Influence of Connectivity on Dung Beetle Communities

ERIC ESCOBAR-CHENA

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

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 and (Roslin 2000, Rös et al. 2012).They are an incredibly well studied group of insects which play an important role in providng ecosystem services for dung removal, secondary seed distribution, and even suppressing populations of parasitic pests(Shepherd and Chapman 1998, Manning et al. 2016). 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.

messy notes INTRODUCTION

These movements are hypothesized to prevent species diversity from declining in fragments, as well as help maintain the ecosystem services provided by these species (at both the patch- and landscape-level)(Burt et al. 2022). Although there is some evidence that animals disperse between patches via corridors, and that connected patches have higher species diversity than unconnected ones, little work to date has investigated the consequences of these corridor-driven patterns for ecosystem services.

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). However, it remains unknown if corridors actually act to reduce the loss of dung beetle species from fragments, if such declines are influenced by inter-specific differences in dispersal capability, and what the consequences of these patterns are for the ecosystems services they provide. One major factor behind this lack of information is the challenge in finding locations where one can assess the role of corridors while also while controlling for confounding factors such as patch size, edge, and corridor length (Haddad 2015).

We sampled the commmunity of of dung beetles at the SRS Corridor Experiment to test the following prediction: Species Richness, Species Diversity, and Functional Diversity will be higher in patches connected by corridors than in unconnected patches.

- First Paragraph: What is the topic of your introduction and why is it important/interesting/relevant?

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.

- Second Paragraph: What is known about this topic already?

Effects of landscape change are already very well studied, accross different taxa . effects of edge, patch size, and direct habitat loss. using corridors to connect fragmented landscapes is also well studied and for many taxa. dung beetles as a model system for studying movement, functional diversity, and ecosystem health. dung beetle populations in connected and fragmented habitats . insect declines in fragmented landscapes.

studying coprophagous insects

- Third Paragraph: What isn't known about this topic and why might it change how we think/act about the topic?

How corridors directly impact dung beetle communitites are changes driven by dispersal ability

Dung beetles have emerged as a model system with which to test spatial ecology hypotheses and (Roslin 2000, Rös et al. 2012).They are an incredibly well studied group of insects which play an important role in providng ecosystem services for dung removal, secondary seed distribution, and even suppressing populations of parasitic pests(Shepherd and Chapman 1998, Manning et al. 2016). 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.

at our study site we can directly compare patch connectivity and patch shape with fragmented landscapes to obtain a strong idea of what landscape features effect dung beetle collection.

- Fourth Paragraph: Why hasn't this thing been studied/assessed/done before?

other work at the corridor project but we are doing dung beetles instead

- Fifth Paragraph: Literally the words "Here we…"

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.

Here sampled the commmunity of of dung beetles at the SRS Corridor Experiment to test the following prediction:

Species richness, diversity, and functional diversity will be higher in patches connected by a movement corridor than in patches that are unconnected.

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. 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.

Insert description above of individual trap

Study site

- description of srs
- experimental design
- conditions during sample period
- historical significance of site and experimental design
- justification for selected patches

Dung beetle sampling

- structure and arrangment of traps
- description of traps
- bait
- sample period
- ID
- biomass if we do biomass

Analyses

1. **Species Richness:** absolute number? non-parametric estimators?

- Michaelis-Menten
- choa?

1. **Species Diversity:** what index should we compare?

- alpha diversity per patch type
- beta between patch types
- hill numbers

1. **Functional Diversity:** Need to assign each species to a functional group: roller, tunneler. dweller, others?

- habitat preference (forest, pasture, generalist)

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

- lets hammer this out
- modeling?
  - glmm with poisson dist reccomended by julian
- beta, abundance, biomass? per site
- species list by sampling blocks (anything with this?)
- habitat preference
- rarefaction

RESULTS

some summary statistics:

Overall, 4995 total dung beetles were collected belonging to 15 species. The most common species were C. vigilans (n=1300), Ateuchus lecontei (n=1112), and Phanaeus igneus (n=919).

1. total number of beetles *from* total number of 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
7. any rare species?

DISCUSSION

1. dont forget o discuss the basic biology…why might a species be so common? why might one be rare?

ACKNOWLEDGMENTS

We thank the USDA Forest Service for maintaining experimental landscapes and assisting in getting established at the site, particularly Sabrie Breland, Ben Overly, and Eva Schwarz. We also thank Thomas Smith for his help in data collection, Sara Escobar-Chena for her help in processing and data entry, and to Nico Acajabon, Jarrett Emory, and Cayla Garmen for their advice in putting together this manuscript.

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

Species	**N**	**Matrix**	**Corridor**	**Winged**	**Rectangular**
Canthon vigilans	1300	x	x	x	x
Ateuchus lecontei	1112	x	x	x	x
Phanaeus igneus	919	x	x	x	x
Aphodius spp.	614	x	x	x	x
Dichotomius carolinus	547	x	x	x	x
Onthophagus pennsylvanicus	202	x	x	x	x
Phanaeus vindex	131	x	x	x	x
Melanocanthon bispinatus	75	x	x	x	x
Boreocanthon probus	47	x	x	x	x
Copris minutus	24	x	x	x	x
Deltochilum gibbosum	14	x	x	x	x
Melanocanthon vulturnatus	7	x	x		x
Onthophagus striatulus	3	x			x
Onthophagus concinnus	2	x		x	
Geotrupes blackburnii	1			x	
Onthophagus tuberculifrons	1	x			

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.

Burt, M. A., J. Resasco, N. M. Haddad, and S. R. Whitehead. 2022. Ants disperse seeds farther in habitat patches with corridors. Ecosphere 13:e4324.

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

patch	**n**
Corridor	1358
Matrix	1587
Rectangle	937
Winged	1117

Costa, C., V. H. F. Oliveira, R. Maciel, W. Beiroz, V. Korasaki, and J. Louzada. 2017. Variegated tropical landscapes conserve diverse dung beetle communities. PEERJ 5.

deCastro-Arrazola, I., N. R. Andrew, M. P. Berg, A. Curtsdotter, J.-P. Lumaret, R. Menendez, M. Moretti, B. Nervo, E. S. Nichols, F. Sanchez-Pinero, A. M. C. Santos, K. S. Sheldon, E. M. Slade, and J. Hortal. 2023. A trait-based framework for dung beetle functional ecology. JOURNAL OF ANIMAL ECOLOGY 92:44–65.

Gray, R. E. J., L. F. Rodriguez, O. T. Lewis, A. Y. C. Chung, O. Ovaskainen, and E. M. Slade. 2022. Movement of forest-dependent dung beetles through riparian buffers in bornean oil palm plantations. JOURNAL OF APPLIED ECOLOGY 59:238–250.

Haddad, N. M. 2015, March 20. Habitat fragmentation and its lasting impact on earth’s ecosystems | science advances. https://www-science-org.lp.hscl.ufl.edu/doi/10.1126/sciadv.1500052.

Haddad, N. M., D. R. Bowne, A. Cunningham, B. J. Danielson, D. J. Levey, S. Sargent, and T. Spira. 2003. CORRIDOR USE BY DIVERSE TAXA. Ecology 84:609–615.

Iwasa, M., Y. Moki, and J. Takahashi. 2015. Effects of the activity of coprophagous insects on greenhouse gas emissions from cattle dung pats and changes in amounts of nitrogen, carbon, and energy. ENVIRONMENTAL ENTOMOLOGY 44:106–113.

Laurance, W. F., J. L. C. Camargo, P. M. Fearnside, T. E. Lovejoy, G. B. Williamson, R. C. G. Mesquita, C. F. J. Meyer, P. E. D. Bobrowiec, and S. G. W. Laurance. 2018. An amazonian rainforest and its fragments as a laboratory of global change. BIOLOGICAL REVIEWS 93:223–247.

Manning, P., E. M. Slade, S. A. Beynon, and O. T. Lewis. 2016. Functionally rich dung beetle assemblages are required to provide multiple ecosystem services. AGRICULTURE ECOSYSTEMS & ENVIRONMENT 218:87–94.

Rös, M., F. Escobar, and G. Halffter. 2012. How dung beetles respond to a human-modified variegated landscape in mexican cloud forest: A study of biodiversity integrating ecological and biogeographical perspectives. Diversity and Distributions 18:377–389.

Roslin, T. 2000. Dung beetle movements at two spatial scales. Oikos 91:323–335.

Shepherd, V. E., and C. A. Chapman. 1998. Dung beetles as secondary seed dispersers: Impact on seed predation and germination. Journal of Tropical Ecology 14:199–215.

Slade, E. M., T. Roslin, M. Santalahti, and T. Bell. 2016. Disentangling the “brown world’ faecal-detritus interaction web: Dung beetle effects on soil microbial properties. Oikos (Copenhagen, Denmark) 125:629–635.