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Impacts of grazing management on biodiversity in northern Kenya rangelands

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Abstract

A critical question in the development of Northern Kenya Carbon Project in the conservancies in northern Kenya associated the Northern Rangelands Trust (NRT), is whether sustainable grazing management can sequester carbon in the soil. This question was explored by first testing Sustainable grazing has shown positive effects on wildlife and plants in previous studies, but impacts on other biodiversity groups in semi-arid rangelands are largely unmeasured. A wet-season survey of species diversity of herbaceous plants, trees, birds, and two indicator insect groups grasshoppers (*Orthoptera*) and dung beetles (Coleoptera: Scarabeidae) was conducted in semi-arid areas (350-500 mm annual rainfall) dominated by grasses and trees of the genus *Acacia* and *Commiphora*. Flora and fauna were observed or captured at a total of 18 sites distributed among three different conservancies (Westgate, Kalama, and Sera), and within each conservancy, in areas with different grazing history: Core, ungrazed for the past 8-15 years, Buffer, grazed in the dry season with restrictions on herd sizes, and Settlement, with unrestricted grazing. In addition, Buffer areas were sampled in typical rangeland and in and near old bomas (corrals in which livestock are kept at night). Totals of 67 herbaceous plant, 24 tree, 83 bird, 31 grasshopper, and 32 dung beetle species were observed or captured across the 18 sites. Species richness for each group was not significantly different among the different grazing histories, but Shannon-Wiener diversity indices were significantly higher for all groups in either core or buffer areas as compared to settlement areas. Species richness or diversity index was higher in Buffer or Core areas than in Settlement areas in 16 of 20 cases, suggesting that reducing grazing intensity may lead to higher biodiversity through both more species and a more even distribution of individuals among species. These results suggest that proposed planned grazing management in semi-arid areas of the Northern Kenya Carbon Project will improve biodiversity and provide a significant ancillary benefit of the project beyond sequestering greenhouse gases in the soil. The study provides both a baseline (Settlement areas) of biodiversity against which future monitoring of biodiversity can be compared and evidence that improved grazing management in the past has increased biodiversity, particularly of trees and herbaceous plants. The study also demonstrates that diversity in areas where grazing is reduced but not eliminated is similar to or higher than in areas where livestock grazing has been virtually eliminated for the past 10-20 years. Consequently there is evidence for claiming that the Northern Kenya Carbon project will increase biodiversity through the implementation of planned rotational schemes that allow rest of forage species during the wet season.

Introduction

Previous studies in the NRT or northern Kenya area[1-5] strongly suggest that planned rotational grazing and rangeland recovery will enhance numbers of large ungulate and associated carnivore species and increase plant diversity[6-9]. However, the impacts of rangeland restoration and soil carbon storage on other potential conservation values are poorly documented. Biodiversity in savanna and grassland habitats, beyond plant and ungulate diversity, is still poorly documented outside major, well-studied protected areas, such as semi-arid rangelands heavily grazed by livestock. Diversity of birds, smaller mammals, reptiles, amphibians, and arthropods in rangelands are generally less than in forested areas, so conservation interest and biodiversity surveys have been focused mainly on forests[10].

By virtue of restoring soil carbon and perennial grass cover, the Northern Kenya Carbon Project (NKCP) is anticipated to the increase species diversity of multiple taxa, including plants[5,11,12], birds[7,13] and arthropods[6,7,9,14] . However baseline biodiversity for multiple taxa and expected increases and in which taxa, are not known. In addition, appropriate sampling methods for rangelands, which can be highly heterogeneous, are not well-established.

In this study, five taxonomic groups were observed or collected in areas that experienced different past livestock grazing practices, including herbaceous plants, trees, birds, and two arthropod groups, the Orthoptera (grasshoppers and allies)[15,16] and dung beetles (Coleoptera, Scarabeidae: Scarabeinae). The two arthropod groups have important functional roles in savannas[17-19], are relatively easily monitored, and provide a likely important indication of how other arthropod groups will respond to project activities[6,20,21]. To assess the impact of grazing management, taxa were sampled in areas that had been largely ungrazed for the past 10-20 years (Core), areas that were only grazed in the dry season over the same period (Buffer), and areas with unrestricted grazing (Settlement). In addition, within Settlement areas, old bomas , or temporary overnight corrals for livestock, were also sampled, since these "glades" of high nutrient soil and high local diversity of various plants and animals[12] can support 40-50% of savanna/grassland species, especially arthropods. Species richness and Shannon-Wiener diversity indices for each taxonomic group were compared among the four different land use histories.

Methods

Study Area

Biodiversity surveys were conducted in three different conservancies in the general vivinity of the lower Ewaso Nyiro River and the southern end of the Mathews Range (0.5 – 1 degree N and 37-38 degrees E)[1]. Mean annual rainfall varied from 350 mm/yr at the Sera Conservancy, to 450-500 mm/yr at sites within the Kalama and Westgate Conservancies. Vegetation was dominated by trees of the genus *Commiphora* in Sera, and of the genus *Acacia* in Westgate and Kalama. Herbaceous plants were predominantly annuals in Settlement areas and a mix of annuals and perennials in the Core and Buffer areas. Kalama and Westgate both border the perennial Ewaso Nyiro River, while semi-permanent water in Sera results from groundwater aggregation in granite bedrock pools in seasonal streambeds (laggas).

Survey Design

Biodiversity was sampled at six sites, defined by a randomly selected plot point, in each of three conservancies, Kalama, Sera, and Westgate. We intended to do a site at Lekurruki Conservancy, but chose not to during the field season due to conflict insecurity. Livestock from Mpus Kutuk were using Lekurruki dry season and Core and Buffer grazing areas during June, and we felt the disruption might have skewed results. Also, there was some insecurity along the road from Isiolo to Lekurruki that could have affected our ability to camp there.

Within each conservancy, plot points were randomly placed at each of three sites, with one of the sites being centered in an old boma (> 10 years since abandonment) in Settlement areas, two sites in Core Areas, and one site in in Buffer areas, yielding a total of 18 sites. It turned out to be not possible to easily find old bomas in Core and Buffer areas, which are relatively far (> 10 km) from water and were used historically mainly for dry season grazing and not for settlement. Plot points served as the origin of sampling for all five taxa. Flora and fauna were sampled on a single day or night at each site in June, 2014, normally at the end of the long wet season. However, in 2014, rainfall from April-June was much lower than normal, leading to a relatively poor expression of herbaceous plants.

Abundance and species composition of five taxa, herbaceous plants, trees, birds, grasshoppers (Orthoptera), and dung beetles (Coleoptera: Scarabeidae) were measured at each of the 18 sites. Plot points served as the origin for sampling all five taxa, producing an integrated sampling design that allowed birds and insects to be sampled at an appropriate scale (250- 500 m) linked to measurement of plants at a smaller scale (30-35 m). Herbaceous plants were sampled in transects of five 2x2 m quadrats separated by 5 m extending due north from the plot point. All species in each 2 x 2 m quadrat were identified to species and their percent canopy cover estimated[11]. Trees included all woody stems > 5 cm in diameter at breast height and taller than 1 m found within a 15 m radius circular quadrat centered on each plot point[7].

Birds were observed from 0700-0900 hours within a 50 m wide x 500 m long belt transect extending due north from the plot. Only birds observed within 25 m of the observer perpendicular to the transect were counted in order to reduce observer bias for larger or louder vocalizing species that might have been more easily detected at distances greater than 25 m. Such belt transects follow established methods for sampling birds in biodiversity surveys[7,22-24].

Insects were collected at 24 stations placed 10 m apart in an east-west transect centered on the plot point. Dung beetles were sampled in 24 pitfall traps at each station. Traps were 15 cm diameter plastic tubs with lids cut in the center to make a 2.5 cm hole for beetle entry. Traps were baited with 200 g fresh cattle dung at dusk and then checked at 0700 the following morning. Grasshoppers were sampled with

25 sweeps of a muslin net, in a path perpendicular to each station, at 0900 each morning. These procedures followed established sweep-sampling methods for grasshoppers[16,20] and pitfall trap methods for dung beetles[23]. All beetles and grasshoppers were identified in the field on the basis of morphological similarity and a previously established reference collection. All morphospecies were identified to actual species by entomologists at the Kenya Museum.

Statistics

Species richness and Shannon-Wiener diversity indices were calculated for the cumulative observed or captured species for each taxonomic group. The standard Shannon-Wiener Index[25] was H, where

$$H = \sum_{i=1}^{n} p_i(-\ln(p_i)) \qquad (1)$$

Where p_i is the relative (proportional) abundance (or in the case of herbaceous plants, canopy cover) of the *i*th species in the sample The influence of the conservancy of origin and history of grazing management was determined with two-way ANOVA with conservancy and land use (Settlement, Old Boma, Buffer, and Core) as factors. The small sample size prevented any meaningful consideration of interactions, such as if grazing management made a difference in one conservancy but not the others. A significance level of a = 0.10 was employed because a one-tailed test (diversity greater where grazing was lower) was used, and because small sample size reduced the power of the test to correct for differences in diversity measures associated with conservancies. Post-test contrasts between means of different conservancies and land use/grazing management were evaluated with Fisher's Least Significant Difference (LSD) tests.

Results

A total of 746 trees, 1481 birds, 1161 dung beetles and 351 grasshoppers were observed or collected in this study. Number of plants was not available because cover was measured, rather than individuals. Samples revealed 67 herbaceous plant, 24 tree, 83 bird, 31 grasshopper, and 32 dung beetle species were observed or collected across the 18 sites. Mean species richness per site was not significantly associated with land use or past grazing management for any of the taxonomic groups (Fig. 2A-6A). Cumulative numbers of species across all three conservancies for each grazing history/land use showed different patterns (Table 1): birds, herbaceous plants and trees exhibited greater cumulative number of species across conservancies in Buffer and Core areas than in Settlements, while dung beetles and grasshoppers both exhibited fewer cumulative numbers of species in Buffer and Core areas compared to Settlement areas.

Table 1 *Cumulative numbers of species of each taxonomic group across all three conservancies for different land use histories.*

	Birds	Plants	Trees	Dung Beetles	Grasshoppers
Buffer	31	37	19	14	15

Core	27	43	11	14	18
Old Boma	25	26	8	16	6
Settlement	22	25	13	20	18

However, both herbaceous plant and tree diversity indices were significantly greater in Buffer than in Settlement areas (plants: F = 2.96, df = 2,15, P = 0.07; trees F = 6.28, df=2,15, P =0.028) (Fig. 1), while diversity indices were greater in Buffer areas, but not significantly so, for the other three taxonomic groups (Fig. 2). Interestingly, old boma sites had significantly greater species richness and diversity indices than Settlement areas only for birds (Fig. 1C, 2C).

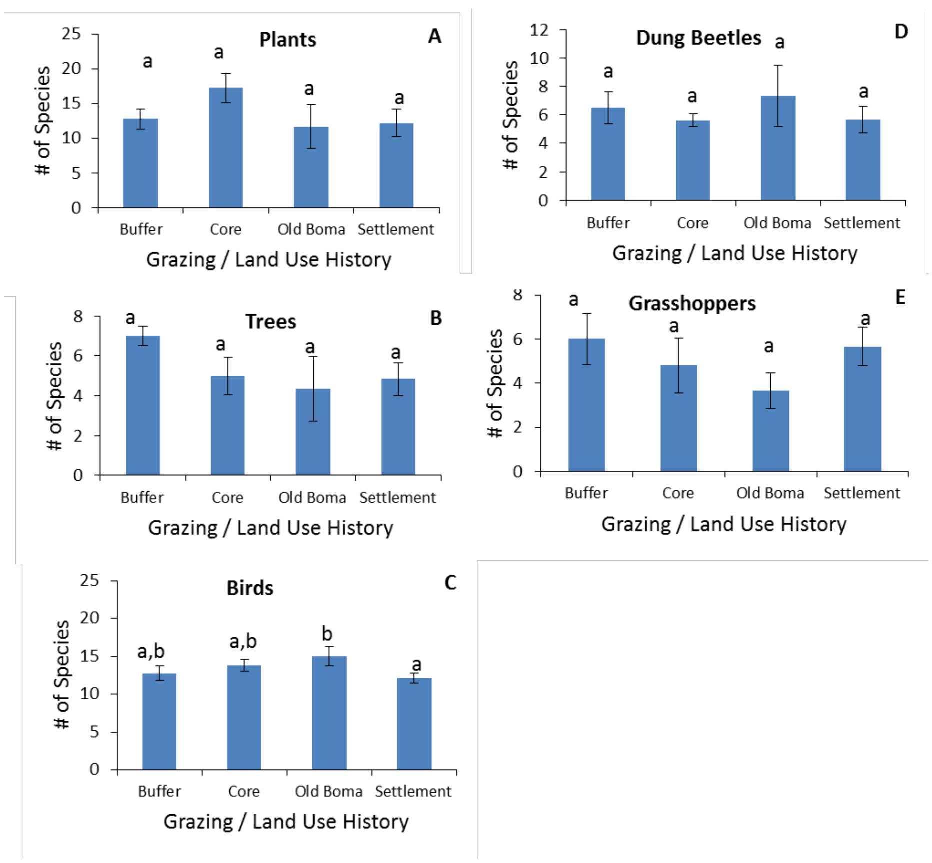

Figure 1. Mean (± SE) Species richness of (A) herbaceous plants, (B) trees, (C) birds, (D) dung beetles, and (E) grasshoppers associated with the four different grazing management/land use histories. Differences in lower case letters indicate significant contrasts following ANOVA.

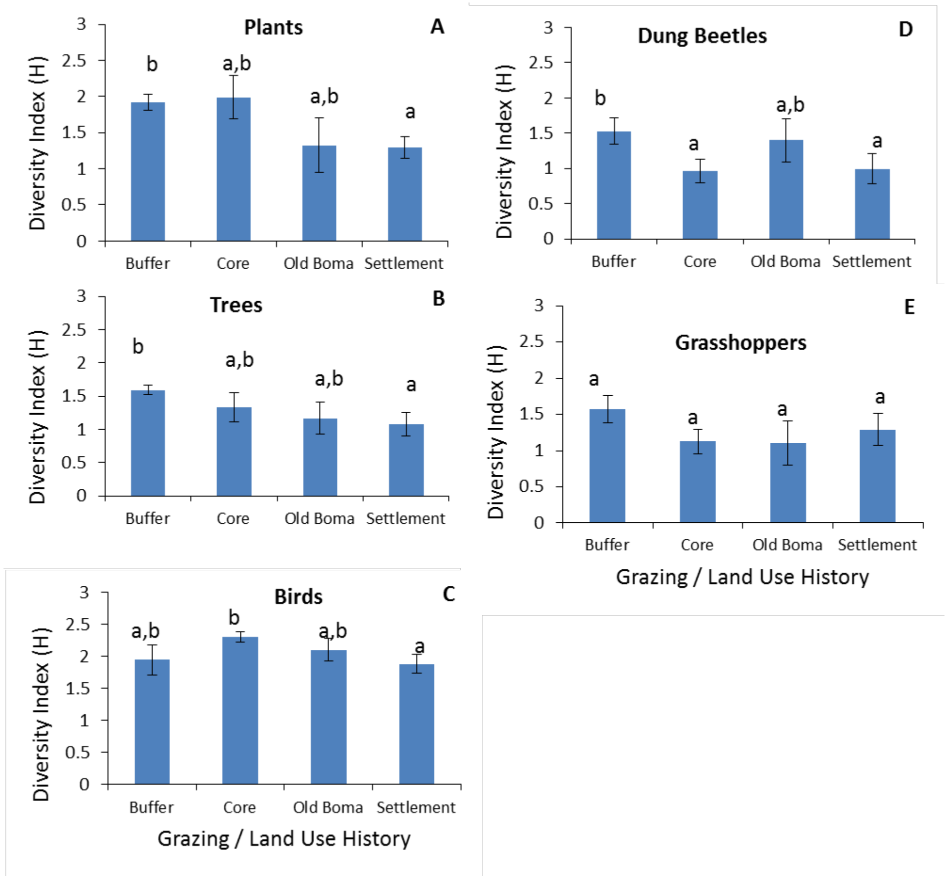

Figure 2. Mean (+ SE) Shannon-Wiener diversity index of (A) herbaceous plants, (B) trees, (C) birds, (D) dung beetles, and (E) grasshoppers associated with the four different grazing management/land use histories. Differences in lower case letters indicate significant contrasts following ANOVA.

Although many of the contrasts in mean species richness or diversity indices were not significant, the five taxonomic groups and two different diversity responses provide multiple tests of the influence of grazing and land use history on biodiversity. Buffer areas had higher species richness or diversity indices than Settlement areas in 10 out of 10 tests (P = 0.001, one-tailed test) and Buffer and core areas combined had higher species richness and diversity indices than Settlement areas in 16 of 20 tests (P = 0.011, one-tailed tests).

10 species endemic to northern Kenya or the Horn of Africa (Ethiopia, Djibouti, Eritrea, Somalia, and northern Kenya) were found among birds, dung beetles, and grasshoppers combined. Of these endemic species, 5 occurred in Core areas, 4 in Buffer areas, and 1 in Settlement areas, and thus significantly more frequently (P = 0.10) in Core or Buffer areas than in Settlement.

Discussion

Although only 18 sites were sampled all taxonomic groups yielded at least 30 species during observation or collection. This suggests that there was sufficient scope in the study to detect differences in species richness and/or diversity indices. However, the variability in diversity measures among conservancies and among sites with the same land use history suggests that the study design used lacked power to detect differences. Future studies could benefit by increasing the number of replicate sites of Buffer, Core, and Settlement within each conservancy and increasing the number of different conservancies sampled. In addition, individual sites probably

The data support the hypothesis that reduced grazing intensity, either by largely excluding livestock or by seasonal controlled grazing yields greater biodiversity among the five indicator taxa studied here (Fig. 1 and 2). All taxonomic groups exhibited higher species richness or the Shannon-Wiener diversity index in Buffer and Core areas compared to Settlement areas in 80% of possible comparisons, a result highly unlikely due to chance ($P = 0.011$). Diversity indices in particular were consistently higher in Buffer areas compared to Settlement areas (10 of 10 possible comparisons), and mean diversity measurements for herbaceous plants and trees were significantly higher in Buffer than in Settlement areas (Fig. 2). Finally, species endemic to northern Kenya or the Horn of Africa occurred more frequently than expected by chance, suggesting that improved grazing management may improve habitats that support rare or endemic species.

Conclusions

Overall, the data support the idea that management to control the time and timing of livestock grazing and allow seasonal rest to livestock and wildlife forage will enhance biodiversity for five distinct taxonomic groups, which serve as indicators of overall biodiversity. The study provides both a baseline (Settlement areas) of biodiversity against which future monitoring of biodiversity can be compared and evidence that improved grazing management in the past has increased biodiversity, particularly of trees and herbaceous plants. The study also demonstrates that diversity in areas where grazing is reduced but not eliminated is similar to or higher than in areas where livestock grazing has been virtually eliminated for the past 10-20 years. Consequently there is evidence for claiming that the Northern Kenya Carbon project will increase biodiversity through the implementation of planned rotational schemes that allow rest of forage species during the wet season.

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