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Abstract: Grassland birds have declined in North America more than any other group of birds over the last 25 years. In 2001, the Conservation Reserve Enhancement Program (CREP), a federal farm program, was initiated in 20 counties in southcentral Pennsylvania to address problems with water quality and soil erosion and to provide habitat for grassland and farmland wildlife. The objectives of our study were to determine how avian abundance, diversity, and productivity within CREP fields varied with field size, vegetation characteristics, and the local landscape, and to compare CREP field use and success with hayfields. In Berks, Dauphin, Franklin, Fulton, Montour, Northumberland, Perry, Schuylkill, Snyder, and Union counties, CREP fields were selected randomly in three size categories: <4 ha (small), 7.5 – 12 ha (medium), and >16 ha (large). We also located hayfields near the CREP fields. We surveyed birds in all fields and nest-searched in a sub-sample of fields. During 2001-2003, we monitored 800 nests of 19 species in 75 fields within 6 counties (Dauphin, Montour, Perry, Schuylkill, Snyder, and Union). Relative abundance of nests and nest success did not differ with field size. Birds nesting in CREP fields had a higher nest success rate than those nesting in hayfields. Obligate grassland species nested more frequently on large, rather than medium or small fields. Nest success did not differ with distance of the nest from the field edge. Characteristics of the landscape (proportions of forest, perennial, and annual herbaceous cover) surrounding the field showed little relation to nest abundance or success. Our study has shown that nest success is higher on CREP fields than hayfields. Within CREP fields, nest abundance and success did not differ with field size but larger fields supported more species and more obligate grassland species. Landscape features showed little effect on use or productivity.

OBJECTIVES

1. To determine if there is a difference in use and productivity between CREP fields and hayfields.

2. To determine the abundance, distribution, and productivity of grassland birds on CREP fields.

3. To determine how field size affects use and productivity of grassland birds.

4. To determine what vegetation characteristics affect the use and productivity of grassland birds, especially the use of warm-season and cool-season grasses, since these are the two dominant plantings within CREP fields.

5. To determine if differing landscape characteristics affect the use and productivity of grassland birds.

INTRODUCTION

Grassland birds have experienced widespread declines throughout the Midwest and eastern United States (Robbins et al. 1986, Bollinger and Gavin 1992, Askins 1993), and have declined more than any other group of birds over the last 25 years (Knopf 1994, Herkert 1995). In Pennsylvania, species such as grasshopper sparrows (scientific names given in Appendix 1), Vesper sparrows, bobolinks, eastern meadowlarks, northern bobwhites, and ring-necked pheasants have declined by 80% or more since the mid 1960s (Sauer et al. 2001). Declines have been attributed to habitat loss and changes on both the breeding grounds (Samson and Knopf 1994) and the wintering grounds (Fretwell 1986). In Pennsylvania, loss of habitat for these species has occurred primarily because of farmland conversion and changes in farming practices.

The Conservation Reserve Enhancement Program (CREP) is a federally-funded program of the United States Department of Agriculture (USDA) that offers farmers the opportunity to take highly erodible and environmentally sensitive land out of production, thereby improving water quality, reducing soil erosion and increasing grassland, wetland and riparian habitat for wildlife (www.fsa.usda.gov/dafp/cepd/ crepqnas.htm). The program provides significant increases in the rental rate farmers are currently offered through the Conservation Reserve Program (CRP), making it more economically feasible for them to participate. Such a program is urgently needed to restore wildlife habitat, particularly that of small game and grassland-nesting birds.

Twenty Pennsylvania counties within the Chesapeake Bay Watershed (a national priority area for recovery) have been identified for enrollment. Within these counties there are 22,685 farms comprising 1,201,662 ha (2,970,000 acres) of farmland, 931,794 ha (2,303,000 acres) of which are cropland. Of the cropland, 288,075 ha (712,000 acres) are considered highly erodible land that should be idled (Tosiano and Capstick 1999). The goal of the CREP Program is to enroll at least 40,460 ha (100,000 acres) in the Pennsylvania program (www.dep.state.pa.us/dep/deputate/polycomm/update/05-26-00/052600u7).

Enrollment of 40,460 ha (100,000 acres) of farmland in Pennsylvania has the potential to significantly benefit grassland-nesting birds, such as ring-necked pheasants and grasshopper sparrows. However, to maximize program benefits, managers need to know how avian use and productivity vary with field size and vegetative structure (density, height, and percent composition of grass [warm or cool-season], forb, and woody vegetation). It is also important to understand whether the immediate surroundings (e.g., wooded or agricultural edge) impact productivity and use.

From work in both forest and grassland habitats, we know that avian use and productivity vary with both local and landscape features (Askins 1993, McGarigal and McComb 1995, Donovan et al. 1997). For example, numerous grassland species including bobolink, Vesper sparrow, and grasshopper sparrow are considered to be area-sensitive and occur rarely in fields below a minimum size (Askins 1993). However, this minimum size is variable depending on location (e.g. Herkert 1994, Vickery et al. 1994, Bollinger 1995, Winter and Faaborg 1999, Horn 2000), with the majority of work done in the Midwest where the landscape is primarily open habitat. Consequently, it is important to understand how grassland species react in a primarily forested state such as Pennsylvania.

Studies in the Midwest have been conducted to look at the effects of CRP practices on wildlife (e.g. King and Savidge 1995, Best et al. 1997, Horn 2000), but these studies may not be directly applicable to the Eastern United States where the landscape matrix is primarily forest and field size is smaller. King and Savidge (1995) examined fields that ranged from 40-80 ha; Best et al. (1997) had an average field size that ranged from 11.5 ha in Michigan to 39.1 ha in Iowa; and Horn (2000) examined fields with a median size in different landscapes of 28 and 27 ha in North Dakota, 15 and 26 in Iowa.

In Pennsylvania, the largest fields available in CREP are approximately 42 ha and the mean is 8.1 ha (Scott Klinger pers. comm.). It has been suggested that predation is higher on nests near a forested edge (Johnson and Temple 1990; see Johnson 2001), which may indicate higher predation in a landscape dominated by forest. In addition, there is evidence that productivity for ring-necked pheasants and other grassland birds, a better measurement of habitat quality, is also dependent on habitat patch size and the vegetative cover (e.g. Johnson and Temple 1990, Horn 2000, McCoy et al. 2001).

METHODS

Our study is designed to test the effects of local and landscape factors on bird use and reproductive success in CREP and hayfields. Fieldwork was conducted in the summers of 2001, 2002, and 2003. A final field session will occur in 2004. The summer of 2001 was a pilot study and methods were then modified for following summers.

Pilot Study – 2001

In 2001, we conducted a pilot study in Montour County. This county had available fields in the Montour Preserve, CRP fields, and CREP fields that already had established cover (CRP roll-overs). From these, we randomly selected 4 fields (2 warm-season and 2 cool-season grass-dominated fields) in 3 size categories: <4.0 ha (small), 7.5 - 12 ha (medium), and >16 ha (large). We also attempted to locate 2 hayfields in each of the size categories. We located 2 small- and 2 medium-sized hayfields but were only able to locate one large hayfield, due to a lack of larger hayfields near the CREP fields.

Avian Abundance and Reproductive Success.--To examine productivity we located active nests by walking through the entire field every 3-4 days watching female and male actions and scanning the vegetation. Nests were marked using colored flagging 10 m to the north of the nest with occasional additional flagging to the south for difficult-to-find nests. Active nests were monitored as the fields were searched to determine success (fledging of at least one young) or cause of failure (either abandonment, the loss of all eggs, or loss of nestlings).

We surveyed birds within each study field using 100 m transects (25m on each side of the transect; Best et al. 1997). Transects were located ≥ 50m from an edge (when possible) and located no closer than 50m from each other. We established as many transects as possible within the field that met the above criteria (Best et al. 1997). We surveyed each field twice (the first between 28 May and 5 June and the second between 28 June and 5 July) to detect early breeders and to detect Neotropical migrants, which tend to breed later. The surveys were conducted from sunrise to 3 hours after sunrise and were not conducted when it was raining or winds were greater than 16 kph (Best et al. 1997).

Local Habitat Characteristics.--We measured 4 aspects of local habitat structure: vegetation density (Robel et al. 1970), height of grass, depth of litter, and amount of vegetative cover (i.e., percent cover of warm- or cool-season grass, ground litter, standing litter [dead stems that are still standing], woody vegetation, forb, and bare ground: Daubenmire 1959). These measurements were conducted at each nest and 3m away from the nest in the 4 cardinal directions after the termination of nesting activity. Each field was sampled using 6 equally spaced points along the already established transects for the bird surveys (McCoy et al. 2001). Field vegetation sampling took place concurrent with the bird surveys. We trained all field assistants to measure the different vegetation characteristics. We also recorded the distance of each nest from edges (e.g., tree lines, agriculture, and roads) using laser range finders (accurate at ± 0.3m at 1000m) to help identify any relationships with productivity and use of the fields by different species.

Field seasons - 2002 and 2003

Field Selection.--In 2002, we separated the 20 counties in CREP into 3 categories by percent forest cover within the county (to select for landscape differences): 19 - 45% (low), 46 - 60% (medium), and 61 - 74% (high) as calculated from the GAP analysis of Pennsylvania (Bishop 1998). We then randomly selected 6 counties (2 from each level of forest cover); from this group, we randomly selected 3 counties (one from each forest cover category) to be both surveyed and nest searched. The other 3 counties were only surveyed. In all 6 counties, we randomly selected 3 fields in each of the 3 size categories. Fields were selected from all CREP fields available that had been planted for more than a year. We also attempted to find 2 medium sized hayfields in each county. We reduced the number of hayfields from the pilot study because of the manpower needed to cover all the fields in a county. We eliminated the small size category because in 2001 the small hayfields combined had only 1 nest. We eliminated the large category because of low availability. Although we attempted to locate 2 hayfields per county, we were only able to locate 1 medium sized hayfield in each county for reasons similar to 2001. In 2003, we used the GAP analysis data to calculate the forest cover surrounding all the CREP fields for which we had digitized information (provided by National Resource Conservation Service biologists). After analyzing the number of fields that we already had in each of the cover categories and size categories, we identified the number of fields in each size category that were needed to equalize the number of fields within each cover category. We then randomly selected fields that fit those criteria. Changes were made to the selections because of changes in the status of fields, incorrect information (fields not actually being of the size indicated), our inability to get permission and our desire to increase the concentration of fields for ease in nest searching (this was done by randomly selecting fields that were within 45 minute drive of concentrations already selected). Hayfield availability was low. We located 1 large, 2 medium, and 4 small hay fields, but because there had been no difference in nest abundance by field size, it was decided to use any hayfield to which we could gain access.

Avian Abundance and Reproductive Success.--In 2002 and 2003, 3 individuals surveyed birds on all the fields. In order to correct for different detection probabilities among the individuals and among different species, we surveyed each field using distance-sampling techniques (Emlen 1971, 1977 and Buckland et al. 2001). Transects were established 100m from an edge and then every 250m until the field was covered. The final transect was at least 50m from the farthest edge. Each field was surveyed twice, the first between 25 May and 11 June and the second between 25 June and 11 July, to detect early breeders and to detect Neotropical migrants, who tend to breed later. Surveys were conducted from sunrise to 3 hours after sunrise, and were not conducted when it was raining, foggy or the winds were greater than 16 kph (Best et al. 1997). Using Program Distance 3.5 (Thomas et al. 1998), we calculated the density of each bird species, for which we had > 60 total observations, using different observer and species detection functions where appropriate.

We located and monitored nests as described under the pilot study. In addition, 3 infrared remote video cameras (Fuhrman Diversified, Inc.) were used to attempt to identify predators. We placed cameras on 16 nests: a dickcissel, 2 field sparrow, 3 song sparrow, and 10 red-winged blackbird. To minimize abandonment the cameras were placed on nests that were currently being incubated (Thompson et al. 1999). Because of the short focal length of the camera, they must be placed within 0.5 m of the nest (usually closer because of obstructions hiding the nest). The power source (a 12 volt deep cycle marine battery) and VHS time-lapse recorder were placed 22m from the camera. There was little disturbance to the nest when changing the battery and tape (every 2 days). We were also able to check the nest from the battery station with a remote viewer so that the contents could be checked without disturbing the nest any more than a “regular” nest. The cameras were left on the nest until the nest either succeeded or failed. Nests were chosen at random, as a camera became available. We attempted to only use species with multiple nests within the field.

Local Habitat Characteristics.--We used the same methods as described for the pilot study.

Landscape Level Analysis.--Land cover characteristics (e.g., forest cover, open cover, and residential cover) were calculated from the GAP analysis of PA (Bishop 1998). Radii were established around each field (0.5 km, 1 km, 2 km, and 5 km) in order to determine the percentage of cover surrounding each field. These data were then to be used to evaluate any effect on the use and productivity of grassland birds.

Data Analysis

We used the Kolmogorov-Smirnov test of normality on all data to determine if the data were normally distributed. Data were transformed if not normally distributed using square root transformations for dependent variables, and logarithmic and arcsine transformations for independent variables (Zar 1999). MINITAB^{tm} (MINITAB, Inc.) was used to calculate all statistics, except the Fisher Exact Test that was calculated using Excel (Microsoft, Inc.). All means are reported $\pm$ one Standard Error. Significance is reported as $p < 0.05$, but a trend is reported when $0.10 > p > 0.05$.

We calculated density (for singing males) using Program Distance to model detection functions. We used only those species with at least 60 detections. This limited the number of species for analysis to bobolink, red-winged blackbird, eastern meadowlark, field sparrow, grasshopper sparrow, and song sparrow. Outlying perpendicular distances were truncated when necessary to better model the data and AIC was used to indicate the most appropriate model. We modeled species differences and observer differences and found that the models that best fit the data were for separate species, and all observers except for red-winged blackbird in which the best model was for the observers to be separated. To calculate density per field, we used the formula: $(n*f(0)/2*L)*10000$ = birds ha^{-1}, with n being the maximum number of birds seen in the field during either survey (this indicates the highest density that would have been present on the field); f(0) is the detection function for that species (and observer for red-winged blackbird); L is the total length of transects in the field (Buckland et al. 2001).

We compared the presence or absence of grassland obligate species within CREP and hayfields using a chi-square test. We used a Fisher's Exact test with nesting data because of the small sample sizes on most hayfields. In order to determine if the number of nesting species differed between CREP and hayfields when size was accounted for, we used a generalized linear ANOVA with field size as a covariate.

We compared density of birds and relative nest abundance between CREP and hayfields using a two-tailed student's t-test. We used a one-tailed test versus a mean of 0 when there were no nests for that species on hayfields. Because year was a significant factor in nest abundance for field sparrows and song sparrows, we used a generalized linear model ANOVA so that year could be used as a covariate. We compared nest success (Mayfield 1961, 1975) between CREP and hayfields using Program Contrast (Sauer and Williams 1989).

To determine if species diversity differed with field size, we performed a linear regression with the number of species nesting in the field as the response variable and field size as the dependent variable. We examined the relationship between field size and the presence/absence of any grassland obligate species (from nesting and survey data) using logistic regression.

Landscape characteristics that were used in the analysis were: percent perennial herbaceous, annual herbaceous, and forest cover (sum of all forest types); mean patch size and mean shape index (FRAGSTATS; McGarigal and Marks 1995), and road density (Myers et al. 2004). The landscape characteristics were calculated from 4 different radii (0.5, 1, 2, and 5km) drawn from the border of the field.

We used a Pearson correlation to compare vegetation variables and to compare within landscape variables to determine independence. We found both sets of variables to be correlated and therefore it was necessary to use Principal Component Analysis (PCA) to create independent variables that could then be used in linear regressions. Principle Component (PC) variables were used with eigen values ≥ 1.0 until the cumulative proportion > 0.75. We report those variables with weights of ≥ 0.40 for the vegetation variables and because there were more highly correlated variables in the landscape analysis weights of ≥ 0.25 were used. PCs were then used as variables in step-wise multiple regressions with enter and exit p values of 0.1. Standard linear regressions were then run to calculate residuals for further analysis.

In order to examine the effect of different edge types on nest success we used both paired t-tests and logistic regression. The paired t-tests were used to compare nest success within a field and their distance to different edge types (agriculture, forest, tree line, and road). We then used logistic regression to compare all fledged and depredated nests and their distance to a tree edge (tree line or woodlot).

RESULTS

Species Use of CREP Fields

We located 800 nests of 19 different species during the 2001, 2002, and 2003 breeding seasons on 75 fields (64 CREP fields and 11 hayfields) in 6 different counties. We surveyed an additional 53 fields (47 CREP fields and 6 hayfields) in an additional 3 counties. The number of species nesting on CREP fields (2001: 3.38 ± 0.62; 2002: 2.11 ± 0.35; 2003: 2.11 ± 0.27) did not differ between years ($F = 2.84$, df = 2, $p = 0.066$). Consequently, the data were pooled for further comparisons. The mean number of species nesting on a field increased with field size ($F = 18.9$, $p = 0.000$; Fig. 3). Small fields (n=24) had 11 species nesting on them (mean 1.33 ± 0.27), medium fields (n=24) had 13 species (mean 2.48 ± 0.29), and large fields (n=18) had 14 species nesting on the field (mean 3.50 ± 0.47).

Because many of the species using the fields are habitat generalists, we examined whether field size affected the presence or absence of nesting obligate grassland species (ring-necked pheasant, bobolink, dickcissel, eastern meadowlark, and grasshopper, Savannah, and Vesper sparrows). There was a significant linear relationship between CREP field size and the presence of a grassland obligate species located during surveying ($G = 8.754$, df = 1, $p = 0.003$) or nesting ($G = 5.926$, df = 1, $p = 0.015$).

Bird Density (Singing Males ha^{-1})

For CREP fields, there was no difference in density by year (Table 1) except for the indigo bunting, which were significantly higher in 2003 than 2002. Because there was no relationship with year (other than indigo bunting), we did not include year in any further analysis of density.

We examined whether field vegetation characteristics (Table 2), field size, perimeter-area ratio, and distance to closest CREP field affected bird density. The indigo bunting showed no relationship with any of the variables (Table 3). Field size, forb, cool-season grass, and downed litter cover were not included in any of the models. There was no trend linking any of the species except that both song sparrows and field sparrows had a positive relationship with increasing woody cover. However, this was only a trend for song sparrows (p=0.07) and field sparrows included a positive relationship with decreasing perimeter-area ratio, vegetation height, warm-season grass, and standing litter cover. Bobolinks and grasshopper sparrows both had distance to the nearest CREP field enter as the first variable, but for grasshopper sparrows, the trend (p=0.08) was a positive relationship, for bobolinks the trend was negative and also included a positive relationship with downed litter depth and a negative relationship with bare ground cover and vegetative density. eastern meadowlarks showed a negative relationship with perimeter-area ratio indicating that there was a higher density with less edge on the field. Red-winged blackbirds showed a negative relationship with warm-season grass and standing litter cover.

We examined the relationship of density within the larger landscape context (Table 4) using the residuals from the regressions of field characteristic analysis. There were no significant relationships for any of the species and the landscape variables. However, red-winged blackbirds showed a trend (p=0.09) with a negative relationship with road density (0.5 and 5km) and with mean patch size (0.5 and 1km) and mean shape index (0.5km). Grasshopper sparrows also showed a trend (p=0.09) with a positive relationship with the percent of perennial herbaceous cover (0.5 and 2km) and annual herbaceous cover (0.5, 2, and 5km) and a negative relationship with the amount of forest (all radii).

Nest Abundance (Nests Located ha^{-1})

Most studies examine relative abundance or density of birds and assume a relationship with actual nesting. In order to show that there is a relationship, we compared density with nest abundance. We found that there was a significant relationship between density and nest abundance for red-winged blackbird, field sparrow, grasshopper sparrow, and song sparrows (the more common species) but not for the less common bobolink, eastern meadowlark, or indigo bunting (Table 5). All the species with a significant relationship had a positive relationship indicating that there were more singing males in a field than nests that were located.

We used the same variables to examine nest abundance as we did for bird density, however the fields were different since we nest searched in a sub-sample of fields (see Table 6 for PCA results for vegetation characteristics). We also included year as a variable for field sparrows since it was significant in univariate testing. No variables entered the model for indigo bunting nest abundance (Table 7). No models included the variables: distance to nearest CREP field, perimeter-area ratio, or PC4. Unlike the density analysis, different species shared variables in their models, though usually with the opposite relationship. Only the models for song sparrows and grasshopper sparrows (p=0.091) had a variable enter in the same direction, a negative relationship with PC2 (increasing forb cover and decreasing down litter cover). While the model for song sparrows only included the variable PC2, grasshopper sparrows also included field size (p=0.087) and PC5 (decreasing woody cover). Field sparrows also included PC5 but with a negative relationship so that nest abundance increased with an increase in woody cover. Field sparrows also included a negative relationship with PC1 and PC3, which indicates an increase in nest abundance with an increase in litter depth and a decrease in vegetative density, cool-season grass and bare ground cover. The red-winged blackbird model was a positive relationship with PC1 indicating an increase in nest abundance with an increase in cool-season grass cover and vegetative density. The wild turkey model included a negative relationship with PC4 (0.06) and a positive relationship with PC1 (0.09) indicating a trend for nest abundance to increase with increasing amounts of woody cover, dense cool-season grass cover, and decreasing dense warm-season grass cover.

We also examined nest abundance with landscape variables as we did with density (see Table 8 for PCA results). Field sparrow, grasshopper sparrow and song sparrow showed no relation with any of the landscape variables. Red-winged blackbirds showed a negative relationship (f=5.86, p=0.03, R^2 (adj)=6.2%) with road density (0.5, 2, and 5km), a negative relationship with forest cover (1km), and a positive relationship with annual herbaceous cover (1km).

Nest Success

The overall nest success for passerine birds on CREP fields was 0.284 ± 0.019 (using the Mayfield Method on all nests in CREP fields; see Table 9 for individual species). The only species that had enough fields with multiple nests to compare were red-winged blackbirds and field sparrows. Red-winged blackbirds and field sparrows both showed a significant linear relationship between Mayfield success and nest success ratio (F=58.49, p=0.000*** R^2(adj) = 76.2%; F=20.72, p=0.002** R^2(adj) = 68.7%, respectively). However, red-winged blackbirds showed a negative trend between Mayfield nest success and nest abundance (F= 3.06, df=1, p=0.098, R^2(adj) = 10.3%), while field sparrows showed no significant relationship (F=0.09,df=1, p=0.770, R^2(adj) = 0.00%). Nest success ratio is comparable with Mayfield success, and neither species showed a density dependent relationship with Mayfield success.

Nest success did not differ among years for any species (Table 10). Red-winged blackbirds did show a trend for higher nest success in 2002 than in 2001 or 2003. In addition, no significant difference was found between passerine species (eastern meadowlark, red-winged blackbird, indigo bunting, field sparrows, grasshopper sparrows, and song sparrows) when comparing all CREP field nests (X^2 = 6.87, df=6, p=0.333). There was not a significant linear relationship between Mayfield nest success and field size for either red-winged blackbirds (F=2.2314, df=1, p=0.152) or field sparrows (F=0.0004, df=1, p=0.951).

To increase the number of fields in the analysis we used nest success ratio as the dependent variable in step-wise regressions with the field characteristics as the independent variables (Table 6 for PCA results of vegetation variables). Red-winged blackbirds were more successful as field size increased (Table 11). Field sparrows were more successful with an increase in litter depth and a decrease in bare ground cover. Song Sparrows had no variables enter the model.

In order to determine if the local landscape features affected productivity, we compared successful and unsuccessful nests with their distances to different field edges (road, tree line, woodlot, and agricultural land; Table 12). Within a field, field sparrow nest success showed a trend to be more successful closer to the closest edge (p=0.088) and to a road (p=0.065), but no difference was detected with distance to trees (not enough nests near agricultural fields). Eastern meadowlarks were more successful farther from a woodlot, but with no difference to any other edge types. Red-winged blackbirds were more successful closer to trees than farther away, though this relationship did not hold when only looking at woodlots. When examining the overall effect of distance to a tree edge and nest success for all nests we found a trend for nests to be more successful closer to a tree edge (see Fig. 2 and Fig. 3; G = 3.122, df = 1, p = 0.077).

We compared nest success with landscape characteristics for the species with >10 fields with nests on them, we used the residuals from the previous field characteristic analysis. No variables entered the regression for red-winged blackbirds or field sparrows. Song sparrows (F=8.15, p=0.014, R^2(adj) = 33.8%), showed a negative relationship with the amount of crop cover (all radii, [-0.265, -0.258, -0.275, -0.250 respectively]), a positive relationship with forest cover (0.5 [0.291], 2 [0.276], and 5km [0.265]), and a positive relationship with MSI (2km [0.259]).

CREP Versus Hayfields

There was a clear difference in nesting species present on hayfields (Fig. 4) than on CREP fields (Fig. 5), though there were fewer hayfields searched than CREP fields. When field size was accounted for CREP fields had significantly more species (n=19) nesting on them (mean 2.24 ± 0.21) than hayfields (n=5, mean 0.73 ± 0.24; F = 10.59, df = 1, p = 0.002).

Because obligate grassland species are of concern, we examined whether there was a difference between their presence on CREP and hayfields. We found no difference in the presence of an obligate grassland species on CREP versus hayfields (X^2 = 0.190, df = 1, p = 0.663; Table 13) or the presence of a nesting grassland obligate species (p=0.281; Table 14). The densities of indigo buntings, field sparrows, grasshopper sparrows, and song sparrows were significantly higher in CREP fields than hayfields, but there was not a significant difference in bobolink, eastern meadowlark, or red-winged blackbird densities (Table 15).

Because nest abundance might differ with year, we examined if the average nest abundance differed with year for CREP fields before we compared CREP fields to hayfields. Only field sparrows and song sparrows showed a significant difference in nest abundance between years (Table 16). Because there was a significant relationship with the year of study for field and song sparrows, we included it as a covariate when comparing nest abundance between CREP fields and hayfields (Table 17). There was significantly higher nest abundance on CREP fields than hayfields for wild turkey, indigo bunting, and field sparrows. eastern meadowlark and song sparrows showed a trend towards higher nest abundance on CREP fields than hayfields. Bobolink, red-winged blackbird, and grasshopper sparrows showed no significant difference in nest abundance.

For red-winged blackbirds (the only species with sufficient nests in hayfields to test), nest success on CREP fields (0.258 ± 0.021) was significantly higher (X^2 = 6.66, df=1, p=0.010) than hayfields (0.146 ± 0.038). When comparing all nests, CREP field nest success (0.284 ± 0.019) was still significantly higher (X^2 = 11.6, df=1, p=0.0007) than hayfields (0.143 ± 0.037).

DISCUSSION

CREP Versus Hayfields

CREP fields are providing an important additional area in Pennsylvania for grassland birds to nest. Without CREP, grassland birds would have to nest in old fields, agricultural fields, pastures, or hayfields. In the Midwest, CRP fields have more nests and more species using them than row crops (Best et al. 1997). Hayfields are much more like grassland than a row crop field and would be expected to be more attractive to grassland birds (this was not directly addressed in this study), and yet we found more species present and nesting in CREP fields than hayfields.

The red-winged blackbird was found to be the most common species on both CREP and hayfields, which is similar to other eastern studies (Bollinger 1995; Giuliano and Daves 2002), and they did not show a difference in the density. However, the average density red-winged blackbirds in our study (0.721 + 0.313) was higher than other studies of hayfields: 0.42 (Frawley and Best 1991, Iowa), 0.16 (Vierling 1999, Colorado), 0.006 (Nelms et al. 1994, North Dakota) and 0.34 (Besser 1985, Iowa), though Bollinger (1995, New York) found a range of 1-3 males 100 m^{-1}. It was also much higher than what Johnson and Schwartz (1993) report for croplands (0.011; eastern Montana, North Dakota, South Dakota, and western Minnesota).

Bobolink and eastern meadowlark were the other two species that showed no difference in density between CREP fields and hayfields. Both of these species were very limited in their presence across the study area, which probably affects our results. Bobolinks have commonly been found on hayfields (Bollinger 1995) and to prefer hayfields to grasslands in other studies (Dale et al. 1997). Bollinger (1995) found that grasshopper sparrows had lower abundances in hayfields that had been mowed the year previously. Horn and Koford (2000) found no difference in abundance of grasshopper sparrows on CRP fields that had been mowed or left idle the previous year. Sample and Ribic (2001) found grasshopper sparrows to be more abundant in dry pasture and prairie than hayfields. In this study, the density grasshopper sparrows was higher on CREP fields than hayfields, and this difference may continue to increase when the number of CREP fields that are mowed yearly decreases as the need to mow for weed control is diminished.

The other species that showed a higher density (indigo bunting, field and song sparrows) all commonly use woody vegetation, which is not found in hayfields. There were not enough fields with bobolinks to compare CREP and hayfield nest abundance. Eastern meadowlarks and song sparrows had only a trend ($p \leq 0.10$) for having higher nest abundance in CREP than hayfields, even though song sparrows only had one nest in a hayfield and eastern meadowlarks didn’t have any nests in hayfields. Like eastern meadowlarks, wild turkeys were not found nesting on hayfields but they showed a significant difference in nesting density on CREP fields from zero. The other species had similar results as was found in the density analysis.

The only species that had enough nests on hayfields to compare nest success was the red-winged blackbird, and they were significantly more successful in CREP fields than hayfields. The difference in success would have been even more pronounced except for the late mowing of hayfields over the past three summers (26 June – 2 July 2001; 20 June – 27 June 2002; 24 June – 3 July 2003 pers. obs.) allowing many birds to raise broods before the first cutting. The hayfields used were mostly timothy, brome, or orchard grass hayfields and not alfalfa, which are cut earlier and would be expected to have an even lower success rate for any birds nesting in them. This study has shown that hayfields are not as good a habitat as CREP fields are for grassland birds.

CREP Field Use and Bird Density

CREP fields in southcentral Pennsylvania are within an agricultural matrix (smaller context) and a forest dominated landscape (large context) because of ridge and valley geology. Field size is much smaller than in the Midwest. Within this make-up, CREP fields were composed mainly of red-winged blackbirds, field sparrows and song sparrows, with bobolink, grasshopper sparrows, and eastern meadowlarks being uncommon, and dickcissels and Henslow’s sparrows practically absent (2 dickcissels were recorded). This is different from the make-up of species in CRP fields in other parts of the country where grasshopper sparrows and dickcissels are the most common species present (Johnson and Schwartz 1993, Best et al.1997, Delisle and Savidge 1997, Klute et al. 1997), though the farthest east these studies cover is Indiana.

Eastern Meadowlark

This species was very uncommon, so the results should be viewed with caution. Their density was lower than that found that by Winter and Faaborg (1999), but their nest success was similar (McCoy et al. 1999, Winter and Faaborg 1999). The only variable that entered a model of density variation was a negative relationship with perimeter area ratio. It has been shown that eastern meadowlark avoid woodlots (Ribic and Sample 2001), i.e. by decreasing the perimeter-area ratio, eastern meadowlarks have more area away from woodlots and other edges. Eastern meadowlarks have also been found to prefer older, heterogeneous fields with sparser vegetation (Bollinger 1995). As the CREP fields become older, it is possible that the density of eastern meadowlark will increase.

Red-winged Blackbird

This was the most common species found on CREP fields and the most variable. For both years, their density was higher than that reported in studies in the Midwest (Johnson and Schwartz 1993, Winter and Faaborg 1999). Nest success was within the range reported in other studies (Moulton 1981, McCoy et al. 1999). There was variation in the variables that showed a significant relationship with density, nest abundance and success. We found red-winged blackbirds to have a higher nest success with field size though they have not been shown to be area sensitive (Johnson 2001). The amount of forb cover did not enter any of the models, but red-winged blackbirds were the only species regularly found in fields with heavy clover cover (pers obs.). Red-winged blackbird was the one species that did not seem to mind a homogeneous field as long as it wasn’t a stand of warm-season grass. It is possible that the addition of CREP to Pennsylvania will help to stop the decline in red-winged blackbirds (Sauer et al. 2001) as their nest success is significantly higher than in hayfields, and they are using a high proportion of the fields.

Field Sparrow

This species was the second most common nesting species on CREP fields, yet their density was fifth. This may be a result of their nesting in the field but singing deeper in the trees and so not being counted during the surveys (pers obs.). Still, their density was much higher than in Missouri (Winter and Faaborg 1999). Their nest success was within the range of other studies (Best 1978, Wray et al. 1982, McCoy et al. 1999). We found that increasing amounts of warm-season grass cover increased density and a decrease in cool-season grass cover increased nest abundance, while McCoy et al. (2001) found no difference in abundance between warm and cool-season grass fields. Field sparrows showed a positive relationship with vegetation characteristics of older fields: little bare ground (also Vickery 1994), increased downed litter and woody cover. However, Herkert (1994) found that field sparrow presence was negatively related to grass height. Best (1978) found that field sparrows nested most commonly in woody vegetation (especially when *Rubus* is considered as woody vegetation) and Vickery et al. (1994) found that field sparrow abundance was positively affected by the amount of high shrub in the field. Field sparrows tended to nest within 50m of a tree edge so it was surprising that they had a negative relationship with perimeter-area ratio and bird density. Field sparrow was the only species to show a significant difference in nest success annually, and this may be because the fields used in 2001 were already established and had more woody vegetation than fields used in following years. CREP should positively affect field sparrow use and productivity as the fields become more established and as woody vegetation encroaches in the fields.

Grasshopper Sparrow

This species was uncommon on CREP fields. Their density was much lower than that found in the Midwest (Johnson and Schwartz 1993, Winter and Faaborg 1999), but the range of nest success was similar (Wray et al. 1982, McCoy et al. 1999, Winter and Faaborg 1999, Balent and Norment 2003). A wide range of vegetation variables has been shown to affect grasshopper sparrow abundance in hayfields and grasslands (Wiens 1969, Whitmore 1981, Johnson and Schwartz 1993, Bollinger 1995, Delisle and Savidge 1997, Winter and Faaborg 1999, McCoy et al. 2001), with short, sparse vegetation, high litter cover, and lower litter depth being common. Abundance has been shown to differ (McCoy et al. 2001) and be similar (Delisle and Savidge 1997) between cool and warm-season grass fields, though the warm-season grass fields with grasshopper sparrows in Delisle and Savidge’s study were mowed 3 out of 4 years.

In our study, none of the vegetation variables entered the model for density, but increasing nesting density was related to an increase in down litter cover and a decrease in forb and woody cover. Field size has also been indicated in a number of studies to positively affect abundance (see review; Johnson 2001), and in our study there was a trend for nest abundance to be positively affected by field size. However, as in Winter and Faaborg (1999), there was no trend for field size when using a univariate model. The only variable to enter the model for density was a positive trend with increasing distance to the nearest CREP field. It is unclear why there was a positive trend for density to increase with distance to nearest CREP field since Ribic and Sample (2001) found a positive relationship with the amount of grassland. While the density in CREP fields is presently low, there should be an increase as the fields become more established and have a higher litter cover. The one factor that might affect an increase in grasshopper sparrows is the increase in vegetative density that can occur without some sort of management of the field.

Song Sparrow

This species was the third most common nesting species on CREP fields, yet had the second highest average density. Nest success was slightly lower than that found by Arcese and Smith (1988). The positive relationship between abundance and woody cover is similar to the positive relationship found with the amount of shrub (Herkert 1994, Vickery et al 1994). While Vickery et al. (1994) found a positive relationship between forb cover and abundance our study found a negative relationship. This was likely due to the extremely dense clover cover on the young fields in our study. We found a positive relationship between nest abundance and down litter cover, while Herkert (1994) found a negative relationship between presence on a field and litter depth. A negative relationship was found with field size by both Herkert (1994, presence) and Vickery et al. (1994, abundance), while field size did not enter any of our models. Our findings agree with McCoy et al. (2001) that there is no difference in abundance between warm and cool-season grass fields. We may not have found any relation to field area because there were a number of larger fields that included woody vegetation that song sparrows used to nest in. CREP fields should see an increase in song sparrows density as they mature and as more woody vegetation encroaches.

Edge Effects and Predation

Predation is the major cause of nest loss (in this study 53% of known nesting outcomes) found in most studies (Best 1978, Wray et al. 1982). In our study nest abandonment was a minor cause of nest loss (10%) with parasitism (4 field sparrow nests were parasitized by brown-headed cowbirds and were subsequently abandoned) and weather (heavy thunderstorms and a freeze led to nests with young being abandoned) being known causes of abandonment.

Since predation is the major cause of nest loss, we attempted to identify nest predators using infrared video cameras but never captured a predation event. We visually identified a number of predators in the fields including: raccoon (*Procyon lotor*), striped skunk (*Mephitis mephitis*), weasel (*Mustela*), house cat (*Felis domesticus*), red fox (*Vulpes vulpes*), and multiple species of snakes (pers. obs.). A wide range of predators has been captured on video predating nests in pastures (9 different species; Renfrew and Ribic 2003) and in grasslands (9 different species; Pietz and Granfors 2000). Edge effects have been implicated in a decrease in nest success especially 50m from woody edges mainly due to an increase in mid-sized mammalian predators (Gates and Gysel 1978, Winter et al. 2000).

In our study, red-winged blackbirds were significantly more successful closer to an edge with trees and eastern meadowlark were more successful farther from a woodlot. Field sparrows showed a trend towards being more successful closer to the closest edge and roads. There may have been no significance because eastern meadowlark, grasshopper sparrow, and red-winged blackbirds nested significantly farther than 50m from a road or tree edge, thereby avoiding the major area of predation. Field sparrows and song sparrows nested closer than 50m to a tree edge but often nested in Multi-flora Rose which may deter mammalian predators and the predation that did occur was incidental not as the result of intentional searching (Vickery et al.1992).

Landscape

Landscape characteristics showed little affect on density, nest abundance, or nest success. However, we did find relationships with landscape features within the 5km radius around the field. The strongest relationship was with song sparrow nest success and the amount of forest cover, crop cover and MSI indicating nest success increased with a decrease in crop cover around the field and an increase in forest cover and fragmentation (increase in MSI). Red-winged blackbirds on the other hand showed a positive relationship with crop cover and a negative relationship with road density and forest cover. Bajema and Lima (2001) found no relationship with landscape features beyond 500m (they measured out to 2000m) for Henslow’s sparrow and the factors closer only showed a trend with water, and the amount of nonsuitable habitat (summed value for any habitat not used by Henslow’s sparrows). Ribic and Sample (2001) found significant relationships for a number of species but their range for landscape analysis was only out to 400m which is smaller than our smallest radius, which may indicate that species are using more field level characteristics than large landscape characteristics.

MANAGEMENT IMPLICATIONS

Our results suggest that larger fields should be targeted for CREP since red-winged blackbird and grasshopper sparrows showed positive relationship with field size and other studies have found a positive relationship for northern harrier, upland sandpiper, Vesper sparrow, Savannah sparrow, Henslow’s sparrow, dickcissel, bobolink, and eastern meadowlark (Johnson 2001). It is possible that these species were not present in any numbers because the fields were too small. Even if field size is not increased, it may be important to cluster fields as closely as possible. Herkert (1994) suggested that some species might use multiple fields if they were close together, and in our study, bobolinks showed a negative relationship with distance to nearest CREP field. In addition, while we found only 2 ring-necked pheasant nests, they were both found on large fields. We also saw another hen with polts in a large field, though we do not know where she nested.

We found little evidence that the type of field edge or distance to edge affected nest success, though many species nested farther than 50m from a tree-lined edge, which is the distance that has been shown to have higher numbers of predators and predation (Gates and Gysel 1978, Winter et al. 2000). There was also little relationship with any of the landscape features. Red-winged blackbirds showed a negative relationship with forest cover while song sparrow showed a positive relationship, which indicates that even fields that are surrounded by forest will draw some species and even increase nest success. Grasshopper sparrows showed no relationship with any landscape characteristic for use or productivity. This may indicate that the field characteristics are more important than the surrounding landscape.

The difficulty of managing field vegetation for the species found on CREP fields is their variety of preferences. Red-winged blackbirds and field sparrows had opposite relationships to warm-season grass, cool-season grass, and standing litter cover, and with vegetation density. Song sparrows and field sparrows showed a positive relationship with woody cover, but grasshopper sparrows showed a negative relationship. Only grasshopper sparrows and song sparrows showed a negative relationship with forb cover, but in many first or second-year fields, the only species nesting in them were red-winged blackbirds because of the thick clover cover. To avoid this, fields should have a lower seeding rate (especially of clover) with added wild flower seed to provide diversity and to provide more space between clumps of vegetation.

Little difference has been shown in preference of species between warm and cool-season grass fields (King and Savidge 1995, Delisle and Savidge 1997). We did detect a higher nest abundance for red-winged blackbirds in cool-season grass, a negative relationship of wild turkey nest abundance with warm-season grass and the presence of bobolinks only on cool-season grass fields. Part of the reason that there may not be a difference at present is that most of the warm-season fields were not yet fully established (standing and downed litter). Delisle and Savidge (1997) do suggest that for grasshopper sparrows switchgrass fields may need to be regularly mowed in order to keep the vegetation useable, even though this might diminish their numbers in the following year. Field and song sparrows used woody vegetation for most of their nests (Best 1978), though field sparrows used switchgrass commonly in fields in which it was present. grasshopper sparrows and eastern meadowlarks tended to nest under a clump of grass (either warm or cool-season) with litter available to cover the nest. Except for red-winged blackbirds and bobolinks that were as dense on hayfields as CREP fields, the other species show a preference for fields with more heterogeneity.

Management plans should include a more intense form of disturbance on the fields than mowing for fields that are becoming too homogeneous (e.g., fire, disking) in order to maintain some diversity and openings in the vegetation. This may be especially important for monoculture switchgrass fields that can become very dense.

This study also shows that for most species there is a linear relationship between the density and nest abundance located on a field. This is important for further research since it takes less manpower to survey fields for density than nest searching. However, if there are sufficient funds then studying productivity provides important data since some species (eastern meadowlark and indigo bunting) were not found to have a significant relationship between density and nest abundance, and the amount of variation explained for the other species ranged only from 16 – 68%. This indicates that there are other factors involved. In addition, nest abundance did not show a relationship with nest success, so even knowing how many nests there are does not indicate how successful they are.

In upcoming field seasons, we hope to expand the range of landscapes surrounding fields to determine if there are landscape effects on bird density, nest abundance and nest success. We are also going to monitor CREP fields in the farthest west portion of the program to see if there is a spatial component to bird use and productivity. We also plan to increase the number of hayfields studied to increase the probability of detecting differences in hayfield and CREP use and productivity. In addition, we plan to increase the number of nests that are monitored by infrared cameras to increase the likelihood that we will identify some of the nest predators.

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Table 1. Comparison of species density (birds ha^{-1}) on Conservation Reserve Enhancement Program fields in south-central Pennsylvania, 2002 and 2003.

	Mean (+SE) [a]			
Year	2003	2004	t-value (df)	P value
BOBO	0.05 (0.05)	0.15 (0.11)	-0.74 (69)	0.465
EAME	0.01 (0.003)	0.01 (0.01)	-0.93 (89)	0.357
RWBL	0.66 (0.11)	0.91 (0.12)	-1.70 (96)	0.093
INBU	0.08 (0.02)	0.21 (0.05)	-2.58 (66)	0.012*
FISP	0.14 (0.03)	0.07 (0.02)	1.90 (96)	0.060
GRSP	0.13 (0.04)	0.11 (0.04)	0.36 (97)	0.716
SOSP	0.42 (0.08)	0.43 (0.06)	-0.34 (97)	0.735

[a]The means reported are actual, but the values used in the t-test were square root +0.5 transformed.

BOBO = Bobolink; EAME = Eastern Meadowlark; RWBL = Red-winged Blackbird; INBU = Indigo Bunting; FISP = Field Sparrow; GRSP = Grasshopper Sparrow; SOSP = Song Sparrow

Table 2. Principal Component Analysis of vegetation variables for Conservation Reserve Enhancement Program fields in south-central Pennsylvania, 2002 and 2003. Only variables with a PCA score ≥| 0.40| are shown.

	PC1	PC2	PC3	PC4	PC5
Litter depth			-0.538		
Vegetation height					0.492
Forb cover	0.536				
Cool-grass cover	-0.538				
Warm-grass cover		0.433			0.537
Downed litter cover	-0.406				
Standing litter cover		0.439			
Woody cover				-0.756	0.449
Bare ground cover			0.501		
Vegetation density			0.459		

Table 3. Independent variables included in stepwise multiple regressions of species density on Conservation Reserve Enhancement Program fields in south-central Pennsylvania, 2002 and 2003.

Species	Adj R^2	Independent variables[a]
BOBO	0.08	-Distance to nearest CREP field (0.05) - PC3 (0.03)
EAME	0.07	-Perimeter-area ratio
RWBL	0.11	-PC2
INBU	0.00	No relationship with any variables
FISP	0.21	-PC4 (0.14) - Perimeter-area ratio (0.04) + PC2 (0.03) + PC5 (0.03)
GRSP	0.03	+Distance to nearest CREP field[b]
SOSP	0.03	-PC4[b]

[a]Principle Component (PC) variables were created from vegetation measurements in the fields (% cover [forb, warm-season grass, cool-season grass, downed litter, standing litter, woody, bare ground], vegetation height, and vegetation density)

[b]Variables with $p<0.10$ all other variables $p \leq 0.05$; variables listed in order in which they were included in model; partial r^2 in parentheses; "+" before variable denotes positive association with density; "-", denotes a negative association. BOBO = Bobolink; EAME = Eastern Meadowlark; RWBL = Red-winged Blackbird; INBU = Indigo Bunting; FISP = Field Sparrow; GRSP = Grasshopper Sparrow; SOSP = Song Sparrow

Table 4. Principal Component Analysis of landscape variables for surveyed Conservation Reserve Enhancement Program fields in south-central Pennsylvania, 2002 and 2003. Only variables with a PCA score ≥| 0.250| are shown.

	PC1	PC2	PC3	PC4	PC5
0.5 km radius					
Mean Patch Size (MPS)[a]			-0.444	-0.313	
Mean Shape Index (MSI)[a]		0.276		-0.309	
Perennial herbaceous cover	-0.259				
Annual herbaceous cover	-0.281				
Forest cover	0.310				
Road density				-0.392	
1 km radius					
Mean Patch Size (MPS)			-0.417	-0.311	
Mean Shape Index (MSI)		0.334			-0.258
Perennial herbaceous cover		0.335			
Annual herbaceous cover					
Forest cover	0.277				0.255
Road density			0.255		0.416
2 km radius			-0.366		
Mean Patch Size (MPS)					
Mean Shape Index (MSI)		0.362			
Perennial herbaceous cover		0.303			
Annual herbaceous cover	-0.254				
Forest cover	0.296				
Road density					-0.346
5 km radius					
Mean Patch Size (MPS)			-0.266		
Mean Shape Index (MSI)		0.333			
Perennial herbaceous cover					0.375
Annual herbaceous cover	-0.263				0.282
Forest cover	0.275				-0.370
Road density				-0.448	

[a]MPS and MSI are calculated using FRAGSTATS (McGarigal and Marks 1995)

Table 5. Linear regression of bird density and nest abundance located on the same Conservation Reserve Enhancement Program fields in south-central Pennsylvania, 2002 and 2003.

Species	Regression equation	Adj R^2	F value	p value
BOBO	Nests ha^{-1} = 0.002 + 0.007 male ha^{-1}	0.1	1.04	0.311
EAME	Nests ha^{-1} = 0.004 – 0.401 male ha^{-1}	0.0	0.16	0.695
RWBL	Nests ha^{-1} = - 0.004 + .529 male ha^{-1}	63.3	101.67	0.000
INBU	Nests ha^{-1} = 0.025 - 0.030 male ha^{-1}	0.0	0.23	0.652
FISP	Nests ha^{-1} = 0.037 + 0.529 male ha^{-1}	22.3	17.65	0.000
GRSP	Nests ha^{-1} = - 0.003 + 0.174 male ha^{-1}	42.5	44.33	0.000
SOSP	Nests ha^{-1} = - 0.006 + 0.180 male ha^{-1}	17.2	13.24	0.001

BOBO = Bobolink; EAME = Eastern Meadowlark; RWBL = Red-winged Blackbird; INBU = Indigo Bunting; FISP = Field Sparrow; GRSP = Grasshopper Sparrow; SOSP = Song Sparrow

Table 6. Principal Component Analysis of vegetation variables for nest searched Conservation Reserve Enhancement Program fields in south-central Pennsylvania, 2001 – 2003. Only variables with a PCA score ≥ |0.40| are shown.

	PC1	PC2	PC3	PC4	PC5	PC6
Litter depth			-0.413			
Vegetation height						0.600
Forb cover		0.500				
Cool-grass cover	0.538					
Warm-grass cover				0.603		
Downed litter cover		-0.523				
Standing litter cover						0.527
Woody cover				-0.618	-0.679	
Bare ground cover			0.562			
Vegetation density	0.419			0.454		

Table 7. Independent variables included in stepwise multiple regressions of nest abundance in Conservation Reserve Enhancement Program fields in south-central Pennsylvania, 2001 - 2003.

Species	Adj R^2	Independent variables[a]
WITU	0.08	-PC4[b] (0.05) +PC1[b] (0.03)
RWBL	0.06	+PC1
INBU	0.00	No variables entered the model
FISP	0.18	-PC5 (0.08) –PC1 (0.05) –PC3 (0.05)
GRSP	0.18	-PC2[b] (0.08)+ field size[b] (0.07) +PC5 (0.03)
SOSP	0.15	-PC2

[a]Principle Component (PC) variables were created from vegetation measurements in the fields (% cover [forb, warm-season grass, cool-season grass, downed litter, standing litter, woody, bare ground], vegetation height, and vegetation density); [b]Variables with a $p<0.10$ all other variables ≤ 0.05; variables listed in order in which they were included in model; partial r^2 in parentheses; "+" before variable denotes positive association with density; "-", a negative association. WITU = Wild Turkey; RWBL = Red-winged Blackbird; INBU = Indigo Bunting; FISP = Field Sparrow; GRSP = Grasshopper Sparrow; SOSP = Song Sparrow

Table 8. Principal Component Analysis of landscape variables for Conservation Reserve Enhancement Program fields in south-central Pennsylvania, 2001-2003. Only variables with a PCA score ≥| 0.250| are shown.

	PC1	PC2	PC3	PC4	PC5
0.5 km radius					
Mean Patch Size (MPS)[a]			-0.444	-0.313	
Mean Shape Index (MSI)[a]		0.276		-0.309	
Perennial herbaceous cover	-0.259				
Annual herbaceous cover	-0.281				
Forest cover	0.310				
Road density				-0.392	
1 km radius					
Mean Patch Size (MPS)			-0.417	-0.311	
Mean Shape Index (MSI)		0.334			-0.258
Perennial herbaceous cover		0.335			
Annual herbaceous cover					
Forest cover	0.277				0.255
Road density			0.255		0.416
2 km radius			-0.366		
Mean Patch Size (MPS)					
Mean Shape Index (MSI)		0.362			
Perennial herbaceous cover		0.303			
Annual herbaceous cover	-0.254				
Forest cover	0.296				
Road density					-0.346
5 km radius					
Mean Patch Size (MPS)			-0.266		
Mean Shape Index (MSI)		0.333			
Perennial herbaceous cover					0.375
Annual herbaceous cover	-0.263				0.282
Forest cover	0.275				-0.370
Road density				-0.448	

[a]MPS and MSI are calculated using FRAGSTATS (Mcgarigal and Marks)

Table 9. Nest success[a] for individual species with ≥ 6 nests in Conservation Reserve Enhancement Program fields in south-central Pennsylvania, 2001-2003.

Species	Number of nests	Number of fields	Mayfield Success Rate
WITU	21	12	0.143 ± 0.072
MALL	7	6	0.419 ± 0.211
EAME	8	5	0.124 ± 0.115
RWBL	468	38	0.258 ±0.021
INBU	13	10	0.121 ± 0.121
FISP	141	28	0.279 ± 0.040
GRSP	19	8	0.126 ± 0.071
SOSP	45	22	0.335 ± 0.079

[a]Mayfield (Mayfield 1961, 1975); WITU = Wild Turkey; MALL = Mallard; EAME = Eastern Meadowlark; RWBL = Red-winged Blackbird; INBU = Indigo Bunting; FISP = Field Sparrow; GRSP = Grasshopper Sparrow; SOSP = Song Sparrow

Table 10. Comparing nest success on Conservation Reserve Enhancement Program fields in south-central Pennsylvannia, for species with ≥ 6 nests per year (2001- 2003), using Program CONTRAST.

	Mayfield nest success ± SE			
Species	2001	2002	2003	X^2 , df, p-value
RWBL	0.221 ± 0.033	0.336 ± 0.042	0.230 ± 0.033	5.32, 2, 0.070
FISP	0.213 ± 0.051	0.443 ± 0.095	0.248 ± 0.097	4.58, 2, 0.101
GRSP	0.316 ± 0.210	0.052 ± 0.062	0.141 ± 0.138	1.66, 2, 0.436
SOSP	0.326 ± 0.169	0.370 ± 0.103	0.196 ± 0.168	0.78, 2, 0.679

RWBL = Red-winged Blackbird; FISP = Field Sparrow; GRSP = Grasshopper Sparrow; SOSP = Song Sparrow

Table 11. Independent variables included in stepwise multiple regressions of nest success ratio (successful nests/number of nests) in Conservation Reserve Enhancement Program fields in south-central Pennsylvania, 2001 – 2003.

Species	Adj R^2	Independent variables
RWBL	0.09	+field size[a]
FISP	0.33	–PC3
SOSP		No variables entered model

[a] field size log transformed; variables listed in order in which they were included in model; “+” before variable denotes a positive association with density; “-“, denotes a negative association.

Table 12. Comparison of successful and unsuccessful nests and their distance from the closest edge, road, tree line, woodlot or agriculture using a paired t-test for nests located in Conservation Reserve Enhancement Program fields in south-central Pennsylvania, 2001-2003.

		Mean distance from edge (+SE)			
Species	Edge Type	Successful	Unsuccessful	T score (df)	P value
EAME	Closest edge	100.0 (25.0)	40.0 (18.0)	1.40 (1)	0.396
FISP	Closest edge	40.2 (14.5)	60.4 (13.9)	-1.87 (11)	0.088
GRSP	Closest edge	75.0 (22.5)	64.5 (6.9)	0.36 (2)	0.754
RWBL	Closest edge	75.1 (7.4)	75.4 (6.4)	-0.05 (21)	0.963
SOSP	Closest edge	37.8 (10.0)	31.5 (6.8)	0.43 (6)	0.681
EAME	Road	162.5 (37.5)	125.0 (60.0)	1.67 (1)	0.344
FISP	Road	79.7 (34.1)	139.9 (20.9)	-3.72 (2)	0.065
RWBL	Road	111.5 (15.0)	126.2 (17.5)	-1.22 (15)	0.240
SOSP	Road	132.8 (55.2)	69.4 (42.0)	1.61 (3)	0.206
FISP	Trees	40.8 (14.6)	54.4 (13.0)	-1.42 (11)	0.185
GRSP	Trees	97.5 (2.5)	65.8 (5.8)	3.85 (1)	0.162
RWBL	Trees	97.9 (9.6)	115.5 (11.0)	-2.26 (20)	0.035
SOSP	Trees	47.5 (12.4)	41.4 (7.3)	0.49 (5)	0.644
EAME	Woodlot	128.5 (46.5)	105.3 (47.3)	31.00 (1)	0.021
FISP	Woodlot	71.1 (29.2)	65.1 (18.3)	0.36 (10)	0.724
GRSP	Woodlot	140 (45.0)	90.5 (19.5)	1.94 (1)	0.303
RWBL	Woodlot	146.1 (18.1)	131.1 (15.6)	1.01 (14)	0.330
SOSP	Woodlot	36.7 (21.6)	51.9 (10.4)	-0.93 (2)	0.449
RWBL	Agriculture	120 (23.3)	135.3 (20.6)	-1.02 (12)	0.326

Table 13. Percentage of Conservation Reserve Enhancement Program fields and hayfields with at least one obligate grassland species[a] located during surveys, south-central Pennsylvania, 2001-2003.

	CREP (n)	Hay (n)
Present	47% (52)	52% (9)
Absent	53% (58)	47% (8)

[a]Ring-necked Pheasant, Bobolink, Dickcissel, Eastern Meadowlark, Grasshopper Sparrow, Savannah Sparrow, and Vesper Sparrow

Table 14. Percentage of Conservation Reserve Enhancement Program fields and hayfields with at least one obligate[a] grassland species found nesting, south-central Pennsylvania, 2001-2003.

	CREP (n)	Hay (n)
Present	25% (16)	18% (2)
Absent	75% (48)	82% (9)

[a]Ring-necked Pheasant, Bobolink, Dickcissel, Eastern Meadowlark, Grasshopper Sparrow, Savannah Sparrow, and Vesper Sparrow

Table 15. Comparison of the mean (± SE) density of birds (birds ha^{-1}) on Conservation Reserve Enhancement Program fields and hayfields in south-central Pennsylvania, 2002 and 2003.

Species	CREP (n=101)	Hayfield (n=12)	T value	p value
BOBO	0.10 ± 0.06	0.15 ± 0.10	-0.48	0.636
EAME	0.01 ± 0.003	0.01 ± 0.01	0.23	0.822
RWBL	0.78 ± 0.08	0.72 ± 0.31	0.18	0.863
INBU	0.14 ± 0.03	0.01 ± 0.01	4.31	0.000
FISP	0.11 + 0.02	0.01 ± 0.01	5.27	0.000
GRSP	0.12 ± 0.03	0.05 ± 0.02	2.25	0.029
SOSP[a]	0.42 ± 0.05	0	8.70	0.000

[a]There were no birds located on hayfields so a one-tailed t-test was performed against a mean of 0.

BOBO = Bobolink; EAME = Eastern Meadowlark; RWBL = Red-winged Blackbird; INBU = Indigo Bunting; FISP = Field Sparrow; GRSP = Grasshopper Sparrow; SOSP = Song Sparrow

Table 16. ANOVA comparisons for each species mean nest abundance (nest ha^{-1}) on Conservation Reserve Enhancement Program fields in south-central Pennsylvania, 2001-2003.

	Mean ± SE				
Years	2001	2002	2003	F value (df=2)	p value
WITU	0.018 ± 0.012	0.027 ± 0.014	0.039 ± 0.017	0.36	0.698
EAME	0.034 ± 0.021	0.00	0.007 ± 0.007	2.95	0.06
RWBL	0.727 ± 0.351	0.315 ± 0.113	0.631 ± 0.117	1.72	0.187
INBU	0.018 ± 0.012	0.018 ± 0.010	0.018 ± 0.011	0.00	0.999
FISP	0.450 ± 0.172[b,c]	0.142 ± 0.056[b]	0.075 ± 0.024[c]	8.61	0.001
GRSP	0.017 ± 0.011	0.025 ± 0.013	0.013 ± 0.008	0.45	0.638
SOSP	0.155 ± 0.070[a]	0.038 ± 0.016[a]	0.049 ± 0.019	3.64	0.032

[a,b,c] Tukey’s comparison test with matching letters having a significant difference

WITU = Wild Turkey; EAME = Eastern Meadowlark; RWBL = Red-winged Blackbird; INBU = Indigo Bunting; FISP = Field Sparrow; GRSP = Grasshopper Sparrow; SOSP = Song Sparrow

Table 17. Comparisons of mean nest abundance (nests ha^{-1}) of Conservation Reserve Enhancement Program fields and hayfields in south-central Pennsylvania, 2001-2003.

	mean ± SE			
Species	CREP	Hay	t or F value df)	p value
WITU[a]	0.031 ± 0.009	0.000	3.32 (1)	0.001***
EAME[a]	0.009 ± 0.005	0.000	1.84 (1)	0.070
RWBL	0.525 ± 0.094	0.460 ± 0.353	0.18 (11)	0.860
INBU[a]	0.018 ± 0.006	0.000	2.76 (1)	0.008**
FISP[b]	0.216 ± 0.055	0.009 ± 0.009	4.65 (1)	0.035*
GRSP	0.020 ± 0.007	0.008 ± 0.008	1.18 (33)	0.247
SOSP[b]	0.063 ± 0.016	0.009 ± 0.009	2.86 (1)	0.095

[a] one-tailed t-test versus mean 0 was used because hayfields had no nests; [b] GLM ANOVA to model year as a covariate; WITU = Wild Turkey; EAME = Eastern Meadowlark; RWBL = Red-winged Blackbird; INBU = Indigo Bunting; FISP = Field Sparrow; GRSP = Grasshopper Sparrow; SOSP = Song Sparrow

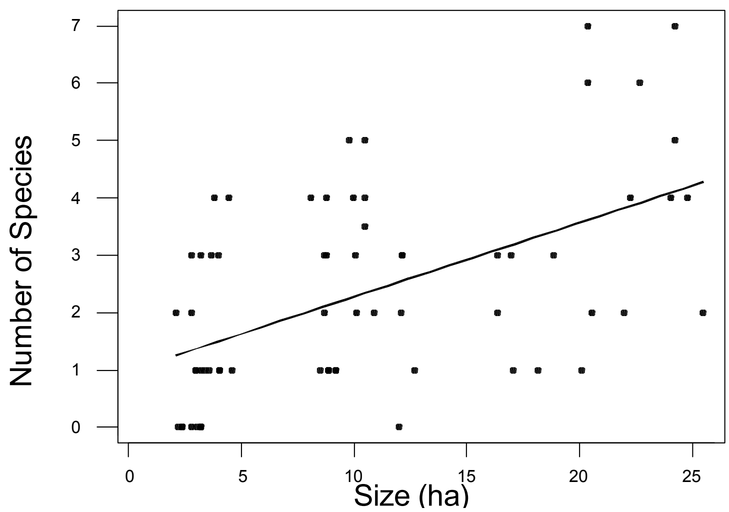

Figure 1. The number of species located nesting on CREP fields during the summers of 2001-2003 in south-central Pennsylvania. Number of species = 0.980683 + 0.129355 size (R-Sq adj. 26.6%).

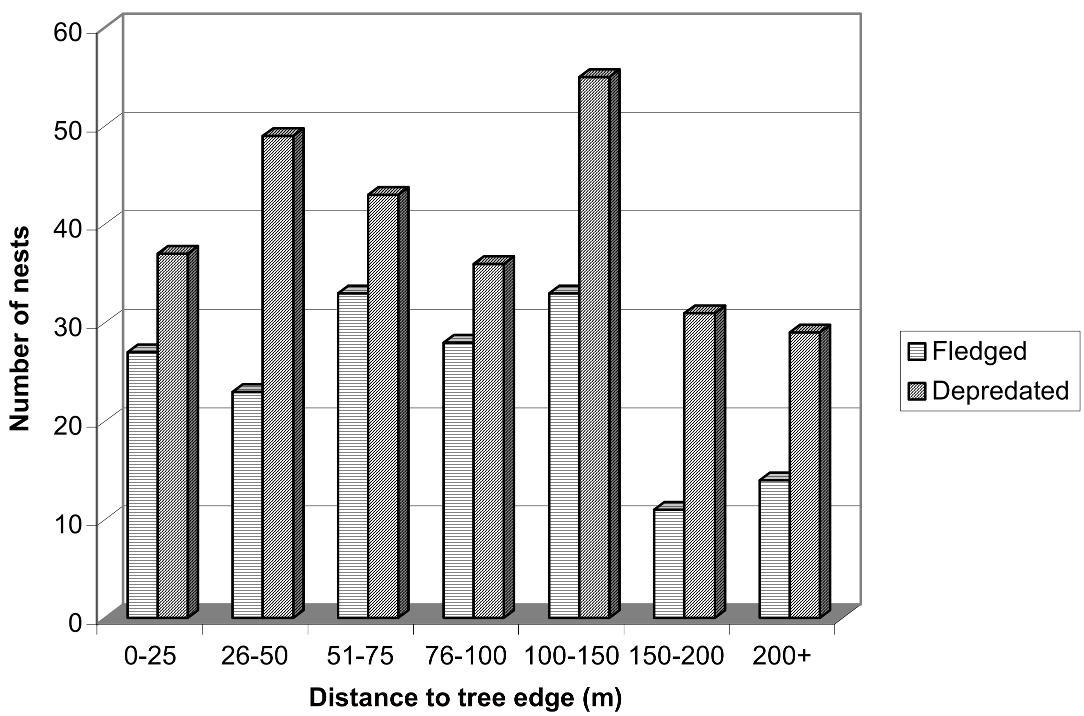

Figure 2. The number of nests that were fledged and depredated by distance category to a tree line or forest for all nests found on Conservation Reserve Enhancement Program fields in south-central Pennsylvania, 2001–2003.

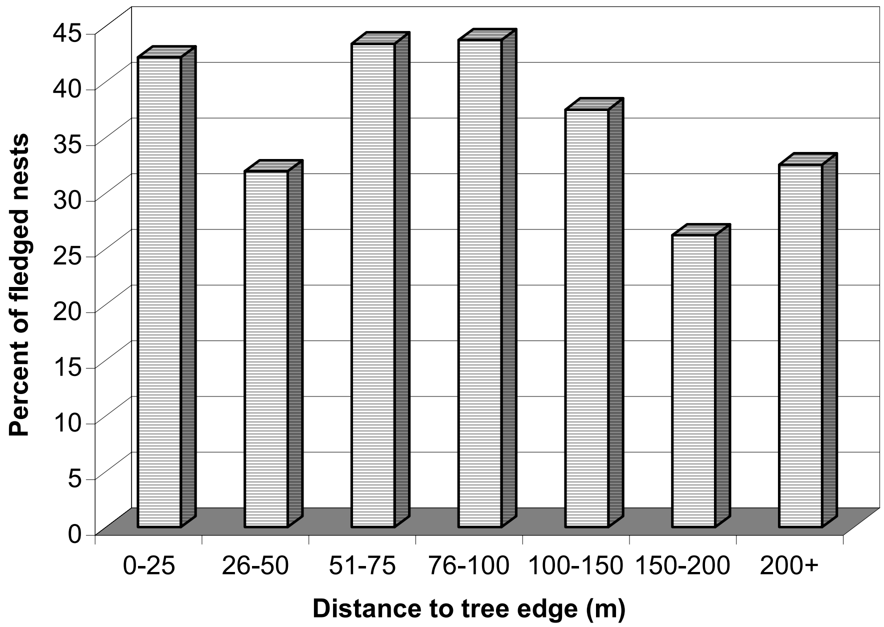

Figure 3. The percentage of nests that fledged in each distance category to a tree line or forest for all nests found on Conservation Reserve Enhancement Program fields in south-central Pennsylvania, 2001–2003.

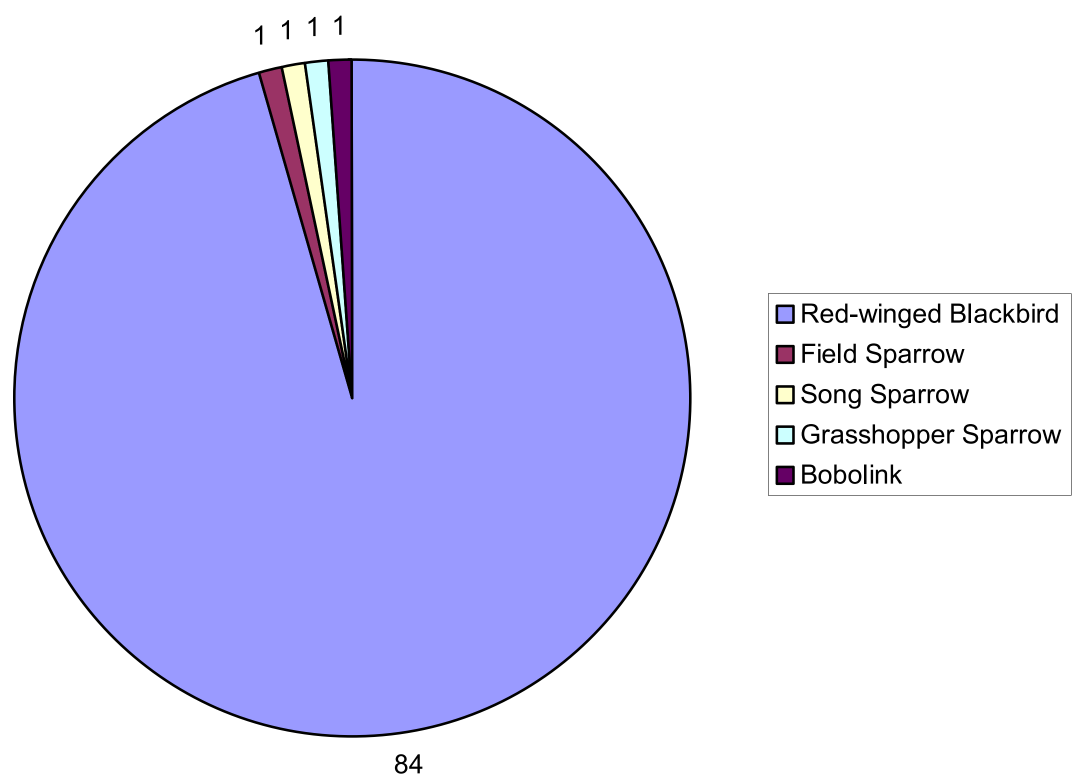

Figure 4. The number of nests, by species, located on hayfields in south-central Pennsylvania, 2001–2003.

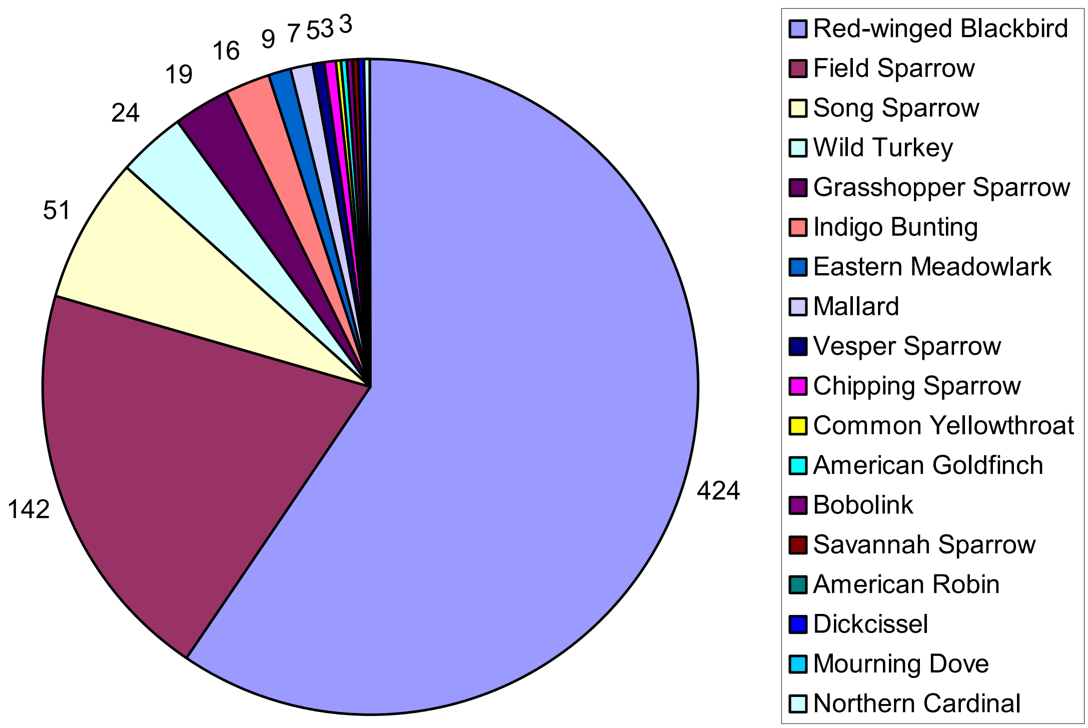

Figure 5. The number of nests, by species, located on Conservation Reserve Enhancement Program fields in south-central Pennsylvania, 2001–2003. Numbers are not shown for those species with < 2 nests.

Appendix 1- Common names, scientific names and abbreviations for bird species mentioned in the text.

Species common name (*Scientific name*)	Abbreviation
Mallard (*Anas platyrhynchos)*	MALL
Northern Harrier (*Circus cyaneus*)	NOHA
Northern Bobwhite (*Colinus virginianus)*	NOBO
Ring-necked Pheasant (*Phasianus colchicus)*	RNPH
Wild Turkey (*Meleagris gallopavo)*	WITU
Upland Sandpiper (*Bartramia longicauda*)	UPSA
Mourning Dove (*Zenaida macroura*)	MODO
American Robin (*Turdus migratorus*)	AMRO
Common Yellowthroat (*Geothlypis trichas)*	COYE
Northern Cardinal (*Cardinalis cardinalis)*	NOCA
Indigo Bunting (*Passerina cyanea)*	INBU
Dickcissel (*Spiza americana*)	DICK
Field Sparrow (*Spiza pusilla*)	FISP
Chipping Sparrow (*Spizella passerina*)	CHSP
Grasshopper Sparrow (*Ammodramus savannarum*)	GRSP
Henslow’s Sparrow (*Ammodramus henslowii*)	HESP
Savannah Sparrow (*Passerculus sandwichensis)*	SAVS
Vesper Sparrow (*Pooecetes gramineus*)	VESP
Song Sparrow (*Melospiza melodia)*	SOSP
Eastern Meadowlark (*Sturnella magna*)	EAME
Bobolink (*Dolichonyx oryzivorus*)	BOBO
Brown-headed Cowbird (*Molothrus ater*)	BHCO
Red-winged Blackbird (*Agelaius phoeniceus)*	RWBL
American Goldfinch (*Carduelis tristis)*	AMGO