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The Longevity of the Magnet Effect: Fire-Herbivory Interactions in Central Kenya

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Abstract

The coexistence of grass and trees that typifies savanna ecosystems is maintained in part by top-down forces including herbivory and fire. Understanding fire-herbivore interactions is an integral step in determining the effect of these forces individually and informs decisions about the use of fire as a livestock management technique. The magnet effect, in which grazers are drawn to an area after it is burned, is one such interaction between fire and herbivores. While the process of the magnet effect has been described, neither its longevity nor the manner through which fire intensity affects its strength is understood. In this study, we explored whether the increase in herbivory pressure predicted by the magnet effect is maintained over long periods after a fire, how fire intensity influences the strength of the magnet effect, and which feeder types are most influenced by the magnet effect. We established five field sites at the Mpala Research Centre in Laikipia, Kenya that ranged in fire intensity and elapsed time since last the burn. We found that the magnet effect is transient on a seven-year scale and affects grazers more than browsers or mixed feeders, though herbivory and grass biomass responses to fire intensity were conflicting. This research clarifies the role of the magnet effect in maintaining savanna ecosystems and can aid agriculturalists seeking to use fire as a management technique by indicating how long after a burn increased palatability of grass can be expected.

Author's Note

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Keywords: Savanna, fire, herbivores, magnet effect

1. Introduction

The savanna ecosystem, which is characterized by the co-dominance of grasses and trees, supports more herbivore biomass than any other terrestrial habitat (Frank et al. 1998, Higgins et al. 2000). This biomass comes not only in the form of wild ungulates, but also of domestic livestock. African pastoralists have long used fire as a management strategy for increasing food availability and quality (Archibald 2005). When a plot of land is burned either naturally or intentionally, it attracts wild and domestic feeders through the increased palatability of re-sprouting grass, nutrient availability, and visibility of predators (Savala and Holdo 2005, Archibald et al. 2005, Riginos and Grace 2007, Allred 2011). This phenomenon is known as the "magnet effect" (Archibald et al. 2005). While the mechanics of the magnet effect are understood, the timescales over which it operates and how it interacts with fire intensity and herbivore feeder type are not known (Archibald et al. 2005, Allred 2011).

In this study, we explored for how long herbivores preferred certain sites due to the magnet after a plot was burned, as well as whether fire intensity or feeder type influenced herbivore preference. If the magnet effect is enduring, we expect a positive feedback to result, causing grass biomass to remain low and herbivory to remain high for long periods post-fire. Conversely, if the magnet effect is transient, grass biomass will rebound within one year and herbivory should concurrently return to pre-fire levels. If fire intensity is positively related to herbivory because severe fires increase grass palatability and nutritional value (Savala and Holdo 2005, Archibald et al. 2005), then burned plots would demonstrate higher grazing pressure than unburned plots. Finally, because domestic grazers and wild ungulates of all feeder types utilize savanna, we investigated how the magnet effect impacts feeder types due to the improved forage quality of grass and tree leaves as well as increased predator visibility (Archibald et al. 2005). If the magnet effect impacts grazers more severely because it primarily affects grass, then we expect grazers to be more prevalent than other feeder types on burned plots.

2. Methods

2.1 Study Site

We conducted this study at the Mpala Research Center (MRC) in the Laikipia district in central Kenya (0°17' N, 37°52' E) on the black-cotton soil, which receives ~450-500 mm rainfall annually. We collected data in February, the middle of the dry season. We set up five 80m by 60m plots: two control plots, one plot that burned at mild intensity one year ago, one plot that burned at severe intensity one year ago, and one plot that burned at severe intensity seven years ago. We surveyed all plots for herbivory and grass biomass by dividing each plot into 12 equal 20m by 20m subplots, which served as "replicates."

2.2 Biomass and Herbivory Data Collection

We quantified biomass using a Disk Pasture Meter (DPM). Starting at one corner of each subplot, we walked five transects spaced 4m apart. DPM measurements were taken every 4m, starting 2m from the edge of the subplot, and resulting in five measurements per transect. To calibrate the DPM values, we used the equation, "calibrated grass biomass = -3019+2260 √(DPM reading)," where calibrated grass biomass is in kg · ha-1. We used dung counts as a proxy for grazing. Data collectors used walking transects to count all dung piles within each subplot. Dung was identified for cow, zebra/donkey, elephant, giraffe, impala, and dik-dik.

2.3 Data Analyses

We used JMP Pro 10 to perform statistical analyses on our data. We ran ANOVA tests to compare means between plots and students' T-tests to compare the means. Tukey tests were used for post-hoc model analysis.

3. Results

We collected a total of 1500 DPM measurements (300 measurements for each of the five plots) and a total of 1659 dung counts (elephant, N=111; equine, N=702; impala/goat, N=139; cow, N=667; dik-dik, N=3; giraffe, N=37). We found that increased grazing pressure results in decreased fuel loads, indicating that the inverse relationship between herbivory and biomass underlies the magnet effect (R^2=0.21, P < 0.0001, N= 1659; Figure 1).

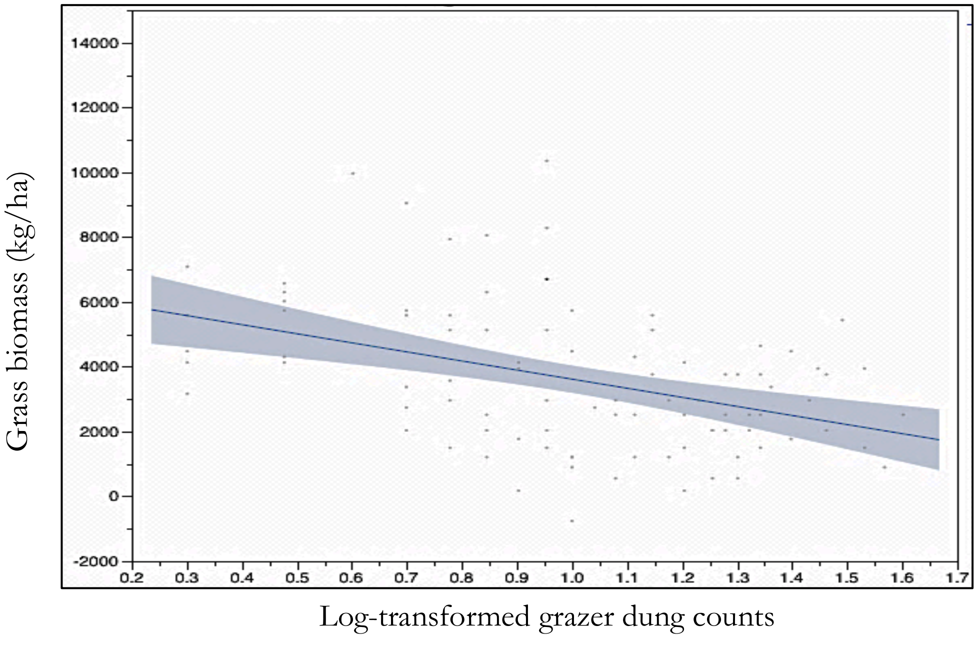

Figure 1. The correlation between grazer dung counts and grass biomass. Grazer dung counts were log-transformed and included counts from cows and equines, defined as donkey or zebra. r^2 = 0.21.

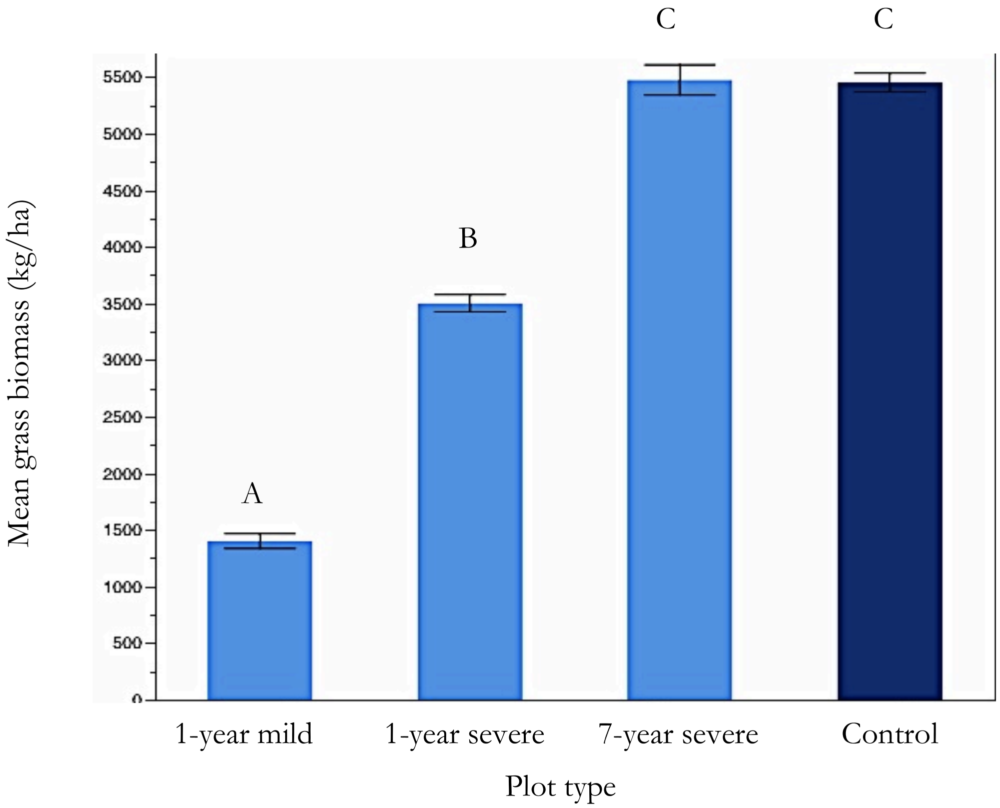

Figure 2. Grass biomass depending on time since fire. Mean grass biomass compared by plot type. Plot types included two one-year plots (mild and severe), one seven-year severe plot and one control plot. Different letters above each bar indicate statistically significant differences between those categories. Error bars indicate one standard error from the mean grass biomass value.

Because the seven-year and control plots demonstrated statistically similar high mean grass biomass (t=1.96, N=1500, P = 0.86) and low mean dung counts (t=1.96, N=1659, P=0.91) when compared to both of the one-year plots (t=1.96, N=1500, P<0.05; Figures 2 and 3), we conclude that the magnet effect is transient. The one-year severe plot demonstrated both marginally significantly higher total dung counts (t=1.96, N=1500, P = 0.077) and significantly higher mean biomass (t=1.96, N=1500, P < 0.0001) than the one-year mild plot (See Figures 2 and 3), contradicting our predictions that higher rates of herbivory result in lower biomass, and that increased fire intensity will produce a stronger magnet effect. We found that the mean number of dung counts responded differently for each plot depending on feeder type ($F_{11,348}$= 90.92, P<0.0001, N=1659), and that the mean number of grazers was both significantly higher than the mean number of any other feeder type across plots, and significantly higher in both one-year plots than in either the seven-year or control plots (Figure 3).

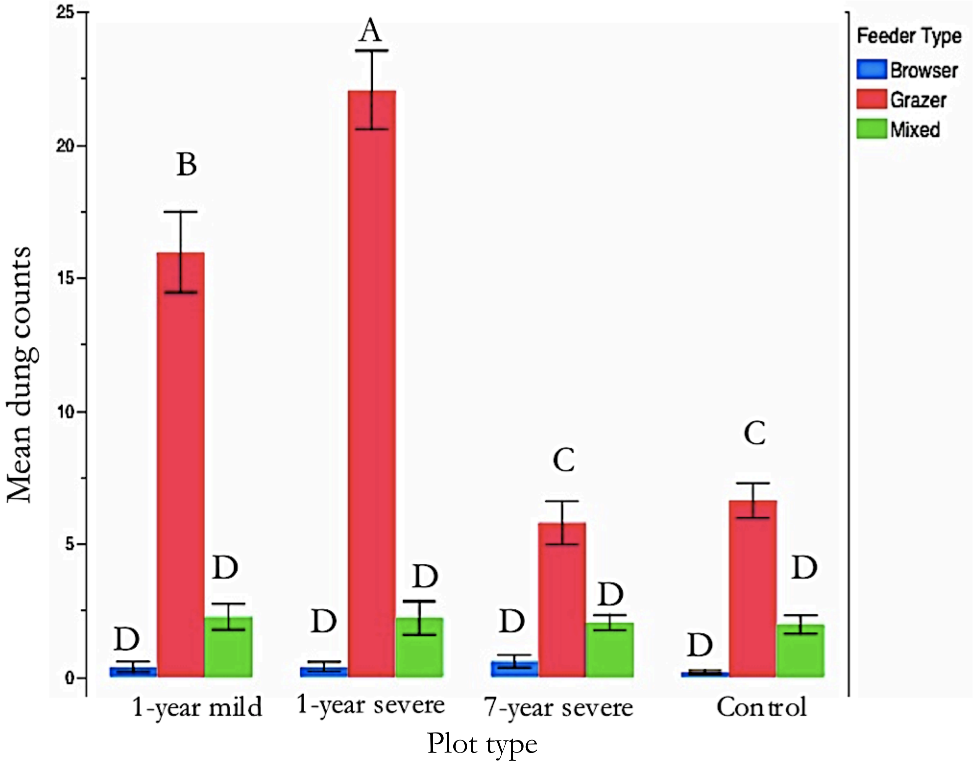

Figure 4. Herbivore type use depending on plot type. Mean dung counts for each of three feeder types compared by plot type. Plot types included two one-year plots (mild and severe), one seven-year severe plot, and one control plot. Browsers included dik-dik and giraffe; grazers included donkey, zebra, and cow; mixed feeders included impala and elephant. Different letters above each bar indicate statistically significant differences between those categories. Error bars indicate one standard error from the mean dung count.

4. Discussion

Our study clarifies the longevity of the magnet effect, indicating that positive feedbacks between herbivores and grass biomass keep fuel loads low for at least one year, but have disappeared by seven years after a burn. Although we identified conflicting responses of herbivory and grass biomass to fire intensity (Figure 4), this ambiguity may have been caused by a number of factors. Firstly, the one-year and seven-year fires were in close proximity to each other, which may have drawn grazers prematurely off the seven-year burn (Archibald et al. 2005). Secondly, all of the burned plots were relatively near a cattle ranch (personal observation), which may have skewed dung counts in favor of cattle and produced more uniform grazing than would otherwise have been observed. Lastly, dung counts are not a perfect proxy for herbivory because of varying herbivore digestion rates and defecation patterns (Archibald et al. 2005). It is also possible that, if fire intensity is sufficient to cause volatilization of vital nutrients such as nitrogen and phosphorus – thereby reducing nutritional quality of future forage (Augustine, 2003) – then the relationship between fire intensity and herbivory is inverse rather than direct.

While we expected that browsers and mixed feeders would also prefer burned plots due to the increased palatability of re-sprouting tree leaves and predator visibility (Archibald et al. 2005, Anderson et al. 2010), this effect did not appear. The absence of this response indicates that the magnet effect is a more powerful determinant of grazer preference than of browser or mixed feeder preference. This information is useful to pastoralists, because it demonstrates that using a burn to increase forage quality will not attract significantly greater numbers of browsers and mixed feeders. It will, however, attract more predators due to increased prey density (Anderson et al. 2010). It is also worth considering that browsers and mixed feeders may not have responded strongly to the magnet effect in this case because none of the fires examined noticeably increased predator visibility (personal observation).

Given our findings, future work should seek to determine exactly when the magnet effect dissipates by assessing finer increments of time between one and seven year burns. Because savannas are regulated by fire and herbivory, understanding how herbivory affects fire regimes and vice versa would increase our understanding of savanna persistence through positive and negative feedbacks (Higgins et al. 2000, Sankaran et al. 2013, Waldram et al. 2008). More complete knowledge of the magnet effect and its impact on long-term fire regimes would inform agriculturalists seeking to use fire as a management technique, as it establishes how long after a burn increased forage quality may be expected (Archibald et al. 2005, McGranahan et al. 2012).

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