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.

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.

Topic Sentence:

Paragraph 2: What we know.

Topic Sentence:

Paragraph 3: What we don't know.

Topic Sentence:

Paragraph 4: Why we don't know it. *(hint: ecosystem services)*

Topic Sentence:

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

Topic Sentence:

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 is an important ecosystem service provided by dung beetles such as enhanced nutrient cycling and soil quality and reduction of parasites on 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) (deCastro-Arrazola et al. 2023). 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 with the exception of beetles of the genus Aphodius, overall 15 species were identified and approximately 5300 individual beetles were collected. - what guides/keys did you do to ID? - did you deposit vouchers and if so where are they available?

Analyses

Overview

1. how many beetles total
2. most common species overall.
3. was. the same species the most common one in all habitats?
4. were there any that were caught in all habitats? Any restricted to only one?
5. any invasive / exotic species?
6. Table: count by species by habitat

Species richness

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

Species diversity

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

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

Functional diversity

1. 1nd 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 dissimiolarity 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. were all species found in all habitats? Were any species found in only 1 habitat?
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*, *Ateuchus lecontei*, and *Phanaeus igneus*.
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 truberculifrons*) 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 habiitat 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 - reasin for highest abundances in matrix and connected patch - lower abundance in rectangle hinting at fragmentation effects Species Richness & Diversity - the role of hbitat connectivity in shaping community structure or lack thereof - why do we think connnected had lowest species richness?? Functional traits and ecological impacts - did corridoors favor a functional trait - why might there be a trait response - implications for ecosystem processes - like duung 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 temmporal variation) - other directions to go (dispersal -> radar, secifically measuring changes in ecosystem services)

Takeaways for conservation and management - dung beetles are robust - what do think about corridor design and considerations for fragmented lanndscapes - 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?

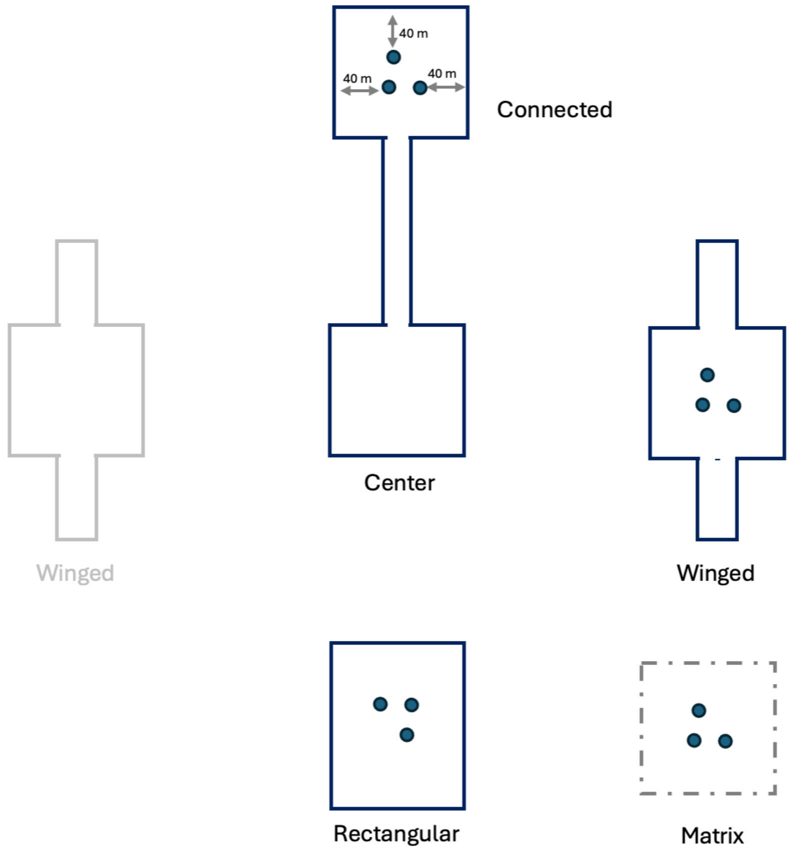

Figure 1: Experimental landscapes indicating location of the pitfall traps.

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**
Canthon vigilans	r	1473	x	x	x	x
Ateuchus lecontei	t	1115	x	x	x	x
Phanaeus igneus	t	958	x	x	x	x
Aphodius Alloblackburneus	d	585	x	x	x	x
Dichotomius carolinus	t	556	x	x	x	x
Onthophagus pennsylvanicus	t	207	x	x	x	x
Phanaeus vindex	t	133	x	x	x	x
Melanocanthon bispinatus	r	83	x	x	x	x
Boreocanthon probus	r	47	x	x	x	x
Copris minutus	t	24	x	x	x	x
Deltochilum gibbosum	r	14	x	x	x	x
Aphodius oximus	d	11	x	x	x	x
Onthophagus striatulus	t	3	x			x
Onthophagus concinnus	t	2	x		x	
Geotrupes blackburnii	t	1			x	
Onthophagus tuberculifrons	t	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.