 2009). Dietary complications from highly concentrated tannin levels because they consume *Vachelia xanthophloea* trees may compromise young giraffe, making them easy and opportunistic prey for predators (Brenneman et al., 2009). It is crucial to understand the behavioral adjustments of giraffes to such changes, given that Vachelia species are important in giraffe's diet.

Studies on giraffe's behavior in Kenya are limited, especially on activity patterns and foraging patterns. Given that little is known about the issue and the importance of this information for informed conservation and management actions, the objectives of this study were to evaluate the effects of seasonal changes on activity time budget and foraging patterns of Nubian giraffe in Kenya's LNNP.

Methods and Study Site

LNNP is a national park that covers 188 km^2 in the Rift Valley in Nakuru County, Kenya (00^0 18'S and 00^0 30'S and 36^0 03' and 36^0 07'E), lying approximately 1759 m above sea level (KWS, 2011). The park is surrounded by the Menengai Crater, Bahati escarpment, and Mau escarpment (KWS, 2011). The park receives an average annual rainfall of 750 mm, distributed evenly between April to June and from October to December. Dry seasons run from July to September and January to March. The dry seasons' daily maximum temperature reaches 28°C and a minimum 9°C. Daily minimum and maximum temperatures during the wet seasons average 8.2°C and 25.6°C (KWS, 2011). The broad habitat types in the park include; grasslands, woodlands, and forests. *Vachellia* woodlands are widespread and linked to high water table areas (Figure 1).

To ensure that sightings were recorded consistently and reliably we conducted pre-visit training in 2018. The park was divided into three equally sized blocks (A, B, and C) covering the entire park. Each block had heterogeneous vegetation, with *Vachellia* woodland, grassland, and bushed woodland as the main types. We used roads that cut across each block as sampling lines. Each transect was 50km in length.

Seven people were involved in the sampling. Three team members monitored giraffe behavior, two captured images for WILD-ID identification, and two identified plant species browsed by giraffe and estimated feeding heights. Behavioral observations then took during the dry (13th- 15th February and 20th-22nd February) and wet seasons (31st May - 2nd June and 11th -13th July) of 2019. Each data collection period lasted three days. We randomly picked a block to survey, then selected one tower (a group of 5-25 giraffes) from that block. For each three-day data collection period, we followed the first group of giraffes encountered in any block during day one; on subsequent days, we focused on the remaining blocks until all blocks had been sampled. Four observations were conducted each day, two in the morning (0800-0900 and 1100-1200) and two in the afternoon (1400-1500 and 1700-1800).

For behavioral observations, we used a scan sampling method to assess how the Nubian giraffe allocates time for daily activities, observing the giraffe from a pickup 50-100m away to minimize disturbing the animals (Altmann, 1974). We waited for 5 minutes before starting observations to allow the giraffe to adjust to our presence. Each hour, we conducted eight scans with each scan lasting five minutes with a 20-minute break after four scans.

Behaviors recorded included moving (running, walking), resting (lying down, standing, and socializing), foraging (biting or/and using the tongue to pull a leaf or twig), licking soil, and drinking. Three people were observing and recording the behavior of each giraffe in the herd once every 5-minutes scan sampling interval. Each person filled in their datasheet. At the start of the observation, we recorded the date, time, season (wet or dry), habitat type (Vachellia woodland, bushed woodland, or open grassland), tower size, and location (GPS coordinates). Each adult giraffe was photographed and identified after the fact using WILD-ID skin pattern-recognition software, to identify them as individuals and later determine the number of giraffes observed in the two seasons.

We documented plant species selection by each giraffe in each 5-minutes scan interval. We defined a foraging record as one plant species consumed by one giraffe during one scan. We identified the plant species selected by each giraffe taxonomically based on named species, photographs, illustrations, or descriptions. We estimated feeding heights visually using Deacon's (2015) classification, with the lowest level being below the knees (1m), the second being from the knees to the belly (1-2m), the third being from the belly to the back (2-3m), the fourth being from the back to the middle of the neck (3-3.5m), the fifth being from the middle of the neck to the head (3.5-4.0m), and the sixth being above the head (>4.0m).
For each season, we took the mean frequency of each activity recorded per hour to derive the percentage of time allocated to each activity overall. We totaled foraging records for each plant species consumed/hour and expressed them as a percentage of all feeding records for that hour, for each season. We calculated the percentage of occurrence of the various activities per hour and season; the percentage of occurrence of a plant species in the foraging records in each season, standard errors, and standard deviation, and presented the results in descriptive statistics. We performed an Independent t-test to test the means of each activity in the two seasons, dry and wet seasons. The dependent variables were the activities (foraging, resting, moving, and drinking water), plant species in the giraffe's diet, and foraging heights while the independent variables included time, season, and habitat types. We tested the differences in means of each forage species in the two seasons using the independent t-test. All statistical tests were significant at a 95% confidence limit if type 1 error (alpha) is less than 5% (0.05) (Zar, 1996). We conducted all statistical analyses using STATA version 12.0.

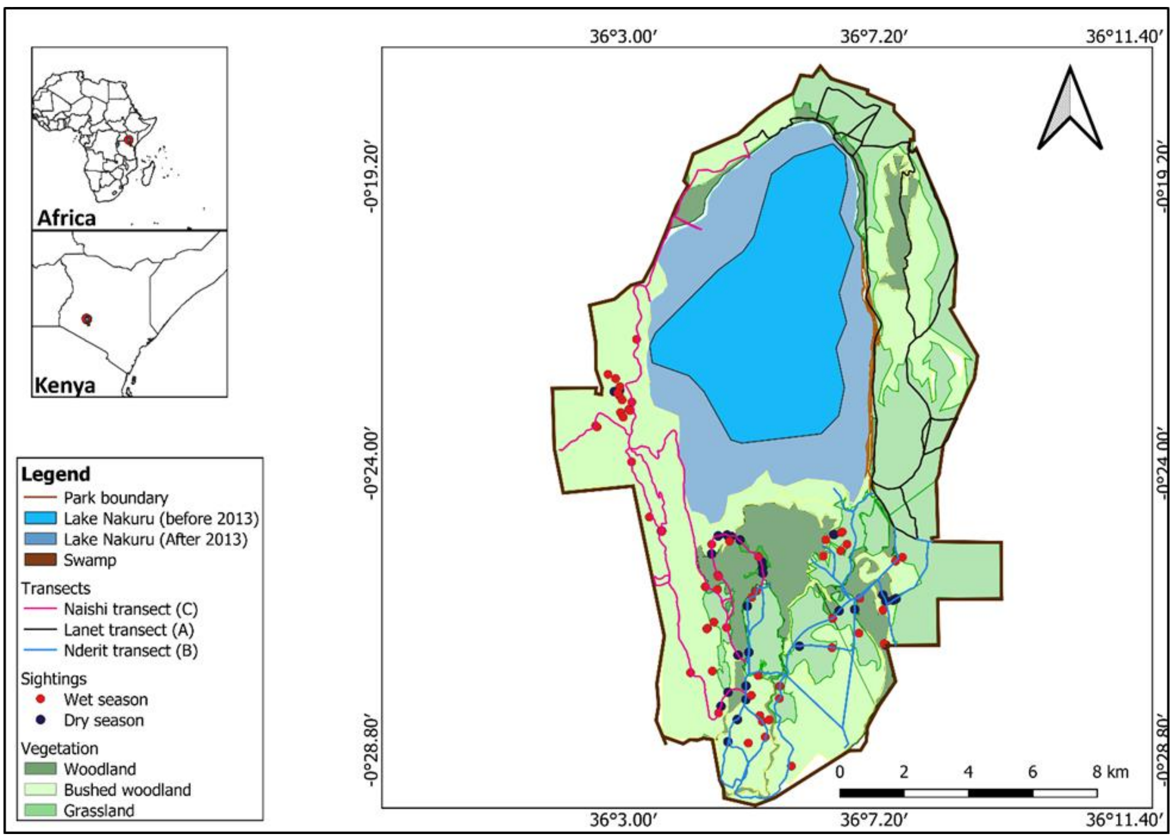

Figure 1: Map of Lake Nakuru National Park showing seasonal spatial distribution of key activity areas of Nubian giraffe in LNNP

Results and Discussion

Nubian giraffe's diurnal activities in the dry and wet season

In the dry and wet seasons, foraging was the principal activity (53% and 57% respectively). From the morning to midmorning of the dry season, giraffe spent over 50% of their time foraging, while resting and moving took 18 to 26% (Figure 2). Giraffe spend most of their time foraging, as observed in the current and other previous studies across Africa (Jeugd and Prins, 2000; Blomqvist and Renberg, 2007; Obari, 2009: Deacon, 2015; Mahenya et al., 2016). However, in Nairobi National Park, giraffe spend more time feeding (78%) (Obari, 2009) as opposed to 55% in this study. This is an indication that food shortage is a problem giraffe are facing in LNNP.

There was a marginal increase in the foraging time of giraffe from the dry to wet season (53 to 57 %) p=0.07. Giraffe allocate more time to move during the dry season when high-quality forage is scarce, in search of patches with high-quality forage (Fennessy, 2004; Dagg, 2014. During periods when temperatures are high, animals reduce foraging time to avoid overheating (Owen-Smith, 2008). During the dry season, the temperature of the study area ranged between 18-19^{0}C in the morning hours and 26-30^{0}C in the afternoon hours, while during the wet season temperatures in the morning hours ranged between 14-18^{0}C and in the afternoon hours 17-24^{0}C.

Movement and resting duration increased from dry to wet season by 22% to 20% and 25% to 22% respectively, although the difference was insignificant (p=0.49 and p=0.16). When the time spent by giraffe was highest (during morning hours) movement and resting time was at the lowest. When resting time was at the highest (afternoon hours), time spent foraging and moving was the shortest in both seasons. In both seasons, afternoon resting time was highest, but more so in the dry season. Giraffe, like other animals, strives to balance between spending a long time (using more energy) searching for high-quality forage plant species or allocating a short time (using less energy) to readily available forage species that are of low quality which are two contrasting strategies (Martin and Hine, 2015)

In both dry and wet seasons, giraffe foraged mainly on riverine *Vachelia xanthophloea* vegetation, which is succulent throughout, reducing the need to drink water. This observation is supported by their physiological adaptations that conserve water coupled with foraging on moisture-rich trees and shrubs (Fennessy, 2004).

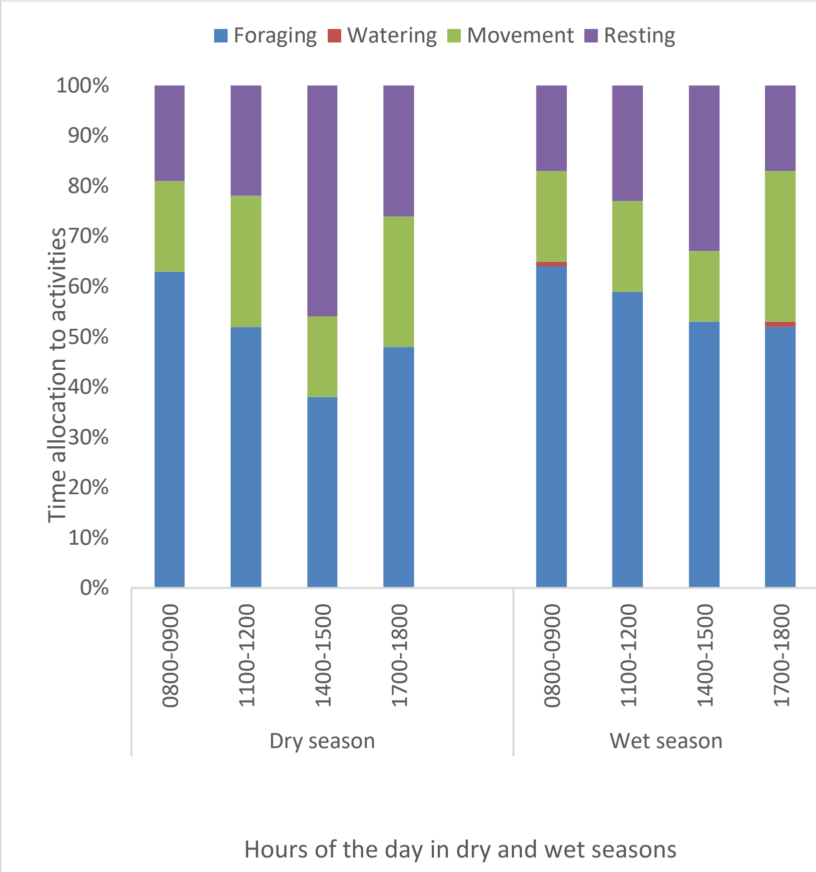

Figure 2: Diurnal activity time budget of Nubian giraffe during the dry and wet seasons

Nubian giraffe's diurnal activities in different habitat types

Giraffe spent most of their time in the *Vachellia* woodland during both dry (60%) and wet seasons (63%). and more so in the morning and mid-morning hours (Figure 3). Selection for this habitat was attributed to the high availability of the preferred forage species mainly *Vachellia xanthophloea* and secondly, giraffe actively forage during this period. In congruence with observations by Deacon and Smit, (2017) abundance of the principal forage species influences the percentage of time spent by giraffe in the different vegetation types.

Giraffe spend most of their afternoon hours in the Vachellia woodland. Vachellia woodlands are characterized by tall *Vachellia xanthophloea* trees that provide shade from the large canopy during the afternoon when temperatures are extremely high, while bushed woodland and open grasslands have few tall trees. Complete avoidance of bushed woodland in the afternoon hours of the dry season when temperatures were high can partially be attributed to the lack of ample shade for the giraffe. The bushed woodland habitat is characterized by fewer *Vachellia xanthophloea* trees with large canopies to provide shade compared to the other habitat types. Similar results were made by Valeix et al., (2008), where giraffe in Hangwe National Park avoided areas with minimal shade in hotter periods of the day when solar radiations were at the maximum. Further, other herbivores, just like the giraffe were also observed to move to more open areas when wind intensity was higher for evapotranspiration-related heat loss (Valeix et al., 2008).

Open grasslands make it easy for giraffe to spot predators, hence the observed high selection of this habitat type during evening hours of the dry season. This behavior by giraffe along with other herbivores reduces the probability of predation. For instance, Owen-Smith, (2008) and Valeix et al., (2009) noted that giraffe and other herbivores moved to more open habitats when the risk of predation was high, e.g. the presence of

lions in their vicinity. Selection for *Vachellia* woodland in all the time sessions during the wet season could be an indicator that the other two habitats were used preferably to compensate for forage deficiencies.
In both dry and wet seasons, giraffe only used the park's southern part (Figure 1). In this study area, the northern part of the park is characterized by a cliff, which makes it difficult for the giraffe to utilize the area. This is escalated by the increased water levels of Lake Nakuru that have reduced the habitat available for giraffe in this part of the park. The narrow strip of the habitat left also increases giraffe's vulnerability to predation hence a likelihood of being avoided. Giraffe, just like other animals, selects a habitat as an outcome of their characteristics (including movement, growth, reproduction), the landscape they inhabit, and the interactions among the animals and the habitat (Godvik et al., 2009; Beest et al., 2016; Thurfjell et al., 2017).

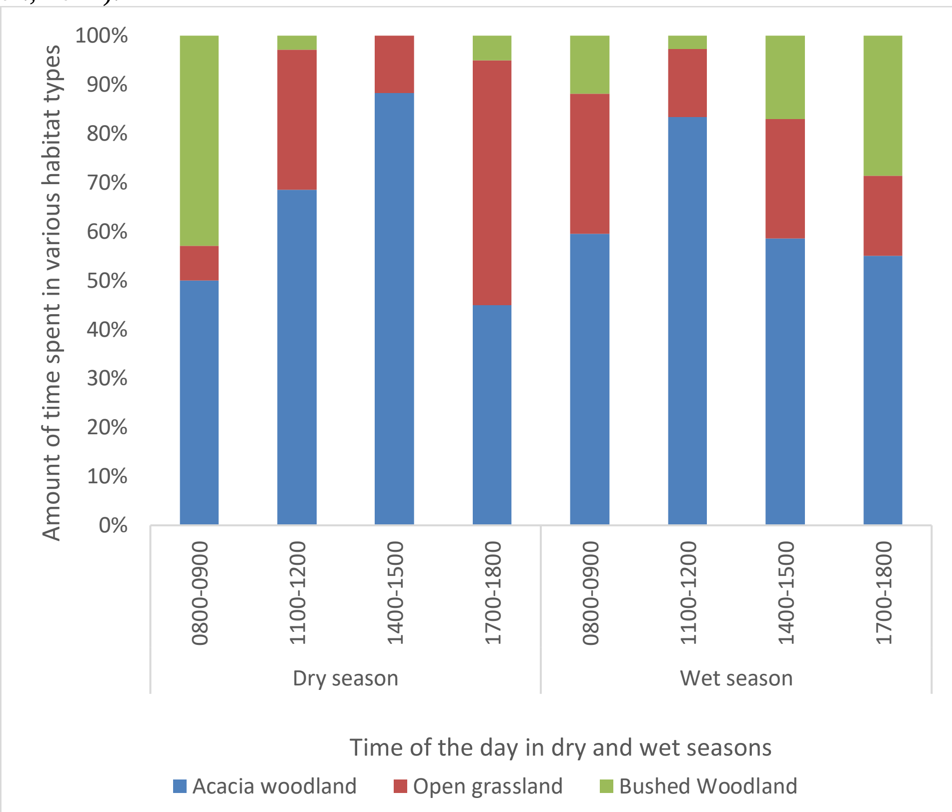

Figure 3: Habitats preferred by Nubian giraffe for various activities at different times of the day during the dry and wet seasons

Nubian giraffe's forage species selection in dry and wet seasons

Giraffe in LNNP forage on *Vachellia xanthophloea* (67%), *Maytenus senegalensis* (19%), *Solanum incanum* (9%), *Maerua triphylla* (2%), *Vachellia gerrardii* (1%), *Vachellia abyssinica* (1%), *Rhus natalensis* (1%), and *Grewia similis* (0.5 %) (Figure 4). In both seasons, *Vachellia xanthophloea*, *Maytenus senegalensis*, and *Solanum incanum* contributed to the bulk of giraffe's diet in dry and wet seasons (Figure 4). They did not only forage on leaves of *Vachellia xanthophloea* but also the barks causing debarking, an indication of the high selection of this species. These results are congruent with observations from other studies that reported Vachellia species to be the most browsed species by giraffe in different regions. For instance, Obari, (2009), Mahenya et al., (2016), Munyaka and Gandiwa, (2018), Williams and Williams, (2018), Gordon et al., (2016) and O'Connor et al., (2015). Vachellia species were seen to have the most nutritive value among 14 woody species in Zambezi National Park in Zimbabwe, with high In Vitro Gas Production (IVGP), low Acid Detergent Fiber (ADF), and low Condensed Tannin (CT) concentration hence preferred by giraffe (Mandinyenya et al., 2019).

During the dry season, *Vachellia xanthophloea* (72%) was more selected over *Maytenus senegalensis* (12%), *Solanum incanum* (11%), *Maerua triphylla* (2%), *Vachellia gerrardii* (2%), and *Grewia similis* (1%) (Figure 4). During the wet season, *Vachellia xanthophloea* (63%) was most selected, followed by *Maytenus senegalensis* (23%) and *Solanum incanum* (8%), while *Maerua triphylla*, *Vachellia abyssinica*, and *Rhus natalensis* (2%) were least (Figure 4). *Grewia similis* and *Vachellia gerrardii* were only browsed in the dry season, while *Vachellia abyssinica* and *Rhus natalensis* were browsed in the wet season (Figure 4). *Vachellia xanthophloea* selection dropped from 72% to 63% (p=0.31) and *Solanum incanum* from 11% to 8% (p=0.42). Giraffe only foraged on *Grewia similis* and *Vachellia gerrardii* during dry seasons (1 and 2%). *Vachellia abyssinica* and *Rhus natalensis* were only browsed during the wet season at 2% each. Selection for *Maytenus senegalensis* increased significantly from 12% in dry to 23% in the wet season (p=0.004). *Maerua triphylla* selection was 2% in both dry and wet seasons.

Vachellia xanthophloea is a riverine tree species; hence it remains green even in the dry season. Selection for *Maerua triphylla* remained more or less the same in the dry and wet seasons while selection for *Maytenus senegalensis* increased from dry to the wet season. This can be explained by the fact that *Maytenus senegalensis* is deciduous, thus reducing the amount of available browse for giraffe during the dry season, while it produces new leaves and flowers on the onset of rain (Dziba et al., 2003; Singh and Kushwaha, 2016). *Maerua triphylla* is a riverine plant species and is also known to occur in evergreen or deciduous woodland, making forage available in both dry and wet seasons (Mbuvi et al., 2019). The increase in plant species' selection from dry season to wet season observed in this study is similar to previous studies elsewhere. Examples of studies are, Parker and Bernard, (2005), Berry and Bercovitch, (2017), Deacon, (2015), and Dziba et al., (2003).

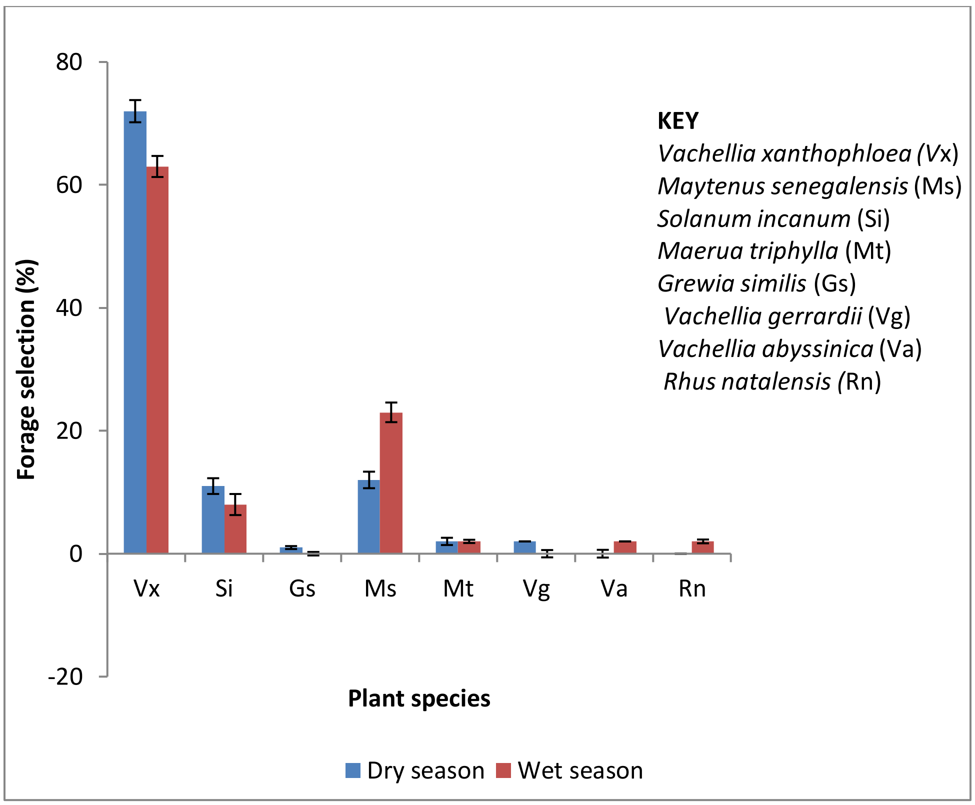

Figure 4: Percentage browse species selection by Nubian giraffe during the dry and wet seasons

Giraffe's preferred foraging heights in dry and wet seasons

During the dry and wet seasons, giraffe preferred browsing at 3.5 m (level 5) (49% and 46%), while 1 m (level 2) was the least preferred (7 % and 4%) (Figure 5). The most preferred foraging height was between

1.7 and 3.7 meters, which is the average body height of an adult giraffe. These heights are also comfortable for the forelegs. Some studies recorded similar results including, Blomqvist and Renberg, (2007), O'Connor et al., (2015), Woolnough and du Toit, (2001), and Mahenya et al., (2016). Some other studies, however, have reported different results; for instance, giraffe were observed to prefer feeding about or above 5 meters by Obari, (2009) in Nairobi National Park. In other studies feeding selection of below 2 meters was noted, e.g., Gordon et al., (2016) observed that giraffe regularly fed on plants below 1.5 m. The different observations could be attributed to differences in vegetation types with variations in species composition of different heights.

Foraging at 2 and 3 meters (levels 3 and 4) increased by 6% (9–15%) during the dry season and 5% (25–30%) during the wet season, respectively (Figure 5). This could be associated with the increased growth of new shoots and leaves at lower levels after rains. The feeding separation reduces competition for forage with other browsers in all seasons.

In both seasons, levels 2 and 3 had the highest number of plant species foraged (Figure 6). *Vachellia xanthophloea*, *Solanum incanum*, *Maytenus senegalensis*, *Maerua triphylla*, and *Vachellia gerrardii* dominated at level 3 (2 m). The number of species foraged at this height, however, decreased as foraging height increased in both seasons. During the wet season, an increase in foraging heights from 1 m to 3.5 m (level 2 to level 5) led to an increase in the number of plant species that giraffe browsed, from 4 to 5 species (Figure 6). *Vachellia xanthophloea*, *Maytenus senegalensis*, *Maerua triphylla*, *Vachellia abyssinica*, and *Rhus natalensis* dominated levels 4 and 5 (Figure 6).

The results of this study support the hypothesis that there is no seasonal effect on the diurnal activity time budget of Nubian giraffe in Lake Nakuru National Park. The results of this study did not entirely support the hypothesis that Nubian giraffe's foraging habits vary significantly between the dry and wet seasons, as there was no significant difference in the selection of *Vachellia xanthophloea*, *Solanum incanum*, and *Maerua triphylla* in the dry and wet season.

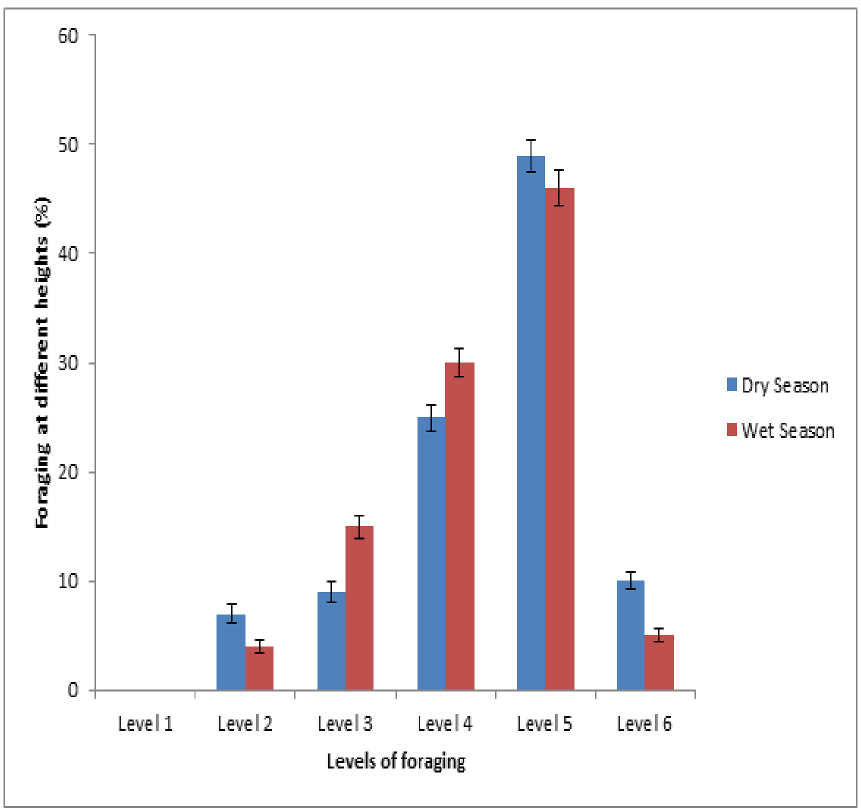

Figure 5: Giraffe's preferred foraging heights in dry and wet seasons

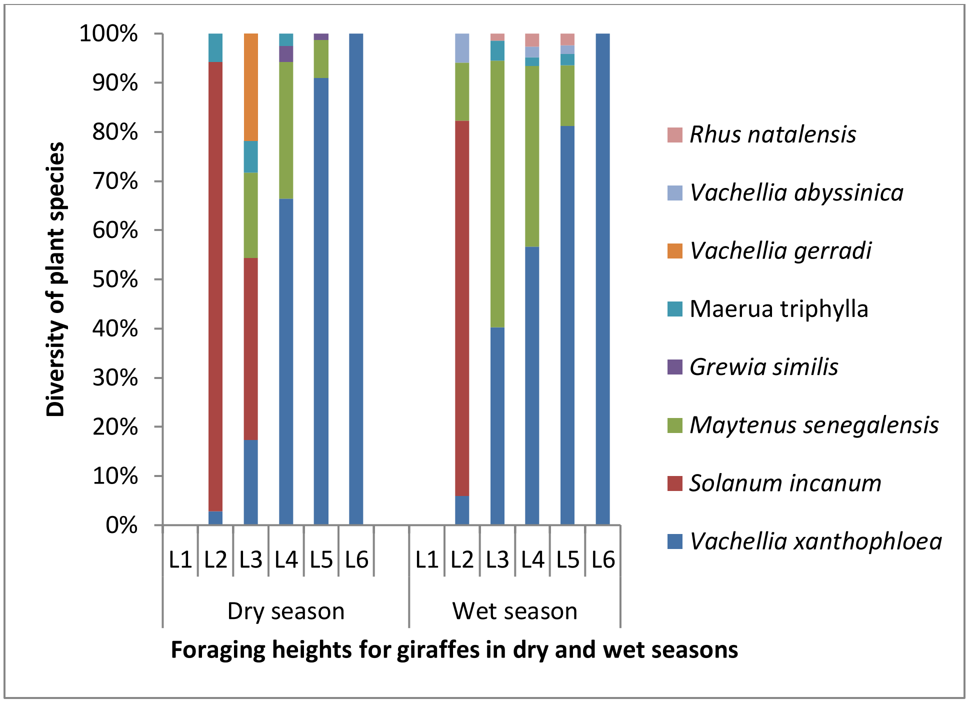

Figure 6: Browse species selection in relation to foraging heights in dry and wet seasons

Conclusions

Nubian giraffe prefer *Vachellia* woodland habitat in LNNP. Seasonal changes do not affect giraffe's diurnal activity time budget in LNNP; foraging is the principal activity in dry and wet seasons. Temperature affects giraffe's activity time budget. Giraffe in LNNP are water-independent and adapted to ASALS. The risk of predation affects where giraffe forage. Evergreen species like *Vachellia xanthophloea*, *Solanum incanum*, *Maerua triphylla*, *Maytenus senegalensis* were used year-round. Out of the eight selected plant species in LNNP, *Vachellia xanthophloea* ranked highest in selection in both seasons. Despite being invasive, *Solanum incanum* was the third-most-selected browse. Giraffe prefer to feed 3.5 meters above the ground despite seasonal differences. This is the average height of an adult giraffe and allows niche separation, minimizing herbivore competition.

Replanting woody species consumed by giraffes in the park should be done in three giraffe habitats. This will expand the diversity of giraffe forage plant species in the park to better meet their dietary needs and reduce possible *Vachellia* woodland over browsing. Active management of the bushed woodland must complement the replanting efforts to decrease predation and promote giraffe redistribution. More water pans and maintaining existing ones would ensure giraffe have water year-round and promote even use of different habitat types hence avoiding overexploitation of *Vachellia* woodland. Lake Nakuru's rising water levels have submerged 2 km of the park, decreasing the giraffe's habitat. If this further threatens their survival in the park, translocation is a plausible option to protect them. To increase the home range of the giraffe and reduce the food shortage, considering the positive impacts of *Solanum incanum* as a food resource for giraffe in the park, despite being an invasive species is plausible

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