

## Articles

# Using Camera Traps to Assess Mammal and Bird Assemblages in a Midwestern Forest

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## Abstract

Ecologists are increasing the use of remote technologies in their research, as these methods are less labor intensive than traditional methods and oftentimes minimize the number of human errors. Camera traps can be used to remotely measure abundance and community composition and offer the potential to measure some phenotypic traits, such as body size. We designed a camera-trap setup that enabled us to capture images of both large and small animals and used our camera-trap design to investigate the community composition of mammals and birds and to estimate the biomass of mammals along two transects in a conservation reserve in Missouri. One transect ran from the edge of an agricultural field to an upland forest, and the other transect ran from the edge of a wetland to an upland forest. Over the 4.5-wk study, our cameras recorded 2,245 images that comprised 483 individuals of 16 species of mammals and birds. Coyotes *Canis latrans* and nine-banded armadillos *Dasypus novemcinctus* were unique to the riparian transect, as were several bird species. Fewer species used the forest immediately adjacent to the agricultural field, but more species used the forest immediately adjacent to the wetland. Biomass estimates from our camera-trap images were similar to those of published accounts. This is the first study to use camera traps to successfully estimate biomass. We showed that the value and utility of camera traps in wildlife studies and monitoring can be expanded by 1) using multiple cameras at different heights from the ground so as to capture different-sized animals and 2) obtaining phenotypic information of the captured animals.

**Keywords:** diversity; edge effects; species composition; biomass; riparian; agriculture

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## Introduction

As anthropogenic activities modify and degrade habitats, landscapes are transforming into a mosaic of natural and human-modified habitats (Lambin et al. 2001). For example, more than 75% of naturally occurring deciduous forests in eastern and midwestern North America were cleared by 1850, primarily for agriculture (Stein et al. 2000). This conversion of native forests has increased habitat fragmentation (Demers et al. 1995; Stephens et al. 2013) and isolated populations that were historically connected genetically, thereby increasing inbreeding depression (Mills 1995; Keller and Waller 2002). Increased fragmentation has also produced more field–forest edges, increasing the negative impacts of edge effects on forest interior species (Hargis et al. 1999; Gehring and Swihart 2003; Elliott and Root 2006). Changes to native landscapes affect species differently, with habitat specialists often being negatively impacted by fragmentation and habitat generalists often benefiting from such changes (Humber and Hermanutz 2011).

Forests across eastern and midwestern North America contain mammal and bird species that are both adversely and beneficially affected by landscape modifications. For example, white-tailed deer *Odocoileus virginianus* and nine-banded armadillo *Dasypus novemcinctus* are forest interior specialists (Humphrey 1974; Taulman and Robbins 1996; Lingle and Wilson 2001; Lingle 2002) and as such should be less common near agricultural fields compared to riparian areas and upland forests. By contrast, raccoons *Procyon lotor*, coyotes *Canis latrans*, and gray squirrels *Sciurus carolinensis* are habitat generalists and should be common in both forested and agricultural habitats (Spritzer 2002; Moorcroft et al. 2006; Lesmeister et al. 2015). Understanding exactly how these and other species respond to landscape changes is important for wildlife management to effectively manage these populations (Andrén et al. 1997).

Technological advancements over the past few decades have revolutionized how biologists monitor wildlife in the field. The use of motion-activated camera traps (Karanth and Nichols 1998; Silveira et al. 2003; Rovero and Marshall 2009), automated identification and tracking systems (Dell et al. 2014), and unmanned aerial vehicles (Jones et al. 2006; Vas et al. 2015) can provide high-throughput methods that vastly decrease manual labor. Camera traps enable researchers to noninvasively determine the occurrence (and even abundance) of a wide range of animals (Srbek-Araujo and Chiarello 2005; Bondi et al. 2010), including rare and endangered species (Karanth and Nichols 1998; Roberts et al. 2006; Smith and Coulson 2012). However, different camera-trap designs optimize what types of species the cameras detect (Gompper et al. 2006; Rowcliffe et al. 2011; Smith and Coulson 2012). Some designs are better for large or small animals (Gompper et al. 2006; Rowcliffe et al. 2011), and others are designed for specific species (Smith and Coulson 2012).

In addition to being able to identify species and individuals, images from camera traps can be used to estimate properties of an animal's phenotype, including

traits such as body size and condition (Kühl and Burghardt 2013). Obtaining information on body size and condition can be vital to many wildlife studies and for monitoring wildlife populations and health (Hilderbrand et al. 2000; Cattet et al. 2002; Crooks 2002). For example, the effects of habitat fragmentation can be body size dependent, as larger animals move longer distances than smaller animals and thus are more affected by fragmentation than smaller animals, which may never leave a fragment during their lifetime (Crooks 2002). However, despite this relatively easy and noninvasive way to estimate body size, we are unaware of any studies that use camera traps to do so.

In this study, we designed a camera-trap array that enabled us to obtain images from large and small mammals, as well as birds. We used this camera-trap design to assess mammal and bird community composition along two survey transects that we positioned in a local field site that had modified and natural habitat types. From the images captured by the camera traps, we estimated the number of individuals captured per day of mammals and birds, as well as the body size of mammals and compared our estimates of biomass to published accounts.

## Methods

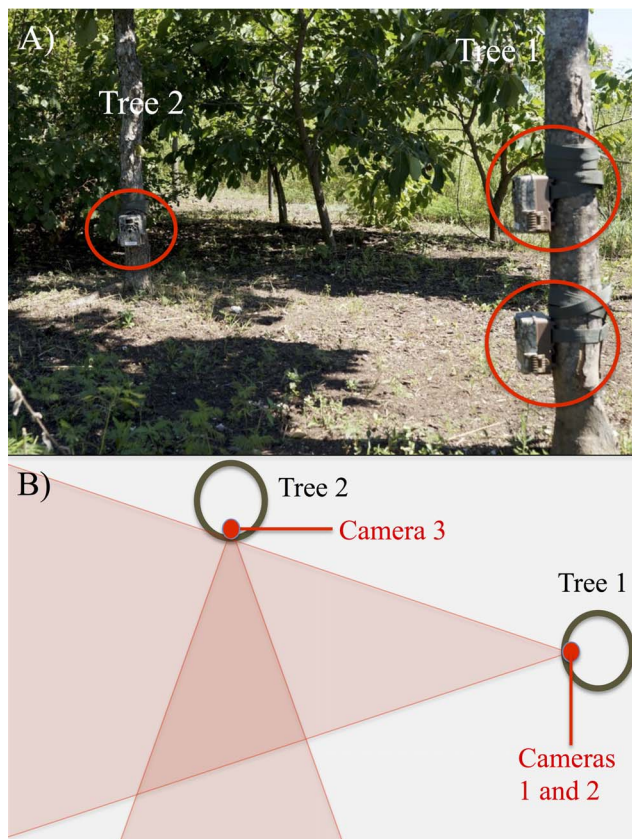
### Study site

We conducted this study at Lindenwood University's Daniel Boone Field Station, located in St. Charles County, Missouri (Lat: 38°39'9.9972"N; Long: 90°51'15.7536"E). This 400-ha field station maintains an annually harvested, 6.5-ha hay field embedded within a 280-ha mixed deciduous forest dominated by black oak *Quercus velutina*, post oak *Quercus stellata*, and white ash *Fraxinus americana*. Interspersed throughout the forested area are 10 small, forested, ephemeral wetlands with emergent vegetation, providing an important local water resource for birds and mammals during the drier summer when we undertook our study (see below). Climate at the field station is highly seasonal, with an average temperature of ~3°C in winter; ~17°C in spring; ~26°C in summer; and ~15°C in autumn. Meteorological data from a weather station at the field station's headquarters showed that the average temperature during the sampling period (June–July 2015) was 24.2°C and the average daily precipitation was 1.68 cm.

### Data collection

Remote camera traps were used to monitor mammal and bird assemblages along two 300-m transects, both positioned to span distinct environmental gradients across the field station. The first transect (termed agricultural) ran from the edge of the 6.5-ha hay field north into the surrounding upland forest, whereas the second transect (termed riparian) ran from a small wetland (~125 m<sup>2</sup>) east into the surrounding forest. At the beginning of the riparian transect, forest bordered





**Figure 1.** Details of our three-camera setup at each plot crossing a transect located in the Lindenwood University's Daniel Boone Field Station, Missouri, during the sampling period from 8 June to 10 July 2015. This setup enabled us to capture images from both large and small animals. (A) Photo of our field setup, with cameras circled in red. (B) Schematic of the camera-trap setup from (A), showing the overlap in the fields of view of the three cameras at each plot. See main text for details.

the wetland on three sides and there was a small mesic meadow to the north.

We monitored each transect over a 32-d period (from 8 June to 10 July 2015). In total, we monitored 42 randomly determined locations (plots) along each transect, each for 48 or 72 h (depending on access to field site), with a total of 3 plots monitored simultaneously on each transect (the sampling order of plots was also randomly determined). At each plot, we positioned three infrared (IR) motion-sensor game cameras (Browning model BTC-5; Prometheus Group, LLC, Birmingham, AL; see manual at [http://btc-omrc.com/wp-content/uploads/2014/02/2014\\_Strike\\_Force\\_Instruction\\_Manual.pdf](http://btc-omrc.com/wp-content/uploads/2014/02/2014_Strike_Force_Instruction_Manual.pdf)) so that their fields of view overlapped, optimizing detection of small-to-large birds and mammals (Figure 1). We attached two of the cameras to the same tree, one 20 cm and the other 50 cm above the substrate, with both cameras pointing in the same direction; the third camera was placed 1–5 m away on a tree at 50 cm above the ground so that its field of view was perpendicular to the other two cameras

(Figure 1). We aimed all cameras parallel to the ground, and we assumed that the total area covered by the three cameras in each plot was approximately the same for all 84 plots. In total, 18 cameras were deployed simultaneously, with 9 each on the agricultural and riparian transects. We removed vegetation in front of the cameras to prevent it from obscuring the field of view and programmed the cameras to capture images immediately after motion was detected, with subsequent photos delayed 5 s to reduce multiple images of the same individual being recorded. The field of view for each camera was 55°. The limits of the IR trigger and the IR flash illumination were 13 and 30.5 m, respectively. Image resolution was set at  $1,920 \times 1,080$  pixels, with each image also recording time and date. This project conformed to the legal requirements for the use of vertebrates in research and was approved by the University of Illinois' Institutional Animal Care and Use Committee (protocol approval 15074). At each camera-trap site, we collected the following additional environmental data: 1) canopy cover (percent) calculated with a spherical densiometer (Forestry Supplies, Jackson, MS); 2) leaf-litter depth (millimeters) estimated as the average litter depth of four random locations near the center of each plot measured with a hand ruler; and 3) environmental temperature (Celsius) measured with iButtons (Maxium Integrated, San Jose, CA) every hour. We deployed the iButtons for the duration that the camera traps were set at each plot so as to determine the maximum and average temperatures of the plot during the deployment of the camera-trap plots.

### Image analysis

We determined the taxonomic identity of all birds and mammals in each image by using published literature and expert opinion. Although most individuals could be identified to species, squirrels *Sciurus* spp. and mice *Peromyscus* spp. were only identified to genus (for simplicity, throughout the rest of the paper, we refer to these taxonomic groups as species). We considered images of the same species (or genus for *Sciurus* and *Peromyscus*) taken within 10 min of each other at the same plot as representing the same individual, unless this was obviously untrue (e.g., different size, antlered vs. nonantlered white-tailed deer). We identified individuals to species for all images for which we were clearly able to identify the individuals. Images that were too blurry to clearly see the animal and images in which the animal was partially blocked, such as by vegetation or low light levels, were not used in the analysis. We estimated the body length of all mammals from each camera-trap image by comparison to standardized images from each plot that included a human observed at specific distances from the cameras. We did this by taking pictures of a person of known height at meter-long increments from the cameras. We estimated the distance that each individual was from the camera by using these images of a person at known distances from the camera.



We then used these pictures to establish pixel lengths at different distances from the camera and used these pixels lengths to estimate the lengths of each individual in the picture. Published length–weight regressions were used to estimate body mass; for white-tailed deer we used  $W = 0.0287L^{3.03}$ , whereas for all other mammals we used  $W = 0.0374L^{2.92}$ , where  $W$  is weight and  $L$  is length (Prothero 1992). We did not calculate the body weight of birds because it was often difficult to determine their lengths. At the species level, we estimated the biomass for all the individuals in which we were able to calculate body length from the image. We combined biomass for both transects to obtain an average for each species. At the site level, we summed mammal biomass across all individuals of all species at each plot and standardized per day.

## Analyses

We binned each plot according to distance from the hay field (agricultural transect) or wetland (riparian transect), with each bin spanning 50 m (i.e., bin 1 contained all plots between 0 and 50 m, bin 2 contained all plots between 51 and 100 m, etc., to 300 m). We binned each transect in this way so as to standardize the number and length of bins in both transects. We then used 1-way analysis of variance (ANOVA) to determine differences in environmental variables along each transect, where environmental variables (average temperature, maximum temperature, leaf-litter depth, and percentage of canopy cover) were response variables and bin number was the explanatory variable. All statistics were done in R (R Core Development Team 2016).

To account for different sampling effort across plots, we calculated abundance as the number of individuals captured per day for each species. To test whether our sampling effort included most-to-all species present, we used rarefaction curves, wherein cumulative species richness is measured over time. When these curves reach an asymptote, it indicates that most species present in that area have been detected.

## Results

### Environmental variables

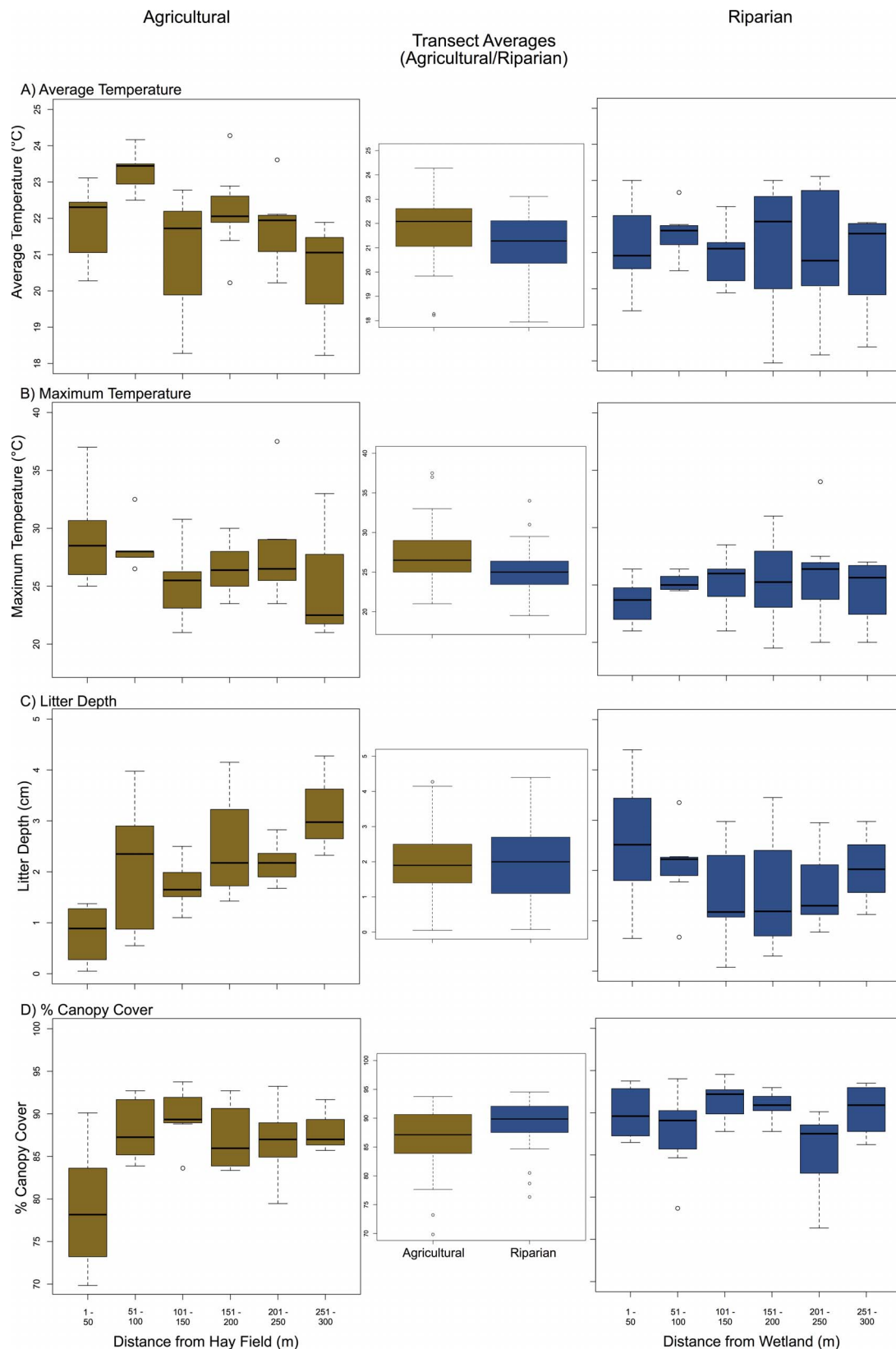
Average temperature varied along the agricultural transect (Figure 2A; ANOVA:  $F_{5,32} = 3.124$ ;  $P = 0.021$ ), with significant differences occurring between bin 2 (51–100 m) and bin 6 (251–300 m;  $P = 0.027$ ) and between bin 2 and bin 3 (101–150 m;  $P = 0.030$ ). Average temperatures did not differ along the riparian transect (Figure 2A; ANOVA:  $F_{1,37} = 0.282$ ;  $P = 0.598$ ). Maximum temperature did not vary with distance along the agricultural transect (Figure 2B; ANOVA:  $F_{5,32} = 1.233$ ;  $P = 0.317$ ) or the riparian transect (Figure 3B; ANOVA:  $F_{1,37} = 1.218$ ;  $P = 0.277$ ). Litter depth did increase with distance from the hay field (Figure 2C; ANOVA:  $F_{5,32} = 4.533$ ;  $P = 0.003$ ). Along the agricultural transect, a Tukey's honestly

significant difference test found that litter depths were significantly different between bin 1 (1–50 m) and bin 4 (151–200 m;  $P = 0.053$ ), bin 1 and bin 5 (201–250 m;  $P = 0.007$ ), and bin 1 and bin 6 (251–300 m;  $P = 0.003$ ). There was no change in litter depth along the riparian transect (Figure 2C; ANOVA:  $F_{1,37} = 2.554$ ;  $P = 0.119$ ). Along the agricultural transect, canopy cover was lowest nearest the hay field (Figure 2D; ANOVA:  $F_{5,32} = 4.443$ ;  $P = 0.003$ ). The canopy cover was significantly different between bin 1 and every other bin number along the agricultural transect (bin 2:  $P = 0.021$ ; bin 3:  $P = 0.002$ ; bin 4:  $P = 0.013$ ; bin 5:  $P = 0.038$ ; bin 6:  $P = 0.007$ ). The canopy cover did not change along the riparian transect (Figure 2D; ANOVA:  $F_{1,37} = 0.446$ ;  $P = 0.508$ ). The data for these analyses can be found in Data S1 (*Supplemental Material*).

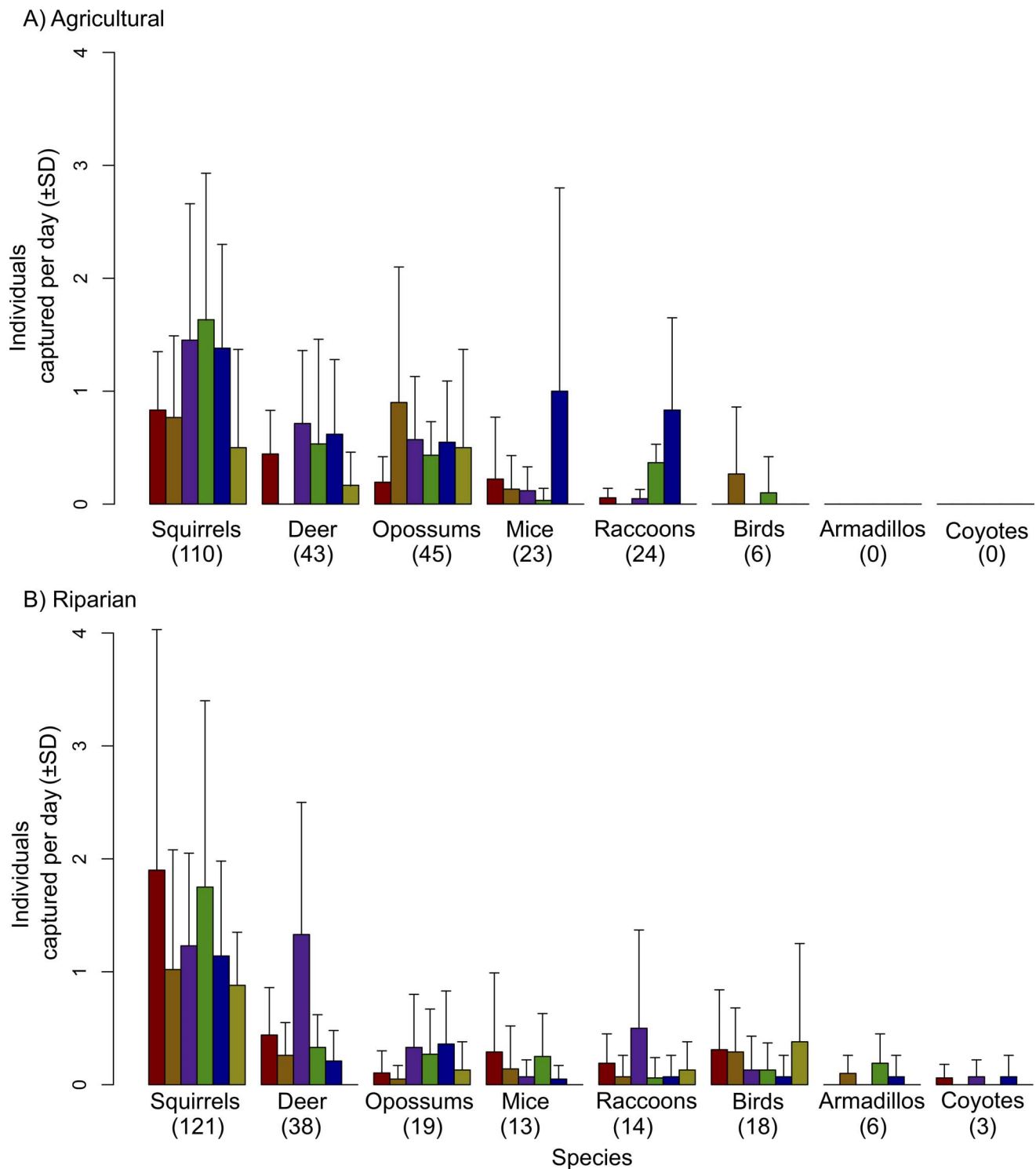
### Species composition and biomass

Using rarefaction curves, we found that cumulative species richness plateaued very early for the agricultural transects and well before the end of the sampling period for the riparian transects (Figure S1, *Supplemental Material*). We recorded at least one mammal or bird from 92% of the plots we sampled; 38 of 42 plots along the agricultural transect and 39 of 42 plots along the riparian transect. In total, we captured 2,245 images that included at least one mammal or bird, representing an estimate of 483 individuals. For mammals, this consisted of 231 squirrels, 81 white-tailed deer, 64 Virginia opossums *Didelphis virginiana*, 38 raccoons, 36 mice, 6 nine-banded armadillos, and 3 coyotes (Table 1). We recorded, in total, 24 birds, with tufted titmouse *Baeolophus bicolor*, wild turkey *Meleagris gallopavo*, and northern cardinal *Cardinalis cardinalis* occurring on both transects and Cooper's hawk *Accipiter cooperii*, blue jay *Cyanocitta cristata*, wood thrush *Hylocichla mustelina*, and barred owl *Strix varia* found only on the riparian transect. Because of their low numbers, all birds were included as a single taxonomic group in subsequent analyses. Squirrels (the most common species on both transects), white-tailed deer, and raccoons were captured at similar rates per day between our two transects (Table 1; Figures 3A and 3B). Virginia opossums and mice were captured more often on the agricultural transect, whereas birds were captured more frequently on the riparian transect (Table 1; Figures 3A and 3B). Nine-banded armadillos and coyotes were recorded only on the riparian transect (Table 1; Figures 3A and 3B), and no species were found exclusively on the agricultural transect.

Along the agricultural transect, squirrels, white-tailed deer, raccoons, and birds were captured most frequently at intermediate distances from the hay field (Figure 3A). Virginia opossums were uncommon nearest the hay field edge, becoming more abundant moving away from the hay field (Figure 3A). Mice were most common farther from the hay field, although they also had relatively high abundances near the hay field (Figure 3A). Along the riparian transect, white-tailed deer, Virginia opossums,



**Figure 2.** Box plots showing how environmental variables differed along each transect in the Lindenwood University's Daniel Boone Field Station, Missouri, agricultural transect (left column) and riparian transect (right column) and comparisons between the two transects in the middle column for the 4.5-wk study period (early June to early July 2015). Environmental variables that we measured included (A) average temperature, (B) maximum temperature, (C) litter depth, and (D) percentage of canopy cover. In general, environmental variables were more consistent along the riparian transect than along the agricultural transect. Average and maximum temperatures decreased with distance from the agricultural field, whereas litter depth and percentage of canopy cover increased with distance from the agricultural field.



**Figure 3.** Abundance per day ( $\pm$ SD) of each species or genus at different distances along the (A) agricultural transect and (B) riparian transect located in the Lindenwood University's Daniel Boone Field Station, Missouri. Each color represents a different distance along the transects: red, 0–50 m; orange, 51–100 m; purple, 101–150 m; green, 151–200 m; blue, 201–250 m; and yellow, 251–300 m. Values in parentheses below each taxa name represent total number of individuals recorded on that transect throughout the 4.5-wk study (early June to early July 2015). We captured images of squirrels *Sciurus* spp., white-tailed deer *Odocoileus virginianus*, Virginia opossums *Didelphis virginiana*, mice *Peromyscus* spp., raccoons *Procyon lotor*, nine-banded armadillos *Dasypus novemcinctus*, and coyotes *Canis latrans*, as well as many bird species. Squirrels, white-tailed deer, and Virginia opossums were the most common animal species captured.

raccoons, and nine-banded armadillos were captured most frequently at intermediate distances from the

**Table 1.** Total number of individuals captured on each transect located in the Lindenwood University's Daniel Boone Field Station, Missouri, during the sampling period from 8 June to 10 July 2015. Numbers in parentheses are the relative abundances for each transect. We captured images of squirrels *Sciurus* spp., white-tailed deer *Odocoileus virginianus*, Virginia opossums *Didelphis virginiana*, mice *Peromyscus* spp., raccoons *Procyon lotor*, nine-banded armadillos *Dasypus novemcinctus*, and coyotes *Canis latrans*, as well as many bird species. Squirrels, white-tailed deer, and Virginia opossums were the most common animal species captured.

	Agricultural transect	Riparian transect
Squirrels	110 (0.44)	121 (0.52)
White-tailed deer	43 (0.17)	38 (0.16)
Virginia opossums	45 (0.18)	19 (0.08)
Mice	23 (0.09)	13 (0.06)
Raccoons	24 (0.10)	14 (0.06)
Nine-banded armadillos	0 (0.00)	6 (0.02)
Coyotes	0 (0.00)	3 (0.01)
Birds	6 (0.02)	18 (0.08)

wetland (Figure 3B). Squirrels and mice had two distinct modes of abundance: near the wetland and at intermediate distances from the wetland (Figure 3B). Birds were most abundant near the wetland and at plots farthest from the wetland (Figure 3B). The data for all these analyses can be found in Data S1 (*Supplemental Material*).

At the individual level, estimated biomass ranged from 0.02 kg for mice to 38.73 kg for white-tailed deer and was similar to that of published accounts for most species (Table 2). Biomass at each plot was also similar between the two transects (agricultural: 13,476  $\pm$  27,616 g; riparian: 12,378  $\pm$  13,842 g). Biomass increased with distance from the hay field but was higher adjacent to the wetland and at intermediate distances from the wetland.

## Discussion

Using remote camera traps, we estimated community composition and abundance of mammals and birds and the biomass of mammals along two transects that traversed two distinct environmental gradients. Our use of multiple cameras per plot—positioned at different heights above the forest floor—increased our ability to

record both small and large species. Cameras placed at standard heights above the ground (~50 cm) often do not capture small mammals and birds (Gompper et al. 2006; Rowcliffe et al. 2011), whereas cameras placed lower can miss large mammals (Rowcliffe et al. 2011). Thus, our multicamera setup, with three cameras, two of which were at different heights (Figure 1), was ideal for capturing large and small mammals and a wide range of bird species. Having multiple cameras with overlapping fields of view also reduced the probability of missing animals due to failure of a single camera to trigger, which can occur for several reasons (Smith and Coulson 2012). Thus, this camera setup was more robust at determining species abundances and community composition of a wider range of mammal and bird species. In addition, this is the first study that we are aware of that uses camera traps to estimate biomass and demonstrates a new type of measurement that can be obtained from camera trapping studies.

The riparian and agricultural transects were environmentally different from one another. The environmental conditions along the agricultural transect were similar to those of other studies that show forests adjacent to agricultural fields are warmer and have less litter depth and canopy cover compared to that of interior forests (Murcia 1995). Average temperature was higher on the agricultural transect compared to that of the riparian transect and varied more along the agricultural transect than along the riparian transect. Likewise, maximum temperature was higher along the agricultural transect compared with riparian transect. Litter depth was similar between the transects but increased significantly with distance from the hay field. Canopy cover was higher on the riparian transect than on the agricultural transect. Canopy cover was quite low in the forest immediately adjacent to the hay field but increased with distance from the hay field. Thus, these results are consistent in showing that human activities, such as clearing forests for agricultural fields, have led to changes in the environmental conditions of the forests along each of these transects, potentially leading to differences in species abundance and community composition along these transects (Murcia 1995).

Virginia opossums were captured more often along the agricultural transect (Figures 3A and 3B) than the riparian transect. Nine-banded armadillos were only

**Table 2.** Average estimated weight ( $\pm$ SD) of each species captured by camera trap crossing a transect located in the Lindenwood University's Daniel Boone Field Station, Missouri, during the sampling period from 8 June to 10 July 2015. We compared estimated weights with values reported in the literature. We found that our estimated weight values were similar to published accounts from the midwestern region for all species except raccoons; the latter values were smaller in our study compared with those of the other studies.

Species	Estimated weight (kg)	Literature weight (kg)	Reference
Squirrels	0.90 $\pm$ 1.36	0.82 $\pm$ 0.017	Reighard et al. 2004
White-tailed deer	38.73 $\pm$ 7.60	39.64–58.06	Pierce et al. 2011
Virginia opossums	3.8 $\pm$ 1.80	3.02 $\pm$ 0.11	Nixon et al. 1994
Mice	0.02 $\pm$ 0.05	0.02 $\pm$ 0.04	Stephens et al. 2014
Raccoons	2.91 $\pm$ 1.52	4.91 $\pm$ 0.18	Clark et al. 1989
Nine-banded armadillos	3.34 $\pm$ 0.84	4.69 $\pm$ 0.55	McDonough 2000
Coyotes	12.56 $\pm$ 0.0	13.6 $\pm$ 0.0	Way and Proietto 2004

present on the riparian transect, corroborating studies that found nine-banded armadillos avoid open habitats and grasslands (Humphrey 1974; Taulman and Robbins 1996). The two species of squirrels at our site are considered habitat generalists and are quite adaptable to novel environments (Wiggers and Beasom 1986; Spritzer 2002; Gonzales 2005; McCleery et al. 2007; Lee et al. 2009), so it was not surprising that they were captured frequently on both transects (Table 1). Similarly, raccoons are a common habitat generalist in the midwestern United States (Lesmeister et al. 2015) and were captured nearly equally between the transects. White-tailed deer, a species often associated with forests (Lingle and Wilson 2001; Lingle 2002), was captured in approximately equal numbers on the two transects. Although white-tailed deer prefer forested habitats, they will still use a wide range of habitats, including open fields (Wiggers and Beasom 1986). Coyotes were captured only on the riparian transect in our study. Coyotes are habitat generalists that will use habitats associated with their prey (Moorcroft et al. 2006; Lesmeister et al. 2015). Coyotes have been shown to be one of the few species that did not avoid agricultural fields (Gehring and Swihart 2003), and it was therefore surprising that they were not captured on the agricultural transect, where their prey were equally abundant as on the riparian transect. Furthermore, these results may change had the study been performed over a longer period that included different seasons. This study was performed during the early summer and several species may have been dispersing, searching for mates, or gestating, any of which could change behaviors and locations where organisms may be found.

The number of individuals captured per day varied along each transect. Along the riparian transect, many species, including squirrels, white-tailed deer, mice, raccoons, and birds, were captured more frequently adjacent to the wetland and at intermediate distances from the wetland. Along the agricultural transect, most species were infrequently captured adjacent to the hay field and were more common at intermediate distances and farther from the hay field. This suggests that mammals and birds frequently use the forest adjacent to the wetland but may avoid the forest adjacent to the hay field. The forest adjacent to the wetland was cooler and potentially provided more refuge for mice and squirrels and other small animals in the form of increased litter depth and for birds in the form of increased canopy cover. The forest adjacent to the hay field was warmer and provided less refuge compared to that of the wetland. Finally, the wetland provides an often essential water resource for many animals. Thus, the forest associated with the wetland transect may provide a slightly higher quality habitat than the forest associated with the agricultural transect.

Estimating biomass with camera traps expands the utility of camera trapping. The average biomass estimations for squirrels, white-tailed deer, Virginia opossums, mice, nine-banded armadillos, and coyotes were quite similar to published accounts from midwestern areas (Table 1). Estimations of biomass for raccoons were less

than reported elsewhere, perhaps because it is not possible to accurately estimate the length of raccoons due to their body shapes or because we had no good profile images of these species. At the site level, biomass was similar along the two transects. Camera-trap studies have previously been limited to estimating presence or absence, abundance and density, and diversity and species richness. Using camera traps to noninvasively measure phenotypic traits can greatly increase their capabilities as an ecological tool (Kühl and Burghardt 2013). In our study, we were able to use camera traps to accurately estimate biomass of most species and hence the amount of biomass moving through each of the plots. As far as we know, this is the first study to use camera traps to obtain body sizes, and we conclude that future wildlife studies and monitoring can use camera traps to obtain body size and incorporate that information into their analyses.

An important caveat in the use of camera traps for wildlife studies is that it can be difficult to accurately determine density and abundances of animals that cannot be individually identified. Species with unique individual markings (e.g., tigers *Panthera tigris* and jaguars *Panthera onca*) can be used in mark-recapture methods (Karanth and Nichols 1998; Soisalo and Cavalcanti 2006). When researchers are unable to identify individuals from markings, it becomes impossible to determine whether each photograph represents separate individuals. However, researchers can take actions to reduce counting an individual more than once. We set our camera traps to have a 5-s delay after a photo was taken and when more than one image of the same species (or genus for *Sciurus* and *Peromyscus*) was taken within 10 min of each other at the same plot, they were considered the same individual, unless they were obviously different individuals (e.g., different body size, antlered vs. nonantlered white-tailed deer). Many researchers have compared camera trapping methods with traditional methods and have found that camera trapping provides comparable and reliable results (Silveira et al. 2003; Tobler et al. 2008; Rovero and Marshall 2009). Others have found that camera traps underestimated abundance and richness compared to those of traditional methods, but these underestimations were not significantly different from those of traditional methods (Roberts et al. 2006; Barea-Azcón et al. 2007). As such, the risk of resampling the same individuals more than once with camera trapping methods does not appear to affect the results any more than it does with traditional methods.

In conclusion, we found that our camera-trap design worked well to estimate abundances and community composition of both large and small mammals and birds. As such, this camera-trap design improves the ability for researchers and wildlife managers to monitor wildlife communities and to provide more accurate measures of diversity and species richness. In addition, we demonstrated that camera traps can be used to estimate body mass of mammals. We were able to use this camera-trap setup to show that abundance and biomass were similar between two transects that traversed different ecotones



in eastern Missouri. Fewer species were found near the hay field, whereas more species were found near the wetland. Nine-banded armadillos and coyotes were unique to the riparian transect, and birds were more common and diverse on the riparian transect. Virginia opossums were more common along the agricultural transects, but no species were unique to the agricultural transect. Wildlife researchers and managers who use camera traps to monitor wildlife populations can benefit from using this type of camera-trap setup and by incorporating estimates of biomass in their studies and monitoring.

### Supplemental Material

Please note: The *Journal of Fish and Wildlife Management* is not responsible for the content or functionality of any supplemental material. Queries should be directed to the corresponding author for the article.

**Data S1.** Data obtained from the 4.5-wk camera trapping study that we performed from early June to early July 2015. These data provide information for each site (i.e., location along transect and dates the site was sampled) as well as the environmental information (average and maximum temperature, litter depth, and percentage of canopy cover) for each site along each transect. These data also provide the number of the individuals of each species captured at each site along each transect as well as the per-day abundance. Finally, these data provide the diversity, species richness, and biomass for each site along each transect.

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**Figure S1.** Rarefaction curves showing sampling saturation for the (A) agricultural transect and (B) riparian transect. In these figures, the cumulative number of species captured is plotted against the duration of the experiment. When curves reach an asymptote, it indicates that the number of species that have been detected represents the species found in that community. Our results indicate that we had reached sampling saturation in ~10 d for the agricultural transect and ~20 d for the riparian transect.

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