

Influence of Connectivity on Dung Beetle Communities

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Abstract

Habitat fragmentation threatens biodiversity across the globe as habitat loss, isolation, and edge effects become increasingly prevalent. Corridors have become an important tool in order to combat the negative effects of fragmentation, however they are difficult to study in natural systems without incurring confounding effects. To observe changes in insect community composition as an effect of landscape features we sampled dung beetles in a landscape scale experiment. We did not see a difference in species richness or diversity, but dung beetle abundances were higher in continuous forest habitat and open habitat patches connected by a corridors than in isolated patches.

TO DO LIST

Methods:

1. add a few sentences on drying, keys used to ID, and depositing vouchers

Analyses

1. Write a short paragraph on how you calculated and compared species richness and diversity (hill numbers, glmm).
2. Write a short paragraph on how you calculated and compared functional diversity (how you measured it, how you compared it)

Results

1. answer the overview questions, then stich them together into a paragraph
 - ~~any species restricted to 1-2 habitat types~~
 - Were all species found in all blocks? Were any restricted to only 1-2 blocks?
 - Were all species found in the matrix? (expect that so, since it is the 'baseline' or 'source' habitat)
 - Number of species in each functional group
 - ~~most common 3-4 species~~
 - any rare species?
 - any invasive / exotic species?

Figures

1. Figure of species richness results.
2. Figure of species diversity results.
3. Figure of biomass of different (R/T/D) functional groups.
4. Figure of abundance of individual species.
5. ~~Figure of the patch layout with pitfalls.~~

33 **Tables**

- 34 1. ~~Table: count by species by habitat.~~
- 35 2. table: results of species richness analyses.
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- 37 4. table: results of functional diversity analyses.

38 **Misc.**

- 39 1. Map of where field site is located.
- 40 2. Pictures of different species, sampling, field sites

INTRODUCTION

Note from EB: *I don't want to see the words 'dung beetles' until paragraph 5.*

Paragraph 1: Overall Topic & Why it is interesting and Important.

As human disturbances continue to expand into natural landscapes, intact habitats are becoming increasingly fragmented. Like many ecological processes, fragmentation is a complex and multifaceted phenomenon bringing about many consequences which can be both positive and negative for ecosystems (Fahrig 2003) (Fletcher et al. 2018). However, as habitats are broken down community structures are significantly altered (Laurance et al. 2018). This alteration of structure typically leads to loss in biodiversity on a global scale and interruptions in ecosystem processes and functions (Haddad 2015).

Researchers today continue to search for strategies to mitigate the negative effects resulting from changes in landscape structure (Noh et al. 2022).

Topic Sentence: Fragmentation is an extensive problem across the globe and it is vital to understand shifts in biodiversity and community structures as a result of trophic cascades.

Paragraph 2: What we know.

Corridors have been shown to be an important mechanism for facilitating the movement of organisms through fragmented landscapes with the goal of minimizing negative consequences of fragmentation (Haddad et al. 2003).

Topic Sentence: Habitat connectivity is generally viewed as beneficial for ecosystems as a whole. We know that patch shape and size can be an influential factor for how populations are configured. Wildlife corridors

Paragraph 3: What we don't know.

With experimental designs we are able to isolate factors might be contributing to ecological patterns and processes.

Topic Sentence: Changes in ecosystem function as a result of shifts in community structure (EB but we may not want to emphasize this given we didn't measure directly)

Potential alternative routes:

- 1) We know far less on how corridors influence functional diversity. Functional diversity is important for the maintenance of ecosystem services, etc, so corridors could help ensure that. (in context of dung beetles that would be feeding guilds (simplest), morphology etc. in deCastro Arrazola et al)
- 2) Studies investigating corridors rarely look at what's in the matrix. The matrix could be a source of diversity that moves into patches and then through corridors or a completely different subset of species. (any other options?) Understanding which of these it is is important because it leads to different conclusions about role of corridors and conservation strategies
- 3) regardless, not a bad idea to discuss both matrix and functional group in discussion.
- 4) and the alternative approach: revamp into around spillover from matrix into patches and if dependent on corridors or edge

Paragraph 5: Here is what we did to address this unknown.

Dung beetles have emerged as a model system with which to test spatial ecology hypotheses (Roslin 2000, Rös et al. 2012). They are an incredibly well studied group of insects which are well known for driving a multitude of ecosystem functions (Hasan et al. 2024). The removal, breakdown, and burial of animal feces drive important ecosystem interactions provided by dung beetles enhancing nutrient cycling and soil quality, the reduction of breeding sites for parasites, and a reduction in methane emissions from dung (Iwasa et al. 2015, Slade et al. 2016). Here, we aim to gain an understanding of how dung beetles, a group of insects well known for strong dispersal ability in order to compete for ephemeral resources (Hanski and Cambefort 1991), interact with corridors in their landscapes. We sampled dung beetle communities in experimental landscapes developed for the express purposes of comparing connected and isolated patches, as well as the effects of patch to edge ratio and distance to edge. To ask the question of (1) how

landscape connectivity impacts dung beetle assemblages dung beetles were collected, identified, and counted with the expectation that biodiversity and abundance would be higher in patches connected by corridors. Additionally we asked (2) Are corridors benefiting any one functional trait over another?

Topic Sentence: Here we talk about dung beetles how they fit into the broader scope of our question and directly state what questions we are asking.

As human disturbances continue to expand into natural landscapes, intact habitats are becoming increasingly fragmented. This degradation lends to loss in biodiversity on a global scale and interruptions in ecosystem processes and functions (Haddad 2015). Effects from isolation can vary, however as habitats are broken down community structures are significantly altered (Laurance et al. 2018). Corridors have been shown to be an important mechanism for facilitating the movement of organisms through fragmented landscapes with the goal of minimizing negative consequences of fragmentation (Haddad et al. 2003). As disturbance continues to intensify, it is becoming increasingly more important to understand how different taxonomic groups. Here, we aim to gain an understanding of how dung beetles, a group of insects well known for strong dispersal ability in order to compete for ephemeral resources (Hanski and Cambefort 1991), interact with corridors in their landscapes.

Dung beetles have emerged as a model system with which to test spatial ecology hypotheses (Roslin 2000, Rös et al. 2012). They are an incredibly well studied group of insects which are well known for driving a multitude of ecosystem functions (Hasan et al. 2024). The removal, breakdown, and burial of animal feces drive important ecosystem interactions provided by dung beetles enhancing nutrient cycling and soil quality, the reduction of breeding sites for parasites, and a reduction in methane emissions from dung (Iwasa et al. 2015, Slade et al. 2016). Local assemblages of dung beetles can be species-rich with species comprising a broad range of functional traits (e.g., size, foraging style, resource-use) (**WOS:000891747700001?**). Previous studies have shown that isolated patches of habitat frequently have lower dung beetle diversity and abundance than areas of continuous habitat, as well as documented their presence in linear strips of habitat that resemble corridors (Gray et al. 2022). Past studies have also focused on how landscape structure alters the community compositions of dung beetles (Costa et al. 2017), yet large landscape scale experimental studies with carefully controlled and replicated treatments are non-existent for this model species.

Here, we aim to determine how connectivity and fragmentation affect Species Richness and Diversity, Abundance, and functional diversity. We sampled dung beetle communities in experimental landscapes developed for the express purposes of comparing connected and isolated patches, as well as the effects of patch to edge ratio and distance to edge. To ask the question of (1) how landscape connectivity impacts dung beetle assemblages dung beetles were collected, identified, and counted with the expectation that biodiversity and abundance would be higher in patches connected by corridors. Additionally we asked (2) Are corridors benefiting any one functional trait over another? Since our experimental system consists of open habitats amongst a forested matrix, we anticipate that species preferring open areas and generalists may be more common in our sampling.

Methods

Study site

Our study took place at the Savannah River Site (SRS), a National Environmental Research Park in southern South Carolina, US (33.208 N, 81.408 W) in four of seven experimental landscapes designed for the purposes of directly observing the impacts of corridors and patch shape on the movements of plants and animals (Tewksbury et al. 2002). Each experimental landscape, termed blocks, consists of four patches of open habitat around a central patch all together within a matrix of pine savanna. In each replicant the central patch (100 x 100 m) is always connected to one peripheral patch with identical dimensions by a 150 x 25 m corridor, this will hereafter be referred to as the connected patch. The remaining patches are either “winged” or “rectangular”. The winged patch is also 100 x 100 m, however they exhibit their characteristic wings in the form of two 75 x 25 m offshoots meant to account for the extra area and edge space the corridor provides. The rectangular patch is 100 x 137.5 m also the same area as the space of the connected patch plus the corridor. Each block has a duplicate of either the winged or rectangle patch, all peripheral patches being 150 m from the center patch. For this study sampling was done in one of each patch type and in one matrix plot per block, all matrix blocks were set up 150 m away from the center as well.

Dung beetle sampling

In the months of July and August 2024 dung beetles were sampled in 4 blocks spread across SRS, baited pitfall traps were placed in one of each patch type and in one matrix plot per block. Traps were placed in groups of 3 in the centers of each patch approximately 250 meters from the midpoint of the central patch 40 m from patch edge. Pitfalls were oriented in a triangular pattern with the bottom two traps positioned towards the center patch, each trap 20 m apart. Plots in the matrix were set up in a similar fashion with the center point 250 m from the center placed equidistant between adjacent patches. Individual pitfall traps consisted of two components, a 10cm tall by 8 cm wide cylinder base topped with a funnel with a 10cm wide rim. Pig feces was suspended above the funnel by a 6.5 cm by 6.5 cm mesh square. For each sample period, traps were baited with pig dung between 8-9 pm and picked up 12 hours later, all beetles captured were stored in ethanol for further processing. In total 16 sampling rounds were carried out with 4 rounds per block, 196 samples were collected.

All dung beetles were counted and identified to species

- We also dried and weighed individuals to estimate biomass
- what guides/keys did you do to ID?
- “Voucher specimens of species I collected will be deposited at the Florida State Collection of Arthropods” (<https://thefsc.org/services/specimen-donations/>)

Analyses

Overview

Species richness

To Test for differences in species richness, we....

1. glmm with poisson dist recommended by julian
2. table: results of analyses.
3. visualization: hill's plots? rank-abundance plots? rarefaction curve?

Species diversity

We used a similar approach to compare species diversity in winged, isolated, and connected patches....

1. glmm with poisson dist recommended by julian
2. table: results of analyses

3. visualization: hill's plots? rarefaction curve?

Functional diversity

1. 1st pass: roller, tunneler, dweller
2. 2nd: morphological measurements like Alonso et al 2022 (see table from decastro 2023, Giménez Gómez 2025)
3. table: results of analyses
4. visualization: biomass of different (R/T/D) functional groups?

Reason for this breakdown: - richness and diversity are “community level” response. abundance is a species-level response. changes in abundance or rank-abundance could have implications for ecosystem services if it is connected to functional group.

Biodiversity between patch types was compared using Hill numbers (Jost 2006). We looked at community composition by increasing magnitudes of diversity components (qD) of 0D (species richness), 1D (Shannon entropy), and 2D (Simpson Diversity). Diversity numbers were calculated in R studio using package iNEXT (Chao et al. 2016). Bray-Curtis dissimilarity values were calculated using package Vegan in R studio. Dung beetles were assigned traits by waste removal guild and habitat preference.

Functional Diversity: Need to assign each species to a functional group: roller, tunneler, dweller, others?
- habitat preference (forest, pasture, generalist) - what stats / computer packages did you use to analyze and visualize the data?

Look through dung beetle pubs and see how/what people compare

RESULTS

Overview

1. total number of beetles from total number of species: 5213 beetles from 16 species.
2. All but four species were found in every patch type. *Onthophagus concinnus* was found in the matrix and winged patches, while *Onthophagus striatulus* was found in matrix habitat and rectangular patches. *Geotrupes blackburnii* and *Onthophagus tuberculifrons* were the only species restricted to one patch type (winged and matrix, respectively).
3. Were all species found in all blocks? Were any restricted to only 1-2 blocks?
4. Were all species found in the matrix? (expect that so, since it is the 'baseline' or 'source' habitat)
5. Number of species in each functional group
6. most common 3-4 species: The 3 most common species were *Canthon vigilans* (N = 1473), *Ateuchus lecontei* (N = 1115), and *Phanaeus igneus* (N = 958).
7. any rare species?
8. any invasive / exotic species?

Species richness

Species diversity

Functional diversity

Overall, 5213 total dung beetles were collected belonging to N = 16 species. The most dominant species were _____ (N = _____), *Ateuchus lecontei* (n=_____), and *Phanaeus igneus* (n=958) (Table 1). All but one species was found in matrix plots. Four species (*Onthophagus striatulus*, *Onthophagus concinnus*, *Geotrupes blackburnii*, *Onthophagus tuberculifrons*) were the only species not representative in every patch type. We had two singleton species, *Geotrupes blackburnii* appearing only once in winged, and *Onthophagus tuberculiofrons* in matrix.

Beetle abundance was significantly higher in matrix plots with 33% (n = 1713) of captures followed by 26% (n = 1359) caught in connected patches, 23% (n = 1199) in winged, and lastly 18% (n = 942) from rectangular patches (Table 2).

Species richness was distinctly different between patch types with matrix plots exhibited the highest richness while connected patches were lowest (Fig. 1). Estimations of Shannon diversity index were fairly uniform between patch types. Simpson diversity indices were similarly even however winged patches showed a lower value.

Notable Bray-Curtis dissimilarity values were between connected and matrix (BC = 0.127), connected and winged (BC = 0.077), matrix and rectangle (BC = 0.318), and matrix and winged (BC = 0.189) (Table 3).

DISCUSSION

Recap main goals into findings abundances in matrix vs connected patch and why this could be happening - source pop to habitat edge

species richness again supporting that matrix is more of an ideal habitat for dung beetle community

diversity indices community structures weren't highly different between patch types

bray curtis hinting at similar land uses between corridor and winged patch - like julians paper corridors benefit certain populations and more fit populations are able to make better use

Interpretation of results Abundance - reason for highest abundances in matrix and connected patch - lower abundance in rectangle hinting at fragmentation effects Species Richness & Diversity - the role of habitat connectivity in shaping community structure or lack thereof - why do we think connected had lowest species richness?? Functional traits and ecological impacts - did corridors favor a functional trait - why might there be a trait response - implications for ecosystem processes - like dung removal papers seed dispersal and yep

Comparing to previous studies - how are things aligning - think about the biology

Limitations and future work - potential confounding factors (seasonality, distance from edge, sampling methodology and temporal variation) - other directions to go (dispersal -> radar, specifically measuring changes in ecosystem services)

Takeaways for conservation and management - dung beetles are robust - what do think about corridor design and considerations for fragmented landscapes - practical applications think about the beetles

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FIGURES & TABLES

1. ~~Table: count by species by habitat.~~
2. table: results of species richness analyses.
3. Figure of species richness results.
4. table: results of species diversity analyses.
5. Figure of species diversity results.
6. table: results of functional diversity analyses.
7. Figure of biomass of different (R/T/D) functional groups.
8. Map of where field site is located.
9. ~~Figure of the patch layout with pitfalls.~~
10. Pictures of different species, sampling, field sites?

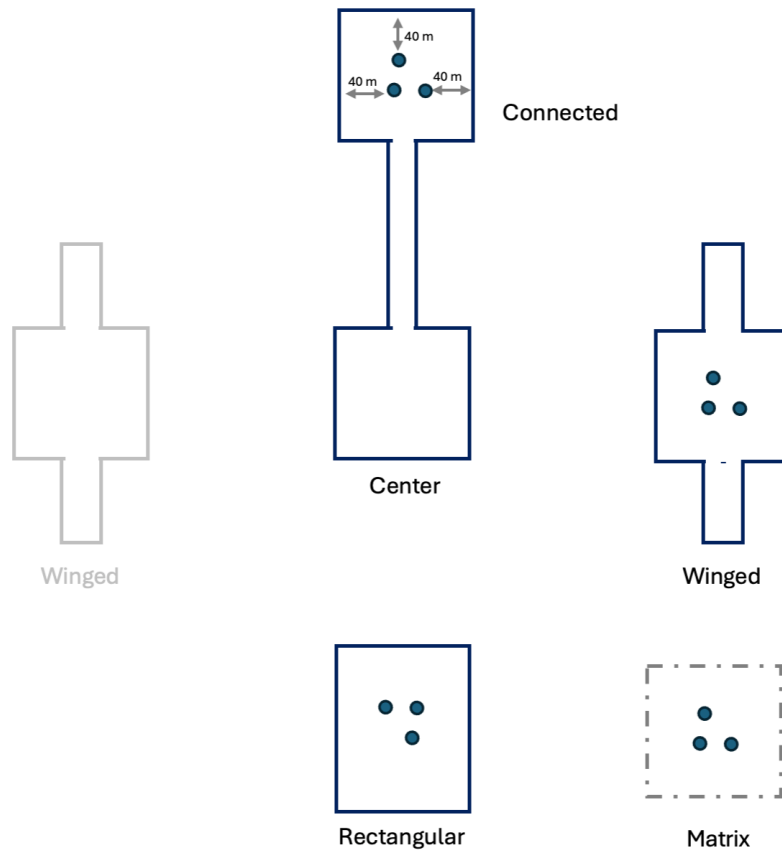


Figure 1: Experimental landscapes indicating location of the pitfall traps.

Table 1: Dung beetle species sampled in the SRS site and their total abundance over the course of the study.

Species	Guild	N	Matrix	Corridor	Winged	Rectangular
<i>Canthon vigilans</i>	roll	1473	x	x	x	x
<i>Ateuchus lecontei</i>	tunnell	1115	x	x	x	x
<i>Phanaeus igneus</i>	tunnell	958	x	x	x	x
<i>Dichotomius carolinus</i>	tunnell	556	x	x	x	x
<i>Aphodius alloblackburneus</i>	dwell	585	x	x	x	x
<i>Onthophagus pennsylvanicus</i>	tunnell	207	x	x	x	x
<i>Melanocanthon bispinatus</i>	roll	83	x	x	x	x
<i>Phanaeus vindex</i>	tunnell	133	x	x	x	x
<i>Boreocanthon probus</i>	roll	47	x	x	x	x
<i>Copris minutus</i>	tunnell	24	x	x	x	x
<i>Deltochilum gibbosum</i>	roll	14	x	x	x	x
<i>Aphodius oximus</i>	dwell	11	x	x	x	x
<i>Geotrupes blackburnii</i>	tunnell	1			x	
<i>Onthophagus concinnus</i>	tunnell	2	x		x	
<i>Onthophagus striatulus</i>	tunnell	3	x			x
<i>Onthophagus tuberculifrons</i>	tunnell	1	x			

Table 2: Total dung beetles captured in all replicates of a patch type.

patch	n
Corridor	1359
Matrix	1713
Rectangle	942
Winged	1199

OTHER REQUIRED TEXT

Dedication

To my family who never stopped supporting me along this journey, my friends who kept me company along the way, and my mentors at VCU who believed in me before I did myself.

List of Abbreviations

1. SRS: Savannah River Site.
2. Another word: And the list continues with another definition.

Biographical Sketch

Eric Escobar-Chena completed his Bachelors education at Virginia Commonwealth University in 2023. During his time there he developed a fondness for insects which grew into a curiosity of the natural world. He later began to explore this curiosity deeper in beginning his graduate education at the University of Florida as a Master's Student under the supervision of Emilio Bruna.