

Estimating the Effect of the Conservation Reserve Program (CRP) Contour Strips on Grassland Birds

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Executive Summary

The USDA Conservation Reserve Program (CRP) provides a mechanism for grassland bird conservation within agricultural landscapes of the US. CRP implementations using contour buffer and filter strip standards have typically been seeded to monocultural plantings composed of non-native brome or native switchgrass. Implementations using diverse, native plant species mixtures – as with reconstructed prairie – may provide additional conservation benefits. This project evaluated CRP practices already in place and compared them to new implementations of prairie strips. The specific objectives of this study were to:

- 1) Evaluate breeding and wintering bird use of current contour buffer/filter strip designs, and compare them to new implementations of prairie strips.
- 2) Assess bird nest success under current contour buffer/filter strip designs, and compare them to new implementations of prairie strips.
- 3) Determine the impact of habitat configuration and management on bird use and nest success within current contour buffer/filter strip and prairie strip designs.

Between 2015 and 2018, we recorded 12,462 bird observations of 78 bird species in 129 site surveys on 12 farms across Iowa. We also located and monitored more than 1,144 nests of 26 bird species on 9 farms in central Iowa to understand impacts on nesting success. We actively shared our work with the agricultural and scientific communities and the public over the period of this grant through four manuscripts, two blog posts, 61 presentations, and 38 media outlets.

Our results indicate that prairie strips change the community composition of breeding birds and increase bird species richness and abundance of corn and soybean crop fields. We further observed an upward trend in bird abundance across establishment years, suggesting benefits increase for some time following installation. Our results on winter bird use are thus far inconclusive. In terms of nest success, the young of three key bird species fledged more often in prairie strips than contour buffer strips: red-winged blackbirds fledged young 4.33 times more often, dickcissels fledged young 4.52 times as often, and vesper sparrows fledged young 4.35 times as often. Red-winged blackbird nests survived longer in areas with more native plant species and intermediate vegetation densities. Dickcissel nests survived longer in areas with more native plant species and lower vegetation densities. Vesper sparrow nests survived longer when there was a greater proportion of high-diversity vegetation within 20 m and when there was less mowing activity nearby. Our results further indicate that red-winged blackbird nest density was similar between prairie strips and contour buffer strips, dickcissel nest density was 1.76 times higher in prairie strips, and vesper sparrow nest density was 3.07 times higher in prairie strips. Red-winged blackbird nest density was higher in areas closer to water bodies. Dickcissel nest density was higher in areas with more diverse vegetation, less mowing activity, and narrower perennial vegetation widths. Vesper sparrow nest density was higher in narrower perennial vegetation widths and more diverse and dense vegetation. For these three species, our results thus far indicate that strip width did not negatively impact nest survival and narrow strips contained high densities of nests, so narrow strips need not be avoided. Further

investigation is needed for other grassland-nesting bird species.

Our results suggest that prairie strips are not ecological traps for nesting birds, and in fact offer an improvement over habitat typically found on commercial corn and soybean farms in Iowa. To maximize conservation benefit to nesting birds, we recommend that conservation features such as contour and filter strips be planted with diverse, native, moderate-density vegetation and be subjected to limited mowing activity after establishment.

Objective 1: Evaluate Breeding and Wintering Bird Use

Breeding Bird Use

We assessed breeding bird use of three treatments: fields with new implementations of prairie strips, fields with existing grass contour strips, and fields with conventional crops and limited grassy conservation features. Each of 12 research sites located on commercial corn and soybean farms consisted of a conventional field and a field with either high-diversity prairie strips or grass contour strips. To assess avian community composition, we conducted 200 m fixed-radius bird point counts (BPCs) during May – July, 2015-2018; a total of 129 site surveys were conducted at between 3 and 6 BPC stations located in each field. An observer identified detected birds by sight and/or sound, and estimated the distance between the observer and the bird with the aid of a handheld rangefinder.

We made a total of 12,462 individual detections of 78 species and 71% of all detections were made using auditory cues. Avian community composition was similar across treatments (Fig. 1), and was typical of farmland bird communities in the region. We did not detect statistically significant differences in species richness among the three treatments when using all bird observations (Fig. 2), but site-by-site comparisons reveal a slightly higher mean richness in fields with prairie strips and grass contour strips than their neighboring conventional crop fields.

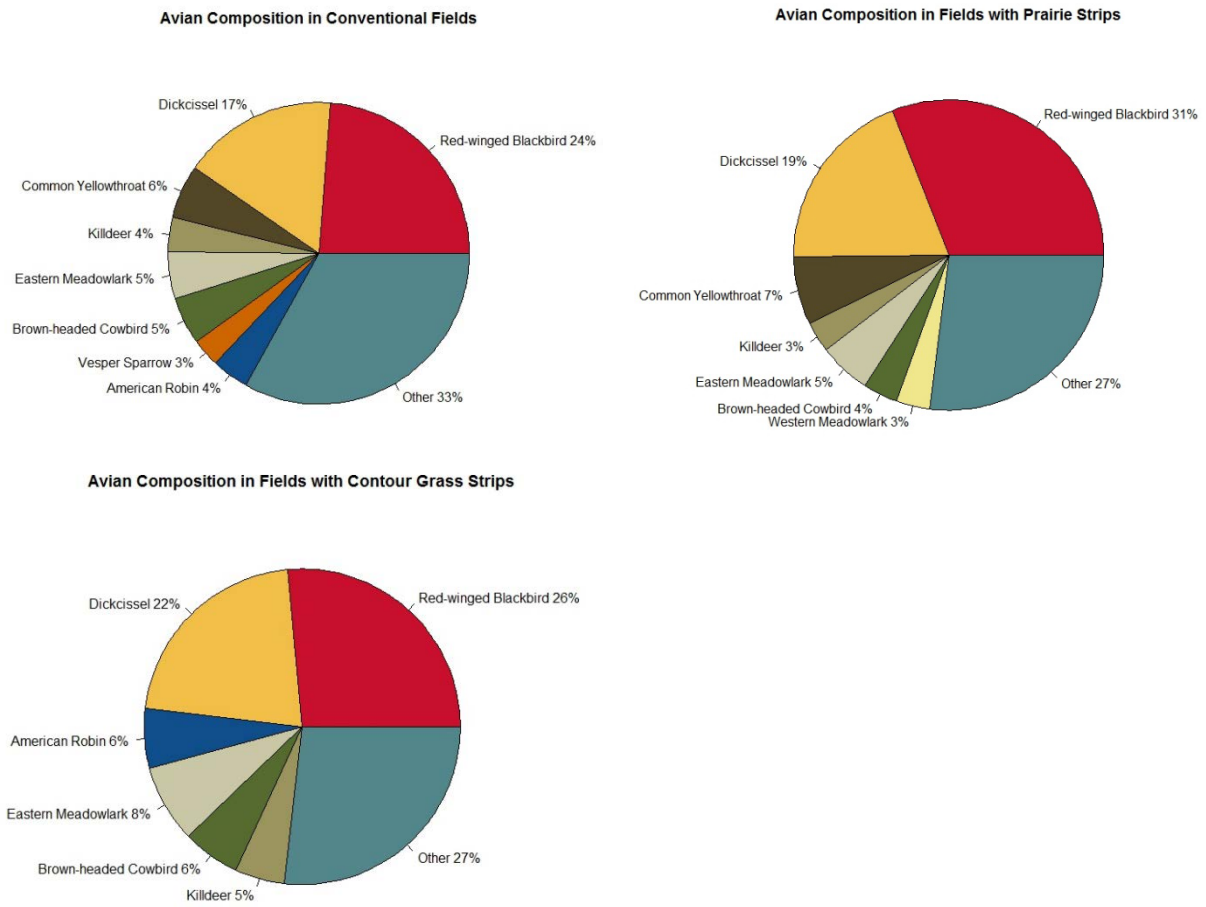


Fig. 1. Avian community composition of fields with only conventional crops, with grass contour strips, and with new implementations of prairie strips.

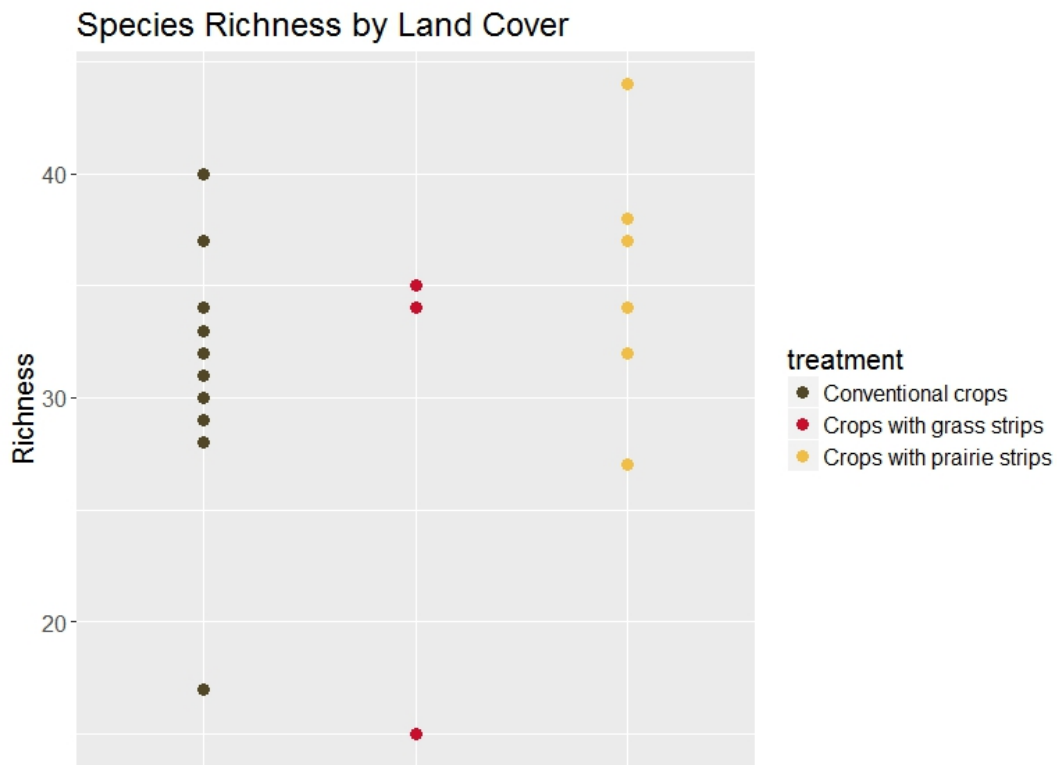


Fig. 2. Species richness across fields with conventional crops, crops with grass contour strips, and crops with newly implemented prairie strips. Points on plot represent individual fields.

We calculated Simpson's diversity index for each field in which we conducted BPCs (Fig. 3). This index takes into account species richness and evenness of the community. Although fields with prairie strips tended to have higher richness than neighboring conventional fields, Simpson diversity was often higher in the latter. This is likely due to a less even community composition being driven by the strong positive response of a few species (i.e., common yellowthroats, dickcissels, and red-winged blackbirds) to the installation of prairie strips.

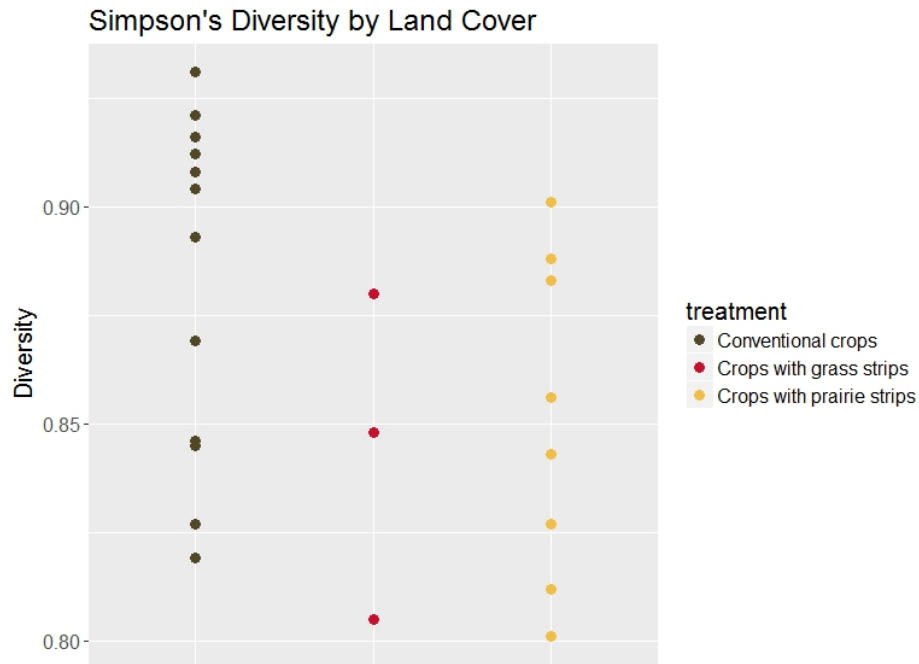


Fig. 3. Simpson's diversity across fields with conventional crops, crops with grass contour strips, and crops with newly implemented prairie strips. Points on plot represent individual fields.

We removed all flyover detections and grouped all detections into 50 m binned intervals to model detection probability functions. Removing flyovers removed a substantial number of detections of species such as barn swallows, tree swallows, brown-headed cowbirds, and American goldfinches, but results in a more accurate depiction of birds' use of the target habitats. We then modeled abundance for each treatment. Avian abundances in conventional fields and fields with prairie strips were significantly different ($p < 0.05$; Fig. 4). Avian abundance in fields with grass strips was not significantly different than either conventional fields or fields with prairie strips. Only three research sites contained grass contour strips and therefore data are limited for this treatment, making detections of statistical differences more difficult. We also assessed the impact of time-since-establishment on the abundance of birds associated with prairie strips (Fig. 5). While data beyond the fourth year post-establishment are limited, we thus far see a trend toward greater numbers of birds following the third year post-establishment. This pattern is expected given that prairie strips are typically mowed during the first 2-3 years following seeding to discourage the growth of annual weeds and encourage the establishment of native plants.

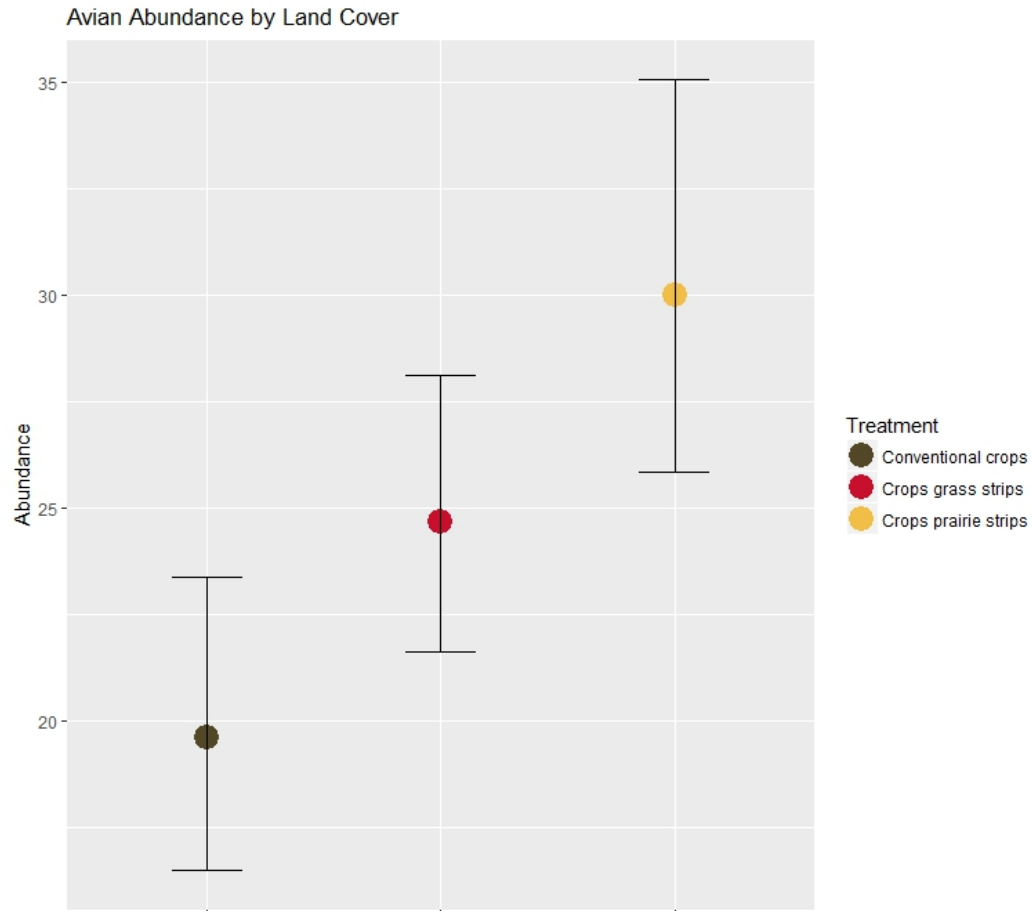


Fig. 4. Abundance of birds associated with fields in conventional crops, crops with grass contour strips, and crops with newly implemented prairie strips. Whiskers indicate upper and lower confidence intervals.

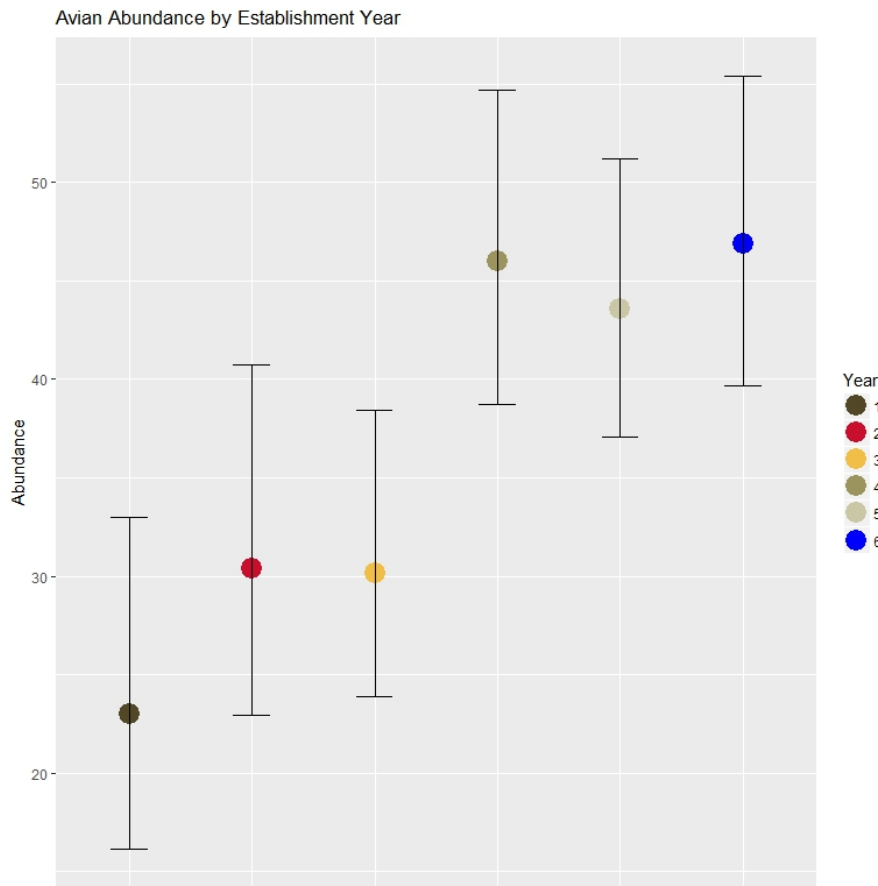


Fig. 5. Avian abundance across establishment years of prairie strip installations. Whiskers indicate upper and lower confidence intervals.

Wintering Bird Use

As a part of our study on songbird breeding season occupancy using Autonomous Recording Units (ARUs) across Iowa, we also sampled deployment locations during winters 2015-2018. Despite this effort, we have concluded that winter soundscapes are relatively void of sound and determination of wintering bird use of prairie strips through the use of ARUs is not possible.

We have since established an alternative winter study investigating the movements and habitat use of Ring-necked Pheasants in fields with prairie strip installations. We have observed substantial anecdotal evidence that pheasant abundance increases in prairie strip fields shortly after implementation especially in areas where roosting cover is limited. During the winter of 2018-2019 we will capture and fit wild pheasant hens with GPS collars to track their daily movements. We expect this pilot study to aid in our understanding of how newly implemented prairie strips impact the winter bird community.

Objective 2: Assess Bird Nest Success

Nest Success

We assessed bird nest success within current contour buffer and filter strip designs and compared them to new implementations of prairie strips. To assess nest success, we estimated Daily Survival Rate (DSR) of nests and determined apparent and estimated true nest density for different conservation practices. For both nest survival and nest density we investigated a number of environmental and management-practice covariates that might guide decision makers to improve conservation practice design and management for multiple benefits, including wildlife habitat for song bird species.

From 2015-2018 we located 1,144 nests of 26 species on 11 commercial farms and restored prairies in central Iowa. Nests were visited periodically until they either succeeded or failed and a number of vegetation and landscape covariates were recorded for each nest. The average nest Daily Survival Rate (DSR) was calculated for each species for which there were sufficient data (red-winged blackbirds, dickcissels, and vesper sparrows). Environmental variables' effect on DSR were modeled using a maximum likelihood approach in Program MARK implemented in the R statistical language. The models that best fit the data were determined using a stepwise AIC model selection process.

Brood parasitism by brown-headed cowbirds was relatively high in all conservation practices. DSRs presented here are for either host or parasite young, whichever is present in the nest. Nest survival rates over an entire nesting attempt can be calculated by compounding the DSR over the length of the nesting period. An additional correction factor for the rate of nest failure caused by brown-headed cowbirds can then be applied to determine the number of nests that successfully fledged host young. We have not yet calculated that correction factor, but will in the future as we prepare for publication.

A list of variables believed to affect nest survival (Table 1) was investigated using a step-wise AIC model selection process. Models where 95% confidence intervals for any effect crossed zero were thrown out. The best supported model and any model within two ΔAIC_c of the top model were passed on to the next round of model selection where they were combined with all other variables under consideration both as additive and multiplicative effects. Stepwise model selection stopped when the top model was the same two rounds in a row.

Variables we think might influence daily survival rate can be grouped in several general categories (Table 1). Nuisance variables are those which are not of direct interest to our study questions, but which may need to be accounted for to make the effect of other variables apparent. For instance, the number of days since incubation began appears to have a large effect on daily survival, and if we ignore that effect, the environmental influences on DSR are less noticeable. Micro-habitat variables are related to the specific location a bird chooses to

build its nest and may be related to environmental or landscape variables of interest. Five-meter neighborhood variables have to do with the vegetation in the area directly surrounding the nest. These are often some of the variables that distinguish prairie strips from low diversity contour buffer strips. Patch-level variables operate on the scale of the entire prairie/contour strip or the larger area around a nest. These variables deal with the configuration of the conservation practice and the surrounding landscape.

Table 1. Variables included in each level of nest survival modeling. Nuisance variables were thought to affect nest success, but were not of interest to the study question being investigated. Micro-habitat variables described the specific placement of the nest. Five-meter neighborhood variables described the vegetation within 5 m of the nest. Patch-level variables described landscape level effects out to approximately 100 m.

Variable name	Description
<i>Nuisance variables</i>	
1	A constant intercept.
AgeD	The number of days since incubation began.
AgeD + AgeD2	The number of days since incubation began, plus the number of days since incubation began squared.
Site	A grouping variable for study site.
Year	A grouping variable for field season.
iButton	An indicator variable for whether the nest had an iButton inserted.
mow_index	The number of vegetation sampling points that were mowed (0-4).
point_mow	An indicator variable for whether the 1 m ² quadrat containing the nest had been mowed.
<i>Micro-habit variables</i>	
nest_ht	The height of the nest rim off the ground (cm).
conceal	The percentage of the nest bowl concealed from 1 above.
veg_ht	The height of 80% of the mass of vegetation within 0.5 m of the nest.
<i>Five-meter neighborhood variables</i>	
VOR	Vegetation density measured with a Robel pole.
VOR + VOR2	Vegetation density measured with a Robel pole plus vegetation density squared.
grass_cvr	The percentage of the 1 m ² quadrat containing the nest covered by living grasses.
forb_cvr	The percentage of the 1 m ² quadrat containing the nest covered by living forbs.
rich5_all	The count of plant species located within 5 m of the nest.
rich5_nat	The count of native plant species located within 5 m of the nest.
richqm_nat	The mean count of native plant species located within the 4 sampling quadrats within 5 m of the nest.
richqt_nat	The total count of native plant species located within the 4 sampling quadrats within 5 m of the nest.
div_all	The average Shannon-Wiener diversity index of all plant species found within

	each sampling quadrat within 5 m of the nest.
div_nat	The average Shannon-Wiener diversity index of all native plant species found within each sampling quadrat within 5 m of the nest.
<i>Patch-level variables</i>	
nest_lc	The functional land cover class (conservation practice) the nest was located in (e.g., block grassland, low diversity strip, establishing prairie strip, mature prairie strip, terrace).
DTE	The distance to a hard habitat edge (m) (e.g., crop edge, stream, road).
DTE + DTE2	The distance to a hard habitat edge (m) plus the distance to a hard habitat edge squared.
log_pchage	The natural logarithm of the age (years) of the habitat patch the nest was located in.
pch_par	The perimeter:area ratio (m:m ²) of the patch the nest was located in.
ppn20hdiv	The proportion of a 20 m radius circle surrounding the nest containing a high plant diversity land cover.
ppn100hdiv	The proportion of a 100 m radius circle surrounding the nest containing a high plant diversity land cover.

Red-winged Blackbird

Red-winged blackbirds made up the largest group of nests we monitored. During four field seasons we located and monitored 593 red-winged blackbird nests suitable for inclusion in this analysis. Red-winged blackbirds are a generalist species that are not of particular conservation interest in Iowa, but which may serve as a model species for other passerines that nest in grasslands.

The model that best described red-winged blackbird nest survival (Equation 1) was the number of days since incubation began plus the count of native species around the nest, plus a quadratic term for vegetation density within 5 m of the nest.

Equation 1. The best-supported model of daily survival rate for red-winged blackbird nests, with intercept and covariates with accompanying beta coefficients. AgeD was the number of days since incubation was initiated, richqt_nat was the total richness of native plants within four sampling quadrats around the nest, and VOR + VOR2 was a quadratic term for vegetation density within 5 m of each nest measured with a Robel pole.

$$DSR_{RWBL} \sim 1.85 - 0.0563AgeD + 0.0373richqt_{nat} + 0.0168VOR - 0.0000712VOR^2$$

Nest age was an important variable in all the species we investigated and likely affects nest survival because varying levels of adult bird activity coming and going from the nest along with noise and odor caused by young birds in the nest can attract nest predators. The closer the nest came to fledging age, the more at-risk it was from failure, primarily due to predation (Fig. 6).

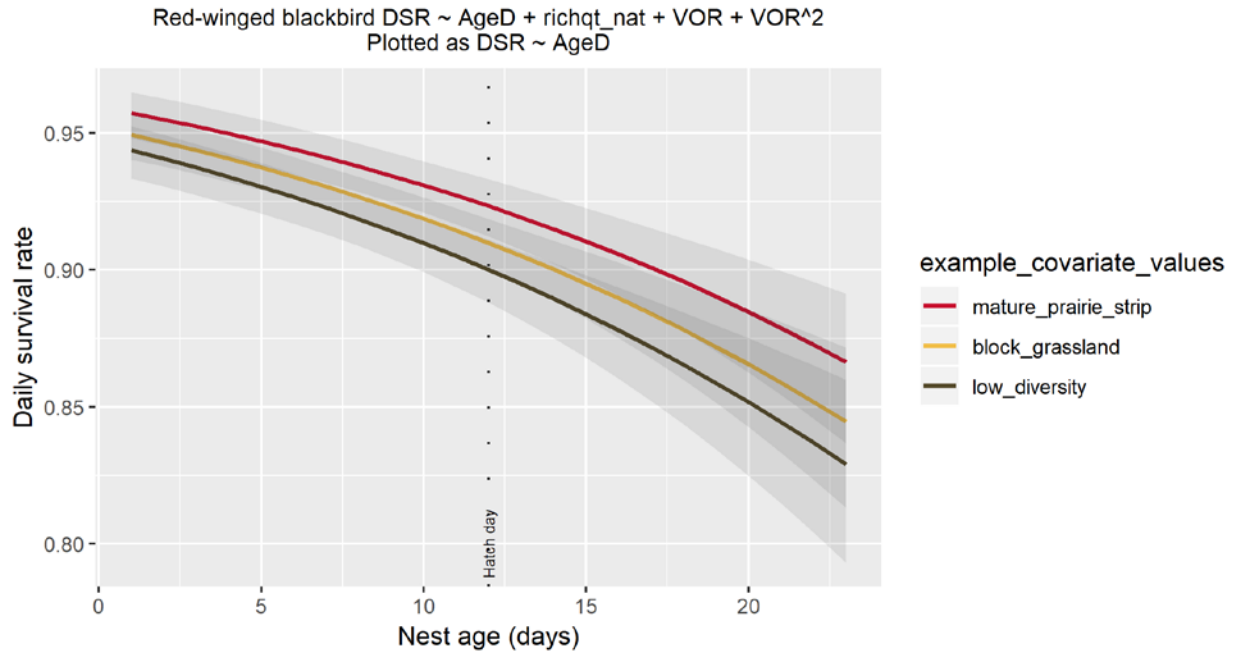


Fig. 6. Daily survival rate of red-winged blackbird nests visualized by nest age and three reference conditions for vegetation measures. Mean native plant species richness and vegetation densities were calculated for nests within mature prairie strips, large block grasslands, and low diversity perennial vegetation areas on farms and used to predict mean DSR for nests with typical covariate values in those conservation practices. Note the 95% confidence intervals are largely overlapping. By itself, the conservation practice the nest was located in was not a significant predictor of DSR, but it serves as a reference condition for vegetation covariates.

Native species richness positively affected daily survival rate of red-winged blackbird nests (Fig. 7), with nests surrounded by a greater number of native plant species surviving at a higher rate than those surrounded by few native plant species. Red-winged blackbird nests with 10 native plant species within 5 m (typical for prairie strips) fledged young 2.13 times as often as nests with only four native plant species within 5 m (typical for low diversity contour buffer strips) (fledge rate_{prairie strips} = 0.096*, CI_{95%} = 0.060-0.143, fledge rate_{low-diversity} = 0.045*, CI_{95%} = 0.026-0.073).

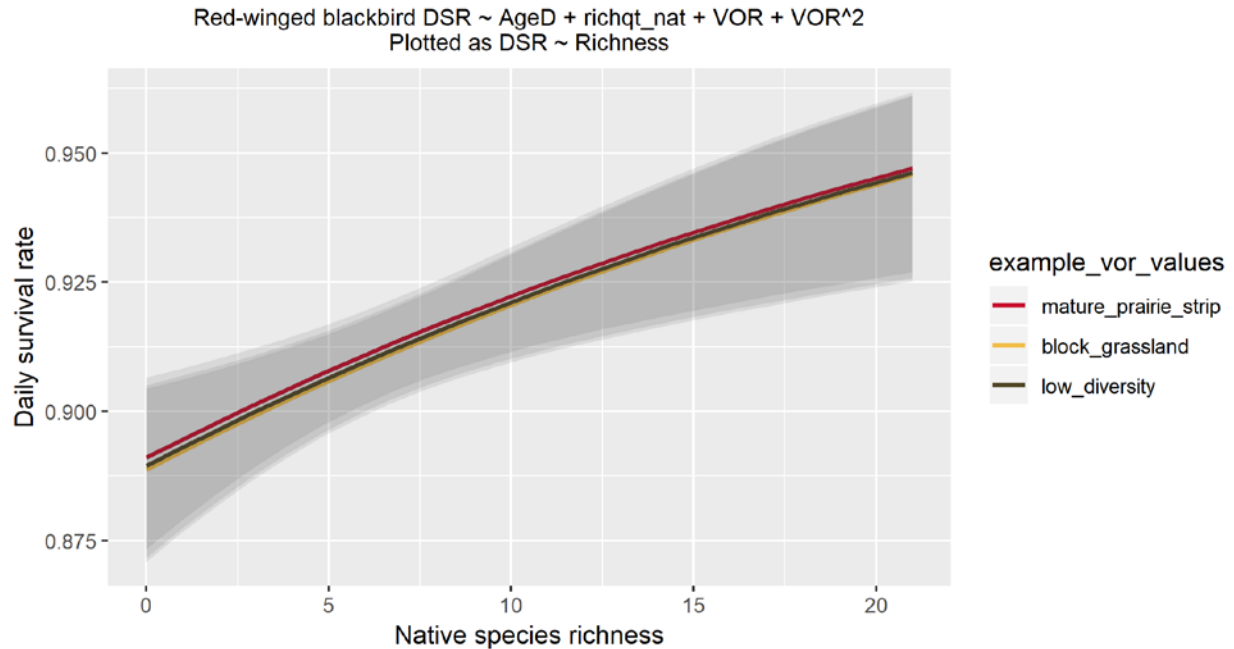


Fig. 7. Daily survival rate of red-winged blackbird nests visualized by native species richness and three reference conditions for vegetation density, for nests 12 days of age. Mean visual obstruction reading was calculated for nests within mature prairie strips, large block grasslands, and low diversity perennial vegetation areas on farms and used to predict mean DSR for nests at age 12 with typical VOR values for those conservation practices. Note the 95% confidence intervals have almost complete overlap. By itself, the conservation practice the nest was located in was not a significant predictor of DSR, but it serves as a reference condition for vegetation covariates.

Daily survival rate increased with increasing vegetation density from 10-120 cm and slowly decreased above 120 cm (Fig. 8). Red-winged blackbird nests with a VOR score of 80 cm (typical for prairie strips) fledged young 1.97 times as often as nests with a VOR score of 45 (typical for low diversity contour buffer strips) (fledge rate_{prairie strips} = 0.052*, CI_{95%} = 0.027-0.088, fledge rate_{low-diversity} = 0.102*, CI_{95%} = 0.071-0.139).

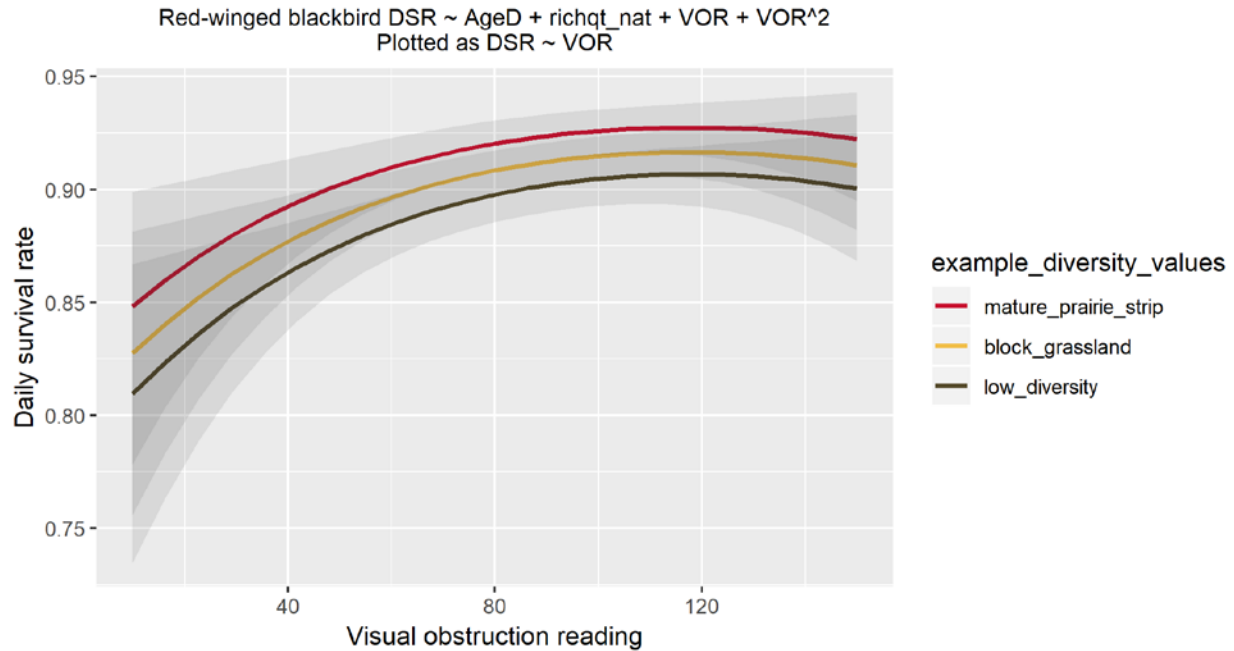


Fig. 8. Daily survival rate of red-winged blackbird nests visualized by visual obstruction reading and three reference conditions for native vegetation richness, for nests 12 days of age. The mean number of native plant species was calculated for nests within mature prairie strips, large block grasslands, and low diversity perennial vegetation areas on farms and used to predict mean DSR for nests at age 12 with typical native species richness values in those conservation practices. Note the 95% confidence intervals are largely overlapping. By itself, the conservation practice the nest was located in was not a significant predictor of DSR, but it serves as a reference condition for vegetation covariates.

Red-winged blackbird nests with both native species richness and vegetation densities similar to prairie strips fledged young 4.33 times as often as those with values similar to low-diversity contour buffer strips (fledge rate_{prairie strip} = 0.128*, CI_{95%} = 0.088-0.176, fledge rate_{low-diversity} = 0.030*, CI_{95%} = 0.014-0.056).

Dickcissel

Dickcissels made up the second-largest group of nests we monitored. During four field seasons we located and monitored 255 dickcissel nests suitable for inclusion in this analysis. Dickcissels are a generalist grassland species that are listed as a Species of Greatest Conservation Need in Iowa. The model that best described dickcissel nest survival (Equation 2) was a fully interactive model incorporating the number of days since incubation began, the square of the number of days since incubation began, the count of native species around the nest, and the vegetation density within 5 m of the nest.

*Equation 2. The best-supported model of daily survival rate for dickcissel nests. $AgeD * AgeD^2$ was a term for the number of days since incubation was initiated, $richqt_nat$ was the total richness of native plants within four sampling quadrats near the nest, and VOR was vegetation*

density within 5 m of each nest measured with a Robel pole. We have presented both the simplified multiplicative nomenclature (A) and the expanded additive nomenclature with interactions and beta values (B).

$$A. DSR_{DICK} \sim AgeD * AgeD^2 * richqt_{nat} * VOR$$

$$B. DSR_{DICK} \sim 5.29 - 1.81AgeD + 0.206AgeD^2 - 0.313richqt_{nat} - 0.0362VOR \\ - 0.00660AgeD:AgeD^2 + 0.191AgeD:richqt_{nat} \\ - 0.0231AgeD^2:richqt_{nat} + 0.0195AgeD:VOR - 0.00199AgeD^2:VOR \\ + 0.00283richqt_{nat}:VOR \\ + 0.000793AgeD:AgeD^2:richqt_{nat} + 0.0000554AgeD:AgeD^2:VOR \\ - 0.00153AgeD:richqt_{nat}:VOR + 0.000173AgeD^2:richqt_{nat}:VOR \\ - 0.00000551AgeD:AgeD^2:richqt_{nat}:VOR$$

Nest age was an important variable in all the species we investigated (Fig. 9). DSRs for the three example covariate values all stayed relatively flat through the incubation period and then diverged during the late nestling period. This could indicate different conservation practices have relatively constant risk of failure during the incubation stage, but diverging varying risk of failure during the nestling stage, likely due to differences in predation rates.

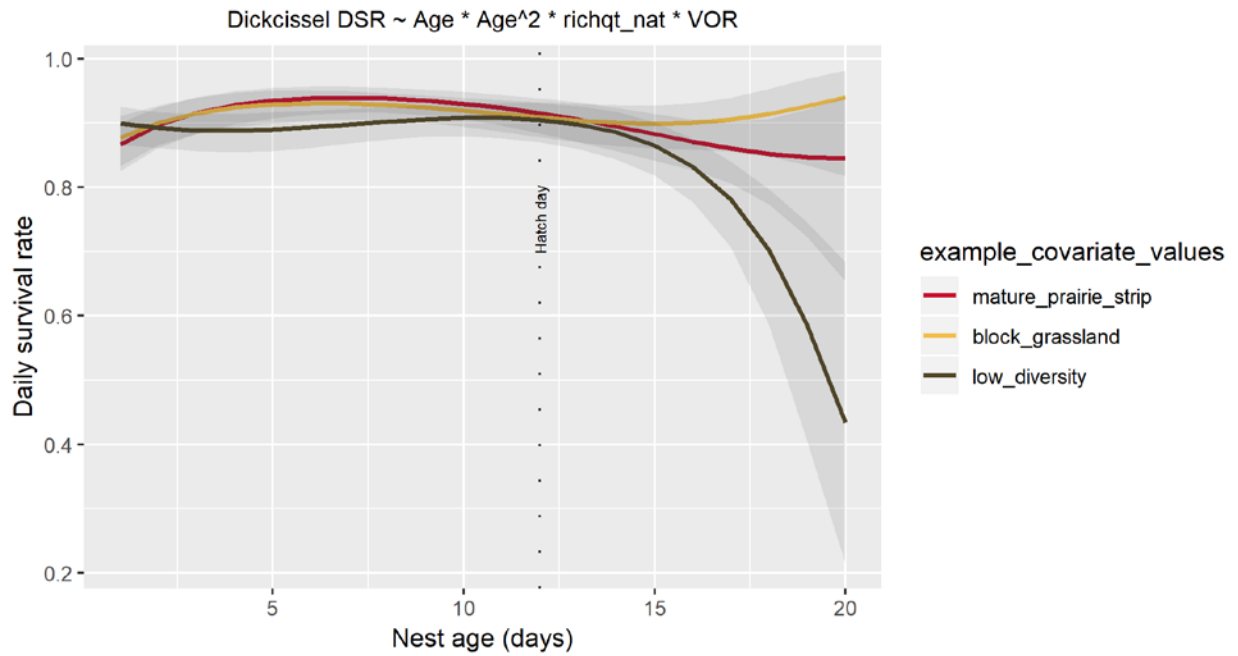


Fig. 9. Daily survival rate of dickcissel nests visualized by nest age and three reference conditions for vegetation measures. Mean native plant species richness and vegetation densities were calculated for nests within mature prairie strips, large block grasslands, and low diversity perennial vegetation areas on farms and used to predict mean DSR for nests with typical covariate values in those areas. Note the 95% confidence intervals are largely overlapping. By itself, the conservation practice the nest was located in was not a significant predictor of DSR, but it serves as a reference condition for vegetation covariates.

Native species richness positively affected dickcissel nest daily survival rate for all ages (Fig. 10), with nests surrounded by a greater number of native plant species surviving at a higher rate than those surrounded by few native plant species. Dickcissel nests with eight native plant species within 5 m (typical for prairie strips) fledged young 5.19 times as often as nests with only three native plant species within 5 m (typical for low diversity contour buffer strips) (fledge rate_{prairie strip} = 0.131, CI_{95%} = 0.049-0.245, fledge rate_{low-diversity} = 0.026, CI_{95%} = 0.004-0.096).

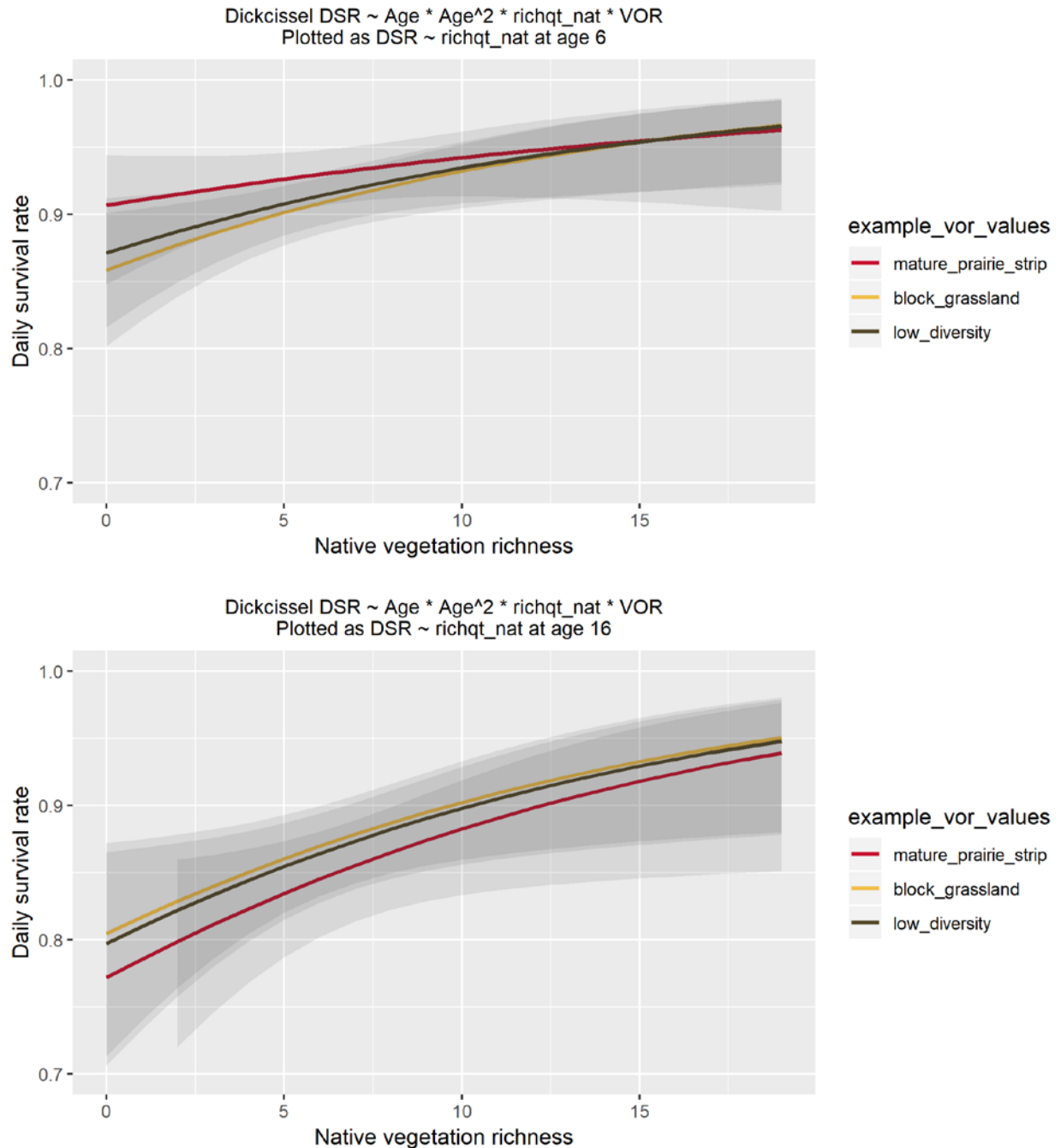
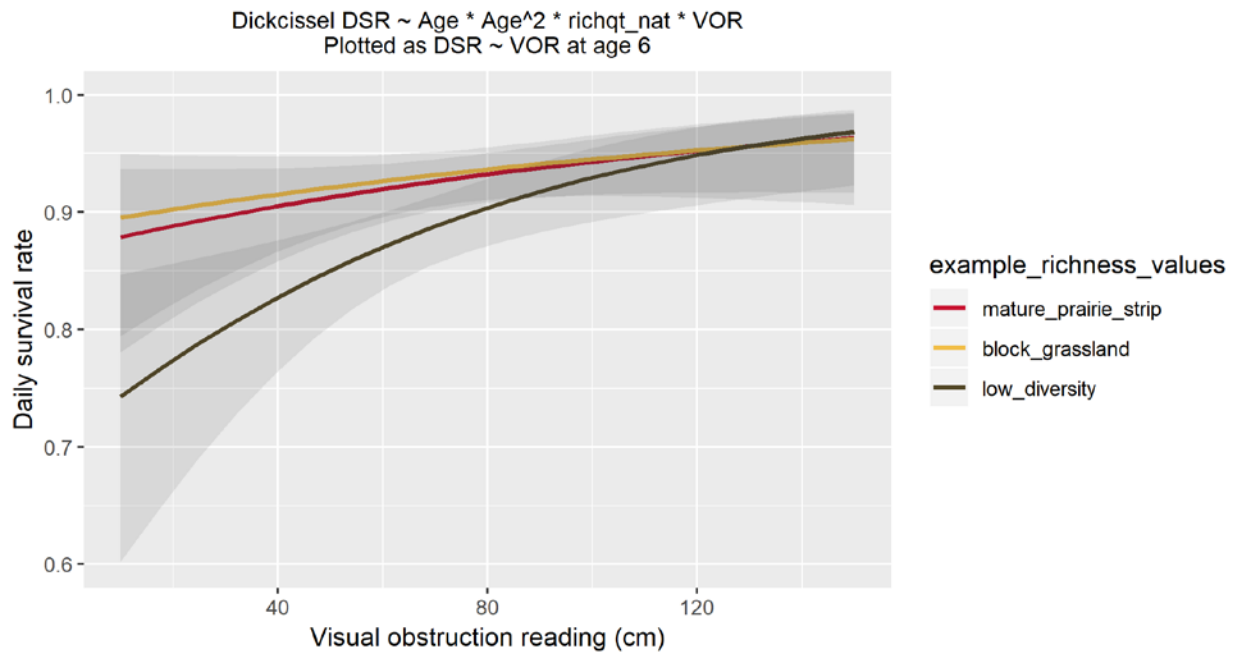


Fig. 10. Daily survival rate of dickcissel nests visualized by native species richness and three

reference conditions for vegetation density, for nests six days (top) and 16 days (bottom) of age. Mean visual obstruction reading was calculated for nests within mature prairie strips, large block grasslands, and low diversity perennial vegetation areas on farms and used to predict mean DSR for nests at both ages with typical VOR values in those conservation practices. Note the 95% confidence intervals are largely overlapping. By itself, the conservation practice the nest was located in was not a significant predictor of DSR, but it serves as a reference condition for vegetation covariates.

Daily survival rate for dickcissel nests increased with increasing vegetation density for nests in the incubation stage (Fig. 11, top), but decreased with increasing vegetation density in the nestling stage (Fig. 11, bottom). Overall, dickcissel nests with a VOR score of 45 cm (typical for low diversity contour buffer strips) fledged young 1.21 times as often as nests with a VOR score of 80 (typical for prairie strips) (fledge rate_{prairie strip} = 0.072, CI_{95%} = 0.024-0.154, fledge rate_{low-diversity} = 0.087, CI_{95%} = 0.021-0.203).



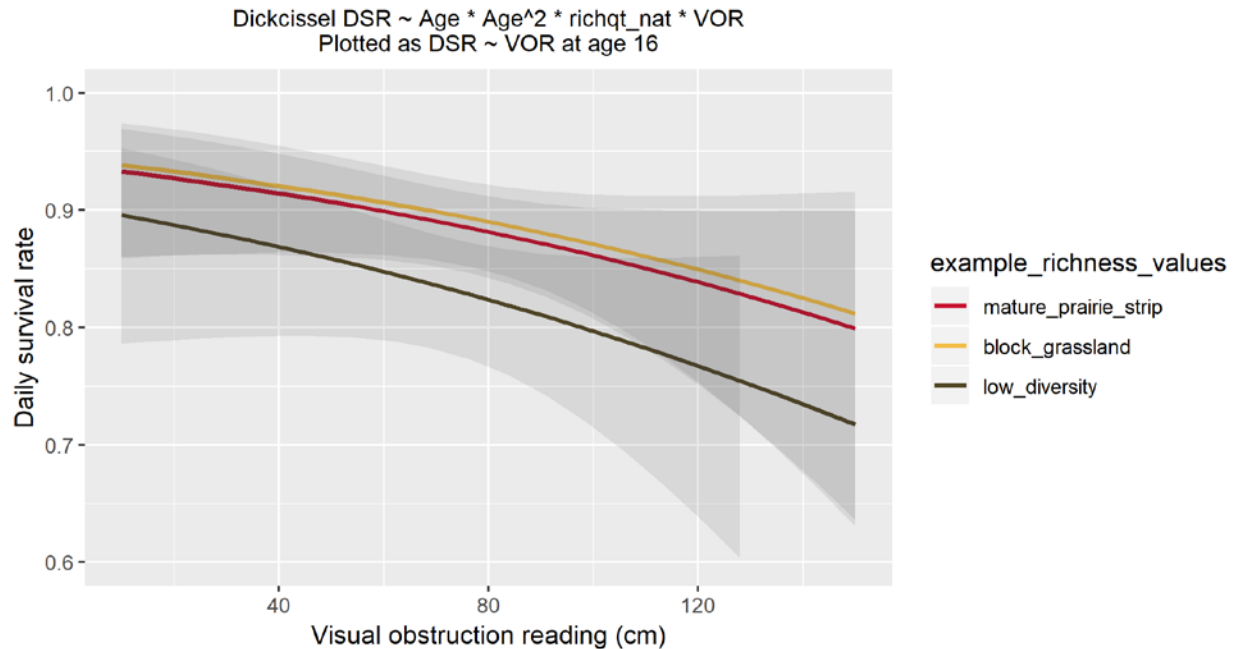


Fig. 11. Daily survival rate of dickcissel nests visualized by visual obstruction reading and three reference conditions for native vegetation richness, for nests midway through the incubation (top) and nestling (bottom) periods. The mean number of native plant species was calculated for nests within mature prairie strips, large block grasslands, and low diversity perennial vegetation areas on farms and used to predict mean DSR for nests with typical native richness values in those conservation practices. Note the 95% confidence intervals are largely overlapping. By itself, the conservation practice the nest was located in was not a significant predictor of DSR, but it serves as a reference condition for vegetation covariates.

Nests with both native species richness and vegetation densities similar to prairie strips fledged young 4.52 times as often as those with values similar to low-diversity contour buffer strips (fledge rate_{prairie strip} = 0.118, CI_{95%} = 0.046-0.221, fledge rate_{low-diversity} = 0.026, CI_{95%} = 0.002-0.119).

Vesper Sparrow

Vesper sparrows made up the smallest analyzable group of nests we monitored. During four field seasons we located and monitored 57 vesper sparrow nests suitable for inclusion in this analysis. Vesper sparrows are an open-country species that are commonly found on farms in Iowa. The model that best described vesper sparrow nest survival (Equation 3) was the number of days since incubation began, plus the proportion of high-diversity vegetation within 20 m of the nest, plus an indicator variable for whether there had been mowing within 0.5 m of the nest before the predicted fledge date.

Equation 3. The best-supported model of daily survival rate for vesper sparrow nests. AgeD was the number of days since incubation was initiated, ppn20hdiv was the proportion of a 20 m radius circle around the nest that contained high plant diversity land cover, and point_mow was

an indicator variable for whether the 1 m² quadrat containing the nest had been mowed.

$$DSR_{VESP} \sim 2.63 - 0.071AgeD + 2.30ppn20hdiv - 1.55point_mow$$

Nest age was an important variable in all the species we investigated (Fig. 12). DSRs for the four example covariate values all trended down throughout the incubation and nestling periods, with younger nests more likely to survive to the next day than older nests.

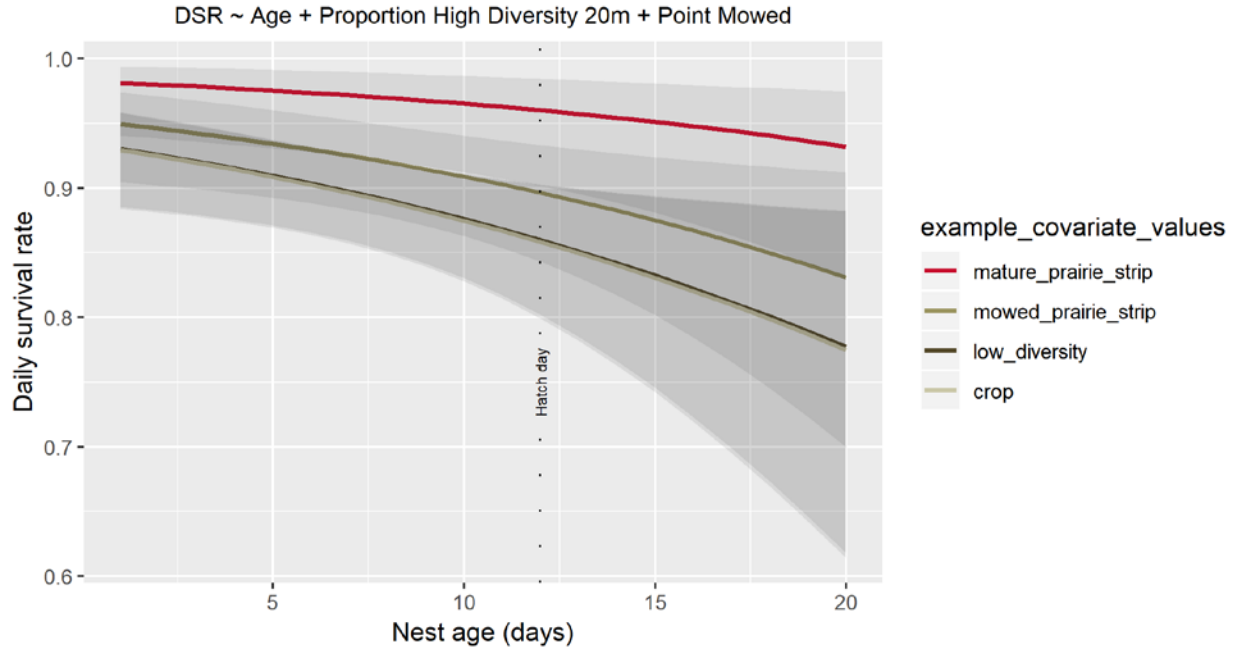


Fig. 12. Daily survival rate of vesper sparrow nests visualized by nest age and four reference conditions for vegetation measures (low diversity and crop lines are nearly identical). Mean proportion of high diversity land cover within 20 m of nests and percentage of nests with mowing within 0.5 m of the nest were calculated for nests within mature prairie strips, mowed prairie strips, low diversity perennial vegetation areas, and crop ground on farms and used to predict mean DSR for nests with typical covariate values in those areas. Note the 95% confidence intervals are largely overlapping. By itself, the conservation practice the nest was located in was not a significant predictor of DSR, but it serves as a reference condition for vegetation covariates.

Proportion of high diversity vegetation within 20 m positively affected vesper sparrow nest daily survival rate (Fig. 13), with nests surrounded by a greater proportion of high diversity vegetation surviving at a higher rate than those surrounded by less high diversity plantings. Vesper sparrow nests with 47.1% of the surrounding 20 m composed of high diversity vegetation (typical for nests in prairie strips) fledged young 9.68 times as often as nests with 0.0% of the surrounding 20 m composed of high diversity vegetation (typical for nests in low diversity contour buffer strips) (fledge rate_{prairie strip} = 0.277, CI_{95%} = 0.081-0.523, fledge rate_{low-}

diversity = 0.028, $CI_{95\%} = 0.003-0.117$).

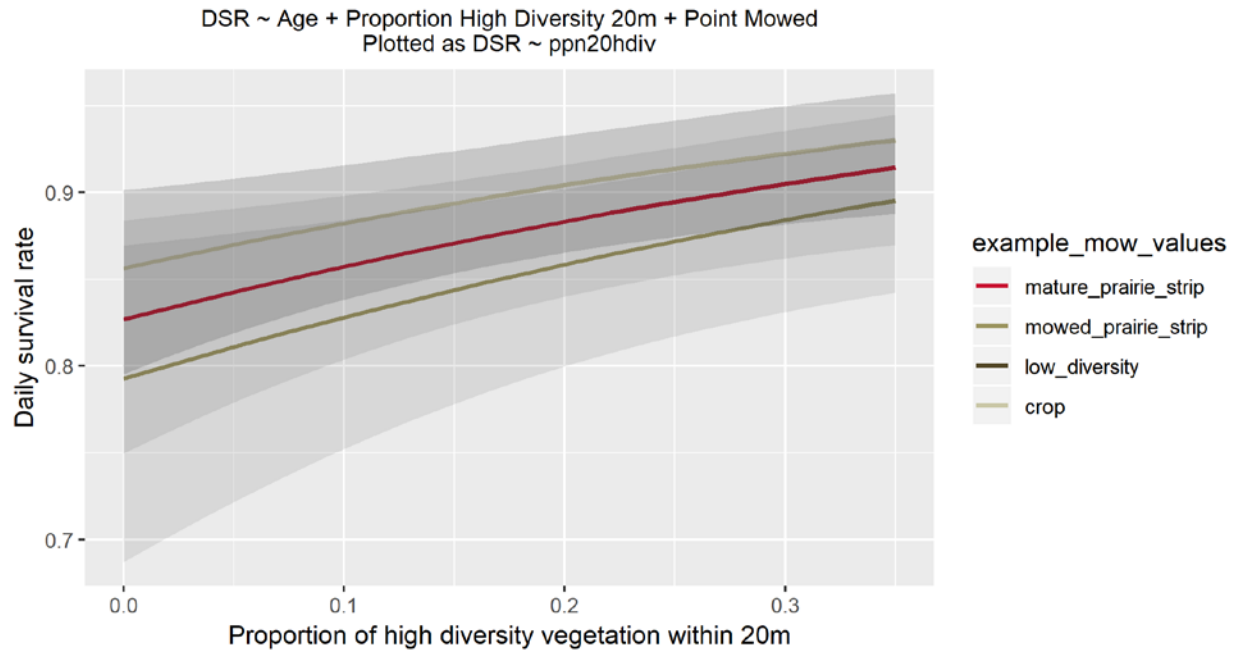


Fig. 13. Daily survival rate of vesper sparrow nests visualized by proportion of high diversity vegetation within 20 m and four reference conditions for mowing activity. Mean point_mow values were calculated for nests within mature prairie strips, mowed prairie strips, low diversity perennial vegetation areas on farms, and crop areas and used to predict mean DSR for nests at age 12 with typical point_mow values in those conservation practices. Note the 95% confidence intervals are largely overlapping. By itself, the conservation practice the nest was located in was not a significant predictor of DSR, but it serves as a reference condition for vegetation covariates.

Mowing activity within 0.5 m of a nest negatively affected vesper sparrow nest daily survival rate (Fig. 14). Vesper sparrow nests with no mowing within 0.5 m fledged young 235.8 times as often as nests with mowing nearby (fledge rate_{no_mow} = 0.164, $CI_{95\%} = 0.053-0.331$, fledge rate_{mowed} = 0.0007, $CI_{95\%} = 0-0.067$). Five of the 57 nests had mowing recorded within 0.5 m during the vegetation survey, and all five of them failed to fledge young. Three of the failures were caused by predation, one by abandonment, and one as a direct result of the mowing, indicating that mowing likely impacts fledging beyond simply destroying the nest outright.

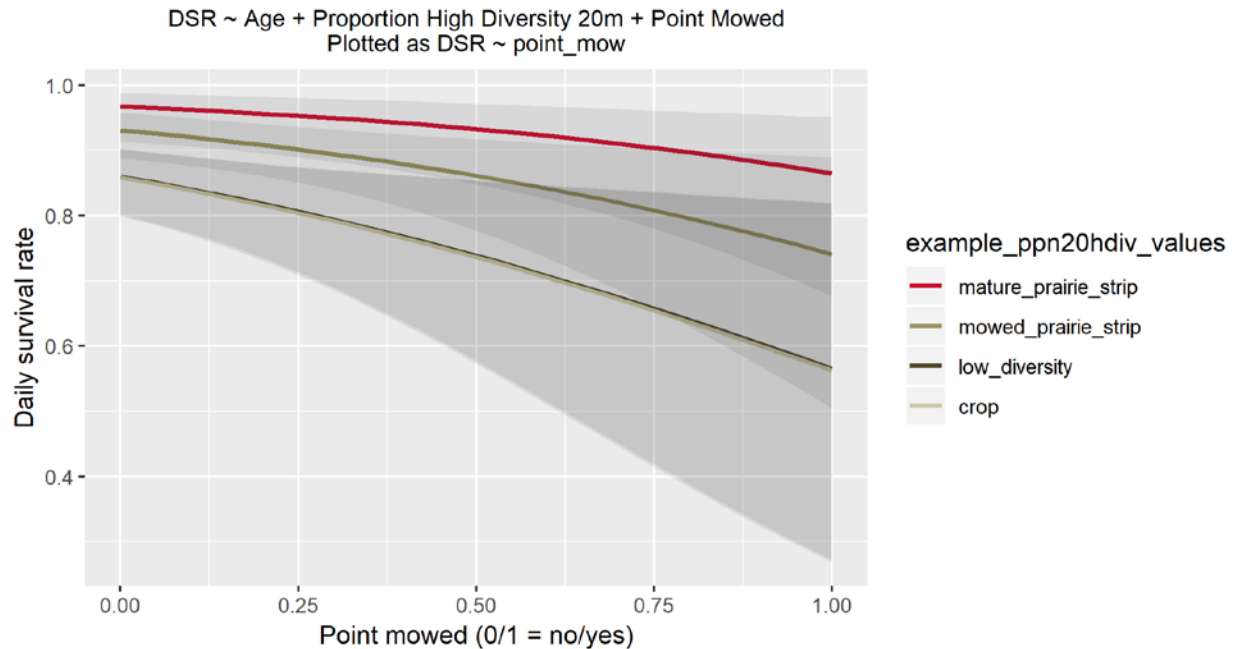


Fig. 14. Daily survival rate of vesper sparrow nests visualized by whether there was mowing activity within 0.5 m of the nest location and four reference conditions for the proportion of high diversity vegetation within 20 m. Mean *ppn20hdiv* values were calculated for nests within mature prairie strips, mowed prairie strips, low diversity perennial vegetation areas on farms, and crop areas and used to predict mean DSR for nests at age 12 with typical *ppn20hdiv* values in those conservation practices. Note the 95% confidence intervals are largely overlapping. By itself, the conservation practice the nest was located in was not a significant predictor of DSR, but it serves as a reference condition for vegetation covariates.

Vesper sparrow nests with both proportion of diverse vegetation within 20 m and mowing activity similar to prairie strips fledged young 4.35 times as often as those with values similar to low-diversity contour buffer strips (fledge rate_{prairie strip} = 0.216, CI_{95%} = 0.054-0.452, fledge rate_{low-diversity} = 0.050, CI_{95%} = 0.008-0.159).

Nest Detection Probability and Nest Density

From 2016-2018 we conducted double-observer plot searches to estimate nest density for multiple bird species across a variety of on-farm conservation practices on 11 sites in central Iowa. Plots were searched once per week by alternating pairs of observers. Pairs of observers did not communicate the presence or location of nests to the other pair so the result of each search was a binomial (1: nest discovered, 0: nest not discovered) where the average outcome could be used to directly calculate a detection probability and model the factors that influenced the probability of discovery in order to obtain more accurate nest density estimates. For example, if only 1 out of 5 plot searches that contained a known nest resulted in a rediscovery, we would be able to estimate that we were only locating around 20% of the nests present on

the landscape.

We conducted 188 plot searches where a nest was known to be present that the searching pair of observers did not know about. These plot searches resulted in re-discoveries in 45 of 188 instances, giving a raw nest detection probability of 23.9%. Covariates believed to affect nest detection probability (Table 2) were included in a step-wise AIC model selection process where the best-supported model was selected after three rounds (Equation 4). We then predicted individual detection probabilities for each search plot, which allowed us to estimate the total number of nests present by species and conservation practice.

Table 2. Variables considered during nest detection model selection. Variables cannot appear in both the detection probability and density estimates, so only nuisance-level random effects were investigated.

Variable	Description
<i>Fixed effects</i>	
1	A constant intercept.
<i>Random effects</i>	
field_season	A grouping variable for field season.
site_abbreviation	A grouping variable for study site.
treatment_name	A grouping variable for conservation practice.
species	A grouping variable for species of nest.
LumpSp	A grouping variable for nest species. Categories were red-winged blackbird, dickcissel, vesper sparrow, other grassland species, and shrub species.

The best supported model for nest detection probability was a fixed intercept plus a random effect of conservation practice nested within site (Equation 4). This shows that detection probabilities were different between sites and between conservation practices, but makes no attempt to model the physical process that drove the differences, since variables such as vegetation density and feature width which might affect detection probability are of more interest for explaining nest density.

Equation 4. The best supported model of nest detection. The best supported model had no fixed effects other than a constant intercept and random effects of conservation practice nested within site.

$$\text{Nest detection} \sim 1 + (1|\text{conservation practice} / \text{site})$$

Beta coefficients for each conservation practice and site were used to predict a detection probability for each search plot based on Equation 4 (Fig. 15). Note that not all sites contained search plots for all conservation practices.

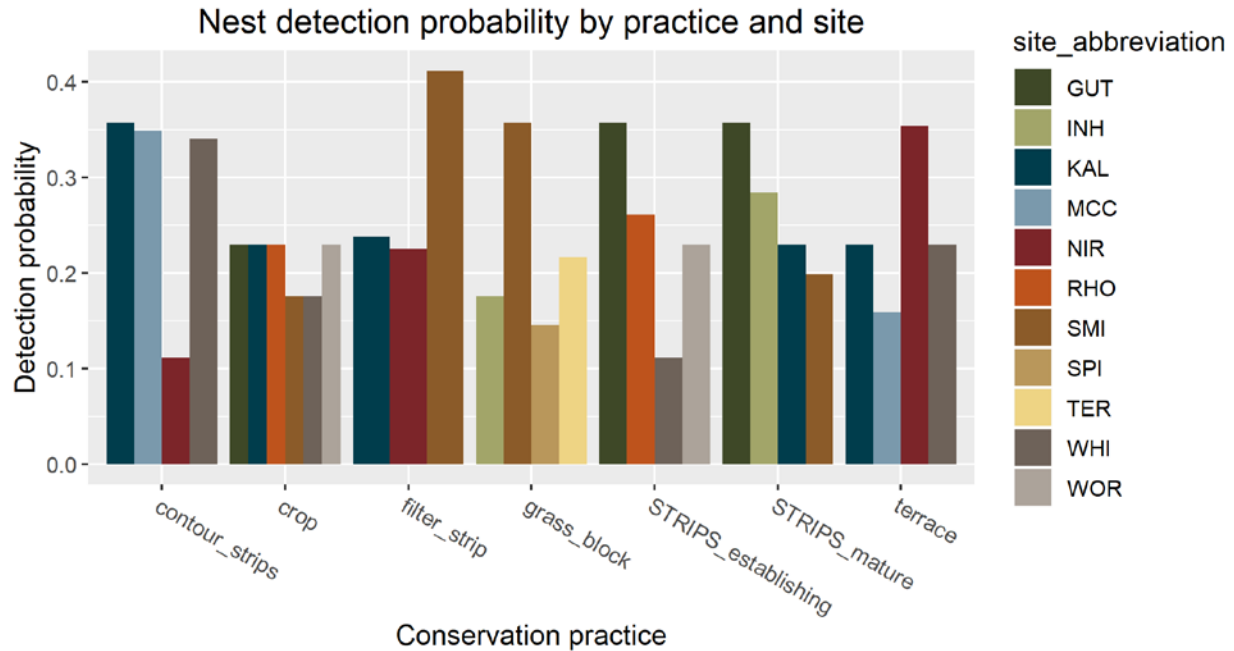


Fig. 15. Predicted nest detection probabilities for conservation practice nested within site.

The number of nests of each species encountered during each search was used to model the variables most important to nest density (Table 3). Count of nests found during each search was used as the response variable in a generalized linear mixed model. The model that best fit the data was chosen through stepwise AIC model selection, where the selected best model was the model with the lowest AIC value two rounds in a row.

Table 3. Random and fixed effects included in model selection for nest density. Nuisance variables were grouping or timing variables that may have affected density but which were not of primary study interest. Landscape variables described the layout of the land cover the plot was situated within and its position on the landscape. Vegetation variables described the vegetative communities present within the search plot.

Variable name	Description
<i>Random effects</i>	
<i>Nuisance variables</i>	
field_season	A grouping factor for study year
site_abbreviation	A grouping factor for each study site
plot_name	A grouping factor for each individual search plot
treatment_name	One of six conservation practices investigated (low-diversity contour buffer strips, crop, filter strip, large block grassland, mowed prairie strips, mature prairie strips, and terrace)
<i>Fixed effects</i>	
<i>Nuisance variables</i>	
week_of_year_scaled	The week of the year the plot search was conducted.

<i>Landscape variables</i>	
feature_width_at_plot_meters_scaled	The minimum distance between hard habitat edges (crop, road, or water) measured at the center of the search plot.
feature_width_at_plot_meters_sq_scaled	The minimum distance squared between hard habitat edges (crop, road, or water) measured at the center of the search plot.
feature_width_at_plot_meters_log_scaled	The natural logarithm of the minimum distance between hard habitat edges (crop, road, or water) measured at the center of the search plot.
distance_to_water_meters_scaled	The minimum distance to semi-permanent water body from the center of the search plot.
distance_to_water_meters_sq_scaled	The square of the minimum distance to semi-permanent water body from the center of the search plot.
distance_to_water_meters_log_scaled	The natural logarithm of the minimum distance to semi-permanent water body from the center of the search plot.
<i>Vegetation variables</i>	
vor_final_mean_scaled	The average vegetation density of the plot measured with a Robel pole at three points along the centerline.
vor_final_mean_sq_scaled	The square of the average vegetation density of the plot measured with a Robel pole at three points along the centerline.
species_richness_all_5m_total_scaled	The number of plant species found within the search plot.
species_richness_native_5m_total_scaled	The number of native plant species found within the search plot.
species_richness_native_quadrats_mean_scaled	The average number of native plant species found within a sampling quadrat within the search plot.
species_richness_native_quadrats_total_scaled	The total number of native plant species found within the sampling quadrats within the search plot.
shannon_wiener_all_scaled	The average Shannon-Wiener diversity index of all plant species found within sampling quadrats within the search plot.
shannon_wiener_native_scaled	The average Shannon-Wiener diversity index of native plant species found within sampling quadrats within the search plot.

Red-winged Blackbird

Red-winged blackbirds construct nests above ground in herbaceous or woody vegetation with enough sturdy stems to support the weight of the nest. They tend to be more obvious than the more cryptic-nesting species, and adult behavioral cues can be useful for locating the nest. We found both raw and detection-probability-adjusted red-winged blackbird nest densities were highest in filter strips and mature prairie strips (Figs. 16-17).

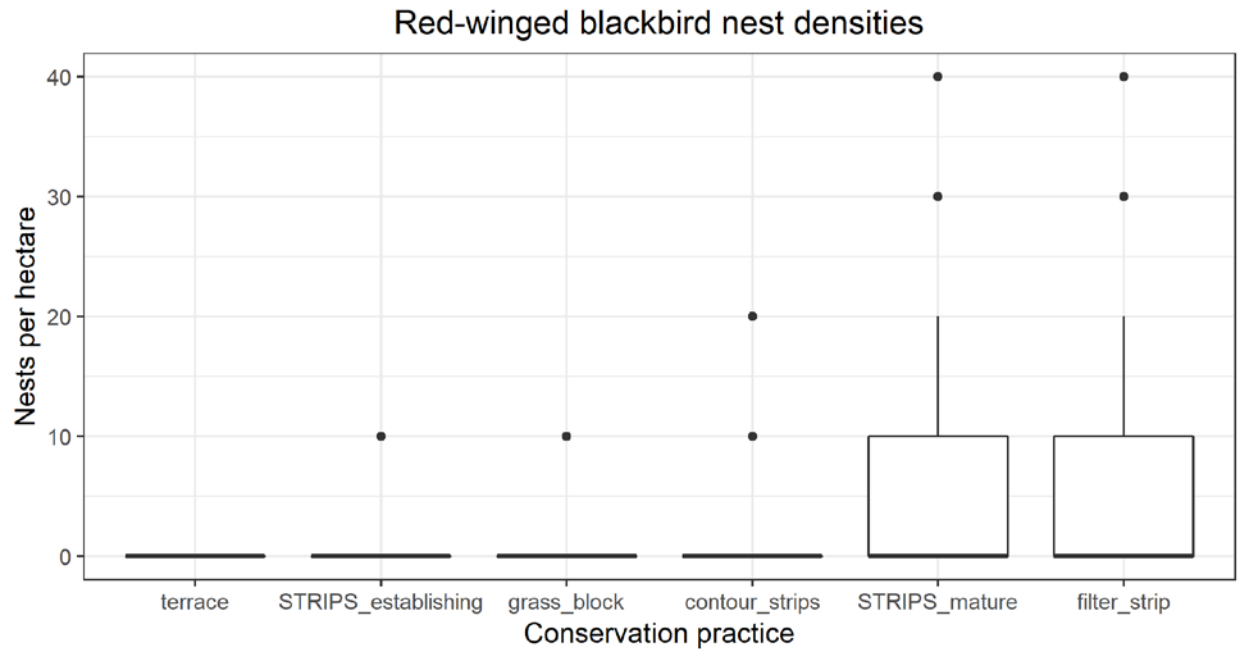


Fig. 16. Red-winged blackbird nests per hectare in six agricultural conservation practices. Nests were found during 3951 standardized plot searches and were summed over 233 plots and 3 years to form 401 plot-years (n), with some plots searched in multiple years.

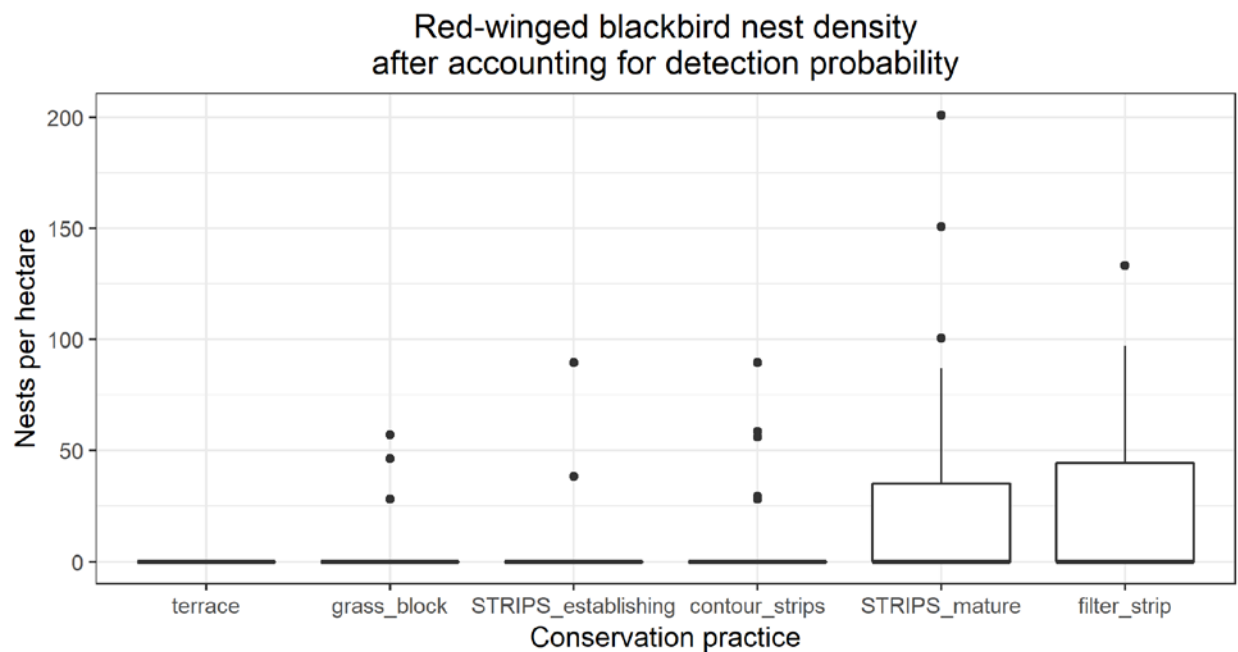


Fig. 17. Red-winged blackbird nests per hectare in six agricultural conservation practices. Nests were found during 3951 standardized plot searches and were summed over 233 plots and 3 years to form 401 plot-years (n), with some plots searched in multiple years. Raw counts of nests were adjusted with the predicted detection probability for each search plot to give an estimate of the combined number of nests found plus the nests that were not discovered.

Red-winged blackbird nest counts per search were used as the response variable in a generalized linear mixed model to determine the combination of environmental variables (Table 3) that best predicted nest counts (Equation 5). The model that best described red-winged blackbird nest density included fixed effects for week of year, plus the natural logarithm of the plot distance to water, plus random effects for search plot nested within year, plus conservation practice.

Equation 5. The best supported model of nests found per search for red-winged blackbirds during 3951 plot searches of 233 plots over 3 field seasons including 6 conservation practice treatments. The response variable was the raw area-adjusted count of new red-winged blackbird nests found during each plot search. The week variable indicated the week of the year each search was conducted in, log-distance to water was the natural logarithm of the minimum distance from the search plot to a semi-permanent water body, year/plot was a random effect for each search plot nested within field season, and conservation practice was also a random effect. All variables were scaled but not centered. An offset for search plot area was used to correct for terrace plots, which were half the area of other treatment types.

$$\text{Nest count} \sim \text{week} + \log(\text{dist. to water}) + (1|\text{year} / \text{plot}) + (1|\text{conservation practice})$$

The best supported model for red-winged blackbird nest density included random effects for plot nested within field season and conservation practice (treatment_name). Both additive effects and the interaction term were well estimated with non-zero variances (Table 4).

Table 4. Summary of random effects in the best supported model of red-winged blackbird nest counts.

Random effects	Name	Variance	Std. Dev.
plot_name:field_season (Intercept)		0.3588	0.5990
treatment_name	(Intercept)	0.6388	0.7992
field_season	(Intercept)	0.1367	0.3697

The best supported model for red-winged blackbird nest density included fixed effects for week of year the search was conducted in, plus the plot distance to water, plus an intercept (Table 5). Week of year had a negative effect on count of nests found during a search, and plots further from water had lower nest counts. All fixed effect variables were well estimated, and statistically significant at the $p = 0.05$ level.

Table 5. Summary of fixed effects in the best supported model of red-winged blackbird nest counts. Both fixed effects and the intercept were well estimated and had p -values < 0.05 .

Fixed effects	Estimate	Std. error	z value	Pr(> z)	Stat. significance
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(Intercept)	-5.7489	1.2273	-4.684	0.00000281	***
week_of_year_scaled	-2.88	0.8821	-3.265	0.0011	**
distance_to_water_meters_log_scaled	-3.3941	0.8413	-4.034	0.0000548	***

Week of the season each plot search was conducted in had a negative effect on the number of red-winged blackbird nests counted. Fig. 18 shows the single-search nest count per hectare, with points showing measured values and a trend-line showing the mean predicted density by search week.

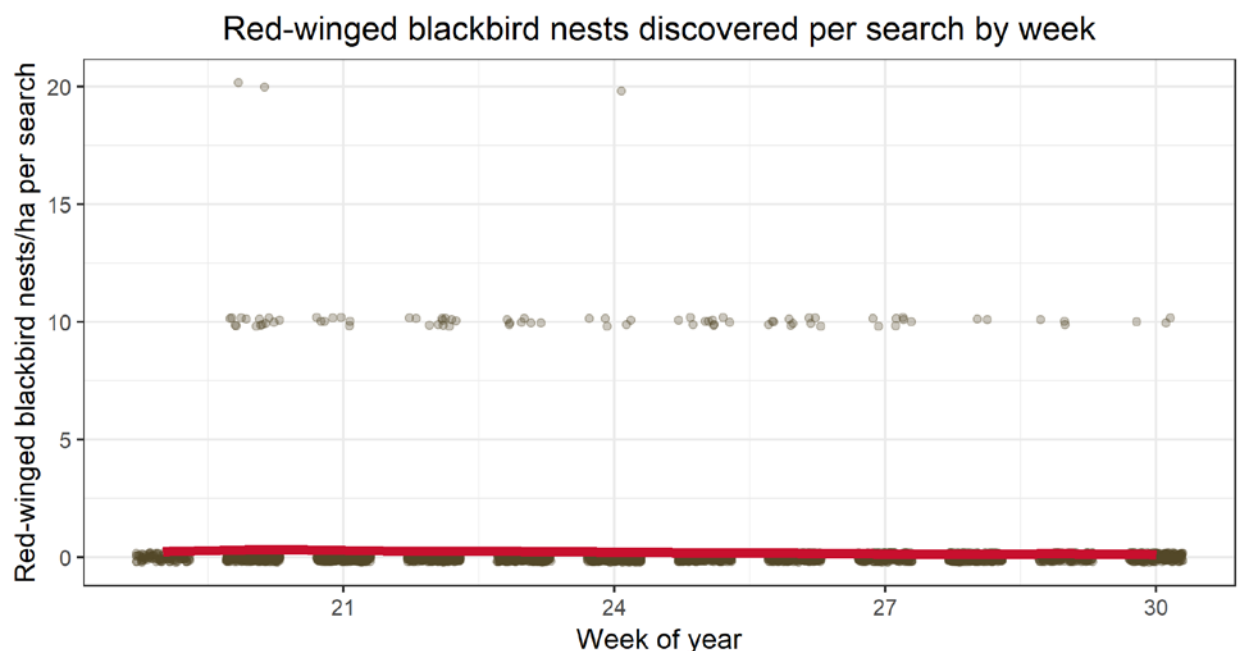


Fig. 18. Red-winged blackbird nests per hectare per search plotted by week of the year. Each dot represents the count of nests found during each of 3951 searches of 233 plots over 3 field seasons. Their positions have been jittered to limit over-plotting. The red line shows a smoothed linear function of the predicted number of new nests per search using the best supported model of nest counts presented in Equation 5. Most of the searches resulted in no new nests discovered, so the bulk of the 3951 searches are jittered around zero on the y-axis.

Plot distance to water had a logarithmically-negative effect on the number of red-winged blackbird nests counted during each plot search. Fig. 19 shows the whole-season nest count per hectare, with points showing measured values and a trend-line showing the mean predicted density for all observed plot distances to water.

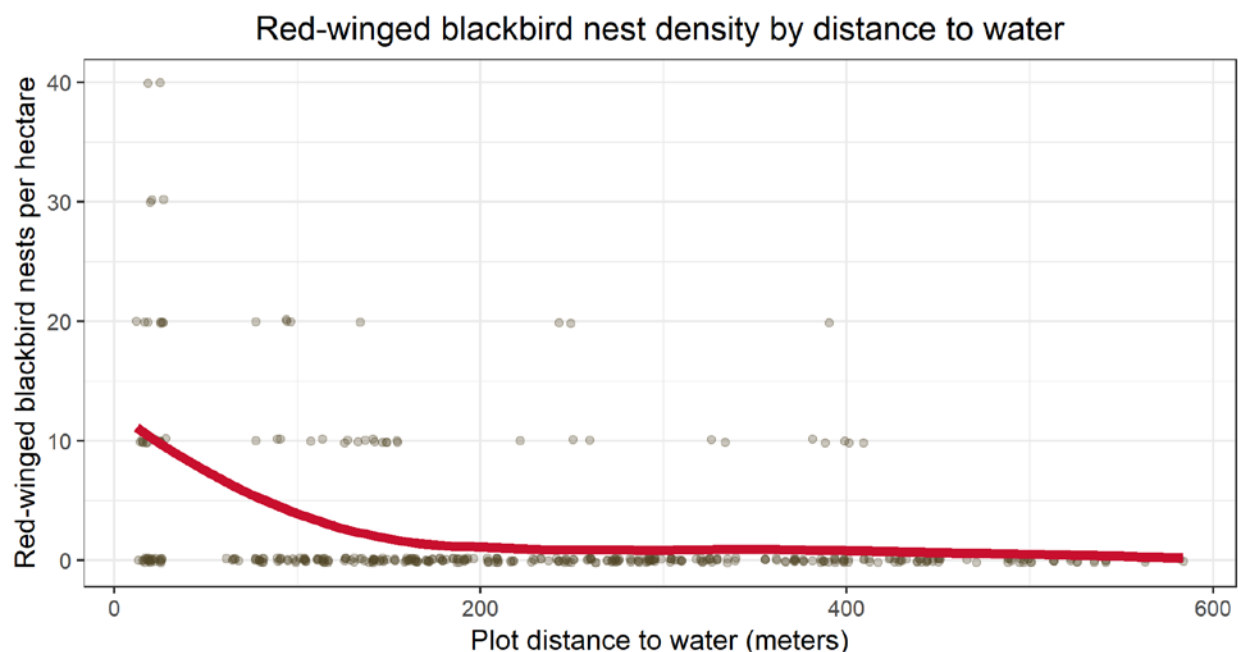


Fig. 19. Red-winged blackbird nests per hectare found during a single season plotted against search plot distance to water. Dots represent each of 401 plot-years of 233 plots searched over 3 field seasons, with some plots searched in multiple years. Positions have been jittered to limit over-plotting. The red line is a smoothed function of the number of nests per hectare for each plot-year predicted by the best supported model presented in Equation 5.

Plots with distance-to-water values similar to those observed for mature prairie strip plots (124.8 m) had 1.20 times the density of red-winged blackbird nests as plots with distance to water values similar to low-diversity contour buffer strips (166.8 m). However, since distance to water is not expected to be different on average for implemented prairie strip and contour buffer strip designs, red-winged blackbird nest densities would be similar in mature prairie strips and contour buffer strips with the same distance to water.

Dickcissel

Dickcissels construct nests above ground in herbaceous or woody vegetation with enough sturdy stems to support the weight of the nest. They tend to nest lower and tuck their nest deeper into the vegetation than red-winged blackbirds. However, they still require some stiff-stemmed vegetation to support the weight of the nest, young, and female. We found both raw and detection-probability-adjusted dickcissel nest densities were highest in prairie strips, with mature prairie strips having higher observed nest densities and establishing prairie strips having higher densities once lower detection probabilities were accounted for (Figs. 20-21).

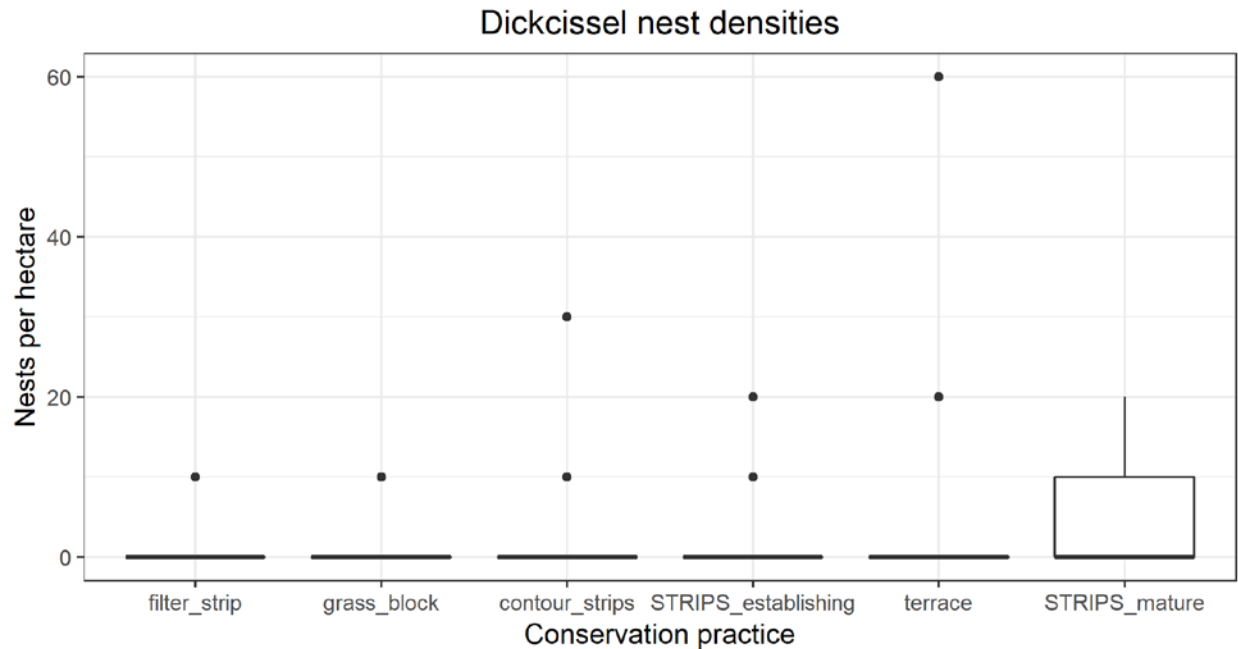


Fig. 20. Dickcissel nests per hectare in six agricultural conservation practices. Nests found during 3951 standardized plot searches were summed over 233 plots and 3 years to form 401 plot-years (n), with some plots searched in multiple years.

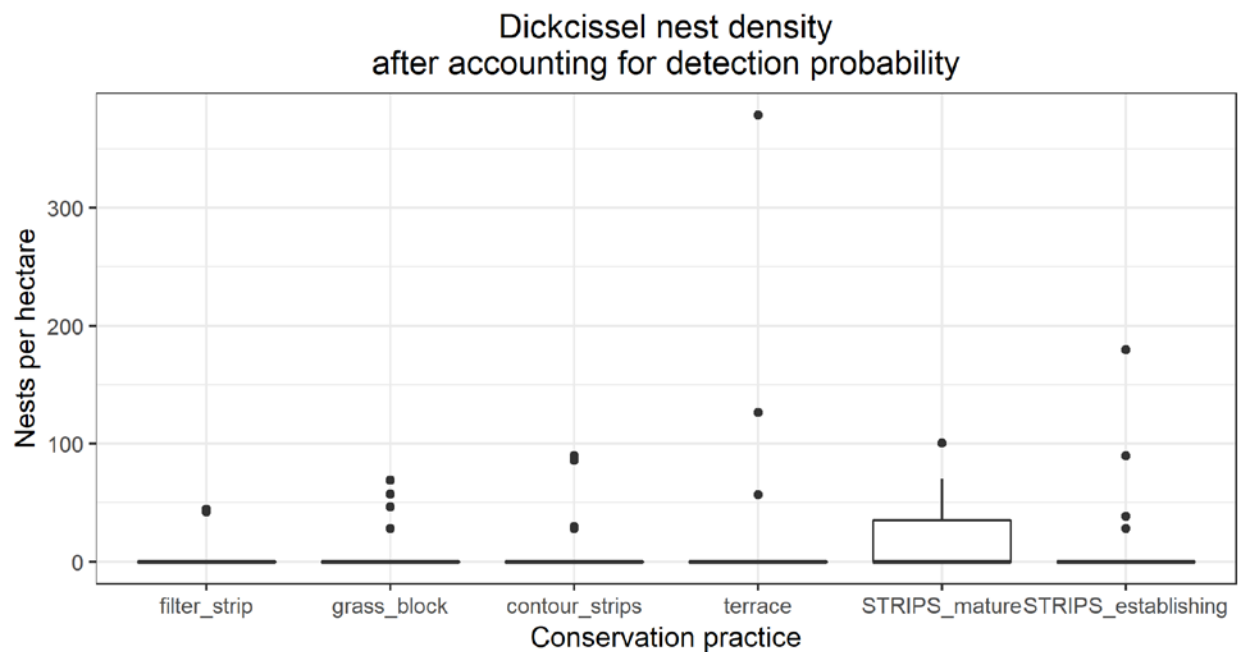


Fig. 21. Dickcissel nests per hectare in six agricultural conservation practices. Nests found during 3951 standardized plot searches were summed over 233 plots and 3 years to form 401 plot-years (n), with some plots searched in multiple years. Raw counts of nests were adjusted with the predicted detection probability for each search plot to give an estimate of the combined number of nests found plus the nests that were not discovered.

Dickcissel nest count per search were used as the response variable in a generalized linear mixed model to determine the combination of environmental variables (Table 3) that best predicted nest counts (Equation 6). The model that best described dickcissel nest density included fixed effects for week of year, plus week of year squared, plus the width of the feature containing the search plot, plus the vegetation diversity within the search plot, plus the mowing activity within the plot, plus a random effect for site.

Equation 6. The best supported model of nests found per search for dickcissels during 3951 plot searches of 233 plots over 3 field seasons including 6 conservation practice treatments. The response variable was the raw area-adjusted count of new dickcissel nests found during each plot search. The week and week² variables form a quadratic expression for the week of the year each search was conducted in, feature width was the minimum width of perennial vegetation surrounding the center of the plot, vegetation diversity was the Shannon-Wiener diversity index for vegetation in the plot, mowing activity was the number (0-9) of vegetation sampling points within the plot that had been mowed by late July, and site was a random effect. All variables were scaled but not centered. An offset for search plot area was used to correct for terrace plots, which were half the area of other treatment types.

$$\text{Nest count} \sim \text{week} + \text{week}^2 + \text{feature width} + \text{vegetation diversity} + \text{mowing activity} + (1|\text{site})$$

The best supported model for dickcissel nest density included a random effect for site. It was well estimated with a non-zero variance (Table 6).

Table 6. Summary of random effects in the best supported model of dickcissel nest counts.

Random effects	Name	Variance	Std. Dev.
site_abbreviation	(Intercept)	0.1825	0.4272

The best supported model for dickcissel nest density included fixed effects for the week of year the search was conducted in, plus week squared, plus the width of the perennial vegetation at the center of the plot, plus the Shannon-Wiener diversity index of vegetation within the plot, plus the mowing activity within the plot, plus an intercept (Table 7). Week of year plus week of year squared had a positive, then negative effect on count of nests found during a search, feature width had a negative effect on nest count, vegetation diversity had a positive effect, and mowing activity had a negative effect. All fixed effect variables were well estimated, and statistically significant at the $p = 0.05$ level.

Table 7. Summary of fixed effects in the best supported model of dickcissel nest counts. All fixed effects and the intercept were well estimated and had p-values $<< 0.05$.

Fixed effects	Estimate	Std.	z	Pr(> z)	Stat. sig.
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		Error	value		
(Intercept)	-53.38629	9.37533	-5.694	0.00000001	***
week_of_year_scaled	80.70955	18.23432	4.426	0.00000959	***
week_of_year_sq_scaled	-39.14252	9.10928	-4.297	0.00001730	***
feature_width_at_plot_meters_scaled	-0.83602	0.30894	-2.706	0.00680800	**
shannon_wiener_all_scaled	0.87478	0.23055	3.794	0.00014800	***
mowing_index	-0.16204	0.05518	-2.937	0.00331600	**

The week of the season each plot search was conducted in had a quadratic effect on the number of dickcissel nests counted. Fig. 22 shows the single-search nest count per hectare, with points showing measured values and a trend-line showing the mean predicted density by search week.

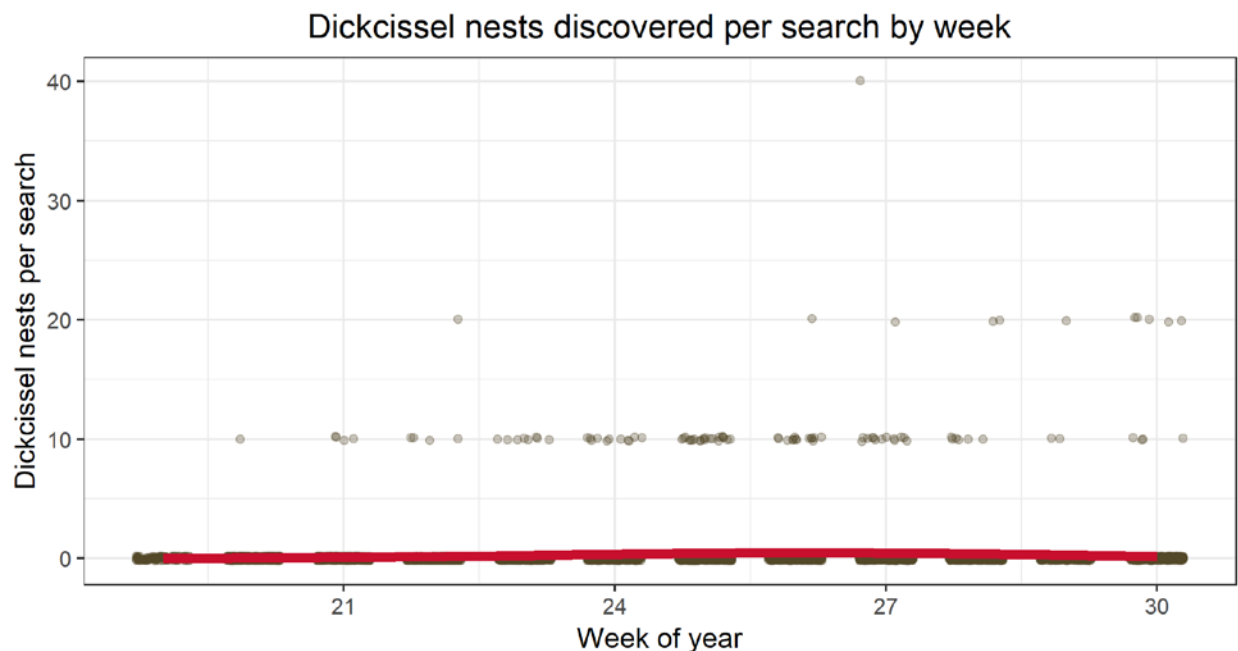


Fig. 22. Dickcissel nests per hectare per search plotted by week of the year. Each dot represents the count of nests found during each of 3951 searches of 233 plots over 3 field seasons. Their positions have been jittered to limit over-plotting. The red line shows a smoothed linear function of the predicted number of new nests per search using the best supported model of nest counts presented in Equation 6. The majority of plot searches resulted in no new nests discovered, so the bulk of the data points are jittered around the zero value on the y-axis.

Width of perennial vegetation at the plot had a negative effect on the number of dickcissel nests counted during each plot search, with narrower features having higher nest densities. Fig. 23 shows the whole-season nest count per hectare, with points showing measured values and a trend-line showing the mean predicted density for all observed feature widths. Plots with average feature width values for mature prairie strips (40.1 m) had 0.94 times as many

dickcissel nests as plots with feature width values average for contour buffer strips (24.4 m), with all other covariate values held equal.

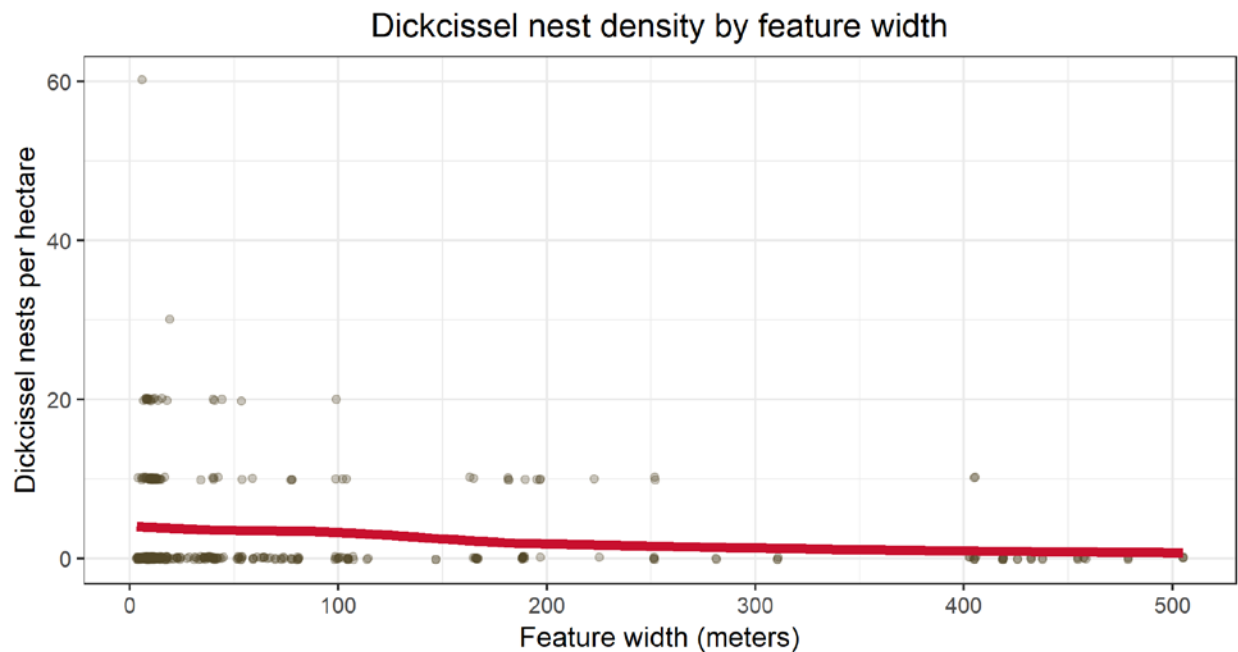


Fig. 23. Dickcissel nests per hectare found during a single season plotted against minimum feature width at the center of each search plot. Dots represent each of 401 plot-years of 233 plots searched over 3 field seasons, with some plots searched in multiple years. Positions have been jittered to limit over-plotting. The red line is a smoothed function of the number of nests per hectare for each plot-year predicted by the best supported model presented in Equation 6.

The Shannon-Wiener vegetation diversity within the plot had a positive effect on the number of dickcissel nests counted during each plot search. Fig. 24 shows the whole-season nest count per hectare, with points showing measured values and a trend-line showing the mean predicted density for all observed diversity index values. Plots with average Shannon-Wiener index values for mature prairie strips (1.16) had 1.76 times as many dickcissel nests as plots with diversity index values average for contour buffer strips (0.57), with all other covariate values held equal.

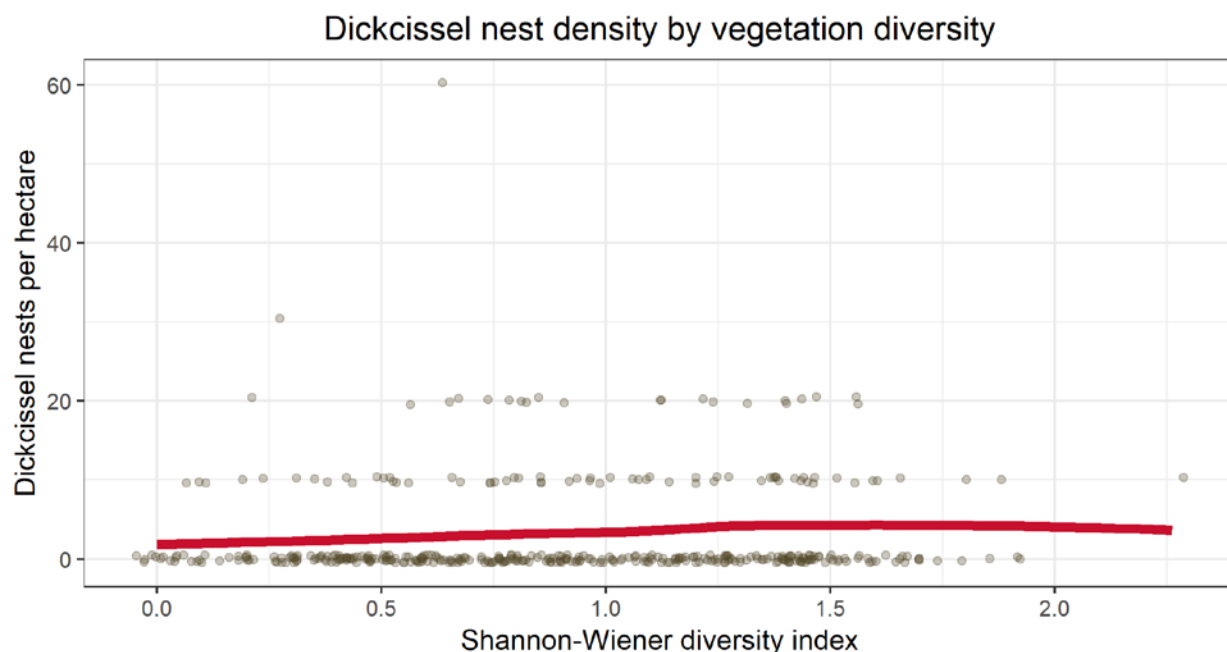


Fig. 24. Dickcissel nests per hectare found during a single season plotted against the Shannon-Wiener plant diversity index for each search plot. Dots represent each of 401 plot-years of 233 plots searched over 3 field seasons, with some plots searched in multiple years. Positions have been jittered to limit over-plotting. The red line is a smoothed function of the number of nests per hectare for each plot-year predicted by the best supported model presented in Equation 6.

Mowing activity within the plot had a negative effect on the number of dickcissel nests counted during each plot search. Mowing index was the number of vegetation sampling points (0-9) within the plot that had been mowed by late July. Fig. 25 shows the whole-season nest count per hectare, with points showing measured values and a trend-line showing the mean predicted density for all observed mowing index values. Plots with average mowing index values for mature prairie strips (0.06) had 0.99 times as many dickcissel nests as plots with mowing index values average for contour buffer strips (0.00), with all other covariate values held equal.

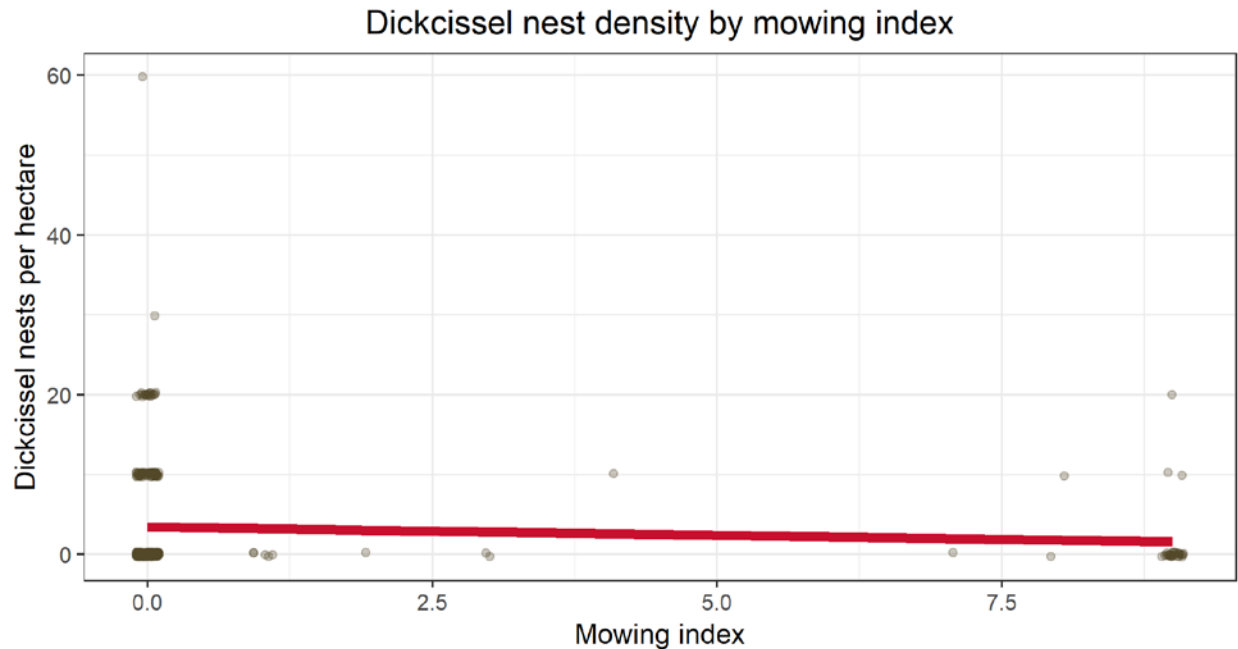


Fig. 25. Dickcissel nests per hectare found during a single season plotted against the number of vegetation sampling points in each plot that had been mowed by late July (0-9). Dots represent each of 401 plot-years of 233 plots searched over 3 field seasons, with some plots searched in multiple years. Positions have been jittered to limit over-plotting. The red line is a smoothed function of the number of nests per hectare for each plot-year predicted by the best supported model presented in Equation 6.

Overall, prairie strip plots had 1.76 times as many dickcissel nests as contour buffer strip plots, for plots that are not mowed and have a moderate width (10.0 m).

Vesper Sparrow

Vesper sparrows construct nests on the ground, typically next to or underneath a living plant or plant litter. They will nest in areas ranging from barren crop fields to dense prairie strips. Their nests are very cryptic and the female often sticks tight to the nest before flushing, limiting the behavioral cue opportunities to locate nests. We found both raw and detection-probability-adjusted vesper sparrow nest densities were highest in establishing prairie strips, followed by low diversity contour strips (Figs. 26-27).

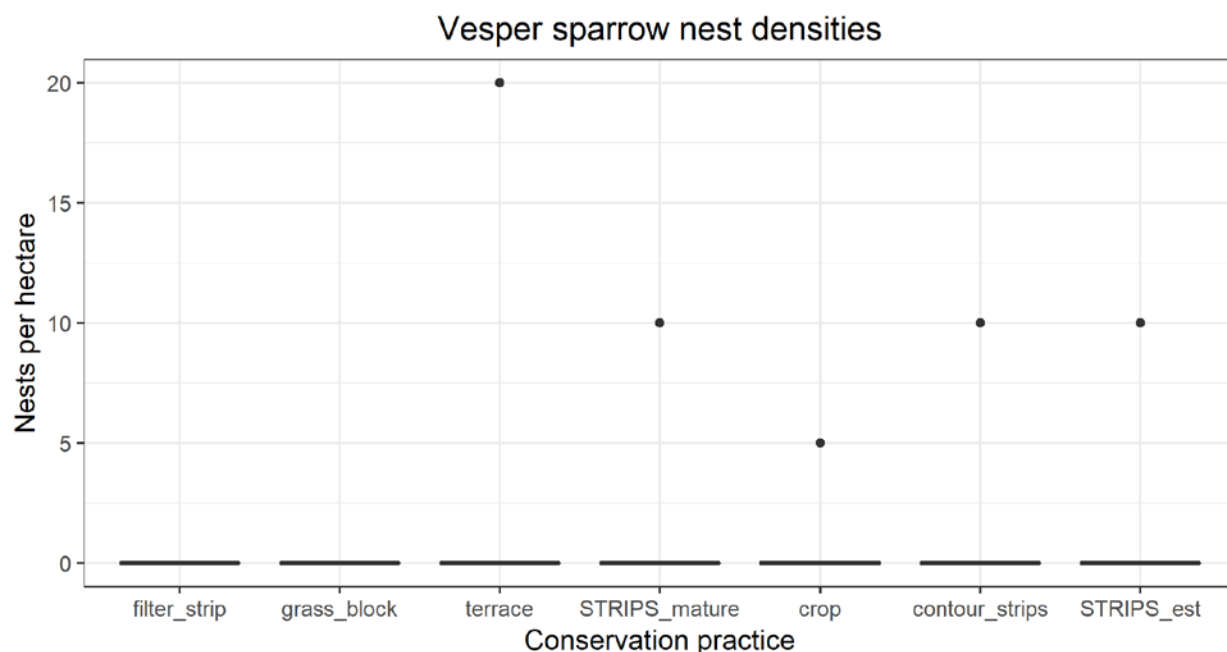


Fig. 26. Vesper sparrow nests per hectare in seven agricultural conservation practices. Nests found during 4570 standardized plot searches were summed over 300 plots and 3 years to form 483 plot-years (n), with some plots searched in multiple years.

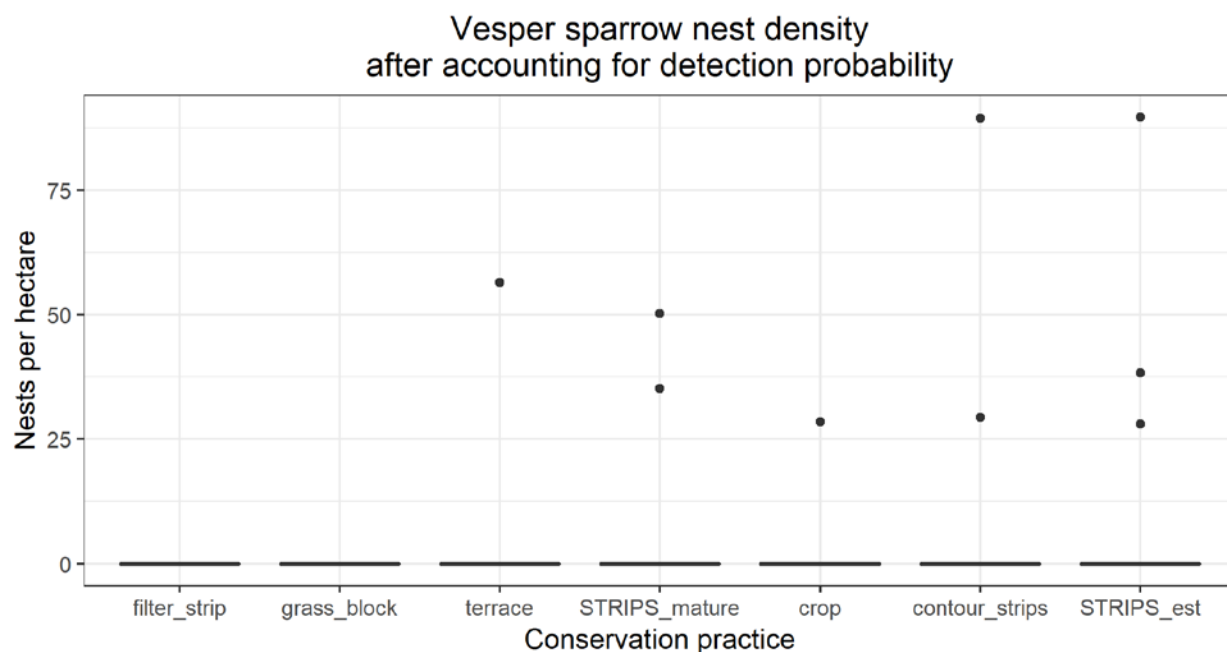


Fig. 27. Vesper sparrow nests per hectare in seven agricultural conservation practices. Nests were found during 4570 standardized plot searches were summed over 300 plots and 3 years to form 483 plot-years (n), with some plots searched in multiple years. Raw counts of nests were adjusted with the predicted detection probability for each search plot to give an estimate of the combined number of nests found plus the nests that were not discovered.

Vesper sparrow nest count per search were used as the response variable in a generalized linear mixed model to determine the combination of environmental variables (Table 3) that best predicted nest counts (Equation 7). The model that best described vesper sparrow nest density included fixed effects for week of year, plus the natural logarithm of the width of the feature containing the search plot, plus the visual obstruction reading within the plot, plus the vegetation diversity within the plot, plus a random effect for conservation practice.

Equation 5. The best supported model of nests found per search for vesper sparrows

during 4570 plot searches of 300 plots over 3 field seasons including 7 conservation practice treatments. The response variable was the raw area-adjusted count of new vesper sparrow nests found during each plot search. The week variable is the week of the year each search was conducted in, log feature width was the natural logarithm of the minimum width of perennial vegetation surrounding the center of the plot, VOR was a measure of vegetation density within the plot, vegetation diversity was the Shannon-Wiener diversity index for vegetation in the plot, and conservation practice was a random effect. All variables were scaled but not centered. An offset for search plot area was used to correct for crop and terrace plots, which were double and half the area of other treatment types respectively.

$$\text{Nest count} \sim \text{week} + \log(\text{feature width}) + \text{VOR} + \text{vegetation diversity} + (1|\text{conservation practice})$$

The best supported model for vesper sparrow nest density included a random effect for conservation practice. It was well estimated with a non-zero variance (Table 8).

Table 8. Summary of random effects in the best supported model of nest counts.

Random effects	Name	Variance	Std. Dev.
conservation_practice	(Intercept)	0.2665	0.5163

The best supported model for vesper sparrow nest density included fixed effects for the week of year the search was conducted in, plus the natural logarithm of the width of the perennial vegetation at the center of the plot, plus the visual obstruction reading within the plot, plus the Shannon-Wiener diversity index of vegetation within the plot, plus an intercept (Table 9). Week of year had a negative effect on count of nests found during a search, log feature width had a negative effect on nest count, vegetation density had a positive effect, and vegetation diversity had a positive effect. Most fixed effect variables were well estimated, and statistically significant at the $p = 0.05$ level, with the exception of Shannon-Wiener diversity index ($p = 0.05510$).

Table 9. Summary of fixed effects in the best supported model of vesper sparrow nest counts. Fixed effects and the intercept were well estimated and had p-values < 0.05, with the exception of shannon_wiener_all_scaled, which was marginally significant at $p=0.05510$.

Fixed effects	Estimate	Std. Error	z value	Pr(> z)	Stat. Sig.
(Intercept)	-8.3875	2.1092	-3.977	0.0000699	***
week_of_year_scaled	-4.3570	1.9459	-2.239	0.02516	*
feature_width_at_plot_meters_log_scaled	-2.2432	0.8868	-2.530	0.01142	*
vor_final_mean_scaled	1.2327	0.3940	3.128	0.00176	**
shannon_wiener_all_scaled	1.0163	0.5298	1.918	0.05510	.

The week of the season each plot search was conducted in had a negative effect on the number of vesper sparrow nests counted. Fig. 28 shows the single-search nest count per hectare, with points showing measured values and a smoothed trend-line showing the mean predicted density by search week.

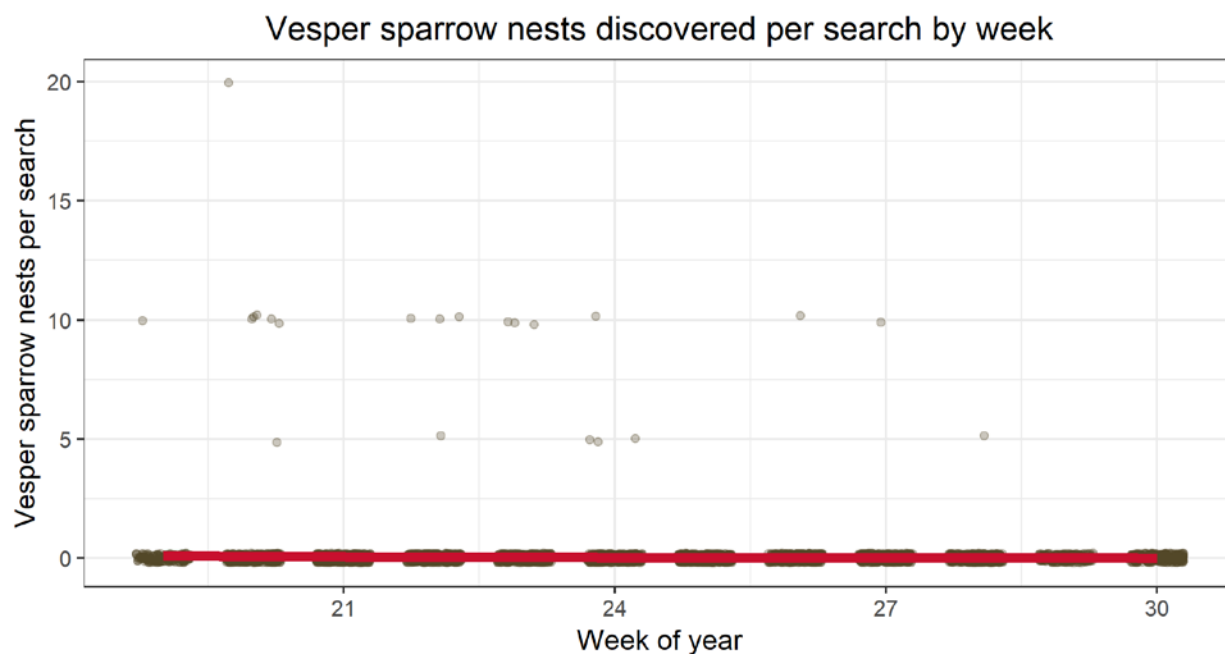


Fig. 281. Vesper sparrow nests per hectare per search plotted by week of the year. Each dot represents the count of nests found during each of 4,570 searches of 300 plots over 3 field seasons. Their positions have been jittered to limit over-plotting. The red line shows a smoothed linear function of the predicted number of new nests per search using the best supported model of nest counts presented in Equation 7.

The width of the perennial vegetation at the center of the plot had a logarithmic negative effect on the number of vesper sparrow nests per hectare over the course of each season. Fig. 29 shows the whole-season nest count per hectare, with points showing measured values and a smoothed trend-line showing the mean predicted density for all feature width values. Plots with perennial vegetation widths average for mature prairie strips (26.4 m) had 0.77 times as

many vesper sparrow nests as plots with perennial vegetation widths average for contour buffer strips (16.5 m), with all other covariate values held equal.

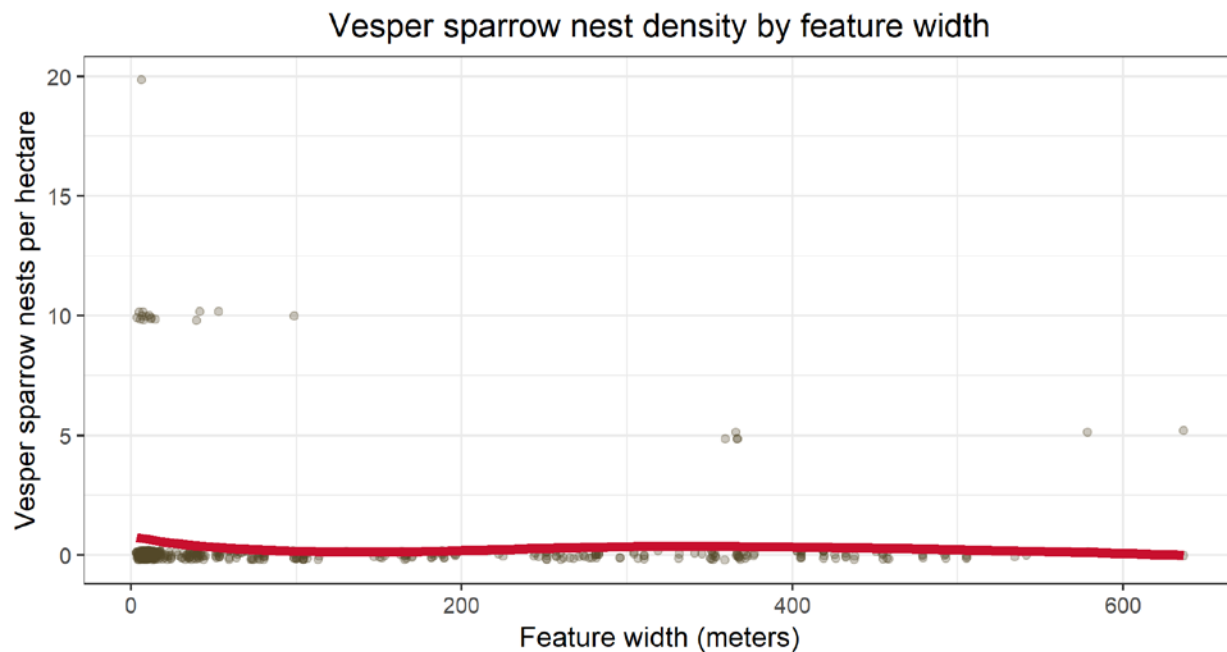


Fig. 29. Vesper sparrow nests per hectare found during a single season plotted against minimum feature width at the center of each search plot. Dots represent each of 483 plot-years of 300 plots searched over 3 field seasons, with some plots searched in multiple years. Positions have been jittered to limit over-plotting. The red line is a smoothed function of the number of nests per hectare for each plot-year predicted by the best supported model presented in Equation 7.

The vegetation density measured as visual obstruction reading within the plot had a negative effect on the number of vesper sparrow nests per hectare over the course of each season. Fig. 30 shows the whole-season nest count per hectare, with points showing measured values and a smoothed trend-line showing the mean predicted density for all vegetation density values. Densities of greater than 200 were typically mature corn fields, which had a much greater change in VOR over the course of the season than did prairie strips or other perennial vegetation. Plots with vegetation densities average for mature prairie strips (78.8 cm) had 1.58 times as many vesper sparrow nests as plots with vegetation densities average for contour buffer strips (45.1 cm), with all other covariate values held equal.

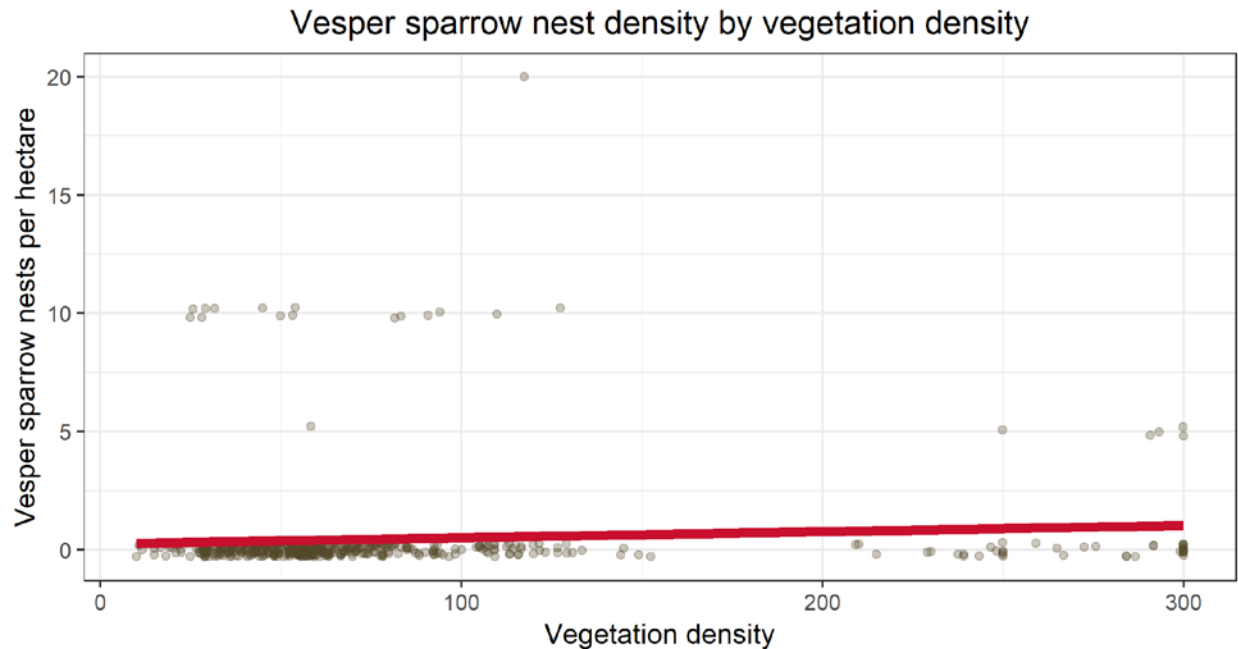


Fig. 30. Vesper sparrow nests per hectare found during a single season plotted against the vegetation density of each search plot. Dots represent each of 401 plot-years of 233 plots searched over 3 field seasons, with some plots searched in multiple years. Positions have been jittered to limit over-plotting. The red line is a smoothed function of the number of nests per hectare for each plot-year predicted by the best supported model presented in Equation 7.

The Shannon-Wiener vegetation diversity index within the plot had a positive effect on the number of vesper sparrow nests per hectare over the course of each season. Fig. 31 shows the whole-season nest count per hectare, with points showing measured values and a smoothed trend-line showing the mean predicted density for all observed diversity index values. Plots with average Shannon-Wiener index values for mature prairie strips (1.16) had 1.94 times as many vesper sparrow nests as plots with diversity index values average for contour buffer strips (0.57), with all other covariate values held equal.

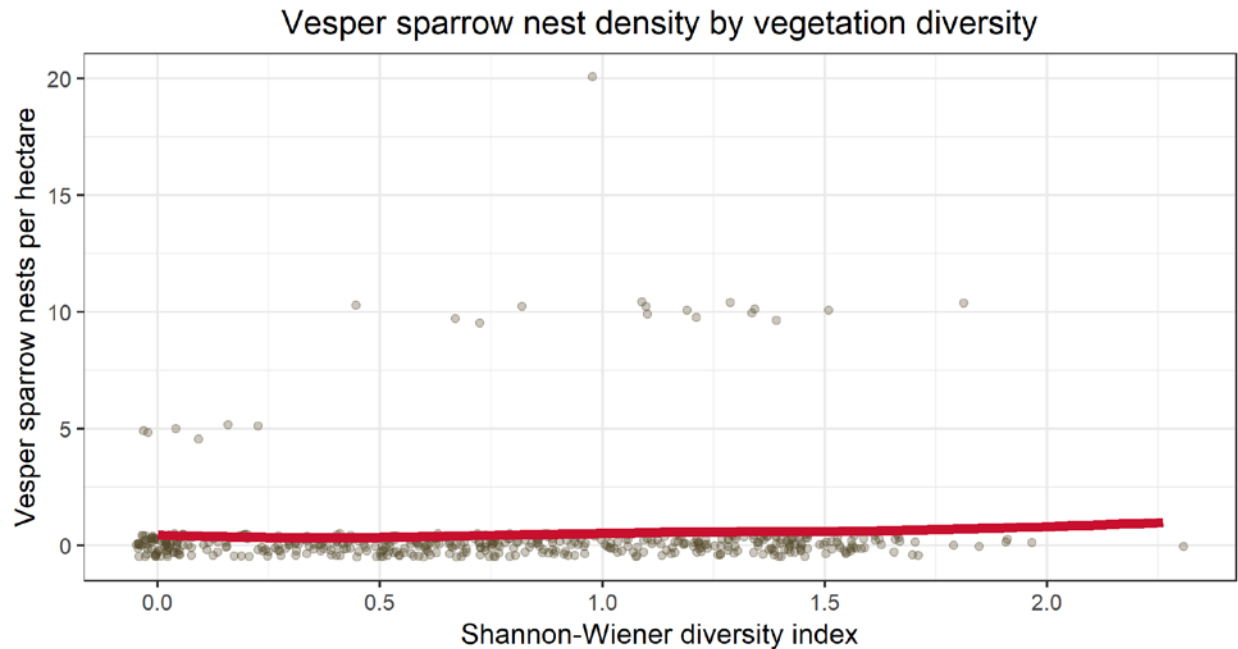


Fig. 31. Vesper sparrow nests per hectare found during a single season plotted against the Shannon-Wiener plant diversity index for each search plot. Dots represent each of 483 plot-years of 300 plots searched over 3 field seasons, with some plots searched in multiple years. Positions have been jittered to limit over-plotting. The red line is a smoothed function of the number of nests per hectare for each plot-year predicted by the best supported model presented in Equation 7.

Plots with a vegetation density (78.8 cm) and diversity (1.16) typical for mature prairie strips had 3.07 times more nests than plots with vegetation density (45.1 cm) and diversity (0.57) typical for contour buffer strips, holding width of perennial vegetation equal (10.00 m).

Objective 3. Determine Impact of Habitat Configuration and Management

When comparing typical contour buffer strips to prairie strips, we found evidence to support higher nest daily survival rates and higher nest densities in mature prairie strips than in contour buffer strips. Bird species have higher daily survival rates in areas where there are more native plant species, intermediate or low vegetation densities, higher percentages of diverse vegetation on the landscape, and less mowing activity.

We hypothesize that higher plant diversity allows birds a larger selection of suitable nesting sites, resulting in nests that are better concealed and built in sturdier vegetation. This makes nests less susceptible to location by predators and nest parasites and possibly better protected from severe weather. Intermediate or low vegetation densities might allow higher nest survival than very dense vegetation because after vegetation diversity is accounted for, the densest vegetation types tended to be monoculture stands of reed canary grass and Canada thistle,

both of which are susceptible to falling over and dumping the nest contents, especially for nests with large nestlings in them.

Since mowing activity can be a direct source of mortality for bird nests, it is not surprising that increased mowing activity results in a decrease of daily survival rate of nests. However it is worth noting that mowing does not always result in nest failure, especially when the land manager has the mowing deck set high off the ground for the purpose of prairie stand establishment. In some of those cases, mowing may be an indirect source of mortality by exposing the nest and increasing subsequent predation risk or risk of failure due to exposure, but this is not always the case.

Some of the variables investigated that were not found to influence nest survival included distance to a hard habitat edge, width of perennial vegetation, and perimeter-area-ratio of the habitat patch. While measures of habitat fragmentation did not have a measurable effect on daily survival rate, it is possible that an effect was present but was too weak for us to detect at current sample sizes.

We found that nest densities were also similar-to or higher in prairie strips compared to contour buffer strips. Nest densities were higher in areas closer to water, in narrower perennial vegetation, with denser vegetation, and with more diverse vegetation. Red-winged blackbirds are a generalist species that closely associate with streams, wetlands, and other wet areas. Distance to water seemed to be the only strong effect on their nest density, despite evidence that other factors had a stronger effect on their nest survival. Both dickcissels and vesper sparrows had higher nest density in narrower conservation features. One possible explanation for this could be that limited habitat availability in the surrounding landscape requires birds to squeeze into smaller areas to find a suitable place to nest. This is somewhat concerning, since it seems this might lead to narrow habitat strips becoming ecological traps; however, our nest survival data indicate that nest survival was not effected by feature width. We will continue to investigate the relationship between habitat fragmentation, nest density, and nest survival.

Nest density was higher in areas with more dense vegetation. Areas with higher vegetation density should offer more nest-building locations simply by virtue of there being more vegetation to build nests in. A typical example of a low-vegetation-density plot would be a smooth brome grass monoculture or an area that had been previously mowed. Either of those examples would provide few suitable nest-building locations compared to a dense mature prairie strip or a dense patch of thistles.

Nest density was also higher in areas with more diverse vegetation. We expect this is due to an abundance of suitable nest-building locations in a diverse prairie strip compared to a contour buffer strip. For red-winged blackbirds and dickcissels, suitable nesting locations in contour buffer strips tend to be limited to small shrubs, thistles, Queen Anne's lace (*Daucus carota*), or other weedy plant species that are stiff enough to support the weight of a nest. As these species are typically not considered desirable in a contour buffer strip, they are actively

removed. In contrast, a search plot in a prairie strip could contain dozens-to-hundreds of suitable nest-building locations in desirable plants such as grey-headed coneflower, little bluestem, or rosinweed.

To better address the concern that narrow prairie strips may represent an ecological trap for nesting birds, further investigation is needed. Some of our findings and non-findings appear to contradict historical habitat studies. Our data suggest that prairie strips function differently than typical farmland habitats, likely because of differences in vegetation composition and structure. With more data and further analysis we may be able to gain insights into some of these processes.

Additional Project Outputs

Manuscripts in Review and Preparation

1. Martin-Schwarze, A. 2017. Extending removal and distance-removal models for abundance estimation by modeling detections in continuous time. Ph.D. Dissertation, Iowa State University, Ames, Iowa, https://www.nrem.iastate.edu/research/STRIPS/files/publication/martinschwarzeadam_2017_dissertation.pdf
2. Stephenson, MD. 2017. Quantifying methods to improve statistical power in grassland and passerine bird nesting studies. M.S. thesis, Iowa State University, Ames, Iowa. http://www.nrem.iastate.edu/research/STRIPS/files/publication/stephenson_2017_msthesis.pdf.
3. Stephenson, MD, LA Schulte, RW Klaver. In press. Quantifying thermal imager effectiveness for detecting bird nests on farms. Wildlife Society Bulletin.
4. Stephenson, MD, LA Schulte, RW Klaver, J Niemi. In preparation. iButton® temperature data loggers increase sample size and precision when estimating daily survival rate for bird nests. Methods in Ecology and Evolution.

Blog Posts

1. Rhinehart, C. 2018. My reflections on a summer field research experience as a developing wildlife professional. <https://www.nrem.iastate.edu/landscape/blog/cory-rhinehart/my-reflections-summer-field-research-experience-developing-wildlife-professional>
2. Stephenson, M.D. 2017. Improving the statistical power of grassland and passerine bird nesting studies: testing two new technologies: <https://www.nrem.iastate.edu/landscape/content/improving-statistical-power-grassland-and-passerine-bird-nesting-studies-testing-two-new>.

Presentations

1. Brandes, E., G. McNunn, L Schulte Moore, E Heaton, A VanLoocke, A Plastina, D Muth. 2017. Ecologic and economic modeling to identify win-wins for nutrient conservation and farmer profitability in agricultural landscapes. Presented Aug. 10th at the Ecological Society of American Annual Meeting, Portland, OR; 25 participants. *(oral)*
2. Dale, J, M Stephenson, L Schulte Moore, and R Klaver. 2016. Bird use of agricultural buffer strips. Midwest Fish and Wildlife Conference, Grand Rapids, Michigan. *(poster)*
3. Dale, J, M Stephenson, L Schulte Moore, R Klaver. 2017. Estimating the effect of perennial vegetation in an agricultural landscape on grassland birds. Midwest Fish and Wildlife Conference, Lincoln, Nebraska; 40 participants. *(oral)*
4. Dale, J, M Stephenson, L Schulte Moore, and R Klaver. 2016. Bird use of agricultural buffer strips. STRIPS Cooperators' meeting, Whiterock Conservancy, Coon Rapids, Iowa; 38 participants. *(poster)*
5. Dale, J, L Schulte Moore, R Klaver. 2017. Human observers vs autonomous recording units: a comparison of two avian research methods. Midwest Fish and Wildlife Conference, Lincoln, Nebraska. *(poster)*
6. Dale, J, M Stephenson, C Labuzzetta, L Schulte Moore, B Klaver, A Janke. 2017. Estimating the effect of perennial vegetation in an agricultural landscape on grassland birds. Presented Sept. 26th at the 24th Annual Conference of The Wildlife Society, Albuquerque, New Mexico; 35 attendees. *(oral)*
7. Giese, J, L Schulte, RW Klaver. 2018. Prairie strips in agriculture: impacts on grassland birds. Annual meeting of the Ornithological Society of America, Tucson, AZ; 40 attendees. *(oral)*
8. Harris, M., M Helmers, L Schulte Moore. 2017. Blurring the lines between working and conservation lands: enhancing bird and pollinator habitat along with water quality using prairie strips. Presented 25 May on a USDA Farm Service Agency webinar. Available at: <https://vimeo.com/220061177>; 23 participants *(webinar)*
9. Heaton, E, L Schulte Moore, I Gronstal Anderson, T Richards, D Muth. 2017. Advancing the bioeconomy: examples of success and opportunities in Iowa and beyond. Presented July 14th at USDA, Washington, DC; 15 participants. *(invited oral)*
10. Kolka, R, L Schulte Moore, and M Helmers. 2017. Science-based trials of rowcrops integrated with prairie strips (STRIPS): Incorporating prairies into agriculture. Minnesota Wetlands Conference, Minneapolis, MN. *(invited oral)*
11. O'Neal, M, L. Schulte Moore. 2017. Ten years of STRIPing at ISU leads to the delivery of multiple ecosystem services. Presented Sept. 25th in the Department of Entomology seminar, Iowa State University, Ames, IA; 20 participants. *(invited oral)*
12. Rentz, M, L Schulte Moore, M Helmers, M Liebman, J Arbuckle, M Harris, J Neal, J. Tyndall, T Youngquist. 2016. Prairie strips from research to adoption. Presented July 18 North American Congress for Conservation Biology, Madison, Wisconsin; 50 participants. *(invited oral)*

13. Schulte Moore, L.A., M. Helmers, M. Liebman and 18 additional authors. 2015. STRIPS: Science-based trials of Rowcrops Integrated with Prairie Strips. Minnesota Department of Natural Resources, St. Paul, Minnesota; 17 participants. *(invited oral)*
14. Schulte Moore, L.A., M. Helmers, M. Liebman and 18 additional authors. 2015. Prairie strips as a cost-effective way to achieve on-and off-farm conservation goals. Iowa Soybean Association Research Conference, Ames, Iowa; ~30 participants. *(invited oral)*
15. Schulte Moore, L.A. 2015. Prairie STRIPS. Iowa Soil and Water Conservation Society Meeting, Prairie City, Iowa; ~30 participants. *(invited oral)*
16. Schulte Moore, L.A. 2015. Tweak, adapt, transform: harnessing the power of prairie for agriculture in Iowa and beyond. Iowa Prairie Conference, Cedar Falls, Iowa; ~200 participants. *(keynote)*
17. Schulte Moore, L.A., M. Helmers, M. Liebman and 18 additional authors. 2015. Prairie STRIPS: from research to action. Iowa State University Department of Plant Pathology Seminar, Ames, Iowa; ~40 participants. *(invited oral)*
18. Schulte Moore, L and the STRIPS team. 2016. Harnessing the power of prairie for agriculture and more. US Botanical Garden, Washington, DC; ~30 participants. *(invited oral)*
19. Schulte Moore, L and the STRIPS team. 2016. Prairie strips as an innovative agroecosystem practice to enhance ecosystem services from farmers' fields. USDA National Institute for Food and Agriculture, Washington, DC; ~15 participants. *(invited oral)*
20. Schulte Moore, L. 2016. Strategic integration of perennials into Iowa agriculture. Meeting with The Nature Conservancy's Climate, Global Lands, and Mississippi River teams, Iowa State University, Ames and Eagle Grove, Iowa; ~15 participants. *(invited oral)*
21. Schulte Moore, L and the STRIPS team. 2016. Who said prairie and corn don't mix? Strategic integration of native plants to improve ecosystem services from agriculture. Natural Capital Symposium and Training, Palo Alto, California; ~75 participants. *(invited oral)*
22. Schulte Moore, L and the STRIPS team. 2016. Prairie STRIPS on the farm. Raccoon River Watershed Association meeting, Perry, Iowa; ~75 participants. *(invited oral)*
23. Schulte Moore, L and the STRIPS team. 2016. Prairie STRIPS. Iowa Chapter of The Wildlife Society meeting, Ames, Iowa; ~100 participants. *(invited oral)*
24. Schulte Moore, L and the STRIPS team. 2016. Prairie STRIPS: from research to action. Utah State University, Logan, Utah; ~45 participants. *(invited oral)*
25. Schulte Moore, L. 2016. Tweak, adapt, transform: growing a resilient agriculture in Iowa and beyond Utah State University, Logan, Utah; ~90 participants. *(invited oral)*
26. Schulte Moore, L and the STRIPS team. 2016. Prairie strips for soil health and more. Soil Health Conference, Ames, Iowa; ~70 participants. *(invited oral)*
27. Schulte Moore, L. 2016. Prairies for nutrient reduction and more. Presented August 24, 2016 at the grand opening of Roeslein Alternative Energy, Smithfield Foods, Princeton, Missouri; 120 participants. *(invited oral)*

28. Schulte Moore, L. 2016. Prairie strips for farm soil, nutrient, and wildlife conservation. Presented July 13 at the ISU Extension Crop Management Clinic, Boone, Iowa; 40 participants. *(invited oral)*
29. Schulte Moore, L. 2016. Protecting soil and water with strips of native prairie. Presented June 23 at the U.S. Dirksen Senate Office Building, Washington, DC; 25 participants. *(briefing)*
30. Schulte Moore, L. 2016. Protecting soil and water with strips of native prairie. Presented June 23 at the U.S. Longworth House Office Building, Washington, DC; 30 participants. *(briefing)*
31. Schulte Moore, L. 2017. Prairie STRIPS, Iowa Weed Commissioners Invasive Species Conference, Ames, IA; 150 participants. *(invited oral)*
32. Schulte Moore, L. 2017. Enhancing agroecosystem performance and resilience with perennials. Production Agriculture Symposium, University of Minnesota, St. Paul, MN; 200 participants. *(oral keynote)*
33. Schulte Moore, L and STRIPS team. 2016. Prairie STRIPS: from research to action. Seminar series at the Institute at Brown for Environment and Society, Brown University, Providence, Rhode Island; 50 participants. *(invited oral)*
34. Schulte Moore, L and STRIPS team. 2016. Prairie STRIPS: from research to action. Seminar series in the School of Natural Resources, University of Nebraska, Lincoln, Nebraska; 25 participants. *(invited oral)*
35. Schulte Moore, L. 2016. Tweak, adapt, transform: growing a resilient agriculture in Iowa. Iowa Community College Biology Teachers' Association. Central Iowa Community College, Fort Dodge, Iowa; 30 participants. *(invited oral)*
36. Schulte Moore, L. 2017. Ten years of prairie strips webinar. Presented March 1 Eastern on a Tallgrass Prairie and Big Rivers Landscape Conservation Cooperative webinar. Available at: <https://tallgrassprairielcc.org/resources#/webinar?page=0>; 45 participants. *(webinar)*
37. Schulte Moore, L. 2017. Prairie STRIPS. Presented 2 March 2017 to the Iowa Weed Commissioners Invasive Species Conference, Ames, Iowa; 150 participants. *(invited oral)*
38. Schulte Moore, L. 2017. Prairie for soil health, nutrient reduction, habitat, and farm profitability. Presented 7 April 2017 to the Missouri State Office of the USDA Natural Resource Conservation Service, Columbia, Missouri; 14 participants. *(invited oral)*
39. Schulte Moore, L. 2017. STRIPS at Neal Smith National Wildlife Refuge. Presented 17 May 17 to Farm (POL 416) class from Furman University, Greenville, South Carolina; 10 participants. *(invited oral)*
40. Schulte Moore, L. 2017. STRIPS at Neal Smith National Wildlife Refuge. Presented 17 May 2017 to Field Ecology of Iowa (BI 348) class from Wartburg College, Waverly, Iowa; 15 participants. *(invited oral)*

41. Schulte Moore, L. 2017. Prairie STRIPS. Presented 25 May 2017 to visitors at the Iowa State University BioEconomy Institute, Ames, Iowa; 5 participants. (*invited oral*)
42. Schulte Moore, L. 2017. Prairie STRIPS. Presented 29 June to the Iowa State University BioEconomy Institute, Ames, Iowa; 5 participants. (*invited oral*)
43. Schulte-Moore, L. and R. Benedict. Can prairies and agriculture co-exist? A tale of two projects. Presented 14 July 2017 at the 2017 Iowa Prairie Conference, Council Bluffs, Iowa; 40 participants. (*invited oral*)
44. Schulte Moore, L. 2017. Your farm as an ecosystem. Presented July 27th at the Saving our Iowa Legacy (SOIL) Conference at Drake University, Des Moines, IA; 50 participants. (*invited oral*)
45. Schulte Moore, L. 2017. Prairie STRIPS: small changes, big impacts. Presented Aug. 1st at the Sand County Foundation stakeholder meeting, Madison, WI; 15 participants. (*invited oral*)
46. Schulte Moore, L. 2017. Prairie STRIPS: small changes, big impacts. Presented Aug. 2nd at the Doudlah Farms field day. Doudlah Farms Organic Field Day, Evansville, Wisconsin; 150 participants. (*invited oral*)
47. Schulte Moore, L. 2017. Prairie strips improve biodiversity and the delivery of multiple ecosystem services from industrial corn-soybean croplands. Presented Sept. 8th in the Department of Biology seminar, University of Minnesota Duluth, Duluth, MN; 50 participants. (*invited oral*)
48. Schulte, L and STRIPS team. 2017. Prairie STRIPS: from research to action. Presented Oct. 19 at School of the Environment seminar, McGill University, Ste-Anne de Bellevue, Quebec; 60 participants. (*invited oral*)
49. Schulte, L and STRIPS team. 2017. Prairie strips improve biodiversity and the delivery of multiple ecosystem services from corn-soybean croplands. Presented Oct. 22 at USDA National Institute for Food and Agriculture Project Directors' Meeting, Tampa, Florida; 40 participants. (*oral*)
50. Schulte, L. 2017. Iowa's prairie ecosystems. Iowa State University Extension – Master Conservationist program. Available at: <https://www.nrem.iastate.edu/wildlife/week-4-iowa-ecosystems-prairies> and <https://vimeo.com/240158675/a6550cb1c6> (*online education module*)
51. Schulte Moore, L. 2018. A 'how to' guide for researchers engaged in landscape change. Annual Meeting of the US-Chapter of the International Association of Landscape Ecology, Chicago, Illinois; 100 participants. (*plenary*)
52. Schulte Moore, L. 2018. Lightening talk for the New Carbon Economy Consortium. Bioeconomy Institute, Iowa State University, Ames, Iowa; 30 participants. (*oral*)
53. Schulte Moore, L and STRIPS team. 2018. Science, conservation, and rural development with prairie STRIPS. USDA National Institute for Food and Agriculture, Washington, DC; 11 participants. (*oral*)

54. Schulte Moore, L, and M Helmers. 2018. What happens when your crop field strips. Iowa Soybean Association Farmer Research Conference, Des Moines, Iowa; 21 participants. *(oral)*
55. Silker, BJ, MD Stephenson, LA Schulte, RW Klaver. 2018. Effect of vegetation composition and structure on daily nest survival in red-winged blackbird (*Agelaius phoeniceus*) and dickcissel (*Spiza americana*) in Iowa. Midwest Fish and Wildlife Conference, Milwaukee, Wisconsin. *(poster)*
56. Stephenson, M, J Dale, L Schulte Moore, and R Klaver. 2016. Avian nest success within agricultural buffer strips. Midwest Fish and Wildlife Conference, Grand Rapids, Michigan. *(poster)*
57. Stephenson, M, J Dale, L Schulte Moore, and R Klaver. 2016. Avian nest success within agricultural buffer strips. Presented August 3 at the STRIPS Cooperators' meeting, Whiterock Conservancy, Coon Rapids, Iowa; 38 participants. *(poster)*
58. Stephenson, M, L Schulte Moore, R Klaver. 2017. Quantifying the impact of thermal data loggers on nest survival and estimation of daily survival rates. Midwest Fish and Wildlife Conference, Lincoln, Nebraska; 25 participants. *(oral)*
59. Stephenson, M, L Schulte Moore, R Klaver. 2017. Quantifying the effectiveness of a thermal imaging device for locating grassland bird nests. Midwest Fish and Wildlife Conference, Lincoln, Nebraska. *(poster)*
60. Stephenson, M, LA Schulte, RW Klaver. 2018. Prairie contour buffer strips serve as bird nesting habitat in Midwestern agricultural landscapes. Midwest Fish and Wildlife Conference, Milwaukee, Wisconsin; 25 attendees. *(oral)*
61. Tyndall, J, JG Arbuckle, P Drobney, MA Harris, MJ Helmers, RK Kolka, M Liebman, ME O'Neal, LA Schulte. 2016. Bridging the conservation lands-working lands divide with a cost-effective strategy to enhance ecosystem services. Midwest Fish and Wildlife Conference, Grand Rapids, Michigan; 50 participants. *(oral)*

News Articles

1. Pheasants Forever Magazine: Summer 2015 issue
2. Parade: <http://parade.com/390582/alisongwinn/earth-day-across-america/>
3. Radish: <http://radishmagazine.com/stories/display.cgi?prcss=display&id=716805>
4. WHO TV: <http://whotv.com/2015/05/19/more-funding-research-for-iowa-prairie/>
5. Iowa Department of Natural Resources Watershed News: <http://www.iowadnr.gov/Environment/WaterQuality/WatershedImprovement/WatershedNews.aspx>
6. The Nature Conservancy's Boone River Program Newsletter: <http://booneriver.org/2015/04/23/boone-river-newsletter-spring-2015/>
7. Ames Tribune: <http://amestrib.com/news/isu-prairie-project-receives-500000-usda-grant>

8. Cedar Rapids Gazette: <http://thegazette.com/subject/news/business/iowa-state-to-study-how-prairie-plants-on-cr-airport-land-stops-farm-runoff-20150522>
9. KCRG News: <http://www.kcrg.com/subject/news/nutrient-runoff-experiment-continues-at-eastern-iowa-airport-20150522>
10. Farm Life Magazine – Summer 2015 issue
11. The Iowa Farm Bureau Federation Spokesman – June 2015 issue
12. Farm News: <http://www.farm-news.com/page/content.detail/id/521224/Lighting-a-spark-for-better-soil.html?nav=5005>
13. Cedar Rapids Gazette: <http://www.thegazette.com/subject/news/business/agriculture/seeing-the-benefits-of-cover-crops-with-radishes-and-rye-20150710>
14. AgriNews: http://www.agrinews.com/news/iowa_news/sloan-reintroduces-strips-of-iowa-prairie-in-crop-fields/article_59acd8f8-db99-5ad9-b049-e6db04df0644.html
15. WHO TV: <http://whotv.com/2015/09/09/strips-program-helps-soil/>
16. Yahoo News: <http://news.yahoo.com/four-ways-farms-could-saves-lives-thousands-fish-200402412.html>
17. The Rock Island Dispatch Argus: http://www.qconline.com/news/local/conference-addresses-declining-bee-population/article_c30492bb-85f9-5809-a077-a8dd3d177d18.html
18. Globe Gazette: http://globegazette.com/business/prairie-strips-program-expands-with-new-grant/article_e2d8f272-09a6-503b-9615-9a481eccae7d.html
19. Lincoln Journal Star: http://journalstar.com/niche/l-magazine/home-and-garden/gardening-for-beneficial-native-bees/article_4f9b8638-f1d4-53a3-8577-e56287586612.html
20. ISSUU: http://issuu.com/farmweek/docs/farmweek_january_5__2015
21. The Non-GMO Report: <http://www.non-gmoreport.com/articles/february-2015/prairie-revival-strips-project-provides-solution-to-agriculture-problems.php>
22. The Organic Center: <http://organic-center.org/uncategorized/lisa-schulte-moore/>
23. Iowa Department of Natural Resources Watershed News: <http://www.iowadnr.gov/Environment/WaterQuality/WatershedImprovement/WatershedSuccesses.aspx>
24. TakePart: <http://www.takepart.com/article/2015/02/03/ag-runoff-drinking-water-pollution-solution>
25. The Washington Post: https://www.washingtonpost.com/national/health-science/iowa-farmers-ripped-out-prairie-now-some-hope-it-can-save-them/2016/08/07/1ff747a2-5274-11e6-88eb-7dda4e2f2aec_story.html

26. The Des Moines Register: <http://www.desmoinesregister.com/story/opinion/editorials/2016/08/13/editorial-restore-bit-iowas-prairie-reap-benefits/88614298/?from=global&sessionKey=&autologin=>
27. Corn and Soybean Digest: <http://www.cornandsoybeandigest.com/conservation/more-prairie-strips-take-root>
28. Knowable Magazine: <https://www.knowablemagazine.org/article/sustainability/2017/whole-food-diet-bees>
29. Harvest Public Media: <http://harvestpublicmedia.org/post/strips-native-prairie-plants-could-reduce-pollution-runoff-farm-fields>
30. High Plains Journal: http://www.hpj.com/crops/iowa-state-university-project-prairie-strips-yield-big-environmental-benefits/article_71eee4d2-9129-5f0f-ae47-53d11acc80d5.html
31. National Geographic: <https://news.nationalgeographic.com/2017/12/iowa-agriculture-runoff-water-pollution-environment/>
32. Wallaces Farmer: <http://www.wallacesfarmer.com/conservation/prairie-strips-viable-conservation-practice>
33. Energy and Environment News: <https://www.eenews.net/stories/1060067497>
34. Iowa State University Daily: http://www.iowastatedaily.com/news/article_4b1e2c04-f8de-11e7-9bc0-6f7aa992cd71.html
35. The Furrow: <https://www.johndeerefurrow.com/2018/02/06/the-place-for-prairie/>
36. CSA News: <https://dl.sciencesocieties.org/publications/csa/articles/63/2/4>
37. Mother Earth News: <https://www.motherearthnews.com/homesteading-and-livestock/sustainable-farming/farming-systems-zm0z18amzphe>
38. Audubon: <https://www.audubon.org/news/on-midwest-farms-prairie-strips-give-grassland-birds-something-sing-about>