Journal of Agriculture Science & Technology JAGST 22 (4) 2023, 1-15

ORIGINAL RESEARCH ARTICLE

Effects of different rangeland management practices on vegetation metrics and wildlife abundance in a semi-closed ecosystem in north-central Kenya

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Abstract

Rangelands contribute at least 30% of terrestrial net primary productivity, making them an important part of natural ecosystems despite low and unpredictable rainfall regimes. Rangelands are sensitive to anthropogenic activities, making management interventions key to maintaining forage quality and quantity for wildlife. This study explored the effects of mowing of grasslands and carrying away (MO), prescribed grazing (PG), and unprescribed grazing (UG) on above-ground biomass, basal gaps, and wildlife abundance at Lewa Wildlife Conservancy in Meru, Kenya. Data collection was done 18 months after treatment for PG and MO, while UG was continuous. Treated blocks were selected in a systematic and random way, while adjacent untreated plots acted as controls. Blocks were divided into 100 m × 100 m grid cells using ArcMap 10.8.1, where sampling plots were drawn. T-statistics and analysis of variance (ANOVA) tests were used to test statistical significance. We found a significant reduction in the above-ground biomass between MO and its control ($t = 4.886$, $p = 0.003$) and between UG and its control ($t = 5.487$, $p = 0.007$). No significant change was observed between PG and its control ($t = 1.192$, $p = 0.287$). MO increased wildlife abundance ($t = -4.670$, $p = 0.003$), while PG ($t = 0.589$, $p = 0.583$) and UG ($t = -0.262$, $p = 0.803$) showed no difference compared to their controls. The mean length of basal gaps between MO and its control decreased ($t = 7.069$, $p = 0.001$), while those between UG and its control increased ($t = -4.053$, $p = 0.001$), with no effect observed between PG and its control ($t = 1.882$, $p = 0.061$). This study recommends the use of mowing of grasslands and carrying away on rangelands as it positively influence the metrics under investigation.

Key words: Prescribed grazing, unprescribed grazing, mowing of grasslands and carrying away, basal gaps, above-ground biomass.

1.0 Introduction

Rangelands include shrublands, grasslands, and savannahs and take up about 50% of the earth's landmass (Bailey, 1996). They are largely arid and semi-arid lands, experiencing low and unpredictable annual rainfall regimes. Despite this, they contribute at least 30% of terrestrial net primary productivity (Field et al., 1998). This underlines their status as important parts of many natural ecosystems, providing an array of ecosystem goods and services (Fox et al., 2009) while remaining sensitive to internal and external factors such as anthropogenic activities

URL: https://ojs.jkuat.ac.ke/index.php/JAGST
ISSN 1561-7645 (online)
doi: 10.4314/jagst.v22i4.1

(Yuanming et al., 2003). The quality of the goods and services provided is dependent on the level of management practises put in place (Fox et al., 2009).

Rangelands are primarily dominated by large wild and domestic mammalian herbivores, more than any other ecosystem (Ogutu et al., 2016). Wildlife in rangelands has been noted to be on the decline in the recent past (Rija et al., 2020; Geldmann et al., 2019), particularly in Africa, with this decline attributed to rangeland degradation (Scholte, 2011). In response to this, ecologists have devised a wide range of management practises to maintain rangeland health and productivity, plant species diversity, and wildlife abundance (Bailey et al., 2019). These strategies include prescribed grazing, burning of grassland, mowing of grassland, and the establishment of exclusion zones. These management practises are meant to improve rangeland health by influencing vegetation metrics and wild ungulates.

Across East African rangelands, grasses and herbaceous plants are the primary sources of sustenance for livestock and wildlife (Tefera et al., 2007). The availability of this natural pasture is dependent on the complex interactions between ecosystem components such as water, climate, soils, plants, and animals (Azimi et al., 2013). On Kenyan rangelands, especially, proper management practises are necessary considering that at least 65% of wildlife roams on communal and private lands (Western et al., 2009).

The north-central Kenya rangelands are intermediate between areas of occasional prolonged droughts in the North and the rainy highlands of Mount Kenya in the south. With the ever-growing population of humans and livestock in Kenya, particularly in the north (FAO and Palladium Group, 2019), competition for resources between livestock and wildlife is notable (Prins, 2000). Since wildlife dispersal is a vital life history trait practised by many wild species (Tucker et al., 2018; Yurco, 2017), they normally move to these north-central rangelands of Kenya for pasture. This has seen the growth of large, semi-closed private conservancies in the region to accommodate a large number of wild animals and promote the best wildlife management practises to grow endangered wildlife species (Sundaresan and Riginos, 2010). Therefore, large private semi-closed systems afford a great opportunity for rangeland management experiments.

The goal of this study was to examine the effects of PG, UG, and MO management practises on above-ground biomass, basal gaps, and wildlife abundance after 18 months of interventions, apart from UG, which was continuous. We predicted that each rangeland management practise is likely to affect the quality and quantity of above-ground biomass differently, influencing wildlife abundance. This was informed by the nature and intensity of each method, where mowing removed vegetation only while the two grazing methods had additional components of trampling and deposition of livestock excreta on the surface.

2.0 Materials and methods

2.1 The study area

The study was undertaken at Lewa Wildlife Conservancy (LWC), located at latitude 0.20N and longitude 37.42E in Meru County, Kenya, and covering an area of approximately 25,000

ISSN 1561-7645 (online)
doi: 10.4314/jagst.v22i4.1

hectares (Figure 1). The habitat can be described as a savannah with at least 2% shrub and tree cover (Dupuis-Desormeaux et al., 2018).

The Conservancy has undergone multiple land uses in the last half-century, namely cattle ranching, partial agriculture, rhino sanctuary, and the current state of a wildlife conservancy. Different management practises have also taken place in the Conservancy, with the recent ones being the construction of elephant exclusion zones, prescribed grazing (PG), unprescribed grazing (UG), and mowing of grasslands and carrying away (MO) (Giesen et al., 2017; Trollope and Trollope, 1999). The Conservancy also forms a crucial habitat for wildlife and hosts several species of conservation concern, namely the critically endangered Black rhino (*Diceros bicornis* ssp. *michaeli*), the near-threatened Southern white rhino (*Ceratotherium simum* ssp. *simum*), the endangered Grevy's zebra *(Equus grevyi)*, the endangered Beisa oryx (*Oryx beisa* ssp. *beisa*), the endangered Lelwel hartebeest (*Alcelaphus buselaphus* ssp. *lelwel*), and the critically endangered Pancake tortoise (*Malacochersus tornieri*) (IUCN, 2020; Giesen et al., 2017).

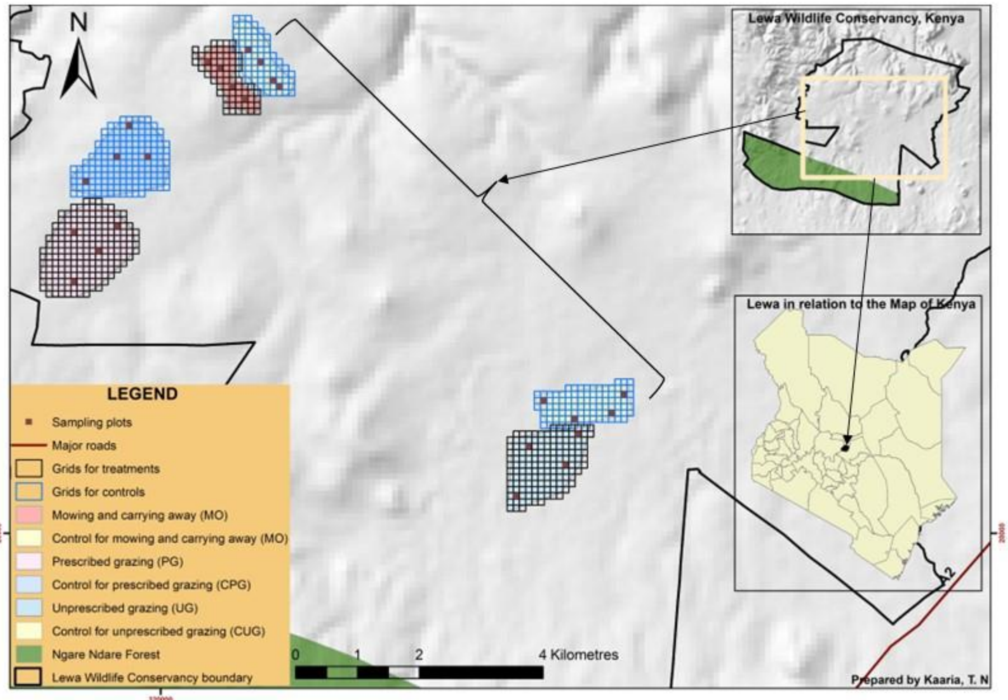

Figure 1: The study area map

2.2 Description of the treatments

2.2.1 Prescribed grazing

Cattle were confined to blocks of known acreage in June 2020. The duration of stay, known as the Animal Days per Acre (ADA), was 25 cows per Day per Acre, which is the known patch size required to feed an adult cow for one day for LWC (Schulz et al., 2014; Butterfield et al., 2006).

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doi: 10.4314/jagst.v22i4.1

2.2.2 Mowing of grasslands and carrying away

A lawn mower was set at a height of 15 cm. The mower was towed by a tractor in June 2020 to cut grass on 120 acres of land. The grass was then gathered by a hay rake, the hay created by a baler, and carried away from the site.

2.2.3 Unprescribed grazing

This took place on approximately 450 acres of government land within the LWC, known as the Livestock Management Department (LMD) area. The livestock (cattle and shoats) from the surrounding communities grazed on this block uncontrollably and considerably intensively throughout and was not stopped at any time, even during the time of the study. This block was demarcated by public and private roads, which were used by the Conservancy rangers to patrol and prevent livestock from accessing the Conservancy. This allowed for a control to be selected within the Conservancy.

2.3 Research design and procedures

Random, systematic selection of the blocks was employed (Mirdeilami et al., 2017). This was done by assigning random numbers to the blocks that received similar treatment separately. The adjacent untreated blocks that matched the physical soil and site characteristics of the selected blocks acted as control plots. Control plots for prescribed grazing were annotated as CPG, unprescribed grazing as CUG, and mowing of grasslands and carrying away as CMO. 100 m x 100 m grid cells were developed using ArcMap 10.8.1 to cover each selected block and its control separately. All complete cells were numbered, and four cells in each block were selected randomly to form a sampling plot (Kimiti et al., 2020; Mirdeilami et al., 2017).

2.4 Data collection methods

2.4.1 Biomass

A modified line-point intercept was employed (Herrick et al., 2017). At every five metres of a 25-metre transect, a 50 cm by 50 cm quadrat was placed. All the vegetation inside the quadrats was clipped and air-dried until it attained a constant weight, and the final weight was recorded to estimate biomass by getting the average weight per sampling plot.

2.4.2 Basal gaps

A 25-m line transect was established where the length of any gap between rooted vegetation was measured in centimetres. The cumulative length of all the basal gaps in each treatment was compared against its control to determine the effects (Kimiti et al., 2020).

2.4.3 Wildlife abundance

Inside each sampling plot, a 4 m by 100 m line transect was established to count wildlife dung piles. We walked through the middle of the transect, counting the dung piles within 2 metres on both sides (Figure 2). Each dung pile was regarded as one individual, and the species responsible was identified using a field guide for wildlife tracks and signs by Stuart (2013) and in consultation with the Conservancy rangers. The dung pile count was repeated twice at an interval of two weeks. To circumvent recounting the dung piles during successive surveys, all

ISSN 1561-7645 (online)
doi: 10.4314/jagst.v22i4.1

the recorded dung piles were smashed during each period the data was collected (Kimuyu et al., 2017). The data obtained was used to estimate wildlife densities per acre of land as follows:

$$D = \frac{n}{lw} \times 4{,}046.86\ m^2 \tag{1}$$

Where;

D	=	*Density of dung piles of a species per acre*
n	=	*Number of dung piles per transect*
l	=	*Length of the transect in metres*
w	=	*Width of the transect in metres*
m^2	=	*Metres squared*

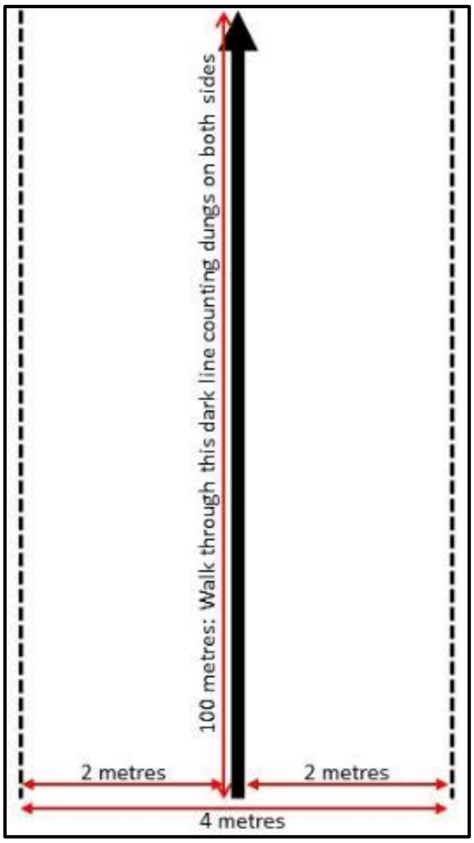


Figure 2: A line transects for the dung survey

2.5 Data analysis and presentation

Data analysis, both descriptive and inferential statistics, was done in R version 4.0.3 (R Core Team, 2022). We used the p=0.05 significance level to test for statistical significance. A two-sample t-test was used to compare differences between a treatment and its control, while the analysis of variance (ANOVA) test was used to compare the magnitude of change (treatment minus control) among treatments. Where significance existed while implementing the ANOVA test, Duncan's multiple range test was used as a post hoc test.

ISSN 1561-7645 (online)
doi: 10.4314/jagst.v22i4.1

3.0 Results

3.1 Effects of management practises on the above-ground biomass

Two-sample t-tests showed a significant reduction in the mean amounts of above-ground biomass between MO (649.13 ± 106.91 SE) and CMO (1335.50 ± 91.12 SE) (t = 4.886, p = 0.003) (Figure 3a) and between UG (1092.06 ± 32.90 SE) and CUG (1651.42 ± 96.50 SE) (t = 5.4866, p = 0.0068) (Figure 3b). No significant change was observed in the mean amounts of above-ground ground biomass between PG (1448.26 ± 161.17 SE) and CPG (1811.65 ± 258.90 SE) (t = 1.1916, p = 0.2867) (Figure 5c).

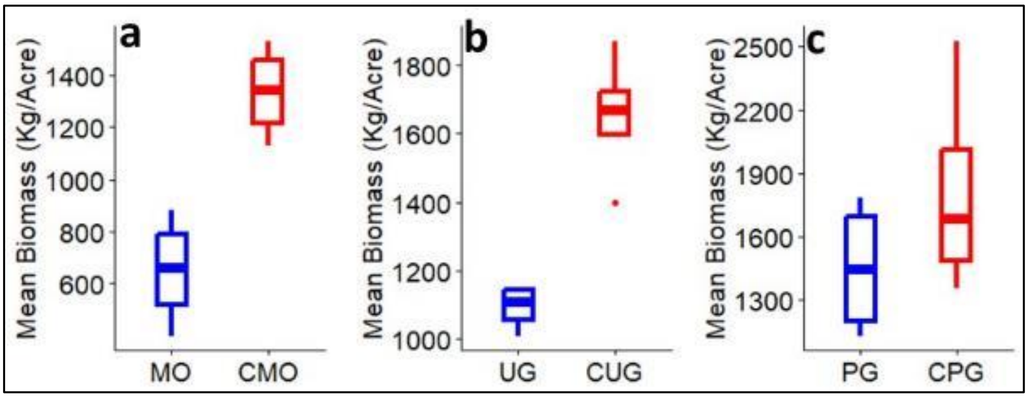


Figure 3: Change in above-ground biomass between a) mowing of grasslands and carrying away and its control; b) prescribed grazing and its control; and c) unprescribed grazing and its control

A one-way analysis of variance (ANOVA) test did not record a significant difference in the magnitude of change between group means in UG (-559.36 ± 145.74 SE), PG (-363.38 ± 173.86 SE), and MO (-686.37 ± 46.13 SE) ($F_{(2, 57)} = 1.482$, p = 0.236) (Figure 4).

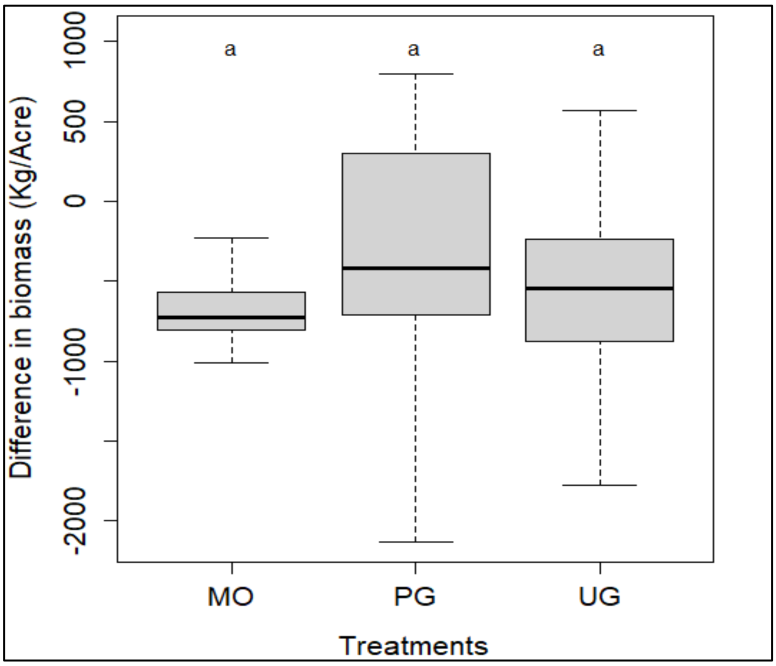


Figure 4: Magnitude of change of above-ground biomass among treatments

ISSN 1561-7645 (online)
doi: 10.4314/jagst.v22i4.1

3.2 Effects of management practises on the basal gaps

Two-sample t-tests showed a significant decrease in the mean length of basal gaps between MO (19.43 ± 1.01 SE) and CMO (35.49 ± 2.04 SE) (t = 7.069, p = 0.001) (Figure 5a) but a significant increase between UG (32.88 ± 2.43 SE) and CUG (22.03 ± 1.13 SE) (t = -4.053, p = 0.001) (Figure 5b). No significant change was observed in the mean length of basal gaps between PG (28.06 ± 1.41 SE) and CPG (32.17 ± 1.67 SE) (t = 1.882, p = 0.061) (Figure 5c).

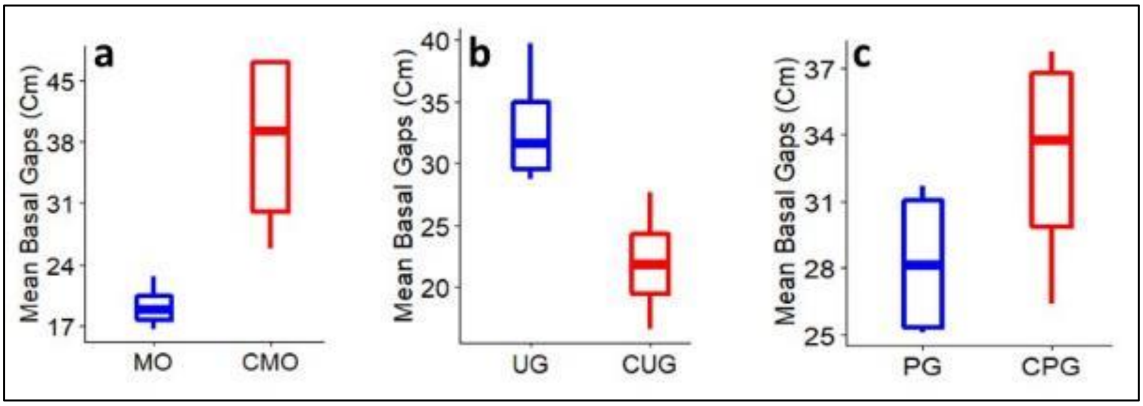
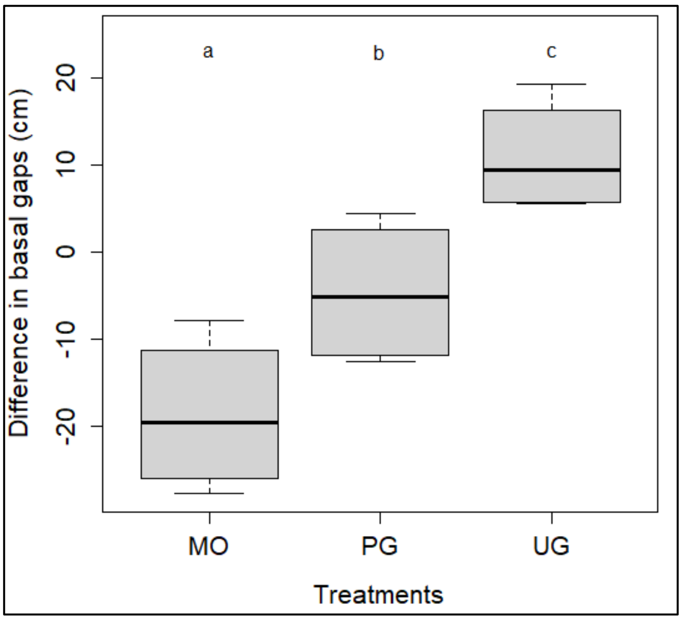


Figure 5: Change in basal gaps between a) mowing of grasslands and carrying away and its control; b) unprescribed grazing and its control; and c) prescribed grazing and its control

A one-way analysis of variance (ANOVA) test recorded a significant difference in the magnitude of change between group means in UG (10.98 ± 3.29 SE), PG (-4.64 ± 4.24 SE), and MO (-18.73 ± 4.55 SE) ($F_{(2, 9)}$ = 13.40, p = 0.002) (Figure 6).

Post hoc pairwise comparisons using Duncan's multiple range test indicated differences between PG and MO (p = 0.037), between UG and MO (p = 0.001), and between UG and PG (p = 0.024).



ISSN 1561-7645 (online)
doi: 10.4314/jagst.v22i4.1

Figure 6: Magnitude of change of basal gaps among treatments

3.3 Effects of management practices on wildlife abundance

Two-sample t-tests showed a significant increase in the mean wildlife densities between MO (460.33 ± 43.02 SE) and CMO (171.99 ± 44.29 SE) (t =-4.670, p = 0.003) (Figure 7a). There was no significant difference observed between UG (619.68 ± 86.08 SE) and CUG (584.27 ± 104.44 SE) (t =-0.262, p = 0.803) (Figure 7b) and between PG (275.69 ± 48.23 SE) and CPG (308.57 ± 28.17 SE) (t = 0.589, p = 0.583) (Figure 7c).

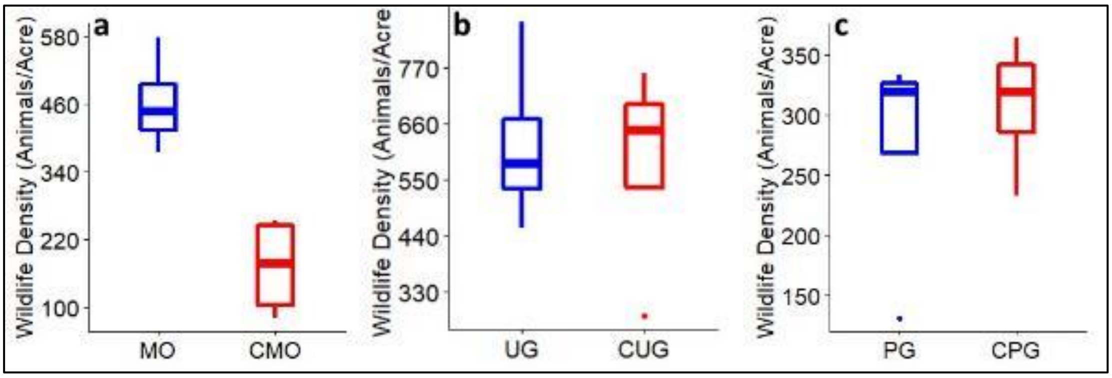


Figure 7: Change in wildlife densities between a) mowing of grasslands and carrying away and its control; b) unprescribed grazing and its control; and c) prescribed grazing and its control

A one-way analysis of variance (ANOVA) test indicated a significant difference in the magnitude of change between group means in UG (35.4100 ± 100.5372 SE), PG (-32.8807 ± 70.3821 SE), and MO (288.3388 ± 37.5154 SE) ($F_{(2, 9)}$ = 5.216, p = 0.0313) (Figure 8).

Post hoc pairwise comparisons using Duncan's multiple range test indicate differences between PG and MO (p = 0.017) and between UG and MO (p = 0.039).

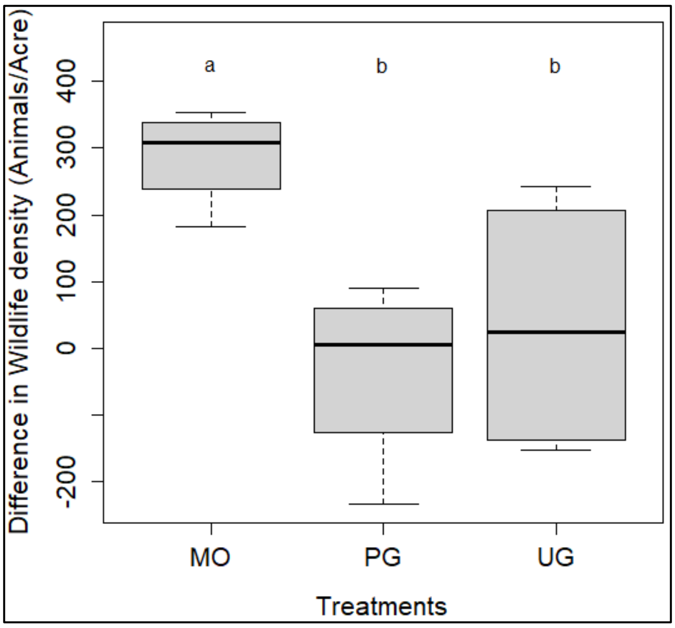


Figure 8: Magnitude of change of wildlife densities among treatments

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ISSN 1561-7645 (online)
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In mowed (MO) and unmowed (CMO) blocks where we recorded differences, we also observed large numbers of buffalo, Plains zebra, Grant's gazelle, elephant, and Lelwel hartebeest (Figure 9).

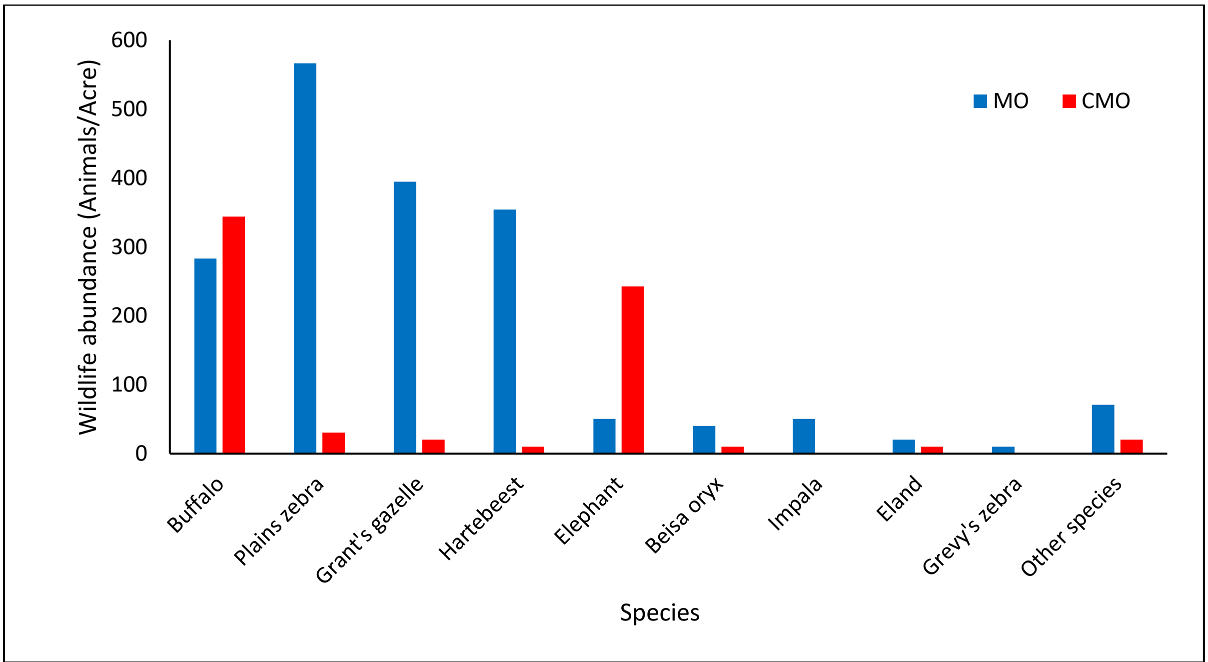

Figure 9: Wildlife abundance in mowed and unmowed blocks. Other species in the x-axis include Somali ostrich (Struthio molybdophanes), Duiker (Sylvicapra grimmia), and African hare (Lepus microtis). Species scientific names; Buffalo (Syncerus caffer), Plains zebra (Equus quagga), Grant's gazelle (Nanger granti), Lelwel hartebeest (Alcelaphus buselaphus ssp. lelwel), Elephant (Loxodonta africana), Beisa oryx (Oryx beisa), Impala (Aepyceros melampus), Eland (Taurotragus oryx), and Grevy's zebra (Equus grevyi)

4.0 Discussion

4.1 Effects of management practices on the above-ground biomass

The concept of rotational prescribed grazing of big herds, popularly known as holistic management, is highly controversial (Savoury, 1991). Some studies have associated the method with success, noting that it reduced above-ground biomass and improved vegetation quality (Kimuyu et al., 2017; Odadi et al., 2017; Teague et al., 2011; Jacobo et al., 2006), while others found no additional value when compared to less intensive but continuous grazing approaches (Carter et al., 2014; Joseph et al., 2002). On the other hand, while mowing has been documented to be costly, it has been recorded to yield similar results as grazing (Schulz et al., 2014).

Comparison of each treatment to its control indicates a significant difference as a result of mowing of grasslands and carrying away as well as unprescribed grazing, while no significant difference was observed from prescribed grazing. The observed differences resulting from the first two practises were similar, making them the preferred recommendations for rangeland practitioners whose main goal is to reduce above-ground biomass. It is worth noting that the magnitude of the difference in effects was not statistically significant between the three

ISSN 1561-7645 (online)
doi: 10.4314/jagst.v22i4.1

methods (Bi et al., 2020; Wang et al., 2019), which was most likely a result of the high variability in plot differences within both prescribed grazing and unprescribed grazing. With this variability within the prescribed grazing plots, we posit that the grazing rate of 25 cattle per acre per day may not be enough to significantly influence the above-ground biomass in the long term. This further supports the notion that the number and assemblage of cattle in grazing schemes are crucial in influencing notable long-term changes (Sargent, 2016).

4.2 Effects of management practises on the basal gaps

Prominent basal gaps increase runoff velocity, expose the land to erosion, and lead to degradation (Kimiti et al., 2020; Odadi et al., 2017). The Lewa Wildlife Conservancy (LWC) is dominated by *Cenchrus mezianus* and *Cenchrus stramineus* grasses, which are only edible while growing but reduce in palatability when fully mature, forming huge stands of lignified grass. Reducing the huge stands of such vegetation to 15 cm through mowing of grasslands and carrying away reduced competition for light by opening the canopies, allowing other grasses and forbs to grow, reducing the basal gaps (Odadi et al., 2011; Schulz et al., 2014).

Unprescribed grazing, by its nature, was intensive and non-stop, hardly allowing existing vegetation to regenerate and new species to grow. This significantly reduced above-ground biomass without allowing recovery, thus increasing the basal gaps, and subsequently exposing the ground to the risk of erosion and degradation (Bi et al., 2020; Brenton, 2016; Kairis et al., 2015).

The goal of prescribed grazing is to reduce the risk of land degradation caused by soil erosion. This is because the previously exposed bare ground is instead occupied by a more herbaceous foliar cover (Odadi et al., 2017). In our case, prescribed grazing that used 25 Animal Days per Acre (ADA) did not influence the basal gaps significantly. Sargent (2016) notes that this grazing scheme in LWC does not yield a clear advantage, and any advantage that may have been present was short-lived.

On the magnitude of change, our results isolate mowing of grasslands and carrying away as the best methods for reducing the basal gaps.

4.3 Effects of management practises on wildlife abundance

Rangeland management practises are important for rangeland health and promoting wildlife abundance (Bailey et al., 2019; Erfanzadeh, 2014).

Mowing as a rangeland management practise led to increased wildlife abundance, and the magnitude of the change was consistent with Mose et al.'s 2013 findings. Mowing of grasslands and carrying away reduced above-ground biomass and basal gaps. This allowed fresh, nutritious vegetation to grow, attracting large wildlife densities. Also, areas with low above-ground biomass form convenient resting and feeding sites for wild ungulates because they offer good visibility for the avoidance of predators (Mose et al., 2013; Hopcraft et al., 2012). Plains zebra (*Equus quagga*) is among the most dominant species in the Conservancy, forms a prey base for predators, and could potentially benefit from the blocks with reduced above-ground biomass.

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We also note that elephants (*Loxodonta africana*) and buffalo (*Syncerus caffer*) are influenced by the quantity of forage rather than quality, which is consistent with Mose et al.'s 2013 findings.

Different studies have different outcomes on the response of wildlife to prescribed grazing, with some studies recording increased wildlife abundance (Odadi et al., 2017; Metera et al., 2010; Teague et al., 2011) and others recording reduced wildlife abundance (Filazzola et al., 2020; Kimuyu et al., 2017). This study did not support either of these conclusions, as no significant difference in wildlife abundance was observed. The same observation was made in blocks with unprescribed grazing. This tendency for wildlife to graze together with livestock is not unusual, as these sites are mostly secure from predators because of the presence of humans (Thaker et al., 2011). Also, the use of acaricides on livestock by herders tends to reduce tick densities in these mixed-use areas, forming favourable resting sites for wildlife (Keesing et al., 2013). This underscores the coexistence between livestock and wildlife as seen on communal and private lands in northern Kenya (Western et al., 2009).

5.0 Conclusion and recommendation

Mowing grasslands and carrying away vegetation reduced above-ground biomass, reduced basal gaps, and increased wildlife abundance. We, therefore, recommend its use, as it positively affected the metrics under investigation. We also recommend time series data be collected to document the time taken for the effects of these management practises to be neutralised.

6.0 Acknowledgement

6.1 Funding

The authors acknowledge The Max and Victoria Dreyfus Foundation, through the Lewa Wildlife Conservancy, for funding the fieldwork.

6.2 Field study permissions

This research was undertaken under the National Commission for Science, Technology, and Innovation (NACOSTI) licence number: NACOSTI/P/22/16956.

6.3 Conflict of Interest

None.

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