Bird feeders as a novel tool to direct seed dispersal in a diffuse mutualism

James Holdgrafer
jholdgrafer@ufl.edu
UF Department of Biology
Thesis adviser: Dr. Marcus Lashley
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Abstract

Bird-mediated seed dispersal influences plant community assembly by impacting seed deposition location. Prior studies have documented the attraction of birds to resources, which could also influence seed dispersal. However, utilizing bird feeders as a land management tool for directing seed deposition has remained largely unexplored. In this experiment, food resources in bird feeders were manipulated to examine whether increasing resource richness increased the richness and observations of (a) birds using feeders and (b) the seeds deposited beneath feeders in excrement. None of the analyses yielded significant results supporting the hypothesized positive relationship between resource, bird and deposited seed richness and observations. However, the means of all treatment levels with food resources were greater than the control treatment with no food resources. These results suggest providing food resources in feeders increases bird and deposited seed observations and richness in comparison to non-food resources, such as perches.

Introduction

Plants dictate resource availability to animals, making plant communities a foundational and influential characteristic of an ecosystem. Plant community assembly and succession is influenced by abiotic factors, such as soil nutrient content (Aerts 1999), and biotic factors, such seed dispersal (Carlo 2016). Manipulating these factors can create drastically different plant communities from the same starting points (Baker 1998). This experiment examines a novel method to direct seed deposition to specific sites and whether resource richness can influence the richness and observations of seed species deposited.

Birds are common and effective seed dispersers in most terrestrial ecosystems (Howe 1997, Naniwadekar et al. 2019, Whelan et al. 2008). Resources that attract birds likely influence movement patterns and seed deposition sites (Saracco et al. 2004). Birds also show variation in resource preference, resulting in differing seed dispersal patterns (Stiles 1980, Howe 1986). However, directing seed deposition by birds to specific sites for native plant restoration is largely unstudied and has the potential to serve as an impactful and novel land management tool (Martínez-López et al. 2019).

This experiment tested the potential of bird feeders as a land management tool by examining how manipulating the richness of available resources in bird feeders influenced: 1) the richness and observations of birds visiting feeders and 2) the richness and observations of seeds deposited beneath feeders through bird excrement. This model system was selected because bird feeders are ubiquitous in the United States, are known to influence bird behavior and can provide a convenient system to manipulate resource availability (Cowie and Hinsley 1988, Lepcyzk et al. 2004, Fuller et al. 2008, Galbraith et al. 2015). To represent variation in resources, bird feeders were stocked with varying compositions of seeds, nuts and insects of various sizes and nutritional content. Experiment results were hypothesized to exhibit a positive relationship between resource, bird and seed richness and observations.

Methods

In 1980, the Nature Conservancy and the University of Florida combined 9,500+ acres of diverse ecosystems in North Central Florida (29°40’22”N 82°01’58”), which has been carefully manipulated by land managers and scientists studying environmental responses to stimuli for over 40 years. This research station, now known as Ordway - Swisher Biological Station (OSBS), was the site of data collection for this experiment. OSBS is a mosaic of carefully managed marshes, oak hardwoods, pine flatwoods and old-field habitats in temperate climate conditions.

Ten blocks were established in old-fields containing vegetation profiles of primarily grasses and herbaceous plants. Two blocks were in further vegetative successional stages with overstories of pine or oak trees. Blocks were spaced approximately one kilometer away from one another. During the set-up of traps, signs of wildlife utilizing the old-field blocks included: deer (*Odocoileus virginianus*), raccoons (*Procyon lotor*), possums (*Didelphis virginiana*), squirrels (*Sciurus niger*), turkeys (*Meleagris gallopavo*), mice (Rodentia), snakes (Serpentes) and various small perching birds (Passeriformes).

Each block contained four bird scat traps placed in the corners of a 10 x 10 m square. Scat traps were constructed out of 2.54 cm diameter PVC piping, zip-ties, pool screen mesh, wooden dowels and bird feeders. Each trap consisted of a horizontal 1 x 1 m mesh screen zip-tied to a PVC pipe frame elevated 1 m off the ground by four PVC pipe legs. A bird feeder was suspended above the mesh screen square by a wooden dowel rod horizontally mounted to two vertical 2 m tall PVC pipes (Figure 1). Ogrmar Hanging Gazebo Wild Bird Feeders were used, which had dimensions of 0.18 x 0.20 x 0.23 meters and an internal volume of approximately 6 cups. Each trap was annotated with both a trap identification number and its corresponding bird feeder identification number. Bird feeder identification numbers were also annotated on each bird feeder.

Figure 1: Bird scat trap set in old-field habitat at Ordway - Swisher Biological Station

Each block had treatments of zero, four, eight and twelve resources within bird feeders. Resources used in the experiment included: wheat (*Triticum* sp.), rye (*Secale cereale*), brown top millet (*Urochloa ramosa)*, white millet (*Panicum miliaceum*), oats (*Avena* sp.), black oil sunflower seeds (*Helianthus annuus*), barley (*Hordeum vulgare*), safflower (*Carthamus tinctorius*), cracked corn (*Zea mays*), Nyjer ® (*Guizotia abyssinica*), peanuts (*Arachis hypogaea*) and black soldier fly larvae (*Hermetia illucens*). To avoid introducing non-native species to the research sites, seeds and nuts used for resources were heat-treated to destroy viability and underwent germination tests to examine treatment efficacy. Heat treatment consisted of heating seeds and nuts with oil contents of 20-60% at 103°C for 17-24 hours and nuts and seeds with oil contents below 20% at 130-135°C for 2-4 hours. Germination tests consisted of placing 20 heat-treated and untreated seeds or nuts in damp paper towels within Ziploc bags stored in dark, room-temperature conditions for 3 weeks. None of the heat-treated seeds germinated. RStudio was utilized to randomly select and assign the resources used for each treatment at each site from a list of 12 different resources. Measuring cups were used to consistently produce a volume of 4 cups of resources within each bird feeder. At each site, a random number generator assigned the placement of the four treatment levels to the four traps.

Each bird scat trap was equipped with a Bushnell Trophy Trail Camera trap to detect bird activity. All cameras used were positioned on tripods 1.14 meters from the edge of the scat trap, with the camera lens at the same level as the center of the bird feeder (approximately 1.50 meters above the ground). All cameras at each site were facing north or south. The direction was decided depending on site-specific conditions, such as roads or vegetation, to minimize non-bird stimulus from setting off camera traps. Each trap was set to high sensitivity with a 10 minute interval and 15 second video recording at 720 x 1080 pixel image resolution.

All 40 scat traps were sampled weekly from 11/20/2020 to 12/31/2020. Sampling protocol involved visiting each trap, collecting bird scat and loose seeds located anywhere on the trap structure and placing collections into a labeled Ziplock bag. In our sampling protocol, loose seeds were seeds not stocked within the bird feeder of the trap being sampled. These seeds were assumed to arrive through scat washed away by rain. At the lab, seeds from samples were counted and identified. These collections were used to create matrices describing the composition of seed communities within the trap at each time point.

ANOVA and TukeyHSD tests were run using the base stats package in RStudio version 1.1.463 to assess whether bird species richness, bird observations, seed species richness and seed observations differed among resource treatments (R Core Team 2019). TukeyHSD tests were run on the ANOVA results to conduct pairwise comparisons among treatments (R Core Team 2019). Figures were produced using the ggplot2 package (Wickham 2016).

Results

Resource Richness' Impact on Bird Species Richness

Resource richness was not a significant predictor of bird species richness ($F_{3,36} = 2.07$; $P = 0.12$; Figure 2a) and pairwise comparisons revealed no significant differences in mean bird richness between treatments (Tables 1 and 2). Mean bird richness increased positively among food resource treatments zero ($\bar{x} = 1.6$; SE = 0.16), four ($\bar{x} = 2.0$, SE = 0.21) and eight ($\bar{x} = 2.2$, SE = 0.13), but decreased at twelve food resources ($\bar{x} = 1.8$, SE = 0.20). Mean bird richness at eight food resources was 1.4 times greater than zero food resources. The mean difference between bird richness at feeders with eight resources and control feeders was 1.43 times greater than the difference between feeders with twelve resources and control feeders, and 7.24 times greater than the difference between feeders with four resources and control feeders (Table 1 and Table 2).

Resource Richness' Impact on Bird Observations

Resource richness was not a significant predictor of bird observations ($F_{3,36}$ = 1.96; P = 0.14; Figure 2b) and pairwise comparisons revealed no significant differences in mean bird observations between treatments (Tables 1 and 2). Bird observation means increased from resource treatments zero to eight, but dropped between resource treatments eight to twelve. Mean bird observations was highest for feeders with eight resources ($\bar{x}$ = 79, SE = 38), and mean bird observations at all feeders with resources (four resources: $\bar{x}$ = 17, SE = 7.7, twelve resources: $\bar{x}$ = 47, SE = 83) were an order of magnitude greater than the control treatment with zero food resources ($\bar{x}$ = 6.6; SE = 1.7). The mean difference between bird observations at feeders with eight resources and control feeders was 1.80 times greater than the difference between feeders with twelve resources and control feeders, and 6.94 times greater than the difference between feeders with four resources and control feeders (Tables 1 and 2).

Resource Richness' Impact on Deposited Seed Species Richness

Resource richness was not a significant predictor of seed species richness ($F_{3,36}$ = 2.66; P = 0.06; Figure 3a) and pairwise comparisons revealed no significant differences in seed richness between treatments (Tables 1 and 2). Mean seed richness exhibited a positive relationship with food resource richness (zero resources: $\bar{x}$ = 0.70; SE = 0.21, four resources: $\bar{x}$ = 0.90; SE = 0.28, eight resources: $\bar{x}$ = 1.9; SE = 0.66, twelve resources: $\bar{x}$ = 2.2; SE = 0.21). Mean seed richness at twelve resources was 3.1 times greater than zero resources. The mean difference between seed richness at feeders with twelve resources and control was 1.25 times greater than the difference between feeders with eight resources and control feeders, and 7.50 times greater than the difference between feeders with four resources and control feeders (Tables 1 and 2).

Resource Richness' Impact on Deposited Seed Observations

Resource richness was not a significant predictor of seed observations ($F_{3,36}$ = 1.41; P = 0.26; Figure 3b) and pairwise comparisons revealed no significant differences in seed observations between treatments (Tables 1 and 2). Mean seed observations exhibited a positive relationship with food resource richness (zero food resources: $\bar{x}$ = 02.00; SE = 1.05, four resources: $\bar{x}$ = 2.30; SE = 1.74, eight resources: $\bar{x}$ = 4.90; SE = 0.700, twelve resources: $\bar{x}$ = 5.40; SE = 1.74). Mean seed observations at twelve resources was 2.7 times greater than zero resources. The mean difference between seed observations at feeders with twelve resources and control feeders was 1.17 times greater than the difference between feeders with eight resources and control feeders, and 11.3 times greater than the difference between feeders with four resources and control feeders (Tables 1 and 2).

Discussion

None of the analyses yielded significant results supporting the hypothesized positive relationship between resource, bird and seed richness and observations at feeders. No significant differences were detected in the richness or observations of birds visiting the feeders with increasing richness of resources. Similarly, seed observations and richness beneath traps was similar across feeders, regardless of resource richness. When comparing means across treatments, a noteworthy trend was detected between bird observations and resource richness. Bird and seed species observations and richness were found to be greater when food resources were provided than when no food resources were provided.

In contrast to Tryjanowski et al. 2015, the richness of bird species observed using the bird feeders was dramatically lower than other study results. Two bird species, the eastern phoebe (*Sayornis phoebe*) and chipping sparrow (*Spizella passerina*), comprised 99% of bird observations. A possible confounding factor influencing the presence of species in the area may have been the timeframe of the experiment, late November and December, when many migratory birds relocate to warmer locations further south.

While not statistically significant, there was a relatively positive relationship between resource richness and bird observations. Mean bird observations increased positively from resource treatments zero to eight, but decreased between treatments eight and twelve. Similar to trends observed by Cornwell and Grubb 2003, this may indicate a threshold of resource richness that, once exceeded, no longer provides any novel resources and does not attract more birds to feeders.

Treatments with food resources yielded higher bird and seed richness and observations than control treatments without food resources. These results suggest providing food resources can increase the abundance and species richness of bird visitations and the species richness of arriving seeds compared to only providing nonfood resources, such as perches.

Although this study did not yield a statistically significant positive relationship between resource, bird and deposited seed richness and observations, bird feeders demonstrate potential for utilization as a land management tool to direct the deposition of seeds to a specific site. Potential applications of this treatment include re-seeding barren sites following tilling or fire disturbances. Increasing the amount of resource richness treatments in future studies could examine the potential resource utilization threshold trends observed in this experiment. Further examination of differences in bird and seed observations and richness across different seasons could reveal an optimal implementation time frame for this tool.

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Supporting Figures and Tables

Figure 2: Bird richness and observation responses to food resource richness. Total bird richness and observations were measured with camera traps in 10 blocks (n=40). Feeders were stocked with random mixtures of food resources at four levels of richness (0, 4, 8 and 12). Resource richness levels are color-coded and the points are jittered to improve visibility.

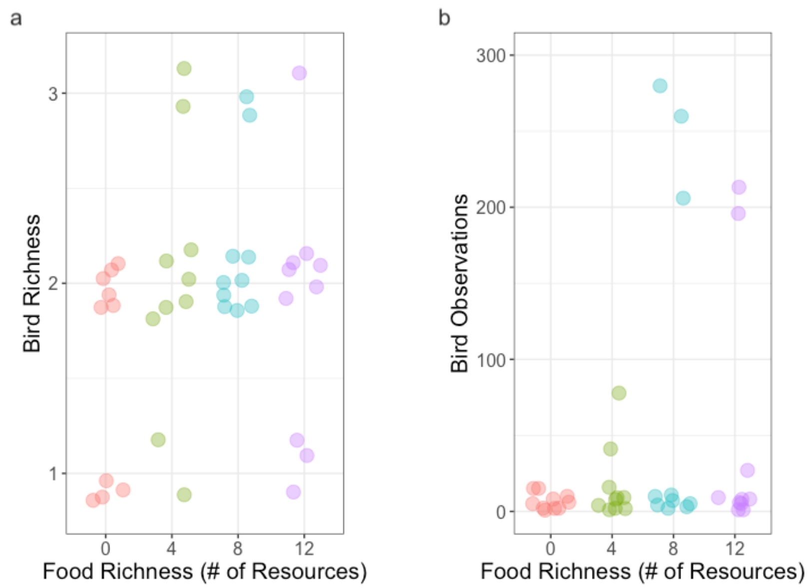

Figure 3: Deposited seed richness and observation responses to food resource richness. Total seed abundance and richness were measured sampling scat traps positioned below bird feeders in 10 blocks (n=40). Resource richness levels are color-coded and the points are jittered to improve visibility.

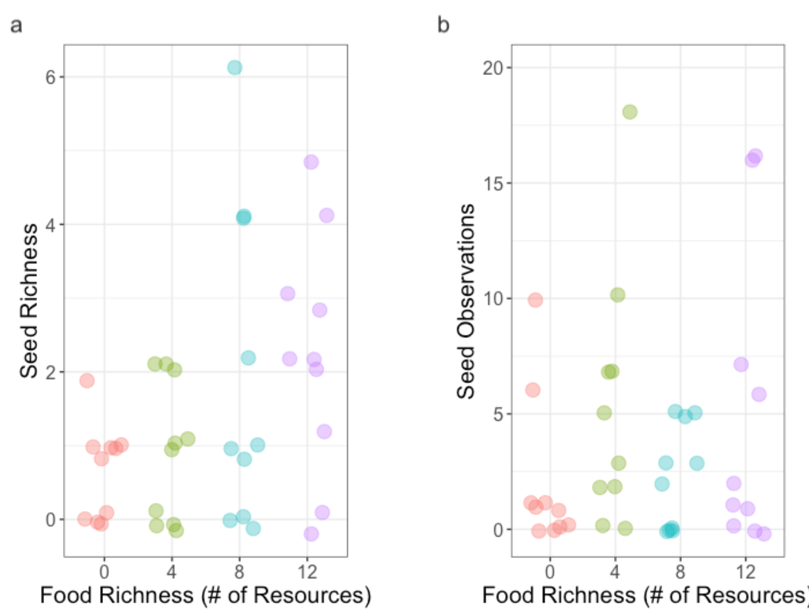

Table 1: Pairwise comparison results of response variables between different treatments

Response Variable	Pairwise Comparison Between Treatments					
	4-0	8-0	12-0	8-4	12-4	12-8
Bird Species Richness	4.375	31.693	22.208	27.318	17.833	-9.485
Bird Abundance	10.4	72.2	40.8	61.8	30.4	-31.4
Deposited Seed Richness	0.2	1.2	1.5	1.0	-1.3	-0.3
Deposited Seed Abundance	0.3	2.9	3.4	2.6	-3.1	-0.5

Table 2: Lower and Upper Confidence Intervals for Pairwise Treatment Comparison

Response Variable	Lower and Upper Confidence Intervals for Pairwise Treatments Comparison											
	4-0		8-0		12-0		8-4		12-4		12-8	
	CI_L	CI_U	CI_L	CI_U	CI_L	CI_U	CI_L	CI_U	CI_L	CI_U	CI_L	CI_U
Bird Species Richness	-0.2837	1.084	-0.0837	1.284	-0.4837	0.8837	-0.484	0.884	-0.8837	0.4837	-1.084	0.2837
Bird Abundance	-78.16	98.96	-16.36	160.8	-47.76	129.4	-26.76	150.4	-58.16	-119.0	-120.0	57.16
Deposited Seed Richness	-1.521	1.921	-0.5210	2.921	-0.2201	3.221	-0.721	2.721	-3.021	0.421	-2.021	1.421
Deposited Seed Abundance	-5.304	5.904	-2.704	8.504	-2.204	9.004	-3.004	8.204	-8.704	2.504	-6.104	5.104