Florida Field Naturalist

PUBLISHED BY THE FLORIDA ORNITHOLOGICAL SOCIETY

VOL. 38, NO. 4 | NOVEMBER 2010 | PAGES 135-189

Florida Field Naturalist 38(4):135-145, 2010.

WHY HAS AN URBAN ADAPTER, THE NORTHERN MOCKINGBIRD (*Mimus polyglottos*), DECLINED IN FLORIDA?

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Abstract.—Many species of common birds, including some known to adapt to urban habitats, have declined in North America. The Northern Mockingbird (*Mimus polyglottos*) is an urban adapter that has declined in Florida by 1.7% per year since 1966. We used mockingbirds in Florida as a case study to determine possible reasons for the paradoxical decline of an urban adapter. We compared mockingbird abundance (measured by the Breeding Bird Survey) to land use, and found that mockingbirds are positively associated with urban and agricultural land uses, but the association with agriculture has weakened over time. The increase in urban habitat is relatively small compared to the decline in agricultural areas, which may explain why this species has declined even in the face of increasing urbanization in Florida. Other factors, such as agricultural intensification and a decline in pastures, may account for the weakening of the association between mockingbirds and agriculture over time.

As human populations continue to grow, it is increasingly important to understand how wildlife responds to human-altered landscapes. Wildlife can be classified as urban avoiders, urban adapters, or urban exploiters depending on whether a particular species avoids, is

Special Editor for this article: James Cox, Tall Timbers Research Station, 13093 Henry Beadel Dr., Tallahassee, Florida 32312.

common in, or depends on areas of human habitation (Blair 1996). Conservationists have generally focused their research effort on urban avoiders because their habitats and populations are presumably in the greatest danger. Butcher and Niven (2007), however, showed that many species of birds that were historically quite common have declined, including species that seemingly adapt to human-altered landscapes (e.g. Common Nighthawk (*Chordeiles minor*), Common Grackle (*Quiscalus quiscula*), and Eastern Meadowlark (*Sturnella magna*)). This is an especially troubling trend for conservation. If we use bird populations as a proxy measure of ecosystem health (NABCI 2009), then the decline of common, widespread species could indicate that ecosystem health has declined on a larger scale than currently recognized. In addition, the decline of common birds indicates that conservationists cannot assume that abundant species are immune to declines and suggests that conservation measures may be necessary for a much larger suite of species than previously imagined (Butcher and Niven 2007).

Numerous hypotheses have been advanced to explain declines of previously abundant species (NABCI 2009). Urban sprawl, agricultural intensification, and natural-resource extraction (e.g. mining and forestry) could all lead to habitat loss and population declines. Alternatively, reductions in habitat quality due to intensification of agriculture, pollution, and climate change could adversely affect wildlife populations directly or indirectly due to changes in predator and prey communities. Finally, urban areas may act as ecological traps that attract birds but fail to provide the conditions necessary for successful breeding or survival (Mannan et al. 2008). While researchers have identified these potential causes, few studies have evaluated them with respect to declining urban adapters.

The Northern Mockingbird, *Mimus polyglottos*, is one of the most common and conspicuous urban birds in the southeastern United States (Derrickson and Breitwisch 1992). The mockingbird is a native species that also occurs in open areas outside of cities. Its nesting densities in north-central Florida are much higher in urban areas than in non-urban areas (Stracey 2010), and it is therefore considered an urban adapter. Florida's human population has more than tripled since 1960 (U.S. Census Bureau 1995, 2009), so it is reasonable to expect that urban areas, and therefore mockingbird numbers, would also be increasing. However, between 1966 and 2007 mockingbirds have declined in Florida by 1.7% annually (Sauer et al. 2008).

A decrease in abundance of this urban adapter in the face of increasing urbanization presents a paradox that we address through an analysis of trends in mockingbird numbers and changes in land use. We first test whether the area occupied by urban land use in Florida is increasing. If we find that urban land use is increasing then we are left with a number of possible explanations for the decline of mockingbirds. Previous data (Stracey 2010, Stracey and Robinson, in press) from north-central Florida demonstrated a positive relationship between urban habitats and mockingbird numbers, but it is possible that mockingbirds are not positively associated with urban land use on a statewide scale. Alternatively, mockingbirds may be associated with urban areas, but may depend on additional habitats, which may be in decline. We hypothesized that mockingbird abundance was associated with land use and that at least one land-use type that is positively correlated with mockingbirds is in decline.

METHODS

We used mockingbird abundance data collected by the Breeding Bird Survey (BBS), which has been conducted annually since 1966. Each year, at the height of the breeding season, each BBS observer conducts 50 point-counts along one or more 24.5-mile (39.4 km) routes. We sought to determine the relationship between mockingbirds and land use along a sample of these routes. Land-use data for the state of Florida were available for 1973, 1993, and 2003; National High-Altitude Photography (NHAP) photographs were the source data for the 1973 survey, and remotely-sensed satellite images (Landsat TM) were the source data for the 1993 and 2003 surveys (USGS and FDEP 1974, FCFWRU 2000, FFWCC 2004, respectively.). In this study we used all 24 BBS routes that were surveyed in all three of these years (Fig. 1).

Land use was classified differently by the land-use surveyors in each of the three years. Therefore, as the first step in defining land-use categories for analysis, we collapsed the original classifications into the following categories to allow comparisons across years: Urban, Agriculture, Rangeland, Forest, and Wetland. We used ArcGIS 9.1 (Esri, Inc., Redlands, California) to define a 1000-m-wide tract centered on each route and extending its entire length, and to calculate the area of each land-use category within each tract. Each route was analyzed as one unit, with land use calculated and mockingbirds counted for the entire route.

We then further refined our categories by including in the model only land-use types that had a correlation with one another of ≤ 0.30. Urban and Forest were correlated (Table 1); we included Urban in the model instead of Forest because previous studies have shown mockingbirds to be positively correlated with urban habitat (Stracey and Robinson, in press). Rangeland met the 0.30 criterion but was removed because of uncertainty about whether rangeland could reliably be distinguished from other habitats such as pastures, and if this distinction was made in the same way by the surveyors in the three study years. Wetland met the 0.30 criterion but was excluded because mockingbirds are not known to use wetland habitats. SPSS (version 12.0; SPSS Inc., Chicago, Illinois) was used for all statistical analyses.

In order to minimize between-year variation in mockingbird census data, we calculated the average number of mockingbirds per route across three years (the year for which we had land-use data and one year preceding and following that year). To meet assumptions of normality, we square-root transformed the mockingbird abundance data.

We conducted an ANCOVA to describe mockingbird abundance as a function of land use, year, and interactions between land use and year. Because there was a significant interaction (Table 2) between agriculture and year, we analyzed the effect of agriculture on mockingbird abundance for each year separately.

Figure 1. BBS routes surveyed in 1973, 1993, and 2003 in Florida that were included in the study.

We were interested in the possible effects that changes in land use over time could have on mockingbird abundance. Therefore, we ran a multiple regression expressing the change in the square root of average mockingbird abundance on each route since the previous study year as a function of the change in land use along that route since the previous study year.

We also sought to determine changes in types of agriculture. Because the spatial resolution of the remotely sensed data did not allow us to distinguish between types of agriculture, we used data from the Census of Agriculture to divide agricultural land use into more precise categories of cropland (land in which crops are regularly planted and harvested; Cutter and Renwick 2003), woodland (land on farms which is wooded and used for pasture or wood products; USDA-NASS 2009), and pasture (land used for grazing animals; USDA-NASS 2009). We calculated the change in area of each type of agriculture across the years of our study. We used these trends to generate hypotheses about the relationship between mockingbirds and different types of agriculture that can be tested in the future.

Table 1. Correlations between land-use categories within 500 m of study routes.

	Urban	Agriculture	Rangeland	Wetland
Agriculture	-0.162			
Rangeland	-0.070	0.303		
Wetland	-0.164	-0.103	0.019	
Forest	-0.382	-0.596	-0.396	-0.197

RESULTS

Average mockingbird abundance was positively associated with urban land use (Table 2). Mockingbird abundance was highly correlated with agriculture in 1973, but this effect weakened over time and in 2003 the relationship between agriculture and mockingbird abundance was not significant (Fig. 2). Change in mockingbird abundance since the previous study year was not correlated with change in urban or agricultural land use since the previous study year (all P's > 0.39).

Along our study routes, agriculture decreased and urban areas increased (Fig. 3). Similar patterns were seen in statewide data from the three study years, although wetlands made up a larger proportion of the state as a whole than of our study routes. Data from the USDA Census of Agriculture showed that total land in farms has declined by half since 1954 (Fig. 4). Total cropland increased until 1978, but has declined by one third since then (Fig. 4). Cropland has become a larger proportion of total land in farms (Fig. 4). Woodlots, pastures, and rangelands have decreased in area (Fig. 4).

DISCUSSION

According to our model, agriculture was highly favorable mockingbird habitat in 1973. By 2003, however, the effect had weakened to the point of non-significance, suggesting that agriculture in Florida has changed in some way that makes it lower-quality mockingbird habitat. Additionally, the amount of land in agriculture has decreased in Florida, both along our study routes (Fig. 3) and in the state as a whole. We propose that this combined deterioration of agriculture as mockingbird

Table 2. Results of ANCOVA describing mockingbird abundance as a function of land use, year, and interactions between land use and year.

Effect	df	F	P
Year	2	4.055	0.022
Urban	1	21.995	<0.001
Agriculture	1	62.229	<0.001
Year*Agriculture	2	6.606	0.002
Year*Urban	2	2.514	0.089

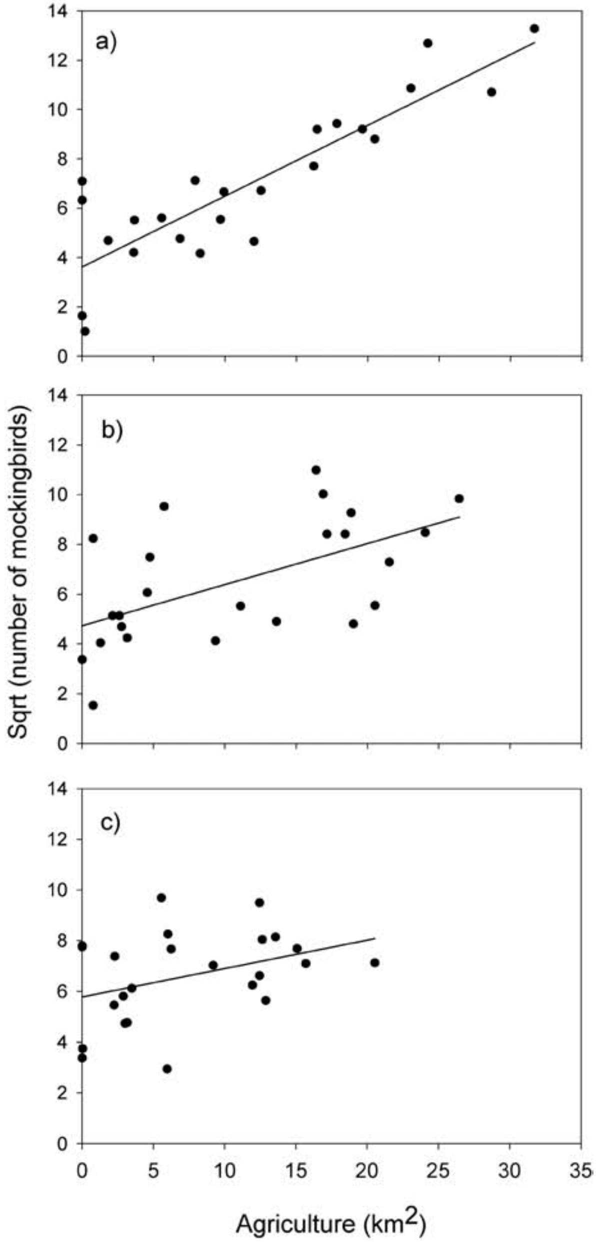

Figure 2. Square root of number of mockingbirds (averaged over three years: study year, previous year, and following year) recorded on each BBS route included in this study as a function of agricultural land use on the route. a) 1973 ($R^2 = 0.763$, $p < 0.001$, $F_{1,22} = 70.888$). b) 1993 ($R^2 = 0.330$, $p = 0.003$, $F_{1,22} = 10.857$). c) 2003 ($R^2 = 0.140$, $p = 0.072$, $F_{1,22} = 3.582$).

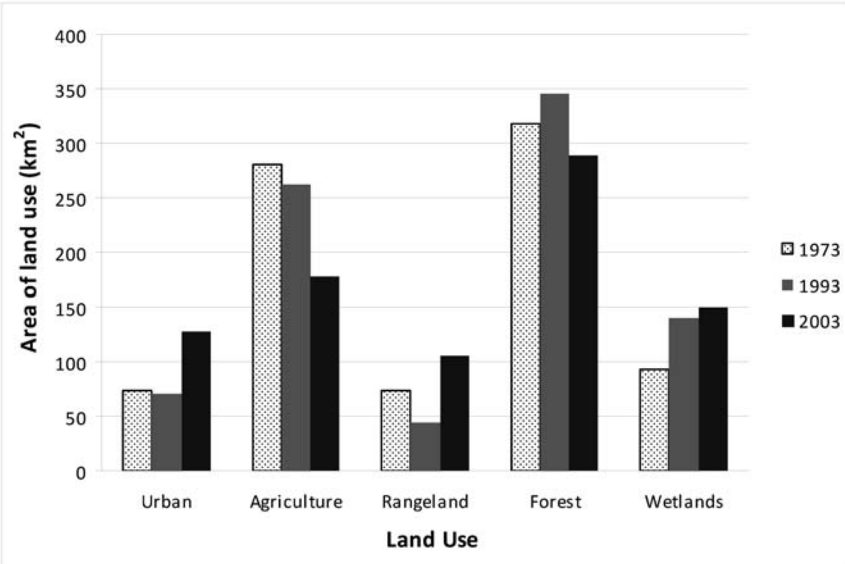

Figure 3. Total area (km²) of land-use categories within 500 m of study routes.

habitat and decrease in the amount of agriculture could be driving the decline in mockingbirds.

Stracey (2010) found that mockingbirds can successfully breed in cattle pastures, likely because the cropped grass provides good foraging, and vegetation along fences provides nesting habitat. Cutright (1981) found that in west-central Florida, mockingbirds were most abundant in pastures and small patches of woodlands growing in drainages, and were less abundant in wet meadows and cropland. A decrease in pastured land could have a significant negative impact on rural mockingbird populations, and the Census of Agriculture has recorded such a decrease statewide (Fig. 4). However, the Census of Agriculture simply summarizes the total extent of each land use without showing how it is distributed, so we cannot compare mockingbird abundance on an individual route to the types of agriculture along that route.

Another agricultural trend that is potentially detrimental to many birds is an increase in the size of fields (NABCI 2009). Tractors, combines, and other farming implements have become larger and commoner, and fields have increased in size to take advantage of the efficiency of this mechanization. The increase in field size leads to a decrease in fencerow and edge habitat (Robinson and Sutherland 2002). In pastures, and likely in cropland, mockingbirds nest in trees along

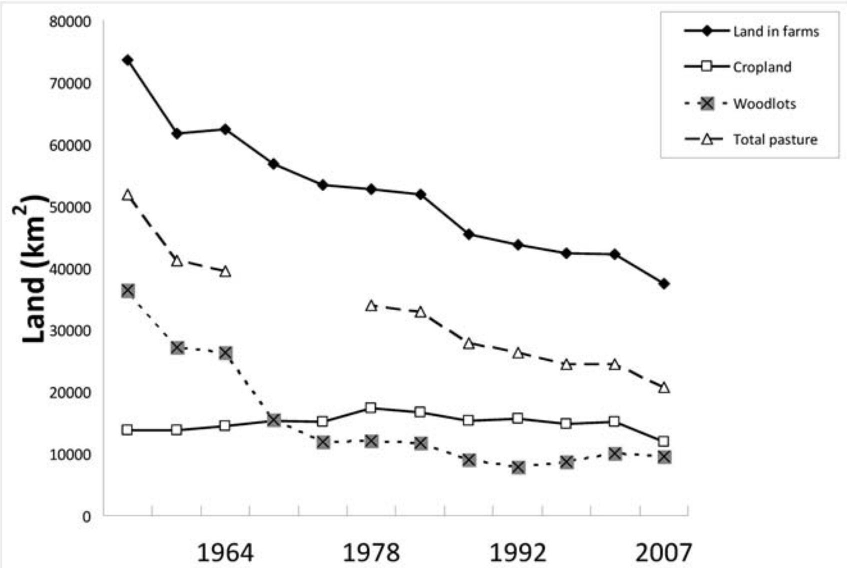

Figure 4. Total area (km²) in Florida in various agricultural land uses (USDA-NASS 2009). "Total pasture" includes subsets of "cropland" and "woodlots" used as pasture.

the edges of fields, or in vines and shrubs growing along fences (personal observation), so loss of fencerows and edges likely equates with a decline in nesting habitat for mockingbirds. Thus land that is classified as cropland today may support fewer mockingbirds than land with the same classification thirty years ago because of this loss of nesting habitat.

Alternatively, use of pesticides could reduce the invertebrate prey available to mockingbirds or cause direct toxicity to mockingbirds (Gibbs et al. 2009). Bellar and Maccarone (2002) found that pesticide use in Kansas had a significant negative correlation with populations of Loggerhead Shrikes, a species whose habitat requirements overlap with those of mockingbirds (Yosef 1996). The combination of larger field sizes and pesticide use could significantly diminish the habitat quality of agricultural areas for mockingbirds. Because of the coarse nature of our land-cover data, we cannot distinguish between these various hypotheses. Therefore, future studies should incorporate point counts in different types of agricultural areas to determine whether mockingbirds are responding to different types of agricultural land use (for example, if they are strongly correlated with pastured land), or if they are responding to changes in agricultural intensity (for example, field size).

While the analysis comparing mockingbird abundance to land use supports the idea that the change in mockingbird abundance is related to the change in land use, our analysis of change since the previous year in mockingbird abundance and land use was not significant. This lack of a relationship could be explained as a result of our method of averaging data across a 24.5-mile-long study route. Because we averaged land use and mockingbirds over the whole route instead of matching each individual point along a route to the land use immediately surrounding that point, the effects of one land use could potentially obscure the effects of another. The test of change since the previous study year could be particularly vulnerable to this limitation; for example, if agriculture decreased between study years while urban increased, the effects of each change on mockingbird abundance could cancel each other out when averaged across the whole route. Presumably, averaging the effects of all land uses across the route gives a conservative estimate of the effects of each, meaning that this method could give us negative results even if a land use actually has a significant effect, but is unlikely to give us false positive results. Therefore, this limitation does not invalidate the correlations we found between land use and mockingbird abundance, but could be affecting our analysis of change since the previous study year. Because there was much less agriculture in 2003 than in previous years, the loss of data points with high values for agriculture could reduce the statistical power of our test of the relationship between mockingbird abundance and agriculture, contributing to non-significant results. Despite these limitations, it is still possible that mockingbirds are responding more strongly to other changes in the environment than they are to land use. It is therefore important that future studies assess the effect of changes in land use on mockingbirds at a finer scale.

Urban had a small correlation with mockingbird abundance in our overall model, and the change in urban had no relationship with the change in mockingbird abundance since the previous study year. It is possible that mockingbirds are not more abundant in urban areas than rural areas, contrary to Stracey and Robinson (in press). Alternatively, these results could be explained by our method of averaging mockingbird abundance over the entire route. The increase in urban habitat is relatively small compared to the decline in agricultural areas, which may explain why this species has declined even in the face of increasingly intensive human land use in Florida.

Uncertainties about how urban areas and various types of agriculture interact with mockingbird numbers highlight the complexity of human-dominated landscapes. Some human activities may benefit bird populations, while others cause harm. Despite being urban adapters, mockingbirds use agricultural areas extensively. This suggests that at least some urban adapters use many different habitats, and that urban areas may not be sufficient to maintain their populations. Conservationists must consider that even urban adapters may be vulnerable to changes in the ways that humans manage the landscape.

Acknowledgments

We thank the Department of Geography at the University of Florida for use of their GIS facilities, Erin Bunting for assistance with ArcGIS, Michelle Rensel for assistance with statistical analyses, and Jim Cox and Tom Webber for comments on earlier drafts.

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