Spring 1999

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David Engle
Oklahoma State University, david.engle@okstate.edu

Tania L. Criner
Oklahoma State University, Stillwater, OK

Jon C. Boren
Oklahoma State University, Stillwater, OK

Ronald E. Masters
Oklahoma State University, Stillwater, OK

Mark C. Gregory
Oklahoma State University, Stillwater, OK

Great Plains Research 9 (Spring 1999): 55-73

RESPONSE OF BREEDING BIRDS IN THE GREAT PLAINS TO LOW DENSITY URBAN SPRAWL

David M. Engle*, Tania L. Criner, Jon C. Boren, Ronald E. Masters, and **Mark S. Gregory**

Division of Agricultural Sciences and Natural Resources
Oklahoma State University
Stillwater OK 74078

ABSTRACT—Low-density development consumes large tracts of the rural landscape surrounding Great Plains cities. Our objective was to determine how low-density sprawl influences the presence of birds. We used logistic regression models developed for two eastern Great Plains study areas for 1966-1990 to determine the probability of occurrence of bird species on the same areas in 1902. The two areas experienced different levels of low-density urban sprawl from 1902-1990. Birds associated with forests and forest edge are expected to decrease in both areas. Some of these are species of high concern. Dickcissel, a grassland bird, is expected to increase in the area of low sprawl, whereas several bird species associated with intense development, such as the house sparrow, are expected to increase in the area with a greater level of urban sprawl. We conclude that changes in land use and human activity associated with urbanization are influencing plains bird communities.

Introduction

Native plant communities are being replaced with managed systems of altered landscape structure, influencing ecological and environmental relationships (Burgess and Sharpe 1981; Krummel et al. 1987; Samson and Knopf 1994; Vitousek 1994). A growing concern is sprawling, low-density development that consumes large tracts of the rural, agricultural landscape in the US (Alig and Healy 1987; Daniels 1991; Beatley and Manning 1997; Theobald et al. 1996). In rangeland areas of the Great Plains, as in the western US in general, the structural integrity of landscapes near urban centers is compromised by conversion of large ranches into smaller ranches, often called ranchettes or acreages (Huntsinger and Hopkinson 1996; Theobald et al. 1996). Similarly, as in numerous other regions of the US, portions of the Great Plains near urban centers are experiencing an increase in net migration of people into nonmetropolitan areas (USDA, Economic Research Service 1997).

Even moderate levels of development in the rural landscape fragments grasslands and forests, and it may reduce the abundance and diversity of native birds (Blair 1996). Many bird species declined significantly in eastern and midwestern North America between 1966 and 1979 (Robbins et al. 1986), a trend that has continued in both northeastern and Midwestern states (Bollinger and Gavin 1992; Herkert 1995). North American Breeding Bird Survey data from eastern North America between 1966 and 1991 confirmed that 16 bird species characteristic of open grassland or savanna and 12 bird species characteristic of shrubland had declined. Only three grassland/savanna bird species and four shrubland species had increased (Askins 1993).

Forest fragmentation by urban sprawl and agricultural development explains some of the decline of songbirds in the hardwood forests of the central US (Robinson et al. 1995; Thompson et al. 1996). The reasons for population declines among grassland birds in the Great Plains are less clear (Knopf 1994). The Conservation Reserve Program, administered by the USDA since 1985, has had a major influence on avian communities in the central United States, reversing some of the influence of agricultural development (Johnson and Schwartz 1993). Conversion of cropland to grassland in the Conservation Reserve Program can benefit some grassland birds (Johnson and Igl 1995; Best et al. 1997). Less is known about the influence of converting native vegetation to cropland or stands of introduced grasses associated with ranchettes. Historical information about bird communities provides a point of reference for preservation efforts. However, we lack sufficient information on pre-European settlement assemblages of native birds to fully guide land use planning necessary to preserve native bird diversity in rural landscapes.

Our objective was to model the presence of bird species on areas in 1902 versus 1990 to determine if changes in land use are reflected in habitat potential for breeding birds. We used logistic regression with North American Breeding Bird Survey data and cover type to determine the probability of occurrence of bird species in years 1902 and 1990 in two rural areas differentially exposed to non-metropolitan human population growth and land use. Both areas lie at the eastern edge of the Great Plains in the transition region between the deciduous forest and tallgrass prairie. The results provide insight into the likely changes in bird presence in rural areas in relation to low density urban sprawl and agriculture in eastern Great Plains.

Study Area

We selected two areas corresponding to North American Breeding Bird Survey routes 024 (Collinsville) and 026 (Bartlesville) (Baumgartner and Baumgartner 1992) because they represent the suburban to rural transition. The areas are located along the eastern edge of the Great Plains where the native vegetation is a transitional oak forest with interspersed grasslands (Bruner 1931; Gray and Galloway 1959; USDA Soil Conservation Service 1981). Route 026 is in sparsely populated Osage County, and route 024, is in Washington County, Oklahoma, closer to metropolitan Tulsa. Tulsa is a major metropolitan area of northern Oklahoma. A special census conducted in 1907 estimated the population of Tulsa to be 7,298 (US Bureau of the Census 1913). By 1990 the population was 361,628 (US Bureau of the Census 1990). Population density of Washington County was 12 per km^2 in 1907 and 44 per km^2 in 1990, whereas the population density of Osage County was 3 per km^2 in 1907 and 7 per km^2 in 1990. In 1990, rural population density of Washington County was 10 per km^2, twice that of Osage County (5 per km^2). Rural population is defined as those people residing in communities of less than 2,500 people (US Bureau of the Census 1990). Route 024 area will be referred to hereafter as the high human density area and route 026 will be referred to as the low human density area.

Methods

We obtained field sheets of North American Breeding Bird Survey (BBS) routes 024 and 026 for 1966-1991 from the U. S. Fish and Wildlife Service Office of Migratory Bird Management, Laurel, Maryland USA. All birds seen or heard in a 3-minute time period within 400 m of each of 50 counting stops spaced at 800-m intervals along each of the 40.2-km routes were recorded annually by an observer in late May or June (Bystrak 1981). Attempts are made to have the same observer on a route for a series of years to maintain data continuity (Sauer and Droege 1989). A detailed description of methodology and the criteria used to determine route location can be found in Robbins and Van Velzen (1967).

To determine cover type on the routes, we used aerial photographs and General Land Office maps. Aerial photographs for 1990 were obtained from the USDA, Agricultural Stabilization and Conservation Service, Aerial Photography Field Office, Salt Lake City, Utah. Photographs were black and white, 60.96 X 60.96-cm enlargements with a representative fraction of

1:7,920. We used portions of the photographs that covered North American Breeding Bird Survey routes to provide coverage of approximately 6,430 ha for each study area. Topographic quadrangle maps (scale = 1:24,000), obtained from the Oklahoma Geological Survey, Norman, Oklahoma USA, were used for geo-registration and to aid in photo-interpretation. The quadrangles indicate both geographical coordinates and specific features such as vegetation, water, roads, and towns.

General Land Office field notes for both areas were obtained from the Oklahoma Department of Libraries, Oklahoma City, Oklahoma USA. The areas were surveyed in 1896 (high human density) and 1908 (low human density). Hereafter, the survey year will be referred to as 1902. Field notes taken by US surveyors, as well as maps derived by the surveyors from their field notes, provide a standardized vegetation sample; and, these notes are usable for quantitative as well as qualitative analysis of the pre-European settlement characteristics of the Midwestern US (Bourdo 1956; Hutchison 1988; Nelson 1997).

We used the cover type data from Boren et al. (1997a) from the 1990 photographs that covered our routes (40.2 km in length and 0.8 km on each side of the route boundary). Boren et al. (1997a) traced polygons of land use cover types on clear acetate overlays to estimate cover in a Geographic Information System (GIS). After tracing was complete, the acetate overlays were scanned with an optical scanner, then edited, rectified, and vectorized using LTPlus (USDA Soil Conservation Service 1991). The images were imported into the GIS Geographic Resource Analysis Support System (GRASS) (Shapiro et al. 1992). The vector maps were patched together to form the complete route. The polygons were labeled as to land use cover type based on the classification scheme of Stoms et al. (1983) (Table 1). The mapping design was a minimum mapping unit area of 0.25 X 0.25 cm on the photographs that resulted in polygons of about 400 m^2 at a representative fraction of 1:7,920. Cover in the vector format was converted to raster images with 5-m resolution. The accuracy of photo interpretation was verified by conducting visual field checks of the classified polygons.

We used General Land Office maps from 1896 and 1908 with a representative fraction of 1:17,182 to trace North American Breeding Bird Survey routes and boundaries that ran along section lines. For portions of routes disjunct from section lines we used points on topographic quadrangles for geo-registering and then plotted the same points on General Land Office maps. Our mapping unit design was a minimum mapping unit area of 0.25 X 0.25 cm on the maps that resulted in polygons of about 1900 m^2 at a

TABLE 1

COVER TYPE DESCRIPTIONS USED
FOR AERIAL PHOTOGRAPHY INTERPRETATION

Cover type	Description
Developed area	Land occupied by residential, industrial, or other human structures and non agricultural activities. Also includes transportation and utility facilities
Cropland	Land cultivated for row crops and cereal grains but excluding grazing by livestock
Pasture land and hay meadows	Includes pasture lands (seeded to exotic grasses and used for grazing by cattle, sheep, goats, and horses) and hay meadows
Native grassland	Natural grasslands with less than 10% canopy cover of shrubs or trees used primarily for grazing by cattle, sheep, goats, and horses
Deciduous forest	Land dominated (>10% canopy cover) by hardwoods, mostly post oak (*Quercus stellata*) and black-jack oak (*Q. marilandica*)
Burned and cleared land	Native grasslands or deciduous forest subjected to herbicides, chaining, or fire to reduce cover of woody plants and used primarily for grazing by cattle, sheep, goats, and horses
Roads	Driveways, black top, gravel, and dirt roads
Water	Lakes, rivers, streams, and ponds
Bare ground	Land with less than 5% vegetative cover

Adapted from Stoms et al. (1983)

representative fraction of 1: 17,182. Cover types were assigned to polygons with the same methods used for aerial photographs. The General Land Office field notes were used to supplement the maps and to assign land use cover type to polygons.

We determined cover types within a 400-m radius, which was the maximum polygon size, around each BBS stop on the breeding bird survey route. For 1902, we used the Geographic Information System GRASS data sets, and for 1990 we used the previously published data (Boren et al. 1997a), which documented cover types in 1966, 1973, 1980, and 1990 using aerial photography for both areas. Boren et al. (1997b) grouped BBS data to correspond to the four dates of aerial photography. Relative abundance for each of the four time periods averaged relative abundance for the four years. Thus, relative abundance of bird species for 1967-1970 correspond to 1968 cover data, 1971-1976 correspond to 1973 cover data, 1977-1984 correspond to 1980 cover data, and 1985-1991 correspond to 1990 cover data. Averaging the data for bird occurrence in this way reduces the influence of adverse weather conditions and observer bias (Bystrak 1981; James et al. 1996).

We used the logistic regressions developed by Boren et al. (1997b) for 1966-1990 to estimate change in selected bird species related to change in land use since 1902. Rather than present the entire assemblage of birds, we selected from those species that had either decreased or increased in ordination space in these areas from 1966-1990, as determined by canonical correspondence analysis (Boren et al. 1999). Each logistic regression used the area of each cover type within a 400-m radius of each BBS stop in 1902 and 1990 to estimate the probability of occurrence of each bird species at each stop along a route (Eyre et al. 1992; Osborne and Tigar 1992). We then averaged the probability of occurrence of each bird species over the 50 BBS stop locations in 1902 and 1990 for each area. We assumed interpretations from the General Land Office maps and surveyor's notes were of similar accuracy as classifications of the 1990 photography. Considering the distinctiveness among cover types (e.g., deciduous forest versus native grassland), we consider this assumption reasonable. Our approach also assumes that the available bird populations were similar between 1902 and 1990. This assumption is problematic because native bird populations, especially migrants, have changed since 1902 possibly because of loss of winter habitat in the tropics (Sherry and Holmes 1993). Furthermore, several exotic bird species have been introduced since 1902. These changes in the bird assemblage complicate interpretations of our model predictions for 1902 bird populations because our regressions are based on 1966-1990 bird census data. At least partially mitigating these complications are the diversity of land cover types across these areas, making the regressions relatively robust. We also limited our analysis to bird species that increased or decreased during the specific time period for which we have census data, 1966 to 1990 (Boren et al. 1999). To gain a more complete picture of the influence of landscape change on bird populations, we included the exotic bird species in our predictions of the 1902 bird populations. We believe this is a reasonable approach because two exotic bird species increased on the high human density area 1966-1990.

Results

The area in native vegetation, defined as having native species as dominants, changed only slightly in 90 years on the low human density area, but decreased markedly on the high human density area. Native grassland, which was the dominant cover type in 1902, was reduced by 462 ha on the low human density area and 600 ha on the high human density area from 1902 to 1990. Deciduous forest on the low human density area was burned and cleared to enhance value for cattle grazing (Fig. 1). Burning and clearing of scrubby oak forest, a common practice among ranchers in the eastern Great Plains, results in a derived grassland dominated by native grasses (Engle et al. 1991). Land in native vegetation, including burned and cleared land, was 3,013 and 2,536 ha in 1902, compared to 2,872 and 1,390 ha in 1990, on the low human density and high human density areas respectively. The largest change in the high human density area was the conversion of almost 1,000 ha of other cover types to pasture land and hay meadows, composed primarily of exotic pasture grasses. Cover types dominated by native plants decreased from 78% to 59% of the high human density area.

These changes in cover types suggest a change in the potential habitat of breeding birds. Estimated changes in abundance of bird species are based on changes in cover types, but it is revealing that most changes in estimated occurrence of birds were consistent with habitat guild designations (Table 2; Figs. 2, 3). Most forest and edge species were predicted to decrease (Figs. 2, 3) since forest habitat decreased on both areas. Native grassland, and burned and cleared land, increased on the low human density area; and, the estimated occurrence of dickcissel, a neotropical migrant and prairie species, was predicted to increase on the low human density area (Fig. 2). However, the probability of occurrence of the grasshopper sparrow, a neotropical

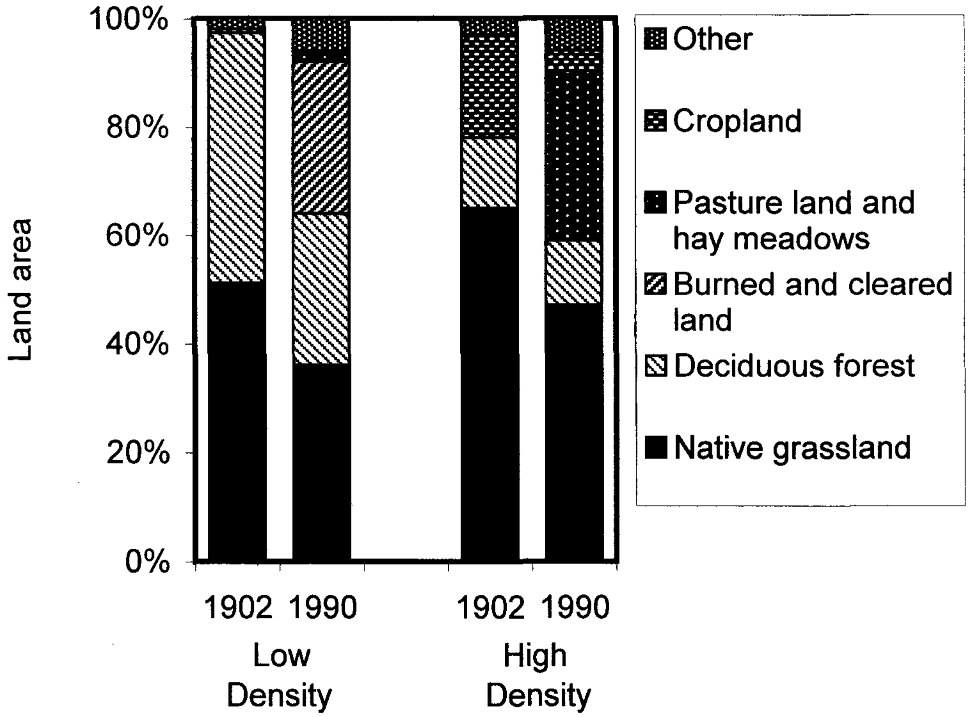

Figure 1. Proportion of land area of cover types in 1902 and 1990 in two areas with BBS data (low=low human density; high=high human density) in the Great Plains of northern Oklahoma. The category identified as other includes developed areas, roads, water, and bare ground.

migrant and grassland bird, decreased slightly; and, the probability of occurrence of the barn swallow, a neotropical migrant associated with human development, increased.

Species associated with development, such as the house sparrow, increased as expected on the high human density area (Fig. 3). The forest and edge species estimated to decline on the low human density area were species of high concern with no prevalent migration type (Fig. 2). The forest and edge species estimated to decline on the high human density area were species of moderate or high concern and were mostly neotropical migrants (Fig. 3). Of all migration types, neotropical migrants are of significant concern to conservationists because of their considerable decline in their North American summer breeding areas (Sherry and Holmes 1993). Three of the five species associated with developed habitats on the high human density area that were estimated to increase were resident species of low concern (Fig. 3).

Land cover type change on the low human density area appears to have favored at lease one prairie bird species of high concern and several neotropical migrants. Native grassland, and burned and cleared land, replaced forest on the low human density area, but on the high human density area, drastically altered cover types replaced forest. Forest and edge species were estimated to decline with this loss of forest on both areas. On the high human density landscape, however, bird species associated with development were predicted to increase.

Discussion

Land cover types changed on these two areas over the 90-year period, which altered the amount of habitat available for birds of specific habitat guilds. Those cover types dominated by native plants (native grassland, deciduous forest, and burned and cleared land) remained high on the low human density area, but the deciduous forest area declined (Fig. 1). The high human density area was modified primarily by an increase in pasture land, much of which is now in monocultures of exotic forage species (Fig. 1), and a decrease in native grassland and cropland (Fig. 1). Habitat area for grassland birds increased, whereas habitat area for forest birds declined considerably, on the low human density area. In the high human density area, an increase in habitat area for grassland birds resulting from conversion of cropland to pasture land was offset by loss of area of native grassland habitat.

Our study areas were in a transitional area of the Great Plains where the eastern edge of the tallgrass prairie meets deciduous forest. Most of the patterns in change of cover type that we observed occurred on both areas. However, our estimates of bird occurrence in the low human density area suggest that if native vegetation persists, bird assemblages in summer breeding habitat are transitional as vegetation fluctuates between native grassland and forest. This fluctuation in vegetation may be in response to natural factors such as drought (Dyksterhuis 1948, Weaver 1968) or to land management practices (Engle et al. 1991). When the area in native grassland increased, the probability of occurrence of the dickcissel, which prefers open grasslands, increased from less than 0.5 to about 0.6 (Fig. 2). Breeding birds, such as the eastern tufted titmouse (Fig 2) and the northern parula warbler

TABLE 2

BIRD SPECIES THAT DECREASED OR INCREASED OVER A 24 YEAR PERIOD (1966 TO 1990) FOR WHICH LOGISTIC REGRESSIONS WERE APPLIED TO AREAS IN 1902 AND 1990
Response of birds from 1966 to 1990 are from Boren at al. (1999).
Species that occurred 3 or fewer times were omitted.

Species	Scientific name	Migration type[a]	Habitat[b]	Concern[c]	Foraging[d]	Nesting[e]
Low human density						
Decrease						
Bewick's wren	*Thryormanes bewickii*	Temp	Edge	High	Ground	Cavity
Blue-gray gnatcatcher	*Polioptila caerulea*	Neotrop	Edge	Moderate	Canopy	Midstory
Eastern tufted titmouse	*Parus bicolor*	Resident	Forest	High	Midstory	Cavity
Field sparrow	*Spizella pusilla*	Temp	Edge	High	Ground	Ground
Painted bunting	*Passerina ciris*	Neotrop	Edge	High	Ground	Shrub
Pileated woodpecker	*Dryocopus pileatus*	Resident	Forest	Moderate	Bole	Cavity
Summer tanager	*Piranga rubra*	Neotrop	Forest	High	Midstory	Midstory
White-breasted nuthatch	*Sitta carolinensis*	Resident	Edge	Moderate	Bole	Cavity
Yellow-breasted chat	*Icteria virens*	Neotrop	Edge	High	Ground	Shrub
Increase						
Barn swallow	*Hirundo rustica*	Neotrop	Develop	Moderate	Aerial	Other
Dickcissel	*Spiza americana*	Neotrop	Prairie	High	Ground	Ground
Grasshopper sparrow	*Ammodramus savannarum*	Neotrop	Prairie	High	Ground	Ground

TABLE 2 (continued).

Species	Scientific name	Migration type[a]	Habitat[b]	Concern[c]	Foraging[d]	Nesting[e]
High human density						
Decrease						
Chipping sparrow	*Spizella passerina*	Neotrop	Forest	Moderate	Ground	Shrub
Common yellowthroat	*Geothlypis trichas*	Neotrop	Edge	Moderate	Ground	Shrub
Great-horned owl	*Bubo virginianus*	Resident	Edge	Moderate	Ground	Cavity
Greater prairie chicken	*Tympanuchus cupido*	Resident	Prairie	High	Ground	Ground
Kentucky warbler	*Oporomis formosus*	Neotrop	Forest	High	Ground	Ground
Northern-parula warbler	*Parula americana*	Neotrop	Forest	High	Midstory	Canopy
Red-shouldered hawk	*Buteo lineatus*	Temp	Edge	Moderate	Ground	Canopy
Yellow-breasted chat	*Icteria virens*	Neotrop	Edge	High	Ground	Shrub
Increase						
American robin	*Turdus migratorius*	Temp	Develop	Low	Ground	Shrub
Common grackle	*Quiscalus quiscula*	Resident	Edge	Low	Ground	Midstory
European starling	*Sturnus vulgaris*	Resident	Develop	Low	Ground	Cavity
House sparrow	*Passer domesticus*	Resident	Develop	Low	Ground	Cavity
Purple martin	*Progne subis*	Neotrop	Develop	Moderate	Aerial	Cavity

[a] Species classified as neotropical migrants (Neotrop), temperate migrants (Temp), and residents (Resident) (Hamel 1992).

[b] Species grouped into designation of habitat occurrence: forest (Forest), forest edge and shrubland (Edge), prairie (Prairie), and developed (Develop) (Hamel 1992).

[c] Species grouped into population trends: low concern (Low), moderate concern (Moderate), and high concern (High) (Hamel 1992).

[d] Species grouped into foraging zones: open zones (Aerial), foliage 0-3m (Ground), foliage 3-10m (Midstory), and trunks and limbs (Bole) (Hamel 1992).

[e] Species grouped into nesting zones: ground (Ground), 0-3m (Shrub), 3-10m (Midstory), >10m (Canopy), cavity (Cavity), and variable heights and substrates (Other) (Harrison 1975).

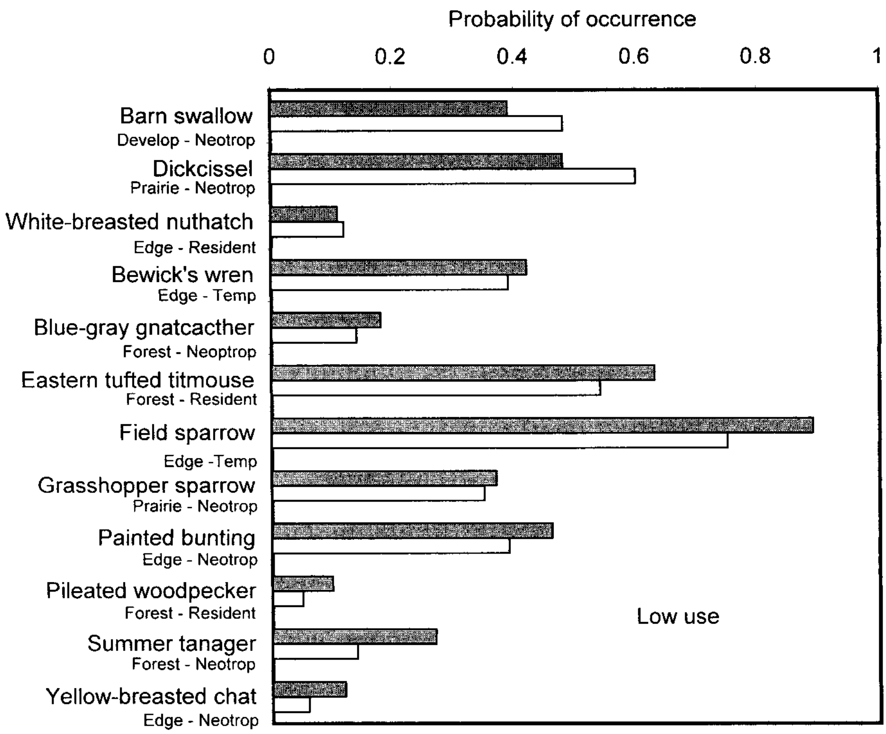

Figure 2. Probability of occurrence of selected birds in 1902 (gray bars) and 1990 (open bars) in the avian community of the low (5 km^{-2}) human density area (low use) predicted from a logistic regression of bird occurrence on cover type developed for 1966-1990. Birds selected either decreased or increased from 1966-1990 as determined by Boren et al. (1999).

(Fig. 3), that prefer forest and edge habitats were predicted to decline with the decline of forests. Deciduous forest decreased by 39% in the low human density area and by 12% in the high human density area. Expected occurrence of forest birds parallels this change in habitat and is quantified by the logistic regression models.

The bird species predicted to decrease on both areas have declined regionally (Hamel 1992). Five of eight of the birds on the low human density area and four of six on the high human density area that were predicted to decline were neotropical migrants (Figs. 2, 3). However, birds predicted to decline on the low human density area were predicted to contain both resident and migratory birds. If true, this suggests that the estimated declines

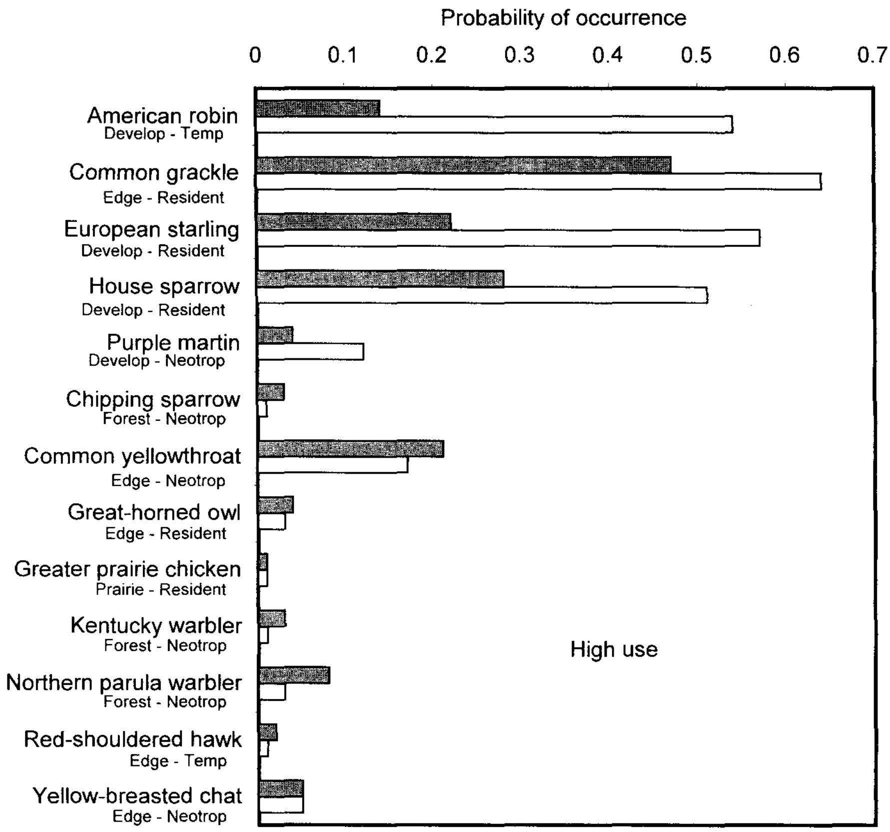

Figure 3. Probability of occurrence of selected birds in 1902 (gray bars) and 1990 (open bars) in the avian community of the high (10 km^{-2}) human density area (high use) predicted from a logistic regression of bird occurrence on cover type developed for 1966-1990. Birds selected either decreased or increased from 1966-1990 as determined by Boren et al. (1999).

were more likely caused by changes to summer breeding habitat than those in wintering habitat. Declines in forest species, primarily neotropical migrants, have been hypothesized to reflect loss of tropical wintering habitat (Terborgh 1989a; Petit et al. 1993; Faaborg et al. 1996); however, the pattern may also reflect loss of temperate breeding habitat in North America (Terborgh 1989a; Terborgh 1989b; Askins 1993; Maurer and Heywood 1993; Knopf 1994; Thompson et al. 1996). Our results on the high human density area are consistent with the expected effect of loss of breeding habitat on neotropical migrants. Flather and Sauer (1996) also found that more neotropical migrants were supported in areas in the eastern United States that had greater amounts of habitats with native vegetation than within areas of high human-dominated land uses.

Land management on the low human density area reduced the available habitat for forest and edge birds and increased the habitat area for prairie birds. The probability of occurrence of three forest and edge species decreased by more than 0. 1 on the low human density area (Fig. 2), reflecting the 39% decrease in deciduous forest and an increase in burned and cleared land. Fire is used on native grasslands of the eastern Great Plains to limit encroachment of woody species (Daubenmire 1968; Sauer 1975; Bernardo et al. 1988). Much of the low human density area is now in large cattle ranches, and extensive burning and clearing of forest had occurred by 1990 to create or to maintain grassland for cattle grazing. An 87% increase in burning and clearing from 1966 to 1990 (Boren et al. 1997a) suggests that most of this activity occurred in the last three decades. Alternately, decreasing deciduous forest and increasing burned and cleared land on the low human density area led to an increase in the probability of occurrence of the dickcissel. Although this species has declined in other areas of North America (Johnson 1996), habitat alterations such as those we documented on the low human density area may have favored it.

Perhaps the most striking change was the predicted increase in bird species associated with human activities. The probability of occurrence of the American robin, common grackle, European starling, house sparrow, and purple martin increased on the high human density area (Fig. 3). Although representing a small proportion of the total land area (Fig. 1), the area in roads, cropland, pasture land and hay meadows increased more than did other cover types on the high human density area. Roads increased by 200%. Pasture land and hay meadows, which were not common on the area in 1902, increased to 31% of the area by 1990 (Fig. 1). We infer that the increased levels of human activity in the high human density area changed breeding bird communities in a manner similar to intensive development associated with urbanization (Beissinger and Osborne 1982). Even low levels of development can provide habitat for species that are associated with development by altering the composition of the plant community and by altering structural diversity (Blair 1996).

We attribute at least part of the predicted changes in bird occurrence on both areas since 1902 to changes in rural land use within the temperate breeding habitat. The estimated decrease in forest and edge species 1902-

1990 can be predicted from decreases in area of deciduous forest during the period (Figs. 2, 3). In contrast, the estimated increase in the dickcissel, a declining prairie bird, in the low human density area over the same time period could be the result of the use of fire and herbicides to convert forest to native grassland and to maintain grassland for forage production for cattle grazing. Finally, bird species associated with human development were predicted to increase as development increased on the high human density area 1902-1990 as native vegetation was converted to human-influenced cover types. Of the model predictions for the different habitat guilds, the most alarming to us is the predicted replacement of forest and edge species in the high human density area by species associated with human development.

Acknowledgments

This research was supported by the Oklahoma Agricultural Experiment Station through project S-1822 and through a grant from the Targeted research Initiative Program. The Director of the Oklahoma Agricultural Experiment station approved the article for publication.

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* Correspondence to: David Engle, Tel.: (405) 744-9623; Fax: (405) 744-5269; E-mail: <dme@agr.okstate.edu>