Human–Wildlife Interactions 9(2):171–179, Fall 2015

Winter habitat associations of blackbirds and starlings wintering in the south-central United States

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Abstract: Birds can cause extensive crop damage in the United States. In some regions, depredating species comprise a substantial portion of the total avian population, emphasizing their importance both economically and ecologically. We used the National Audubon Society Christmas Bird Count data from the south-central United States and mixed-effects models to identify habitat factors associated with population trend and abundance for 5 species: red-winged blackbird (*Agelaius phoeniceus*), common grackle (*Quiscalus quiscula*), rusty blackbird (*Euphagus carolinus*), Brewer's blackbird (*Euphagus cyanocephalus*), and European starling (*Sturnus vulgaris*). Overall, we found positive associations between bird abundance and agricultural land-cover for all species. Relationships between abundance and other land-cover types were species-specific, often with contrasting relationships among species. Likewise, we found no consistent patterns among abundance and climate. Of the 5 species, only red-winged blackbirds had a significant population trend in our study area, increasing annually by 2.4%. There was marginal evidence to suggest population increases for rusty blackbirds, whereas all other species showed no trend in population size within our study area. Our study provides managers who are interested in limiting crop damage in the south-central United States with novel information on habitat associations in the region that could be used to improve management and control actions.

Key words: blackbird, climate, habitat, human–wildlife conflict, mixed-effects, population trend, starling

Icterid blackbirds and European starlings (*Sturnus vulgaris*) collectively cause nearly $1 billion in crop damage and control efforts each year in the United States (Linz et al. 1996, Pimentel 2007). These species also have the capacity to transmit diseases to both livestock (Gaukler et al. 2008, 2009) and humans (Chick et al. 1980), causing additional economic and social damage. These species, including red-winged blackbirds (*Agelaius phoeniceus*), common grackles (*Quiscalus quiscula*), rusty blackbirds (*Euphagus carolinus*), and Brewer's blackbirds (*Euphagus cyanocephalus*), along with European starlings, congregate in agricultural areas, forming mixed-species flocks that can exceed millions of individuals (Figure 1). Because these species have the potential to cause damage to agricultural crops and spread infectious diseases, there is great interest in understanding the habitat factors associated with their distribution and abundance.

Despite their ability to use abundant agricultural food resources, there is concern regarding the long-term viability of some blackbird species. For example, the International Union for the Conservation of Nature (IUCN; 2007) changed the status of rusty blackbirds from Least Concern to Vulnerable because of recent population declines. Similarly, red-winged blackbirds are experiencing widespread population declines (Weatherhead 2005, Sauer et al. 2013). Although changes in agricultural

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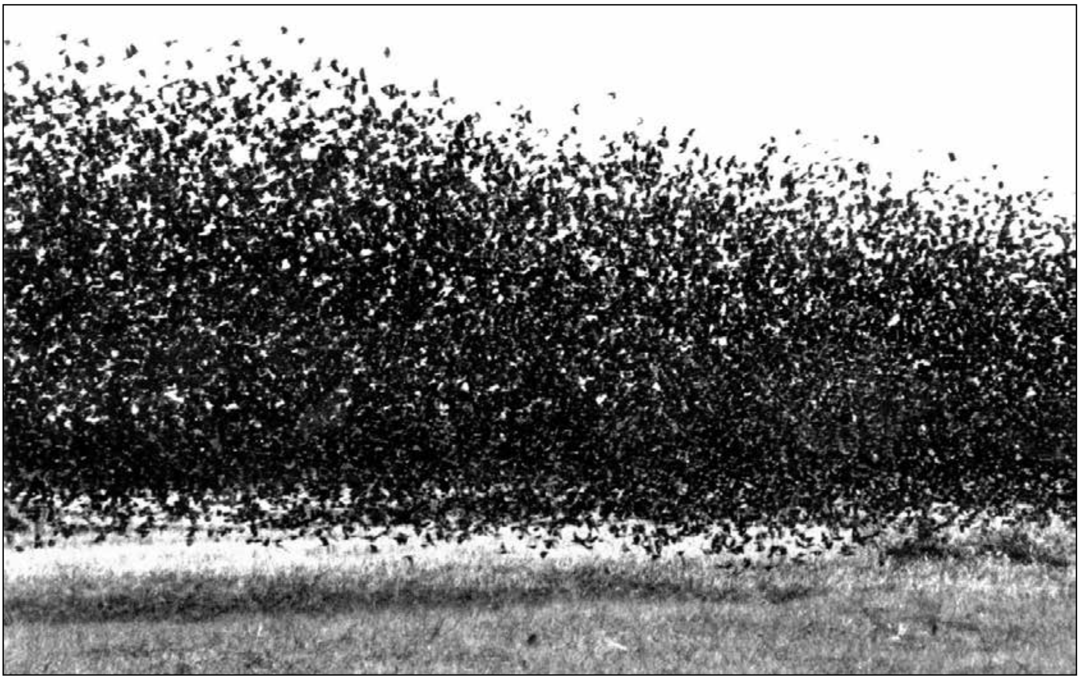

Figure 1. A cloud of blackbirds swarming over an agricultural field.

practices have been identified as potential causes for declines in blackbird abundance (Besser et al. 1984, Blackwell and Dolbeer 2001), habitat conditions on the wintering grounds may be contributing to declines in abundance (Greenberg et al. 2011). However, little is known of the wintering ecology of these or other blackbird species. Thus, there is a need to identify factors associated with abundance and trend on the wintering grounds for these and other species for both conservation and crop damage mitigation purposes.

Large-scale monitoring programs, when coupled with appropriate analytical methods, have the capacity to inform wildlife conservation and management programs (Sauer et al. 2003, 2004). Such programs can combine the benefits of large spatial coverages with long-term data, providing spatio-temporal data that are typically unattainable with targeted studies. In doing so, these programs often serve as the basis for understanding broad-scale habitat associations (Thogmartin et al. 2007) or regional population trends (Link and Sauer 2002). Here, we apply advanced modeling techniques to fill in key knowledge gaps related to the winter ecology of crop damaging bird species in the south-central United States.

Methods

We limited our study area to the states of Alabama, Arkansas, Kansas, Louisiana, Mississippi, Missouri, Oklahoma, Tennessee, and the eastern half of Texas. Collectively, this area (2,018,766 km$^{2)}$ approximates the southern half of the Mississippi Flyway and harbors the greatest overlap in starling and blackbird wintering areas (Orians 1985, Martin 2002). Within this area, we used data from all Christmas Bird Count (CBC; National Audubon Society 2010) surveys collected between the winters of 1988–1989 and 2008–2009. The CBC is a citizen science program administered by the Audubon Society in which volunteers identify and count all birds encountered on a single day within 457-km^2 circles (n = 333 in our study area). Surveys are conducted once each winter between December 14 and January 5 and have been conducted annually since 1900. These data have been used to address questions related to avian population dynamics (Link et al. 2008, Greenberg et al. 2011). From each survey, we extracted the number of individuals observed of each target species (Brewer's blackbird, common grackle, European starling, red-winged blackbird, rusty blackbird) and the total number of hours surveyed.

Within each survey circle, we calculated the total area in each of 9 land-cover types that were reclassified from the National Landcover Database (NLCD; Homer et al. 2007, Vogelman et al. 2001). These types were open water, developed, barren, forested, shrubland, non-natural woody (e.g., orchards, plantations), herbaceous upland (grassland), herbaceous cultivated (farmland), and wetland (Anderson et al. 1976). Because unique land-cover values were not available for each year, we assigned values from the 1992 NLCD to surveys conducted between the winters of 1988–1989, 1997–1998, and from the 2001 NLCD to all surveys conducted after 1997–1998. We also obtained annual and winter (November to January) estimates of minimum temperature (T_{min}), maximum temperature (T_{max}), mean temperature (T_{avg}), and total precipitation (P) from the National Oceanic and Atmospheric Administration (NOAA) climatological summaries for each site. We obtained summaries from the NOAA weather station (National Climatic Data Center, <http://www.ncdc.noaa.gov/cdo-web/datatools>) nearest to the CBC survey site, with a maximum distance of 32 km. We hypothesized that annual metrics would be representative of conditions affecting habitat (e.g., vegetation) structure, while short-term winter estimates would be representative of in situ weather conditions experienced by birds in our study area (Forcey et al. 2007).

We modeled abundance of each species using mixed-effects models with a Poisson link (Bates 2010). Our models followed the form:

$$\log (Y_{ijk}) = \beta_0 + \gamma_i + \gamma_j + \gamma_k + \boldsymbol{\beta}\mathbf{X} + \xi_{ijk},$$

where Y_{ijk} is the expected abundance, β_0 is the marginal intercept, γ_i, γ_j, and γ_k are the random intercept terms associated with the North American Bird Conservation Initiative's Bird Conservation Region (BCR, <*www.nabci-us.org*>), year, and site respectively, $\boldsymbol{\beta}\mathbf{X}$ is the vector of fixed effects coefficients associated with covariates, and ξ_{ijk} is an observation-level random effect to account for overdispersion (Martin 2003). We included random effects for BCR, site, and year to account for regional, local, and temporal heterogeneity in abundance. Our fixed effects included terms for each of the land-cover types, climatic variables, a term representing population trend, and an offset based on the number of hours in each survey, to control for varying survey effort (Link and Sauer 1999). The random effect for year describes year-to-year variability over and above that described by the long-term trend. We estimated the population trend for each species (v), expressed as annual percentage change, using the following formula:

$$v = (e^{\beta} - 1) * 100,$$

where β is the coefficient for the population trend effect in our abundance model. Exponentiating the trend coefficient β (e^{β}), thus, moves the estimate of trend from the log scale to the count scale (i.e., the scale of the observations). We chose this approach rather than using the empirical counts to estimate population trend so that we could account for bias associated with variation in survey effort and observation error associated with the sampling process. We calculated 95% confidence intervals on population trend by replacing the parameter estimate β in the above formula with the 95% confidence limits on β from our abundance model.

Land-cover and climatic variables were standardized prior to analyses. We selected the best model for each species based on minimization of Akaike's Information Criterion (AIC) scores when varying the number of fixed effects in our model, while always retaining the effects for population trend and survey effort (Burnham and Anderson 2002). In each case, the best model was unambiguous (ΔAIC >2).

Results

We used 5,295 surveys from our study area (Table 1). The number of surveys reporting ≥1 individual ranged from 1,938 (36.5%) for rusty blackbirds to 5,195 (98.1%) for European starlings. With the exception of farmland, for which each species showed a positive relationship, there were no consistent patterns among species in their responses to different land-cover types (Table 2). The only other variable present in the best models for each species was the proportion of developed area, although for red-winged blackbirds and Brewer's blackbirds this parameter estimate overlapped zero (Table 2). The barren and non-natural woody land-cover types were the only ones not included in the final model for ≥1 species.

Similarly, the effects of climate on bird abundance were highly variable, with both temperature and precipitation metrics exhibiting positive and negative associations with bird abundance (Table 2). Annual precipitation was the only climate variable that was included for ≥2 species, although the effects of this variable were small and inconsistent among species (Table 2). Winter precipitation was present in the final model only for rusty blackbirds and European starlings, exhibiting divergent relationships for the 2 species. Likewise, metrics of winter temperature were included only in models for rusty blackbirds and European starlings, exhibiting a negative association with abundance for each species. All of the T_{avg} metrics and annual T_{max} were absent from all of the final models.

Table 1. Species-specific count summaries for National Audubon Society's Christmas Bird Count surveys used in models of blackbird abundance in the south-central United States. Means are the average count during 1988 to 2009, inclusive, whereas the minima and maxima are year-specific observations within that 21-year period.

Species	Minimum	Maximum	Mean
Red-winged blackbird	0	52,915,000	66,042
Rusty blackbird	0	50,000	56
Brewer's blackbird	0	250,268	295
Common grackle	0	4,229,095	6,590
European starling	0	20,001,850	8,722

Of the 5 species, only red-winged blackbirds showed a strong population trend in our study area, increasing by 2.4% (95% CI = 0.9 to 3.9) per year. There was marginal evidence to suggest a population increase for rusty blackbird, with confidence intervals slightly overlapping zero (95% CI = -0.004 to 5.4) despite the largest estimate of annual change (2.7%) of the species examined. The remaining species all had confidence intervals widely overlapping zero, suggesting little to no change in population size during the 20 years of our study (Brewer's blackbirds = 1.03% [95% CI = -1.4 to 3.5], common grackles = -0.81% [95% CI = -2.4 to 0.76], European starlings = -0.55% [95% CI = -1.5 to 0.4]) .

Discussion

We examined the effects of land-cover and climate on the abundance of 5 crop-damaging bird species in the south-central United States. We found that blackbirds and starlings exhibit variable responses to land-cover types and climate on their wintering grounds. Our results consistently indicated that bird abundance was higher in areas with farmland for each species. The positive associations between abundance and farmland were not surprising, as these species commonly use agricultural resources for food (Linz et al. 2011). We also found generally positive associations between abundance and the amount of developed area. This result was not entirely surprising for common grackles or European starlings, both of which are often associated with anthropogenically altered habitats (Feare 1984, Peer and Bollinger 1997). We found inconsistent patterns among abundance and climate metrics, with positive and negative associations to temperature and precipitation (Table 1). Given that these species are highly mobile and that, in most cases, these relationships were relatively weak, there may be little reason to expect long-term or seasonal climate patterns to influence abundance, at least at the scale we measured them. The strong positive association between Brewer's blackbird abundance and both forest and shrubland was unexpected, as this species is generally not associated with such habitats (Stepney 1975). However, its strong association with other land-cover types may indicate that this species simply has a low baseline abundance and that virtually any semi-natural or productive habitats are beneficial for this species, or, conversely, that it can display high levels of plasticity in habitat selection.

Our use of mixed-effects models allowed us to separate the components of variation in counts attributed to the sampling process (i.e., the random effects) and those attributed to environmental factors. Similar approaches have been used to model population trends (Link and Sauer 1998, 2007) and spatial abundance patterns (Thogmartin et al. 2004) for bird species from other large-scale survey data. An additional benefit of this approach

Table 2. Fixed-effects parameter estimates (β) and standard errors (SE) from best models of bird abundance in the south-central United States. Missing values indicate parameter was not included in best model.

Parameter	Red-winged blackbird		Rusty blackbird		Brewer's blackbird		Common grackle		European starling	
	β	SE	β	SE	β	SE	β	SE	β	SE
Population trend	0.0240	0.0077	0.0264	0.0135	0.0103	0.0125	-0.0081	0.0079	-0.0055	0.0048
Developed	0.0340	0.0659	0.2750	0.1120	-0.0234	0.1340	0.1870	0.0801	0.2100	0.0397
Farmland	0.2780	0.0446	0.2860	0.0798	0.7640	0.1000	0.1720	0.0604	0.1420	0.0269
Forested	-0.1060	0.0512	0.0837	0.0935	0.4690	0.1040	-	-	-	-
Grassland	-	-	-	-	0.9530	0.1260	-0.3710	0.0794	-	-
Shrubland	-	-	-0.2310	0.1550	0.6060	0.1290	-	-	-0.0760	0.0364
Water	0.1680	0.0870	-	-	-	-	-0.1940	0.1130	-	-
Wetland	-	-	-	-	-	-	-	-	-0.1100	0.0452
Annual P[1]	0.0425	0.0252	-	-	-0.0653	0.0494	0.0634	0.0320	-	-
Winter P	-	-	-0.0048	0.0646	-	-	-	-	0.0570	0.0206
Annual T_{min}[2]	-	-	-	-	0.8400	0.2320	-	-	-	-
Winter T_{max}[3]	-	-	-	-	-	-	-	-	-0.1220	0.0317
Winter T_{min}	-	-	-0.5310	0.1360	-	-	-	-	-	-

[1] Precipitation
[2] Minimum temperature
[3] Maximum temperature

is that we were able to account for sampling variation in counts when estimating population trend. Failure to account for variation that is introduced by the sampling process can lead to biased and imprecise estimates of population trend (Humbert et al. 2009). Additionally, our use of an observation-level random effect (ξ_{ijk}) allowed us to account for overdispersion in our data, a common problem with the analysis of count data. Our inclusion of an offset term to account for variation in sampling intensity also likely improved our estimates (Link and Sauer 1999). However, we were unable to fully account for the unknown quality of the data. We assumed in our modeling efforts that the individual counts contained within the data were accurate. Violations of this assumption would lead to less precision in our parameter estimates than we report here, but likely would not change the general conclusions unless systematic bias in reported counts was present.

Although previous studies have attempted to use large-scale survey data to estimate population size (Thogmartin et al. 2014), we, instead, focused on population trends. Contrary to our expectations, based on most reported accounts, we found evidence of increasing red-winged blackbird populations in our study area. Most reports of red-winged blackbird population trends suggest moderate declines occurring at both localized scales and throughout the species' range (Blackwell and Dolbeer 2001, Weatherhead 2005, Sauer et al. 2013). However, our estimates differ from most previous estimates in that they are from a region where the species is less well-studied and during a period (winter) in which little is known of their ecology. For example, population trend estimates from analyses of Breeding Bird Survey data represent a much greater geographic range than our study area and are based on surveys conducted during the breeding season (Sauer et al. 2013). This divergence in estimated population trends highlights the need for research emphasizing the full annual cycle for avian species, as patterns evident during 1 part of the year may not represent those during another. These seasonal differences were not as obvious in the other species we studied, with no significant trends in population size. However, it is worth noting that rusty blackbird had marginal evidence of population increases in our study area because the species was recently listed as Vulnerable by the IUCN, due to population declines. The reasons for this increase in our study area are unclear, as rusty blackbirds are thought to be experiencing population declines throughout their range (Greenberg et al. 2011). One plausible explanation is that loss of suitable wintering habitat outside of our study region has forced more individuals into our study area during the winter, and, thus, population-level declines may still be occurring despite regional increases in abundance. Additional research into the population dynamics of this species may be warranted. Although European starling populations were abundant and had the capacity to display high levels of behavioral plasticity, we failed to find any evidence of their increasing. This constancy in population size may be the result of intensive population control efforts, which are often focused on this nonnative species during periods of crop damage (Homan et al. 2013).

A potential shortcoming of our approach is that we did not address spatial patterns in population change within our study area, as addressing such issues generally requires finer resolution data than were available to us. Our use of covariates for BCR and site would effectively remove residual spatial variation in our estimates. However, hierarchical spatio-temporal models have the ability to identify and estimate spatial variation in population trends within a study area (e.g., Ross et al. 2012) and may prove useful in future studies.

Most recent studies pertaining to blackbirds and European starlings have focused on breeding biology or crop damage prevention and management, largely overlooking the ecology of these species on their wintering grounds in the south-central United States, an area that has experienced rapid and substantial changes in land-use in recent years (e.g., Hamilton et al. 2014). Although our study provides useful information regarding this knowledge gap, there are still numerous questions regarding the ecology and management of these species. For example, we know little of the survival rates of these species during winter, and such information could prove useful in developing management strategies by identifying the life-stages and demographic rates with the greatest influence on population size (Wisdom et al. 2000). Effective management requires an understanding of the ecological processes governing population dynamics, and we suggest that future research should emphasize the identification of such processes and their effects on avian populations.

Acknowledgments

We are grateful to the numerous individuals who contributed to the Christmas Bird Count and to the National Audubon Society for collecting and managing their bird-count data. We appreciate the comments of 2 anonymous reviewers on an earlier version of this manuscript, as well as those provided by K. Lohman and J. Waide. Any use of trade, product, or firm names are for descriptive purposes only and do not imply endorsement by the U. S. Government or North Dakota State University.

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