Response to Feedback from Reviewer 1

Summary

Animals impact elemental cycling in many direct and indirect ways. Evidence from several biomes demonstrates that even after death, animal carcasses can change the biogeochemistry of ecosystems and these impacts can be long lasting. Most studies of carcass impacts on ecosystems, however, are done on small to medium (1kg to 200kg) sized animals. In this contribution, the authors investigate the effects of elephant megacarcasses on the biogeochemistry of soils and plants. The authors report significant effects of elephant carcasses on components of soil and plant elemental cycling and they discuss how these effects may be important components of spatiotemporal heterogeneity in ecosystems.

General comments

1) Overall, I found the writing good. The authors have crafted a nice narrative that makes a compelling case that megacarcasses can be important parts of ecosystems and therefore we need to learn more about the impacts of these carcasses on ecosystems.

AUTHORS' RESPONSE: Thank you! We appreciate your kind words and thoughtful review.

2) I have a few questions about the analysis. The effective sample size is 10. Obviously, it is hard to find carcasses (I would have great difficulty in finding 10 fresh moose carcasses in my system!) but the authors are trying to squeeze a lot of information out of very few data points. I have the following specific questions about the analysis:

i) While I like the transect approach, the design may have been stronger if the authors had random transects (ie, transects with no known carcass) like Risch et al. work. This would strengthen inference.

AUTHORS' RESPONSE: Thanks for the suggestion, and we definitely appreciate the value of control/random sites. In fact, our original plan was to use random transects as controls (Risch et al. 2020), but during a pilot experiment we realized that high landscape heterogeneity (differences in hill slope, vegetation, water drainage, proximity to termite mounds, etc.), all of which have implications for nutrient distribution across the landscape (Venter et al. 2003; Holdo & McDowell, 2004), made the random transects challenging for interpretation as controls. Instead, we looked at our pilot data to see whether there was a consistent size of the impact site and found that soil nutrients were elevated until about 5-8m away from the center of the carcass site. Past this 5-8m radius, soil nutrients dropped to consistently lower levels, indicative of background concentrations. Thus, we designed the sampling scheme of 0.5m, 2.5m, 5m, 10m, and 15m distances away from the carcass site to capture both the impact of the elephant carcass and the background ("control") concentration of soil nutrients (at the 10m and 15m distance). There was never a significant difference in nutrient concentrations between the 10 and 15m distances, suggesting our sampling scheme successfully captured the transition from the influence of the elephant carcass through to the background level of nutrients in the matrix soils.

We have updated the methods section of the manuscript as follows (lines 146-150): “We treated the 10-15m distances as representative of background concentrations of nutrients based on pilot data showing that the effect of elephant carcasses on soil nutrient concentrations was undetectable at this distance away from the carcass site, similar to studies on the carcasses of other large vertebrates (e.g., Towne, 2000; Bump et al. 2009).”

Venter FJ, Scholes RJ, Eckhardt HC. Abiotic template and its associated vegetation pattern. In: JT Du Toit, KH Rogers, HC Biggs, eds. The Kruger experience: ecology and management of savanna heterogeneity. Washington, DC, USA: Island Press, 83–129, 2003.

Holdo, R. M. & McDowell, L. R. Termite mounds as nutrient-rich food patches for elephants. *Biotropica*, 36, 231-239, https://doi.org/10.1111/j.1744-7429.2004.tb00314.x, 2004.

ii) lines 180-183. The author’s approach to checking for normality of response data does not seem sound to me. The assumption of normality (for linear models) is normality in light of the model, i.e., investigating the normality of residuals is a more common approach to this. Either way, it is often better to avoid transforming the data and generalized linear models do allow for a lot of flexibility to fit different error distributions. For example, the gamma family in glm is very flexible and can handle log-normal data sets. Did the authors try different families of error distributions before transforming their data?

AUTHORS’ RESPONSE: Thanks so much for this suggestion. We have revised our analysis and implemented the gamma family (link = log) in for all of our models now instead of log-transforming and have updated the text in the methods accordingly. We have updated all results accordingly. Even with this change in the structure of the analyses, the major patterns across the different analyses did not change. In fact, these changes actually strengthen the major patterns in the results showing the importance of elephant carcasses in savanna nutrient dynamics.

We have updated the methods as follows (lines 253-256): “For each response variable, we ran five generalized linear mixed models using the gamma family (link = log) in the package *lme4* (Bates et al. 2015): (*i*) soil type + distance + soil type × distance interaction, (*ii*) soil type + distance, (*iii*) soil type, (*iv*) distance, and (v) a null model indicating no significant difference in slope or intercept after accounting for carcass site.”

iii) lines 187-189. How many data points did the authors have per estimated parameter in the most complex model here?

AUTHORS’ RESPONSE: For each of these models, we had 50 observations total (10 sites x 5 samples per site). In our most complicated model, that averages to ~17 observations per parameter, which is above the recommended 10 observations per parameter (Burnham & Anderson, 2002).

We have updated the methods as follows (lines 257-258): “Each model included 50 observations (10 sites x 5 distances per site).”

iv) line 194. This is fine but I think Burham & Anderson would say that any model within deltaAIC of 2 of the null model should not be considered to be supported. In several cases, the authors interpret top models that are ranked above the null but within deltaAIC of 2 of the null as supported (e.g., lines 217-218, 218-221).

AUTHORS’ RESPONSE: With the updated model structure (see response to 2.iii), there are now only three response variables (soil water, soil pH, and foliar calcium) for which the null and another model fall within a ΔAICc value of 2 (Table S1). In all three cases, we will interpret this as the results not supporting a relationship between the response variable and soil type, distance from the carcass, or soil type by distance interaction.

v) what R^2 are the authors reporting? In the captions of Tables S1 and S2 (thank you for providing full AIC and coefficient tables), the authors state “R^2 is the proportion of variance explained by a model”. This is unclear. These are mixed models, and the most common approach is to report the marginal R^2 and conditional R^2. Is the R^2 in these tables one of those or another pseudo R^2? This is critical for many reasons but most importantly, given the small sample size and large number of mixed-models, I would expect at least one of the models to not converge. There are many indicators when a mixed-model does not converge and one of the best is when the marginal R^2 = conditional R^2. Without having both of these pieces of information, the reader is unable to adequately assess the fit of the models. Other indicators of models not converging are coefficients estimates or errors that are very large or very small (i.e., 0 – see next comment).

AUTHORS’ RESPONSE: We have updated supplemental tables to include both marginal and conditional R^2 values. The only place where we had issues with model non-convergence was soil phosphate; two of the five models failed to converge and are indicated in Table S1.

vi) I am confused by the magnitude of Table S2 sodium and iron coefficients and/or the scale of reported on the y-axis of Figure 5 for these. The iron coefficients in Table S2 seem small relative to the Figure 5c? Or am I misreading things?

AUTHORS’ RESPONSE: The original models for soil and leaf micronutrients used log-transformed data, which meant that the coefficients and standard errors were in log units as well. When plotting, we back-transformed the data to make the axis scales easier to interpret, which is why the values in the table and the figures were different. The updated models (see response to 2.iii) still use a log link, so the model outputs in the updated tables are still in log units as well. Again in this version, we exponentiated when calculating the prediction lines so that we could plot them with the raw data, which we believe is visually more intuitive than figures with axes on the log scale. We have updated the table captions for clarification as follows: “Coefficients (± standard error) are shown for each predictor and model and are in log units.”

3) the reporting of results could be improved. I recommend, the authors report: top ranked models (AIC + measure of independent fit like R^2). Then report effect size or relationships

(coefficients). I found key statistics to be missing throughout. Statements like "Phosphate concentrations were greater in granitic soils…" would be more informative if they included the coefficient + error in parenthesis. Coefficients can be reported for the top-ranked model or from model averaged results when there are several competing models.

AUTHORS' RESPONSE: We appreciate this feedback and have updated the tables accordingly, including AIC values, marginal and conditional R^2, and coefficients + standard error (see below). We considered including coefficients for the top-ranked models in the text of the results section. However, because the coefficients are in log units, we found that they were not biologically intuitive in a string of text, reducing the clarity and ease of reading. Thus, instead of including coefficients in the text, we refer readers to the appropriate tables for statistical results, where the coefficients are easier to interpret in their full context.

4) in section 3.2 I think the reader may be more interested in coefficients and confidence intervals around those relationships than p-values that are currently reported.

AUTHORS' RESPONSE: We have removed the p-values from this section and refer readers to the appropriate table, as described above in response to comment 3.

Specific comments:

5) I found the use of three different terms that mean similar things (nutrient flows, ecosystem processes, nutrient availability) in the introductory sentence confusing. I recommend the authors replace "nutrient availability" with "ecosystem processes" or "nutrient flows". Surely living animals (not just carcasses) influence nutrient availability (which is just a part of a continual nutrient cycle).

AUTHORS' RESPONSE: We have edited that line for consistency in phrasing (lines 51-53): "Living animals affect nutrient flows through ecosystems (Schmitz et al. 2018), but we have only recently acknowledged that the nutrients from animal carcasses could also influence ecosystem processes (Barton et al. 2013; Monk et al. 2024).

6) line 83. I believe there is no "e" at the end of the citation Risch et al.

AUTHORS' RESPONSE: We have corrected the citation. Thanks for catching it!

7) lines 96-111. How do these elephants die? As someone with no experience with megacarcasses, I would appreciate some insight on the causes of death. Most large herbivore deaths in my empirical systems are from predation which I assume is not the case for elephants.

AUTHORS' RESPONSE: We received GPS coordinates for carcasses from KNP rangers, who also keep record of the cause of death for each elephant. The reviewer is right that predation tends not to be a major issue for elephants, and none that we know of died from it. Most of the elephants in our dataset died of natural causes such as old age, illness, injury, or, in the case of one young bull, a territorial dispute that ended in his death.

We have updated the methods section as follows (lines 139-140): “Most elephants died of old age, illness, injury, or, in the case of one young bull, fighting over territory.”

8) really excellent job with clear hypotheses and nice work carrying forward these hypotheses throughout the ms – really makes the job easier for the reader.

AUTHORS’ RESPONSE: Thank you!

9) lines 132-133 Why 10cm deep core? Is that mineral soil only?

AUTHORS’ RESPONSE: We used a 10cm core to ensure that we captured the soil surface horizon. It is a commonly used depth and is more conservative than shallower sampling. Prior work on the soil impacts of carcasses uses this depth (Bump, Peterson, & Vucetich, 2009; Monk et al. 2024). Moreover, previous work in the same system has shown that soil auger sampling depths of 7.5-10cm are sufficient for detecting differences in N, C, and soil micronutrients (Gray & Bond 2015, Holdo & Mack 2014). We have added these citations to the methods (lines 145-146).

Bump, J. K., Peterson, R. O., & Vucetich, J. A. Wolves modulate soil nutrient heterogeneity and foliar nitrogen by configuring the distribution of ungulate carcasses. *Ecology*, 90, 3159–3167, https://doi.org/10.1890/09-0292.1, 2009.

Monk, J. D., Donadio, E., Smith, J. A., Perrig, P. L., Middleton, A. D., & Schmitz, O. J. Predation and biophysical context control long-term carcass nutrient inputs in an Andean ecosystem. *Ecosystems*, 27, 346–359, https://doi.org/10.1007/s10021-023-00893-7, 2024.

Gray, E. F. & Bond, W. Soil nutrients in an African forest/savanna mosaic: Drivers or driven? *South African Journal of Botany*, 101, 66-72, https://doi.org/10.1016/j.sajb.2015.06.003, 2015.

Holdo, R. M. & Mack, M. C. Functional attributes of savanna soils: contrasting effects of tree canopies and herbivores on bulk density, nutrients and moisture dynamics. *Journal of Ecology*, 102, 1171-1182. https://doi.org/10.1111/1365-2745.12290, 2014.

10) the discussion is well done – concise and touches on all hypotheses.

AUTHORS’ RESPONSE: Thank you!

11) Figure 1 is an outstanding visual!

AUTHORS’ RESPONSE: Thank you!

12) in figures 2-5 I recommend the authors consider reminding the reader of the sampling resolution because the jitter of points makes it impossible to see what distances were measured below 5m.

AUTHORS' RESPONSE: We have updated the captions in figures 2-5 to include sampling resolution as follows: "Points represent individual measurements taken at 0, 2.5, 5, 10, and 15m and are offset to be visible when they would otherwise overlap."

Response to Feedback from Reviewer 2

Summary:

Reed and coauthors present a well-written study on the impacts of megacarcasses (elephants) to soil biogeochemistry after up to 2 years of decomposition. The authors examined 10 carcass hotspots with 5 carcasses each on two different soil types. They quantified soil major and trace element chemistry as well as plants associated with the hotspots to determine if carcasses influenced soil N and P chemistry and if those elements were subsequently enriched in vegetation. The current version of this manuscript does not adequately describe the methods in enough detail to make the work reproduceable. Additionally, the handling of the data for statistical analyses is strange and non-standard. The discussion needs to be re-written to better emphasize the importance of the work (as framed in the introduction). I think this work has potential to be an important contribution, but there needs to be some major revisions.

AUTHORS' RESPONSE: Thanks for all of your feedback. We have made substantial changes in response to your suggestions, including rewriting the methods section to include more details on the lab analyses. We have also updated our statistical analyses to use the gamma family of generalized linear mixed models, which allows us to run non-normally distributed data without the log transformation. These changes add to the methodological clarity and statistical robustness of this research, and they actually strengthen the major patterns in the results showing the importance of elephant carcasses in savanna nutrient dynamics. Finally, we have updated the text to ensure that the functional distinctiveness of megacarcass relative to smaller carcasses carries through from the introduction to the discussion.

General comments:

- The importance of this study in adding to our knowledge about nutrient transfer at carrion hotspots is not emphasized clearly in the discussion. The introduction frames how megacarcasses may be "functionally different than smaller carcasses" but never returns to this aspect in the discussion, which is really where this work could add to our knowledge. Adding more to the discussion would help address this issue and would make the impact of the work clearer.

AUTHORS' RESPONSE: Thanks for the suggestion. To more clearly link our results to the functional differences between megacarcasses and smaller carrion, we have updated the discussion as follows (lines 441-451): "The magnitude of nutrient inputs from megacarcasses, as well as the substantial size and duration of their impact zones, means their impacts on ecosystem processes may be functionally distinct from smaller carrion. Indeed, there is evidence that carcass size strongly impacts scavenger food web structure (Moleón et al. 2015; Morris et al. 2023). Moreover, the attraction of animals to carcasses via scavenging, predation, or mourning (Goldenberg & Wittemyer, 2020) could have positive feedbacks on nutrient cycling (Bump, Peterson, & Vucetich, 2009; Monk et al. 2024), which may be magnified by carcass size. Thus, the impacts of megacarcasses on savanna ecosystem processes may be dissimilar to the effects of small carrion and more similar to other more persistent contributors to savanna ecosystem

processes, such as termite mounds (Davies et al. 2016), cattle bomas (Augustine, 2003), and even mass animal mortality events (Subalusky et al. 2017, 2020)."

- Parts of the results belong in the discussion, and I've tried to highlight those below in specific comments.

AUTHORS' RESPONSE: Thanks for pointing this out. We have edited and/or removed those sentences from the results section and focused on them in the discussion, as described in response to specific comments below.

- The methods need significantly more specific details, highlighted in specific comments.

AUTHORS' RESPONSE: We have substantially updated the methods section in the manuscript (section 2.3) to include specific details on the lab analysis methods, and we address specific comments below as well.

- Additionally, there were no control soil or plant samples examined here. Please describe in the methods why there were no controls.

AUTHORS' RESPONSE: The reviewer raises an important point here, and we definitely appreciate the value of control/random sites that other studies of carrion have used. In fact, our original plan was to use random transects as controls (Risch et al. 2020), but during a pilot experiment we realized that high landscape heterogeneity (differences in hill slope, vegetation, water drainage, proximity to termite mounds, etc.), all of which have implications for nutrient distribution across the landscape (Venter et al. 2003; Holdo & McDowell, 2004), made the random transects challenging for interpretation as controls. Instead, we looked at our pilot data to see whether there was a consistent size of the impact site and found that soil nutrients were elevated until about 5-8m away from the center of the carcass site. Past this 5-8m radius, soil nutrients dropped to consistently lower levels, indicative of background concentrations. Thus, we designed the sampling scheme of 0.5m, 2.5m, 5m, 10m, and 15m distances away from the carcass site to capture both the impact of the elephant carcass and the background ("control") concentration of soil nutrients (at the 10m and 15m distance). There was never a significant difference in nutrient concentrations between the 10 and 15m distances, suggesting our sampling scheme successfully captured the transition from the influence of the elephant carcass through to the background level of nutrients in the matrix soils.

We have updated the methods section of the manuscript as follows (lines 146-150): "We treated the 10-15m distances as representative of background concentrations of nutrients based on pilot data showing that the effect of elephant carcasses on soil nutrient concentrations was undetectable at this distance away from the carcass site, similar to studies on the carcasses of other large vertebrates (e.g., Towne, 2000; Bump et al. 2009)."

Venter, F. J., Scholes, R. J. & Eckhardt, H. C. Abiotic template and its associated vegetation pattern. In: J. T. Du Toit, K. H. Rogers, H. C. Biggs, eds. The Kruger

experience: ecology and management of savanna heterogeneity. Washington, DC, USA: Island Press, 83–129, 2003.

Holdo, R. M. & McDowell, L. R. Termite mounds as nutrient-rich food patches for elephants. *Biotropica,* 36, 231-239, https://doi.org/10.1111/j.1744-7429.2004.tb00314.x, 2004.

The handling of the data for statistical analyses is non-standard and not clearly justified. If data were non-normally distributed (it seems like some datasets were and some were not), why not just use a non-parametric statistical test rather than log-transforming the data? It is a bit strange to log-transform some data but not all. The approach of adding 0.001 to zero values is also not correct (described below in specific comments).

AUTHORS' RESPONSE: We have updated our model selection procedure to use the gamma family with a log link for our generalized linear mixed models rather than transforming the data beforehand (see RC1, 2.ii).

We have re-run the analyses using 0.005 mg/L as the replacement value for any zeros in the soil ion concentration data, as that is half of the detection limit (0.10 mg/L) and have updated the results section, tables, and figures accordingly. This update did not result in any changes to statistical significance or model performance in the results. We have updated the methods as follows (lines 169-179):

"Plant-available P was extracted from 4 g of soil and 30 ml extraction fluid (1:7.5 ratio) using an acid–fluoride solution (P Bray-1), measured colorimetrically using a Systea EasyChem200 analyser, and expressed as mg/kg. The detection limit was 0.5 mg/kg, and plant available P measurements <0.5 mg/kg were replaced with half the detection limit (0.25 mg/kg) (Croghan & Egeghy, 2003; Keenan & Beeler, 2023). Water-soluble nitrate and phosphate anions were extracted from volume on volume 100 ml soil and 200 ml deionized water, analyzed by ion chromatography on a Metrohm 930 Compact Flex System, and measured as mg/L. Ammonium (also 1:2 water extract) was analyzed colorimetrically using a Systea EasyChem200 analyzer and measured as mg/L. Detection limits for soil ions were 0.01 mg/L, and soil ion concentrations measured as <0.01 mg/L were replaced with half the detection limit (0.005 mg/L)."

- The presentation of elemental data for soil and plant composition is non-standardized throughout. Some data (i.e., iron) are presented as mg/kg (is this soil dry weight?), while others are presented as % (Ca% of what?) in the same figure (figure 5 for example). Other data are presented as mg/L (figure 2). Part of this confusion is from the missing details in the methods that clearly explain how these data were generated. In several of the figures there is a statement about back-transformed data, which is also confusing.

AUTHORS' RESPONSE: We appreciate the attention to detail here from the reviewer. We have updated the manuscript so that soil ions, soil anions, and foliar micronutrients are all

in mg/kg. Soil and foliar nitrogen are given as the percentage of dry weight that is nitrogen, as this is the standard unit of measurement for the instrument used (IRMS). We appreciate you pointing this out and agree that including these methodological details aids greatly in interpretation.

With regards to the comment on back-transformed data, we originally were log-transforming the nutrient data prior to analysis. For aid in visual interpretation of the results, we had displayed the data in its original units. Now that we have updated the model structure and are no longer log-transforming before analysis, we have removed mentions of back-transformation from the manuscript.

- I can appreciate that finding carcasses that have decomposed for the same amount of time is challenging, but 1 month to 26 months is a huge range of time (at least from what we know from not megacarcasses). The biogeochemical processes occurring at a carcass decaying after 1 month postmortem is very different than a carcass that has been decaying for 26 months (from smaller carcasses). It would be useful to see some of the data, particularly ammonium, plotted as a function of postmortem interval (months) even if that is not a variable that could be included in statistical analyses because of the small sample size. It would also be helpful to see if the postmortem interval for the 10 carcasses is evenly distributed between the two soil types or if one has more fresh carcasses and the other has older carcasses, that could help with interpretation of the results.

AUTHORS' RESPONSE: Thanks for the suggestion! We have added analysis and figures to the manuscript testing for a relationship between key soil metrics and carcass age. We found that soil ammonium, phosphate, and respiration potential all decrease significantly with carcass age. In fact, the trends are so compelling that we have added this figure to the main text (Figure 5). This figure suggests the pattern of elevated soil nutrients that we found may be even stronger when considering younger carcasses given how quickly the nutrients decline with age.

We ran a t-test to test for a difference in mean carcass age across soil types and found no significant difference between the two groups ($P = 0.294$).

We have added these updates to the methods section as follows (lines 280-283): "Finally, to test the impact of carcass age on key soil metrics, we ran exponential decay functions for soil ammonium, nitrate, phosphate, and respiration verses carcass age for samples from the center of the carcass site (0.5m sampling location). We also performed a t-test to verify that there was no difference in mean carcass age across soil types."

And to the results section as follows (lines 343-347): "Soil ammonium, phosphate, and respiration potential all decreased significantly with carcass age (Figure 5A-C). The exponential decay model for nitrate failed to converge due to an outlier with extremely high soil nitrate (1454 mg/kg) at 258 days post-death (Figure 5D). We ran a t-test to test for a difference in mean carcass age across soil types and found no significant difference between the two groups ($P = 0.294$)."

- I think it may be useful to add some photos to supplemental information (or even the main text) showing what the carcasses/sites looked like (maybe representative images from a fresher carcass and one that is older).

AUTHORS' RESPONSE: Thanks for the suggestion! We have added a supplemental figure (Figure S1) that shows two carcass sites – one is fresh and on basaltic soil, and the other is older and on granitic soil.

Specific comments:

- Lines 99-100: There should be more details provided on the soil type and what makes the granitic soils "nutrient poor" compared to soils developed from a basalt protolith. Because soil type becomes an important part of this study, the details of the soil types need to be expanded in the introduction.

AUTHORS' RESPONSE: Thanks for the suggestion. Kruger National Park has two primary soil types – a clay-rich soil derived from basalt ("basaltic") and a sandy soil derived from granite ("granitic"). Basalitic soils have clay particles with relatively large surface area, thereby enabling them to retain larger quantities of water than granitic soils, which drain water more quickly and therefore are lower in water-soluble nutrients (Buitenweref, Kulmatiski, & Higgins, 2014).

We agree that these distinctions are important for understanding the impacts of carcass-derived nutrients on different soil types and have updated the methods section as follows (lines 122-126): "The two dominant soil types in KNP are granitic soils (inceptisols) and basaltic soils (versitols or andisols) (Khomo et al. 2017). The clay-rich basaltic soils have relatively large surface area, enabling them to retain larger quantities of water than granitic soils, which drain water more quickly and therefore are lower in water-soluble nutrients (Buitenweref, Kulmatiski, & Higgins, 2014; Rughöft et al. 2016)."

Khomo, L., Trumbore, S., Bern, C. R., & Chadwick, O. A. Timescales of carbon turnover in soils with mixed crystalline mineralogies. *SOIL*, 3, 17-30, https://doi.org/10.5194/soil-3-17-2017, 2017.

Buitenwerf, R., Kulmatiski, A. & Higgins, S. I. Soil water retention curves for the major soil types of the Kruger National Park. *Koedoe*, 56, a1228, http://dx.doi.org/10.4102/koedoe.v56i1.1228, 2014.

- Line 132: Include a citation or discuss why soil samples were collected to a depth of 10 cm rather than the upper 5 cm. For decomposition studies, typically the upper 5 cm is examined, not the upper 10 cm.

AUTHORS' RESPONSE: We used a 10cm core to ensure that we captured the soil surface horizon. It is a commonly used depth and is more conservative than shallower sampling. Prior work on the soil impacts of carcasses uses this depth (Bump, Peterson, & Vucetich, 2009; Monk et al. 2024). Moreover, previous work in the same system has shown that soil auger sampling depths of 7.5-10cm are sufficient for detecting differences in N, C, and soil micronutrients (Gray & Bond 2015, Holdo & Mack 2014). We have updated the text in the methods to include these references (lines 145-146).

Bump, J. K., Peterson, R. O., & Vucetich, J. A. Wolves modulate soil nutrient heterogeneity and foliar nitrogen by configuring the distribution of ungulate carcasses. *Ecol.,* 90, 3159–3167, https://doi.org/10.1890/09-0292.1, 2009.

Monk, J. D., Donadio, E., Smith, J. A., Perrig, P. L., Middleton, A. D., & Schmitz, O. J. Predation and biophysical context control long-term carcass nutrient inputs in an Andean ecosystem. *Ecosyst*., 27, 346–359, https://doi.org/10.1007/s10021-023-00893-7, 2024.

Gray, E. F. & Bond, W. Soil nutrients in an African forest/savanna mosaic: Drivers or driven? *S. Afr. J. Bot.,* 101, 66-72, https://doi.org/10.1016/j.sajb.2015.06.003, 2015.

Holdo, R. M. & Mack, M. C. Functional attributes of savanna soils: contrasting effects of tree canopies and herbivores on bulk density, nutrients and moisture dynamics. *J. Ecol.,* 102, 1171-1182, https://doi.org/10.1111/1365-2745.12290, 2014.

- Line 145: More details are needed beyond "measurements of soil ion concentrations". What instrumentation was used? What specific extraction protocol was followed? I'm assuming deionized water was used (1:2 soil to deionized water?), but those details are not provided. How long were samples mixed (shaking platform?), what speed, etc.

AUTHORS' RESPONSE: We have updated the relevant portion of the methods as follows (lines 166-179): "We sent 250 g of each soil sample to Eco-Analytica laboratory at the North-West University in Potchefstroom, South Africa for measurements of soil concentrations of ammonium $[NH_4]^+$, nitrate $[NO_3]^-$, phosphate $[PO_4]^{3-}$, and plant-available P. Samples were air-dried and sieved through < 2mm mesh prior to chemical analysis. Plant-available P was extracted from 4 g of soil and 30 ml extraction fluid (1:7.5 ratio) using an acid–fluoride solution (P Bray-1), measured colorimetrically using a Systea EasyChem200 analyser, and expressed as mg/kg. The detection limit was 0.5 mg/kg, and plant available P measurements <0.5 mg/kg were replaced with half the detection limit (0.25 mg/kg) (Croghan & Egeghy, 2003; Keenan & Beeler, 2023). Water-soluble nitrate and phosphate anions were extracted from volume on volume 100 ml soil and 200 ml deionized water, analyzed by ion chromatography on a Metrohm 930 Compact Flex System, and measured as mg/L. Ammonium (also 1:2 water extract) was analyzed colorimetrically using a Systea EasyChem200 analyzer and measured as mg/L. Detection limits for soil ions were 0.01 mg/L, and soil ion concentrations measured as <0.01 mg/L were replaced with half the detection limit (0.005 mg/L)."

- Line 148: “mass spectrometry”—elaborate on what this means with respect to instrumentation used to analyze cations. Here and throughout the methods, please also include what standards were used for the different analysis types.

AUTHORS’ RESPONSE: We have updated the relevant section of the methods as follows (lines 182-197): “To determine whether soil anions were distinct and elevated at the center of carcass sites relative to soil further from the center, concentrations of sodium (Na), magnesium (Mg), iron (Fe), calcium (Ca), potassium (K), and phosphorus (P) cations were measured using microwave-assisted digestion. Air-dried and sieved (>2 mm) soil samples, weighed to 0.2 g, were microwaved in 9 ml 65% nitric acid (HNO_3) and 3 ml 32% hydrochloric acid (HCl) according to EPA 3051b in a Milestone, Ethos microwave digester with UP, Maxi 44 rotor. A period of 20 minutes allowed the system to reach 1800 MW at a temperature of 200 °C which was maintained for 15 minutes. After cooling, the samples were brought up to a final volume of 50 ml and analyzed on an Agilent 7500 CE ICP-MS fitted with CRC (Collision Reaction Cell) technology for interference removal. The instrument is optimized using a solution containing Li, Y, Ce, and Tl (1 ppb) for standard low-oxide/low interference levels (≤ 1.5%) while maintaining high sensitivity across the mass range. The instrument was calibrated using ULTRASPEC® certified custom mixed multi-element stock standard solutions containing all the elements of interest (De Bruyn Spectroscopic Solutions, South Africa). Calibrations spanned the range of 0 – 30 ppm for the mineral elements Ca, Mg, Na, and K and 0 – 0.3 ppm for the rest of the trace elements. Elemental concentrations were expressed as mg/kg.”

- Lines 146-150: Clarify if these analyses were conducted on the water extracts.

AUTHORS’ RESPONSE: We have clarified as follows (lines 174-179): “Water-soluble nitrate and phosphate anions were extracted from volume on volume 100 ml soil and 200 ml deionized water, analyzed by ion chromatography on a Metrohm 930 Compact Flex System, and measured as mg/L. Ammonium (also 1:2 water extract) was analyzed colorimetrically using a Systea EasyChem200 analyzer and measured as mg/L. Detection limits for soil ions were 0.01 mg/L, and soil ion concentrations measured as <0.01 mg/L were replaced with half the detection limit (0.005 mg/L).”

- Line 152: Were stable isotope analyses conduct on oven-dried soil? 10 g is an exceptionally large amount of soil—how much was actually analyzed with EA-IRMS? Were samples powdered prior to combustion?

AUTHORS’ RESPONSE: We have clarified as follows (lines 202-204): “Samples were oven-dried at 60°C for 48 hours and milled to a fine powder using a Retsch MM400 mill (Germany). The powdered samples were weighed (2 – 60 mg) prior to combustion at 950°C.”

- Line 154 (and throughout with respect to stable nitrogen isotope results): The authors refer to “^{15}N” measurements, but surely this should be presented as the ratio of 15/14N and in delta notation? In the methods here there also needs to be more description of

the standard, the materials used for linearity, and the analytical precision of the instrument.

AUTHORS' RESPONSE: We have changed the notation throughout the manuscript to $\delta^{15}N$. We have updated the methods to include information on standards and precision as follows (lines 205-211): "A high organic carbon (HOC) soil standard (0.52 ± 0.02 %N), along with two international reference standards (USGS40 ($\delta^{15}N$ -4.52% AIR) and USGS41 ($\delta^{15}N$ +47.57% AIR)) were used for calibration. The N elemental content was expressed relative to atmospheric N as N_2 $\delta^{15}N$AIR (‰). The quantification limit for $\delta^{15}N$ on the IRMS is 1 nA (nanoAmp), and the quantification limit for %N is 0.06%. The precision for %N was 0.02% and for $\delta^{15}N$ is ±0.11%, determined using the HOC standard, which was run multiple times throughout the analysis."

- Line 175: More details on the ICP-MS are needed, including standards, detection limits, etc. Additionally, were these samples digested in nitric acid? Water? How long were they microwaved?

AUTHORS' RESPONSE: We have updated the relevant section of the methods as follows (lines 182-197): "To determine whether soil anions were distinct and elevated at the center of carcass sites relative to soil further from the center, concentrations of sodium (Na), magnesium (Mg), iron (Fe), calcium (Ca), potassium (K), and phosphorus (P) cations were measured using microwave-assisted digestion. Air-dried and sieved (>2 mm) soil samples, weighed to 0.2 g, were microwaved in 9 ml 65% nitric acid (HNO_3) and 3 ml 32% hydrochloric acid (HCl) according to EPA 3051b in a Milestone, Ethos microwave digester with UP, Maxi 44 rotor. A period of 20 minutes allowed the system to reach 1800 MW at a temperature of 200 °C which was maintained for 15 minutes. After cooling, the samples were brought up to a final volume of 50 ml and analyzed on an Agilent 7500 CE ICP-MS fitted with CRC (Collision Reaction Cell) technology for interference removal. The instrument is optimized using a solution containing Li, Y, Ce, and Tl (1 ppb) for standard low-oxide/low interference levels (≤ 1.5%) while maintaining high sensitivity across the mass range. The instrument was calibrated using ULTRASPEC® certified custom mixed multi-element stock standard solutions containing all the elements of interest (De Bruyn Spectroscopic Solutions, South Africa). Calibrations spanned the range of 0 – 30 ppm for the mineral elements Ca, Mg, Na, and K and 0 – 0.3 ppm for the rest of the trace elements. Elemental concentrations were expressed as mg/kg."

- Line 182: Adding some random number to each variable is not a standard way to handle data that are zero in your dataset (or if it is, there is no citation here and I am not familiar with that approach). Typically for geochemical data (like what was generated with ICP-MS), you can replace zero values with ½ the detection limit to remove non-zero data. There are other more technical ways to deal with zero values from a statistical standpoint, but the ½ the detection limit is the easiest and has the longest history of use. Please justify the use of your approach or re-run the analyses following a standard method for handling non-zero data in a geochemical dataset.

AUTHORS' RESPONSE: We have re-run the analyses using 0.005 mg/L as the replacement value for any zeros in the soil ion concentration data, as that is half of the detection limit (0.10 mg/L). We have updated the results accordingly, but this update did not result in any changes to statistical significance or model performance in the results. We have updated the methods as follows (lines 169-179): "Plant-available P was extracted from 4 g of soil and 30 ml extraction fluid (1:7.5 ratio) using an acid–fluoride solution (P Bray-1), measured colorimetrically using a Systea EasyChem200 analyser, and expressed as mg/kg. The detection limit was 0.5 mg/kg, and plant available P measurements <0.5 mg/kg were replaced with half the detection limit (0.25 mg/kg) (Croghan & Egeghy, 2003; Keenan & Beeler, 2023). Water-soluble nitrate and phosphate anions were extracted from volume on volume 100 ml soil and 200 ml deionized water, analyzed by ion chromatography on a Metrohm 930 Compact Flex System, and measured as mg/L. Ammonium (also 1:2 water extract) was analyzed colorimetrically using a Systea EasyChem200 analyzer and measured as mg/L. Detection limits for soil ions were 0.01 mg/L, and soil ion concentrations measured as <0.01 mg/L were replaced with half the detection limit (0.005 mg/L)."

- Line 255: The part of the sentence that reads "…we found evidence that N from carcasses had moved from soils into plants" does not belong in the results section. This is interpretation and should be moved to the discussion.

AUTHORS' RESPONSE: We have edited this sentence to read (lines 322-323): "Consistent with our third hypothesis, we found elevated foliar nutrient concentrations in *U. trichopus* at elephant carcass sites."

We include interpretation in the first paragraph of the discussion (lines 355-358): "Together, these results indicate that carcass-derived nutrients move into soil and subsequently get absorbed by plants over relatively short time scales, cycling essential nutrients such as N from carrion into the soil and then back into aboveground nutrient pools."

- Lines 256-258: Similar comment as above where the content of this sentence is interpretation and should be moved to the discussion.

AUTHORS' RESPONSE: We have deleted the following clause from that sentence: "….indicating that the high N content in leaves closer to the center of a megacarcass site likely had an animal origin."

- Lines 295-297: I'm not quite sure I understand the logic presented here. First, soil microbial biomass was not measured. The respiration potential (through production of CO2) was measured, but heterotrophic activity (which is how respiration can be interpreted) consumes oxygen. I think the phrasing here needs to be re-worked to not imply that the soil respiration (and the communities producing CO2) are not necessarily the same that are driving nitrification.

AUTHORS' RESPONSE: We have edited this sentence to focus on heterotrophic activity rather than nitrification. It now reads (lines 378-380): "Soil nitrate (Figure 2B) and soil respiration potential (Figure 3) were also elevated near the center of carcass sites, indicating higher rates of activity of heterotrophic microbes (Prosser, 2011).

- Lines 304-305: There are prior studies that demonstrate the impact of increased organic C during decomposition on soil microbial processes that should be cited here (see studies by DeBruyn and colleagues)

AUTHORS' RESPONSE: Thanks for the suggestion. We have added two relevant citations to these lines from DeBruyn and colleagues (lines 382-383).

Keenan, S. W., Schaeffer, S. M., Jin, V. L. & DeBruyn, J. M. Mortality hotspots: nitrogen cycling in forest soils during vertebrate decomposition. *Soil Biol. Biochem.,* 121, 165-176, https://doi.org/10.1016/j.soilbio.2018.03.005, 2018.

Keenan, S. W., Schaeffer, S. M., and DeBruyn, J. M. Spatial changes in soil stable isotopic composition in response to carrion decomposition, *Biogeosciences,* 16, 3929–3939, https://doi.org/10.5194/bg-16-3929-2019, 2019.

- Lines 310-311: I'm not sure that this is phrased correctly. Phosphorus (predominantly as phosphate) is considered immobile in soil partly because of low solubility because it is often sorbed with Ca, Fe, Al or organics, and the release of P is tightly controlled by soil (or fluid) pH. N does not face the same sorts of sorption immobilization constraints. I think if you rephrased it to clarify that P and N are held within different reservoirs within soils that make them behave differently (and add some citations), that would help.

AUTHORS' RESPONSE: Thanks for the feedback. We have expanded that section to better explain the differences in how N and P are held in soils and agree that this adds clarity. The lines now read (lines 398-401): "This lag could occur because phosphate easily forms chemical bonds with other soil ions (e.g., iron and aluminum in acidic soils and calcium in basic soils). Nitrate does not form these bonds and therefore has greater water solubility and mobility in soils and may be more readily taken up by plants (Wiersum, 1962; Arai & Sparks, 2007)."

We have also added a second citation:

Aria, Y. & Sparks, D. L. Phosphate reaction dynamics in soils and soil components: a multiscale approach. *Adv. Agron*., 94, 135-179, https://doi.org/10.1016/S0065-2113(06)94003-6, 2007.

- Lines 324-328: As mentioned above, because the composition of the two soil types were not included, this part of the discussion is not supported by the results. It's unclear if the authors here are trying to say that the basaltic soils contain more nutrients after being impacted by decomposition or if the native state of the soils (background conditions) are more nutrient rich. I think if the introduction described the background

chemistry of the two soil types this would be better supported. Additionally, basalt and granite contain different types of minerals and therefore additional sources of elements like P. I don't know what the specific mineralogy is of these two rock types in KNP, but it might be worth exploring. In particular, the presence of apatite (Ca-P bearing mineral) in the granite might also be contributing to elevated P measured in the granite soils.

AUTHORS' RESPONSE: Thanks for bringing this up. We have updated the text to clarify that our results confirm a well-established pattern in the literature – that the background state of basaltic soils is more nutrient-rich than granitic soils. What we find interesting here is the significant interaction between soil type and distance with regards to ammonium and phosphate concentrations (Table S1; Figure 2). Ammonium and phosphate levels are elevated at the center of carcass sites in granitic soils relative to basaltic soils, but the difference between soil types disappears as distance from the carcass site increases. These results suggest that the impact of elephant carcasses on these soil ions is greater in the nutrient-poor granitic soils relative to basaltic soils.

We have updated the text in the discussion to better explain the importance of this soil type by distance interaction (lines 424-431): "Our results confirmed the previously-established trend that basaltic soils are overall more cation rich than granitic soils, with greater concentrations of P, K, Fe, Mg, and Ca (Figure 2G; Figure S3B-E; Gertenbach, 1983; Craine, Morrow, & Stock, 2008; Wigley et al. 2014). However, soil ammonium, $\delta^{15}N$, and phosphate were all higher in the granitic soils towards the center of carcass sites, decreasing steeply to be similar to basaltic soils about 10 m from the carcass center (Figure 2C-E). These results indicate that the impact of organic matter from megacarcasses may be stronger in relatively nutrient-poor and sandy granitic soil compared with nutrient-rich and clayey basaltic soil."

We have also updated the methods (lines 122-126) to include more information on the background differences between the two soil types, as described above.

- Figure 5 (and others): I'm a little bit confused by the figure caption. I think it would be better to present this as selected elements plotted as a function of distance. These are not the results of generalized linear mixed models, but the selection of how to present the data were informed by the models.

AUTHORS' RESPONSE: We have changed the text in the figure captions to clarify that we are plotting all the parameters that were included in the top model(s) for a given response variable (Tables S1-2), which is standard practice. We hope this change in language is clearer.

Response to Feedback from Reviewer 3

This manuscript presents data on the influence of elephant carcasses on nutrient availability in South African savanna soils. It would be a surprise if a decaying elephant did not increase nutrient concentrations in the proximity of the carcass, but there are some interesting differences among nutrients in terms of the distance over which the effects extend. There are parallels with other nutrient hotspots in tropical ecosystems, including glades in African savannas (e.g. Augustine 2003) and leafcutter ant nests in tropical forests (e.g. Hudson et al. 2009) - it would be worth introducing these into the discussion for comparison. I have several questions about methodology and results that should be addressed before this manuscript could be acceptable for publication.

AUTHORS' RESPONSE: Thank you for all of your feedback. We have made substantial changes in response to your suggestions, including rewriting the methods section to include more details on the soil lab analyses. We have updated the introduction to better explain the importance of cations and cation exchange in savanna soils. We have also updated the discussion to more thoroughly address the ecological significance of our results, including comparison with other nutrient hotspots.

The most significant critique throughout this review was concern that freezing the soil samples prior to ion analysis may have resulted in elevated ammonium and nitrate levels. We agree that this is an important concern, but we are reassured by the findings in the literature showing that nitrogen measurements (especially nitrate) are relatively robust to storage method. Indeed, in Turner and Romero (2009) (a paper the reviewer cites), freezing did not impact nitrate concentrations relative to fresh soils except in cases of high soil acidity, which were not present in our study. Other studies show that nitrate is unaffected by freezing treatment for at least seven weeks post collection, well within the time frame of analysis for our samples (Esala, 1995; Sollen-Norrlin & Rintoul-Hynes, 2024). Soil ammonium can increase when frozen, although the increase is often relatively small (<1 mg/kg per week frozen; Esala 1995, Fig. 1). It is true that freezing can have a large impact on ammonium in peaty soils, but freezing has only minimal effects on ammonium measurements in clay soils such as ours (Esala, 1995; Sollen-Norrlin & Rintoul-Hynes, 2024). Further, we have compared the soil % nitrogen, nitrate, and ammonium values from the 15m distance in our study (essentially representing the background levels of nutrients in the soils in Kruger) to those found in other soil analysis research in Kruger, and our values are consistent with that prior research (Aranibar et al. 2003; Rughöft et al. 2016; see table below). Our foliar N:P values were consistent with the Kruger literature as well. We found much higher soil nitrogen values at 0-5m distances from the carcass site than those found in these papers, but that is what we hypothesized would happen with nutrient inputs from elephant carcasses. Moreover, even if the absolute values of nitrogen in our study are elevated due to freezing, which there is little evidence to support, there is no reason that the effects of freezing would differ with distance from an elephant carcass, so we are confident that the overall trends in this manuscript are robust.

Metric	Source	Mean	Range	Method
Soil N	Reed et al.	11.4%	5 – 16%	Stable isotope analysis
	Aranibar et al. 2003		~5 – 23%	Stable isotope analysis
Soil Nitrate	Reed et al.	57.1 mg/kg	11.1 – 95.7 mg/kg	1:2 water extract analysis
	Rughöft et al. 2016	28.9 mg/kg	0.0 – 121.9 mg/kg	2:5 water extract analysis
Soil Ammonium	Reed et al.	1.38 mg/kg	0.01 – 6.5 mg/kg	1:2 water extract analysis
	Rughöft et al. 2016	11.3 mg/kg	0.7 – 33.3 mg/kg	2:5 water extract analysis
Soil Plant-Available P	Reed et al.	2.20 mg/kg	0.01 – 9.62 mg/kg	P Bray I
	Craine et al. 2008	38.52 mg/kg	3.23 – 85.43 mg/kg	P Bray II
Leaf N:P Ratio	Reed et al.	7.0	2.5 – 13.9	
	Craine et al. 2008	5.8	3.2 – 9.2	

*For Reed et al., we used values from the 15m distance, and for Craine et al. 2008, we used values from the control plots, as in both cases these best represent the background levels of soil nutrients.

Aranibar, J. N., Macko, S. A., Anderson, I. C., Potgieter, A. L. F., Sowry, R. & Shugart, H. H. Nutrient cycling responses to fire frequency in the Kruger National Park (South Africa) as indicated by stable isotope analysis. *Isotopes Environ. Health Stud.,* 39, 141-158, https://doi.org/10.1080/1025601031000096736, 2003.

Rughöft, S., Hermann, M., Lazar, C. S., Cesarz, S., Levick, S. R., Trumbore, S. E. & Küsel, K. Community composition and abundance of bacterial, archaeal and nitrifying populations in savanna soils on contrasting bedrock material in Kruger National Park, South Africa. *Front. Microbiol.,* 7, https://doi.org/10.3389/fmicb.2016.01638, 2016.

Craine, J. M., Morrow, C., & Stock, W. D. Nutrient concentration ratios and co-limitation in South African grasslands. *New Phytol.,* 179, 829–836, https://doi.org/10.1111/j.1469-8137.2008.02513.x, 2008.

Esala, M. J. Changes in the extractable ammonium- and nitrate-nitrogen contents of soil samples during freezing and thawing. *Commun. Soil Sci. Plant Anal*., 26, 61-68, https://doi.org/10.1080/00103629509369280, 1995.

Sollen-Norrlin, M. & Rintoul-Hynes, N. L. J. Soil sample storage conditions affect measurements of pH, potassium, and nitrogen. *SSSAJ*, 88, 930-941, https://doi.org/10.1002/saj2.20653, 2024.

Turner, B. L. & Romero, T. E. Short-term changes in extractable inorganic nutrients during storage of tropical rainforest soils. *SSSAJ*, 73, 1972-1979, https://doi.org/10.2136/sssaj2008.0407, 2009.

Line 38 – these are not graves. A grave is an excavation for burial.

AUTHORS' RESPONSE: We have changed the word gravesite to carcass site.

Line 77 – what about the amounts of cations in an elephant?

AUTHORS' RESPONSE: This is an interesting question. We estimated the N, P, and C quantities in an elephant based on the body size to macronutrient scaling rules described in Sterner & Elser (2002). Unfortunately, we are not aware of a well-established scaling rule for cations that would allow us to estimate cation concentrations in elephant tissue.

Sterner, R. W. & Elser, J. J. Ecological Stoichiometry: The Biology of Elements from Molecules to the Biosphere. Princeton University Press. 2002.

Line 89 – cations are not micronutrients. Is there direct evidence for widespread (or any) cation limitation of growth in savanna ecosystems?

AUTHORS' RESPONSE: Cation exchange is essential for soil fertility, and there is evidence of cation limitation (particularly K^+ and Ca^{2+}) on African savannas (Lathwell & Grove, 1986; Agbenin & Yakubu, 2006). We have edited the manuscript to refer to these elements as cations rather than micronutrients for clarity. We have also updated the introduction to include this information as follows (lines 91-95): "Aboveground, plant growth in African savannas is strongly limited by nutrient availability, most commonly N and P, but also by cations such as Ca, K, and magnesium (Mg) (Jobbágy & Jackson, 2004; Ries & Shugart, 2008; Pellegrini, 2016), and there is evidence of cation limitation of plants (particularly K^+ and Ca^{2+}) on African savannas (Lathwell & Grove, 1996; Agbenin & Yakubu, 2006)."

Agbenin, J. O. & Yakubu, S. Potassium-calcium and potatssium-magnesium exchange equilibria in an acid savanna soil from northern Nigeria. *Geoderma*, 136, 542-554, https://doi.org/10.1016/j.geoderma.2006.04.008, 2006.

Lathwell, D. J. & Grove, T. L. Soil-plant relationships in the tropics. *Annual Review of Ecology and Systematics*, 17, 1-16, https://www.jstor.org/stable/2096986, 1986.

Line 99 – please include classifications for the granitic and basaltic soils in one of the internationally recognized systems. In Soil Taxonomy these are presumably Inceptisols / Alfisols and Vertisols, respectively?

AUTHORS' RESPONSE: Thanks for the suggestion. The granitic soils are inceptisols, while the basaltic soils may be versitols or andisols (Khomo et al. 2017). We agree that these classifications are important for understanding the impacts of carcass-derived nutrients on different soil types and have updated the methods section as follows (lines 123-127): "The two dominant soil types in KNP are granitic soils (inceptisols) and basaltic soils (versitols or andisols) (Khomo et al. 2017). The clay-rich basaltic soils have relatively large surface area,

enabling them to retain larger quantities of water than granitic soils, which drain water more quickly and therefore are lower in water-soluble nutrients (Buitenweref, Kulmatiski, & Higgins, 2014; Rughöft et al. 2016)."

Khomo, L., Trumbore, S., Bern, C. R., & Chadwick, O. A. Timescales of carbon turnover in soils with mixed crystalline mineralogies. *SOIL*, 3, 17-30, https://doi.org/10.5194/soil-3-17-2017, 2017.

Buitenwerf, R., Kulmatiski, A. & Higgins, S. I. Soil water retention curves for the major soil types of the Kruger National Park. *Koedoe*, 56, a1228, http://dx.doi.org/10.4102/koedoe.v56i1.1228, 2014.

Line 138 – freezing soil has implications for subsequent measurements of extractable nutrients (e.g. Turner and Romero 2009). This should be mentioned here. Given the apparently very high values for some measurements (see below) I suspect that pretreatment had a major impact on results.

AUTHORS' RESPONSE: As detailed above, we acknowledge that freezing may have an impact on soil nitrogen measurements, though the literature is mixed on this topic. Generally, it seems that freezing more often impacts concentrations of ammonium but not nitrate (Esala, 1995; Turner & Romero, 2009; Sollen-Norrlin & Rintoul-Hynes, 2024). Indeed, in the Turner and Romero (2009) paper that the reviewer cites, freezing did not impact nitrate concentrations relative to fresh soils except in cases of high soil acidity, which were not present in our study. They write, "Frozen storage of the Pipeline Road and Fort Sherman soils preserved NO3 at similar concentrations to fresh samples (Table 2), but caused a marked decline for the acidic Albrook soil, indicating a possible effect of soil pH on NO3 stability. (Note: NO3 determined after 3 mo of storage in the Albrook soil)" (pg. 1974). The impacts of freezing on ammonium are also relatively minimal (<1 mg/kg per week of freezing according to Esala, 1995). Thus, based on what is known from the literature any impacts of freezing on the concentrations of nutrients in our samples were likely quite minimal. Further, we have compared the soil % nitrogen, nitrate, and ammonium values from the 10 and 15m distances in our study (those most similar to the background soils in Kruger) to those found in other soil analysis research in Kruger, and our values are consistent with that prior research (Aranibar et al. 2003; Rughöft et al. 2016).

Metric	**Source**	**Mean**	**Range**	**Method**
Soil %N	Reed et al.	11.4%	5 – 16%	Stable isotope analysis
	Aranibar et al. 2003		~5 – 23%	Stable isotope analysis
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	Rughöft et al. 2016	28.9 mg/kg	0.0 – 121.9 mg/kg	2:5 water extract analysis
Soil Ammonium	Reed et al.	1.38 mg/kg	0.01 – 6.5 mg/kg	1:2 water extract analysis
	Rughöft et al. 2016	11.3 mg/kg	0.7 – 33.3 mg/kg	2:5 water extract analysis
Soil Plant-Available P	Reed et al.	2.20 mg/kg	0.01 – 9.62 mg/kg	P Bray I
	Craine et al. 2008	38.52 mg/kg	3.23 – 85.43 mg/kg	P Bray II
Leaf N:P Ratio	Reed et al.	7.0	2.5 – 13.9	
	Craine et al. 2008	5.8	3.2 – 9.2	

*For Reed et al., we used values from the 15m distance, and for Craine et al. 2008, we used values from the control plots, as in both cases these best represent the background levels of soil nutrients.

If freezing the samples did alter the measured soil ammonium concentrations, there is no reason to believe that the effect size would differ with distance from the carcass. Thus, even if absolute values are elevated by freezing, for which there is little evidence in the literature, the overall trends of decreasing ammonium and nitrate with carcass distance should still stand.

We have updated the methods section as follows (lines 158-161): "We chose to freeze samples rather than storing at room temperature based on literature demonstrating that the impacts of freezing on soil nitrate and ammonium concentrations are fairly minimal, except in specific cases of high soil acidity or peaty soils that were not present at our field site (Esala, 1995; Turner & Romero, 2009; Sollen-Norrlin & Rintoul-Hynes, 2024)."

Aranibar, J. N., Macko, S. A., Anderson, I. C., Potgieter, A. L. F., Sowry, R. & Shugart, H. H. Nutrient cycling responses to fire frequency in the Kruger National Park (South Africa) as indicated by stable isotope analysis. *Isotopes Environ. Health Stud.,* 39, 141-158, https://doi.org/10.1080/1025601031000096736, 2003.

Rughöft, S., Hermann, M., Lazar, C. S., Cesarz, S., Levick, S. R., Trumbore, S. E. & Küsel, K. Community composition and abundance of bacterial, archaeal and nitrifying populations in savanna soils on contrasting bedrock material in Kruger National Park, South Africa. *Front. Microbiol.,* 7, https://doi.org/10.3389/fmicb.2016.01638, 2016.

Craine, J. M., Morrow, C., & Stock, W. D. Nutrient concentration ratios and co-limitation in South African grasslands. *New Phytol.,* 179, 829–836, https://doi.org/10.1111/j.1469-8137.2008.02513.x, 2008.

Esala, M. J. Changes in the extractable ammonium- and nitrate-nitrogen contents of soil samples during freezing and thawing. *Commun. Soil Sci. Plant Anal*., 26, 61-68, https://doi.org/10.1080/00103629509369280, 1995.

Sollen-Norrlin, M. & Rintoul-Hynes, N. L. J. Soil sample storage conditions affect measurements of pH, potassium, and nitrogen. *SSSAJ*, 88, 930-941, https://doi.org/10.1002/saj2.20653, 2024.

Turner, B. L. & Romero, T. E. Short-term changes in extractable inorganic nutrients during storage of tropical rainforest soils. *SSSAJ*, 73, 1972-1979, https://doi.org/10.2136/sssaj2008.0407, 2009.

Line 145/146 – please explain the difference between phosphate and plant-available P. As written, it appears they were both measured in the water extracts. Most plant-available P tests are not conducted in water (e.g. Olsen, Mehlich, Bray, etc).

AUTHORS' RESPONSE: We have updated the methods section as follows to include more details on soil nutrient analyses, including distinguishing between the methods used for phosphate and plant-available P (lines 166-179): "We sent 250 g of each soil sample to Eco-Analytica laboratory at the North-West University in Potchefstroom, South Africa for measurements of soil concentrations of ammonium $[NH_4]^+$, nitrate $[NO_3]^-$, phosphate $[PO_4]^{3-}$, and plant-available P. Samples were air-dried and sieved through < 2mm mesh prior to chemical analysis. Plant-available P was extracted from 4 g of soil and 30 ml extraction fluid (1:7.5 ratio) using an acid–fluoride solution (P Bray-1), measured colorimetrically using a Systea EasyChem200 analyser, and expressed as mg/kg. The detection limit was 0.5 mg/kg, and plant available P measurements <0.5 mg/kg were replaced with half the detection limit (0.25 mg/kg) (Croghan & Egeghy, 2003; Keenan & Beeler, 2023). Water-soluble nitrate and phosphate anions were extracted from volume on volume 100 ml soil and 200 ml deionized water, analyzed by ion chromatography on a Metrohm 930 Compact Flex System, and measured as mg/L. Ammonium (also 1:2 water extract) was analyzed colorimetrically using a Systea EasyChem200 analyzer and measured as mg/L. Detection limits for soil ions were 0.01 mg/L, and soil ion concentrations measured as <0.01 mg/L were replaced with half the detection limit (0.005 mg/L)."

Line 158 – was there any inorganic C in the samples? Savanna Vertisols developed in basalt can have considerable carbonate concentrations, albeit often in subsoil. Soil pH values would help indicate this possibility – how did carcasses affect soil pH?

AUTHORS' RESPONSE: We did not directly measure inorganic C, but we did measure soil pH and found no significant difference in soil pH with soil type or distance from the carcass center. We have added this result to the manuscript (Table S1, Figure S4B).

Line 161 – was moisture standardized prior to the incubations?

AUTHORS' RESPONSE: We did not standardize moisture prior to incubations, since the impact of carcasses on soil moisture was one of our questions (Figure S5 in original manuscript, Figure S4 below). However, we did account for soil moisture after the incubations following the methods process described in lines 227-230: "After soil respiration measurements, we determined sample dry weight by drying each sample at 60°C for 24-48 hours until stable mass was achieved. We subtracted dry weight from starting weight to obtain soil water content. Finally, we used the dry weights and the Ideal Gas Law to standardize all respiration measurements to CO_2 $\mu g\ h^{-1} g\ dry\ soil^{-1}$." These methods are described in further detail in Lemoine et al. 2024, which is cited earlier in that paragraph.

Lemoine, N. P., Budny, M. L., Rose, E., Lucas, J., & Marshall, C. W. Seasonal soil moisture thresholds inhibit bacterial activity and decomposition during drought in a tallgrass prairie. Oikos, 2024, e10210, https://doi.org/10.1111/oik.10201, 2023.

Line 182 – an alternative is to set values to ½ detection limit.

AUTHORS' RESPONSE: We have re-run the analyses using 0.005 mg/L as the replacement value for any zeros in the soil ion concentration data, as that is half of the detection limit (0.10 mg/L). We updated the results accordingly, but this update did not result in any changes to statistical significance or model performance in the results. We have updated the methods as follows (lines 169-179): "Plant-available P was extracted from 4 g of soil and 30 ml extraction fluid (1:7.5 ratio) using an acid–fluoride solution (P Bray-1), measured colorimetrically using a Systea EasyChem200 analyser, and expressed as mg/kg. The detection limit was 0.5 mg/kg, and plant available P measurements <0.5 mg/kg were replaced with half the detection limit (0.25 mg/kg) (Croghan & Egeghy, 2003; Keenan & Beeler, 2023). Water-soluble nitrate and phosphate anions were extracted from volume on volume 100 ml soil and 200 ml deionized water, analyzed by ion chromatography on a Metrohm 930 Compact Flex System, and measured as mg/L. Ammonium (also 1:2 water extract) was analyzed colorimetrically using a Systea EasyChem200 analyzer and measured as mg/L. Detection limits for soil ions were 0.01 mg/L, and soil ion concentrations measured as <0.01 mg/L were replaced with half the detection limit (0.005 mg/L)."

Line 188 – I understand that there were insufficient carcasses to allow inclusion of carcass age in models. However, major differences would be expected between carcasses aged 1 month vs 2.5 years. Is there any way to provide an indication of the magnitude of the age effect? How would distance effects look if young carcasses were excluded, for example?

AUTHORS' RESPONSE: Thanks for the suggestion! We have added analysis and figures to the manuscript testing for a relationship between key soil metrics and carcass age. We found that soil ammonium, phosphate, and respiration potential all decrease significantly with carcass age. In fact, the trends are so compelling that we have added this figure to the main text (Figure 5). This figure suggests the pattern of elevated soil nutrients that we found may be even stronger when considering younger carcasses given how quickly the nutrients decline with age.

We have added this update to the methods section as follows (lines 280-282): "Finally, to test the impact of carcass age on key soil metrics, we ran exponential decay functions for soil ammonium, nitrate, phosphate, and respiration verses carcass age for samples from the center of the carcass site (0.5m sampling location)."

And to the results section as follows (lines 343-345): "Soil ammonium, phosphate, and respiration potential all decreased significantly with carcass age (Figure 5A-C). The exponential decay model for nitrate failed to converge due to an outlier with extremely high soil nitrate (1454 mg/kg) at 258 days post-death (Figure 5D)."

Line 228 – It is perhaps not surprising that P concentrations showed little variation with distance, given that P was measured in water extracts (i.e. the extraction is recovering a relatively small pool of soluble P).

AUTHORS' RESPONSE: This is an interesting point. The results included in this manuscript are soil phosphate (1:2 water extract) and plant-available P (P Bray-I), but we also measured mineral phosphorus (P31) in mg/kg using the same method we did for soil Na, Mg, Fe, Ca, and K—microwave-assisted digestion in a solution of 9 mL 65% nitric acid (HNO_3) and 3 mL 32% hydrochloric acid (HCl) (lines 182-197). We have added this result to the manuscript (Figure 2G; Table S1), thereby increasing the proportion of total soil P covered by our analyses. All three individual measurements of soil P (phosphate, plant-available P, and mineral P) indicate an interaction between distance and soil type in which P decreases with distance from the carcass center, but only in granitic soils.

Line 230 – how is plant-available P defined here?

AUTHORS' RESPONSE: Plant-available P refers to P measured via the P Bray I method. We have updated the methods as follows (lines 169-174): "Plant-available P was extracted from 4 g of soil and 30 ml extraction fluid (1:7.5 ratio) using an acid–fluoride solution (P Bray-1), measured colorimetrically using a Systea EasyChem200 analyser, and expressed as mg/kg. The detection limit was 0.5 mg/kg, and plant available P measurements <0.5 mg/kg were replaced with half the detection limit (0.25 mg/kg) (Croghan & Egeghy, 2003; Keenan & Beeler, 2023)."

Line 286 – Soil extractable nutrients should be expressed on the basis of dry soil, not volume.

AUTHORS' RESPONSE: We have updated the manuscript so that here and throughout, soil ion concentrations are given in mg/kg soil rather than mg/L.

Line 286 - these very high extractable nitrogen concentrations are presumably in part a consequence of soils being frozen prior to analysis. Another factor is time between sampling and freezing - or storage prior to freezing. Please provide a statement about sample treatment prior to analysis (time from sampling to freezing, storage conditions during this time, etc, as relevant).

AUTHORS' RESPONSE: We have updated the methods section to include more details on soil storage as follows (lines 154-158): "Soil samples were stored in a cooler during fieldwork. On the day they were collected, we used 5 g of each soil sample for soil respiration measurements (described below). The rest of each sample was stored in plastic bags in a -20°C freezer until nutrient analyses; they were stored in coolers with ice blocks during the transition from the freezer at the field site to the freezers at the labs."

As we discuss above, there were likely negligible, if any, impacts of freezing on nitrate concentrations given the data available in the literature. Similarly, the impacts on ammonium were likely also minor. Further, we have also compared our measured nitrogen concentrations to those from other studies performed in Kruger (% N, Aranibar et al. 2003; ammonium and nitrate,

Rughöft et al. 2016; see table below). We used the 15m distance in our dataset for comparison, since that is most representative of the baseline nitrogen concentrations. Our values were similar to those found by other researchers in Kruger, which increases our confidence that the measurements we took are accurate. The nitrogen concentrations that we found at the 0-5m distances are indeed much higher than those found elsewhere, but we attribute this to the presence of the elephant carcass.

Metric	Source	Mean	Range	Method
Soil %N	Reed et al.	11.4%	5 – 16%	Stable isotope analysis
	Aranibar et al. 2003		~5 – 23%	Stable isotope analysis
Soil Nitrate	Reed et al.	57.1 mg/kg	11.1 – 95.7 mg/kg	1:2 water extract analysis
	Rughöft et al. 2016	28.9 mg/kg	0.0 – 121.9 mg/kg	2:5 water extract analysis
Soil Ammonium	Reed et al.	1.38 mg/kg	0.01 – 6.5 mg/kg	1:2 water extract analysis
	Rughöft et al. 2016	11.3 mg/kg	0.7 – 33.3 mg/kg	2:5 water extract analysis
Soil Plant-Available P	Reed et al.	2.20 mg/kg	0.01 – 9.62 mg/kg	P Bray I
	Craine et al. 2008	38.52 mg/kg	3.23 – 85.43 mg/kg	P Bray II
Leaf N:P Ratio	Reed et al.	7.0	2.5 – 13.9	
	Craine et al. 2008	5.8	3.2 – 9.2	

*For Reed et al., we used values from the 15m distance, and for Craine et al. 2008, we used values from the control plots, as in both cases these best represent the background levels of soil nutrients.

Aranibar, J. N., Macko, S. A., Anderson, I. C., Potgieter, A. L. F., Sowry, R. & Shugart, H. H. Nutrient cycling responses to fire frequency in the Kruger National Park (South Africa) as indicated by stable isotope analysis. *Isotopes Environ. Health Stud.,* 39, 141-158, https://doi.org/10.1080/1025601031000096736, 2003.

Rughöft, S., Hermann, M., Lazar, C. S., Cesarz, S., Levick, S. R., Trumbore, S. E. & Küsel, K. Community composition and abundance of bacterial, archaeal and nitrifying populations in savanna soils on contrasting bedrock material in Kruger National Park, South Africa. *Front. Microbiol.,* 7, https://doi.org/10.3389/fmicb.2016.01638, 2016.

Craine, J. M., Morrow, C., & Stock, W. D. Nutrient concentration ratios and co-limitation in South African grasslands. *New Phytol.,* 179, 829–836, https://doi.org/10.1111/j.1469-8137.2008.02513.x, 2008.

Line 308 – the high available P and tissue N:P ratios (see below) indicate that there is no P limitation here. This might limit the likely influence of carcasses on foliar P, as found here (i.e. foliar P is not a strong indicator of the extent to which carcasses change P availability in general).

AUTHORS' RESPONSE: Thanks for bringing this up. We appreciate your comments here and below suggesting that P limitation might not be strong at our sites, and we have updated this paragraph in the discussion as follows (lines 394-409):

"Elevated soil phosphate (Figure 2E) and plant-available P (Figure 2F) at the center of carcass sites were also consistent with expectations from the literature (Bump et al. 2009a; Parmenter & MacMahon, 2009). However, elevated P levels in soil did not translate to elevated P in grass leaves (Figure 4C), which could suggest a lag between trends in soil and plants that is longer for P than for N. This lag could occur because phosphate easily forms chemical bonds with other soil ions (e.g., iron and aluminum in acidic soils and calcium in basic soils). Nitrate does not form these bonds and therefore has greater water solubility and mobility in soils and may be more readily taken up by plants (Wiersum, 1962; Arai & Sparks, 2007). However, it is also possible that P limitation in Kruger is not as strong as it is in some other African savanna systems (Pellegrini, 2016). The foliar N:P ratios measured in this experiment were higher closer to the center of the carcass site (median 9.38 at 0 m and 4.83 at 15 m), indicating that N limitation may be relatively stronger further from the carcass site, and P limitation may be relatively stronger closer to the center (Figure 4D, Table S2). These relatively high foliar N:P ratios at the center of carcass sites are similar to those found in N fertilization studies in Kruger (Craine et al. 2008), further supporting the idea that the influx of N from megacarcasses may shift the soil from relatively more N limited to more P limited."

We also compared our plant-available P and foliar N:P ratios with other studies in Kruger and found that our plant-available P results were actually lower, while our foliar N:P ratios were in about the same range.

Metric	**Source**	**Mean**	**Range**	**Method**
Soil Plant-Available P	Reed et al.	2.20 mg/kg	0.01 – 9.62 mg/kg	P Bray I
	Craine et al. 2008	38.52 mg/kg	3.23 – 85.43 mg/kg	P Bray II
Leaf N:P Ratio	Reed et al.	7.0	2.5 – 13.9	
	Craine et al. 2008	5.8	3.2 – 9.2	

Craine, J. M., Morrow, C., & Stock, W. D. Nutrient concentration ratios and co-limitation in South African grasslands. *New Phytol.,* 179, 829–836, https://doi.org/10.1111/j.1469-8137.2008.02513.x, 2008.

Line 322 – water-extractable P represents a tiny proportion of the total soil P, so reliance on this procedure probably limits the possibility of detecting change in soil P.

AUTHORS' RESPONSE: We have updated the results to include mineralized P in soils in addition to phosphate and plant-available P, as described above in response to line 228.

Line 323- 330 – this text largely repeats results.

AUTHORS' RESPONSE: Thank you for this feedback. We have updated this section to better integrate statements of results with their interpretations, with the new text reading (lines 423-431): "The contributions of megacarcasses to soil macronutrient and cation pools were strongly associated with soil type. Our results confirmed the previously-established trend that basaltic

soils are overall more cation rich than granitic soils, with greater concentrations of P, K, Fe, Mg, and Ca (Figure 2G; Figure S3B-E; Gertenbach, 1983; Craine, Morrow, & Stock, 2008; Wigley et al. 2014). However, soil ammonium, $\delta^{15}N$, and phosphate were all higher in the granitic soils towards the center of carcass sites, decreasing steeply to be similar to basaltic soils about 10 m from the carcass center (Figure 2C-E). These results indicate that the impact of organic matter from megacarcasses may be stronger in relatively nutrient-poor and sandy granitic soil compared with nutrient-rich and clayey basaltic soil."

Line 340 - missing here is a discussion of the ecological consequences of the findings. What are the implications for plant and microbial ecology in savanna ecosystems?

AUTHORS' RESPONSE: Thanks for this feedback. We have updated the discussion section to include a paragraph on the importance of these nutrient hotspots for savanna ecosystem functioning (lines 441-451): "The magnitude of nutrient inputs from megacarcasses, as well as the substantial size and duration of their impact zones, means their impacts on ecosystem processes may be functionally distinct from smaller carrion. Indeed, there is evidence that carcass size strongly impacts scavenger food web structure (Moleón et al. 2015; Morris et al. 2023). Moreover, the attraction of animals to carcasses via scavenging, predation, or mourning (Goldenberg & Wittemyer, 2020) could have positive feedbacks on nutrient cycling (Bump, Peterson, & Vucetich, 2009; Monk et al. 2024), which may be magnified by carcass size. Thus, the impacts of megacarcasses on savanna ecosystem processes may be dissimilar to the effects of small carrion and more similar to other more persistent contributors to savanna ecosystem processes, such as termite mounds (Davies et al. 2016), cattle bomas (Augustine, 2003), and even mass animal mortality events (Subalusky et al. 2017, 2020)."

Figure 2B, C – these values should be presented in mg/kg soil.

AUTHORS' RESPONSE: We have updated the manuscript so that here and throughout, soil ion concentrations are given in mg/kg soil rather than mg/L. To do this conversion, we multiplied the volume in mg/L by 2 based on the 1:2 soil to water extraction ratio, as the reviewer helpfully described below.

Figure 2B – these are extremely high nitrate concentrations, even out to 15 m. For example, 100 mg/L is equivalent to 200 mg/kg based on a 1:2 soil to water extraction ratio. Extractions done quickly after sampling and in 2 M KCl are in the range of 1-5 mg/kg. This seems to be a clear indication of storage effects.

AUTHORS' RESPONSE: We have found our N measurements to be consistent with other studies in Kruger. As we discuss in several places above, there is unlikely to be any significant storage effects on these measurements.

Metric	Source	Mean	Range	Method
Soil %N	Reed et al.	11.4%	5 – 16%	Stable isotope analysis
	Aranibar et al. 2003		~5 – 23%	Stable isotope analysis
Soil Nitrate	Reed et al.	57.1 mg/kg	11.1 – 95.7 mg/kg	1:2 water extract analysis
	Rughöft et al. 2016	28.9 mg/kg	0.0 – 121.9 mg/kg	2:5 water extract analysis
Soil Ammonium	Reed et al.	1.38 mg/kg	0.01 – 6.5 mg/kg	1:2 water extract analysis
	Rughöft et al. 2016	11.3 mg/kg	0.7 – 33.3 mg/kg	2:5 water extract analysis
Soil Plant-Available P	Reed et al.	2.20 mg/kg	0.01 – 9.62 mg/kg	P Bray I
	Craine et al. 2008	38.52 mg/kg	3.23 – 85.43 mg/kg	P Bray II
Leaf N:P Ratio	Reed et al.	7.0	2.5 – 13.9	
	Craine et al. 2008	5.8	3.2 – 9.2	

*For Reed et al., we used values from the 15m distance, and for Craine et al. 2008, we used values from the control plots, as in both cases these best represent the background levels of soil nutrients.

Aranibar, J. N., Macko, S. A., Anderson, I. C., Potgieter, A. L. F., Sowry, R. & Shugart, H. H. Nutrient cycling responses to fire frequency in the Kruger National Park (South Africa) as indicated by stable isotope analysis. *Isotopes Environ. Health Stud.,* 39, 141-158, https://doi.org/10.1080/1025601031000096736, 2003.

Rughöft, S., Hermann, M., Lazar, C. S., Cesarz, S., Levick, S. R., Trumbore, S. E. & Küsel, K. Community composition and abundance of bacterial, archaeal and nitrifying populations in savanna soils on contrasting bedrock material in Kruger National Park, South Africa. *Front. Microbiol.,* 7, https://doi.org/10.3389/fmicb.2016.01638, 2016.

Craine, J. M., Morrow, C., & Stock, W. D. Nutrient concentration ratios and co-limitation in South African grasslands. *New Phytol.,* 179, 829–836, https://doi.org/10.1111/j.1469-8137.2008.02513.x, 2008.

Figure 2B, C – are these values as NO3/NH4 or on an N basis?

AUTHORS' RESPONSE: These values are on an N-basis (as are the values from Rughöft et al. 2016 in the tables above), and we have updated the figure legend to clarify.

Figure 2D – please express stable isotope ratios as $\delta^{15}N$. This may be how the results are presented, but this is not clear from the units.

AUTHORS' RESPONSE: We have changed the notation here and throughout the manuscript to $\delta^{15}N$.

Figure 2F – these are very high available P concentrations for a natural ecosystem, although there is no mention of the method used.

AUTHORS' RESPONSE: We have updated the methods section to include the method used to measure plant-available P as follows (lines 169-174): "Plant-available P was extracted from 4 g of soil and 30 ml extraction fluid (1:7.5 ratio) using an acid–fluoride solution (P Bray-1), measured colorimetrically using a Systea EasyChem200 analyser, and expressed as mg/kg. The detection limit was 0.5 mg/kg, and plant available P measurements <0.5 mg/kg were replaced with half the detection limit (0.25 mg/kg) (Croghan & Egeghy, 2003; Keenan & Beeler, 2023)."

In comparison with the literature, we found that our soil plant-available P values were actually lower than those from other studies performed in Kruger on the same granitic and basaltic soil types.

Metric	Source	Mean	Range	Method
Soil Plant-Available P	Reed et al.	2.20 mg/kg	0.01 – 9.62 mg/kg	P Bray I
	Craine et al. 2008	38.52 mg/kg	3.23 – 85.43 mg/kg	P Bray II

*For Reed et al., we used values from the 15m distance, and for Craine et al. 2008, we used values from the control plots, as in both cases these best represent the background levels of soil nutrients.

Craine, J. M., Morrow, C., & Stock, W. D. Nutrient concentration ratios and co-limitation in South African grasslands. *New Phytol.,* 179, 829–836, https://doi.org/10.1111/j.1469-8137.2008.02513.x, 2008.

Figure 4 – it looks like foliar N:P ratios are around 4 (2% N, 0.5%P) – these very low values that suggest strong N limitation. This is incompatible with the very high nitrate values presented in Figure 2. This further indicates storage problems with N measurements.

AUTHORS' RESPONSE: The reviewer brings up an interesting point about the stoichiometry of the grass we sampled around the elephant carcasses. We now analyze foliar N:P ratios and found that they were overall higher in granitic soils compared to basaltic soils and decreased with distance from the carcass center in both soil types. The median foliar N:P ratio was 9.38 at the 0m distance and 4.83 at the 15m distance, which may indicate that N limitation may be relatively stronger further from the carcass site, and P limitation may be relatively stronger closer to the center. We have added these new results to the manuscript (Figure 4D, Table S2).

Interestingly, some previous work in Kruger with this same species of grass, as well as other grasses, showed that N:P ratios in grasses responded similarly to the addition of N fertilizer (Crane et al. 2008). Under control nutrient conditions the grasses in their study had a N:P of 5.8 on average. But similar to our study, under N fertilization grasses had a N:P of 9.9 on average. These data argue against the reviewer's point that having high N availability in the soil necessarily increases the N:P to high levels that one would expect to indicate P limitation. This example, and the data we present above, suggest that the storage methods for the soils that we used are not impacting our dataset.

We have updated the discussion as follows (lines 406-409): “These relatively high foliar N:P ratios at the center of carcass sites are similar to those found in N fertilization studies in Kruger (Craine et al. 2008), further supporting the idea that the influx of N from megacarcasses may shift the soil from relatively more N limited to more P limited.”

Craine, J. M., Morrow, C., & Stock, W. D. Nutrient concentration ratios and co-limitation in South African grasslands. *New Phytol.,* 179, 829–836, https://doi.org/10.1111/j.1469-8137.2008.02513.x, 2008.

Augustine, D. J. (2003). Long-term, livestock-mediated redistribution of nitrogen and phosphorus in an East African savanna. Journal of Applied Ecology, 40(1), 137-149.

Hudson et al. (2009). Temporal patterns of nutrient availability around nests of leaf-cutting ants (Atta*olombica*) in secondary moist tropical forest. Soil Biology and Biochemistry, 41(6), 1088-1093.

Turner, B. L., & Romero, T. E. (2009). Short-term changes in extractable inorganic nutrients during storage of tropical rain forest soils. Soil Science Society of America Journal, 73, 1972-1979.

AUTHORS’ RESPONSE: Thank you for providing these references. We have found the Turner and Romero (2009) manuscript particularly instructive in interpretating the soil nitrogen data. We have updated the discussion to include comparisons with other types of savanna nutrient hotspots (lines 441-451): “The magnitude of nutrient inputs from megacarcasses, as well as the substantial size and duration of their impact zones, means their impacts on ecosystem processes may be functionally distinct from smaller carrion. Indeed, there is evidence that carcass size strongly impacts scavenger food web structure (Moleón et al. 2015; Morris et al. 2023). Moreover, the attraction of animals to carcasses via scavenging, predation, or mourning (Goldenberg & Wittemyer, 2020) could have positive feedbacks on nutrient cycling (Bump, Peterson, & Vucetich, 2009; Monk et al. 2024), which may be magnified by carcass size. Thus, the impacts of megacarcasses on savanna ecosystem processes may be dissimilar to the effects of small carrion and more similar to other more persistent contributors to savanna ecosystem processes, such as termite mounds (Davies et al. 2016), cattle bomas (Augustine, 2003), and even mass animal mortality events (Subalusky et al. 2017, 2020).”