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Do Native Warm-season Grasslands Near Airports Increase Bird Strike Hazards?

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ABSTRACT.—Bird aircraft collisions (bird strikes) are a recognized safety hazard and land uses that attract birds hazardous to aircraft should be avoided on and near airports. Many airfields contain large areas of anthropogenic grassland habitats, often dominated by cool season grasses. Land managed as native warm season grasses (NWSG) potentially could increase bird strike hazards on and near airports by attracting hazardous birds and harboring small mammals that are prey for hazardous raptors. We investigated bird and small mammal communities at three NWSG areas and three adjacent on airfield grassland areas in western Ohio, U.S.A. to determine whether NWSG increased bird strike hazards. Species specific differences in bird abundance and density were evident between the two landcover types, presumably the result of differences in plant community characteristics. Seven species of birds were found exclusively in NWSG or airfield grasslands. Birds of species categorized as 'moderate' to 'extremely high' in regard to hazard (severity) level to aircraft accounted for only 6% and 2% of all birds observed in airfield grasslands and NWSG areas, respectively. Small mammal capture success was approximately three times higher in NWSG areas, although raptor abundance did not differ between the two landcover types. Our findings suggest that NWSG might be considered a viable land use adjacent to airfields; however, similar research at additional locations, including larger NWSG areas, should be conducted.

INTRODUCTION

Grassland birds have experienced population declines in the U.S.A. with habitat degradation and loss implicated as major reasons (Herkert, 1995; Vickery *et al.*, 1999; Brennan and Kuvlesky, 2005). As a result, many states have implemented programs to manage grassland birds (Sample *et al.*, 2003; Ribic *et al.*, 2009). Civilian airports and military airfields, as well as adjacent areas, often provide some of the largest available grassland areas and might serve as potential breeding habitat (Norment *et al.*, 1999; Brennan and Kuvlesky, 2005); however, this type of land management within or near airport environments could increase the frequency and abundance of birds hazardous to aircraft and consequently the risk of bird strikes.

Wildlife and aircraft collisions cause serious safety hazards to aircraft. Wildlife strikes cost civilian aviation at least $718 million annually in the U.S.A. (Dolbeer *et al.*, 2012). Wildlife hazardous to aviation includes those species of wildlife that are frequently involved in collisions with aircraft and cause damage to aircraft during such events (Dolbeer *et al.*, 2012). Gulls (*Larus* spp.), waterfowl such as Canada geese (*Branta canadensis*), raptors [hawks (Accipitriformes) and owls (Strigiformes)], and blackbirds (Icteridae)/European Starlings (*Sturnus vulgaris*) are the bird species presently causing the most concern at

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airports (Dolbeer *et al.*, 2000; Dolbeer and Wright, 2009; DeVault *et al.*, 2011). Sound management techniques that reduce numbers of birds and mammals hazardous to aircraft on and near airports are therefore critical for safe airport operations (U.S. Department of Agriculture, 1998; Blackwell *et al.*, 2009). It is worth emphasizing that such management should be focused on those species most hazardous to aircraft, *i.e.*, those most likely to cause aircraft damage when struck. Some species, especially small birds that rarely congregate into large flocks, rarely cause damage to aircraft when struck, and therefore should not be prioritized for management (DeVault *et al.*, 2011).

Large scale killing of birds to solve conflicts is often undesirable or impractical (Dolbeer, 1986; Dolbeer *et al.*, 1995). Nonlethal frightening techniques to disperse birds from airports are available (Marsh *et al.*, 1991; Cleary, 1994) but can be cost prohibitive or only temporarily effective (Dolbeer *et al.*, 1995). Habitat management within and adjacent to airport environments is the most important long term component of an integrated wildlife damage management approach to reduce the use of airfields by birds and mammals that pose hazards to aviation (Transport Canada, 1994; U.S. Department of Agriculture, 1998; Washburn *et al.*, 2007).

Researchers have investigated the attractiveness of several land use practices [*e.g.*, vegetation management (Seamans *et al.*, 2007; Washburn and Seamans, 2007); bio-solids application (Washburn and Begier, 2011)] to wildlife at airports. Areas managed for native warm season grasses (NWSG) provide habitat for a variety of grassland wildlife and protection for rare plants due to the heterogeneity of cover and diversity of plants typically found in remnant or restored NWSG grasslands (Packard and Mutel, 1997). However, land managed as NWSG habitat has not been evaluated for its attractiveness to birds hazardous to aircraft. Grasslands managed as NWSG habitats have the potential to attract hazardous birds and, if so, this land use would therefore not be recommended on or near airports (Federal Aviation Administration, 2007). The objectives of our study were to quantify and compare: (1) plant communities, (2) bird use, and (3) small mammal use of airfield grasslands and NWSG areas.

METHODS

STUDY AREAS

Due to the limited availability of native warm season grasslands (NWSG) within the region, we were able to only study three airfields in western Ohio with NWSG landcover in close proximity (Table 1). Although the NWSG study areas are relatively small in size relative to the airfields (Table 1), they are representative of this very uncommon habitat type and are at or greater than the 5 to 55 ha area requirement for five species of area sensitive grassland birds (Herkert, 1994a); consequently, we believe they have the potential to provide habitat for those species.

Mean annual precipitation at the northwestern Ohio (*i.e.*, Toledo) study area is 866 mm per year with 55% falling as rain during Apr. through Sep. (Stone and Michael, 1984). Average daily temperatures are 21.1 C during summer and −3.3 C during winter. Mean annual precipitation at the southwestern Ohio (*i.e.*, Dayton) study areas is 1003 mm per year with 64% falling as rain during Apr. through Sep. (Miller *et al.*, 2004). Average daily temperatures are 23.4 C during summer and −0.6 C during winter.

Airfield grasslands in this study were typical of landcovers found on airports throughout the Midwestern United States (*e.g.,* DeVault *et al.*, 2009). They are managed in accordance with air safety regulations and mowed periodically during the growing season (*e.g.,* the average height of vegetation during the growing season was 27 cm). An integrated wildlife

TABLE 1.—Location, area (in ha), and distance (km) between 3 native warm-season grassland (NWSG) areas adjacent to airfields and airfield grasslands on 3 airports in western Ohio, U.S.A. where plant and bird communities were studied during Dec. 2009–Nov. 2010

Study site	Landcover type	Area (ha)	Latitude, Longitude	Location	Distance (km) between paired grasslands
Toledo Express International Airport	Airfield	370	41°35′13″, −83°48′29″	Swanton, OH	3.3 to 7.7
Oak Openings Preserve Metropark	NWSG	21	41°33′08″, −83°51′08″	Swanton, OH	3.3 to 7.7
Dayton International Airport	Airfield	663	39°54′08″, −84°13′10″	Vandalia, OH	1.5 to 5.8
Paul Knoop Prairie	NWSG	50	39°53′17″, −84°16′08″	Vandalia, OH	1.5 to 5.8
Wright-Patterson Air Force Base	Airfield	686	39°48′26″, −84°20′47″	Fairborn, OH	1.0 to 3.6
Huffman Prairie Flying Field	NWSG	51	39°48′21″, −84°03′29″	Fairborn, OH	1.0 to 3.6

damage management program is conducted at each of the three airports to reduce the risk of wildlife and aircraft collisions. The NWSG areas in this study are typical of the remnant and restored NWSG habitats found in western Ohio. Periodically, prescribed burning had been conducted on the NWSG areas examined in this study (most recently at both the Oak Openings and Huffman Prairie plots) to remove woody species, halt succession, and lower fuel loads.

Both NWSG and airfield grasslands were comprised of a high proportion of grasses, with forbs, legumes, and woody plants comprising a smaller part of the vegetation. NWSG areas were dominated by a variety of native grasses [*e.g.*, little bluestem (*Schizachyrium scoparium*), Indiangrass (*Sorghastrum nutans*), big bluestem (*Andropogon gerardii*)], forbs [*e.g.*, goldenrod (*Solidago* spp.)], and woody plants [*e.g.*, blackberry (*Rubus* spp.)]. Cool season grasses [*e.g.*, tall fescue (*Lolium arundinaceum*), Kentucky bluegrass (*Poa pratensis*)], and legumes [*e.g.*, clovers (*Trifolium* spp.)] dominated the vegetation in airfield grassland areas.

We randomly established six permanent survey points, three in airfield grasslands and three in NWSG, at each of the three paired study areas. Survey points were at least 0.5-km apart to ensure spatial independence. Survey points in the three airfield grasslands and two of the NWSG areas (the Paul Knoop and the Huffman Flying Field Prairies) were contained within larger areas of the same landcover type (*i.e.*, they were surrounded by areas of similar grassland habitat and composition). However, the three survey points in the Oak Openings Preserve Metropark encompassed NWSGs areas that were contained within a forested landscape.

PLANT COMMUNITIES

We quantified plant communities by randomly establishing and sampling 30 1-m^2 herbaceous plots within 70 m of each survey point within NWSG and airfield grasslands during spring 2010 (3–19 May) and fall 2010 (13–20 Oct.). We visually estimated the total vegetative canopy cover (%), bare ground (%), litter (%), and canopy cover (%) of each individual plant species for each herbaceous sampling plot (Bonham, 1989). Plant species richness was determined by identifying and counting the total number of different plant species within each herbaceous sampling plot (Bonham, 1989).

Vegetation data (mean vegetation height, plant species richness, and plant community characteristics) were nonnormally distributed and could not be transformed satisfactorily. Thus, we used Mann–Whitney U-tests (Zar, 1996) to compare mean vegetation height, plant species richness, and plant community characteristics between NWSG and airfield grasslands study areas for spring and fall 2010 separately.

BIRDS

We conducted four bird surveys per month from Dec. 2009 to Nov. 2010 at random start times (two during sunrise to noon, two during noon to sunset) at each of the survey points. We traveled quietly to the point and allowed 2 min to elapse before we began the 5 min survey (Bibby *et al.*, 2000; Buckland, 2006). We identified all birds observed to the lowest possible taxonomic level and recorded the number and activity of all birds in or over the survey plot (*i.e.*, within the focal landcover). Although birds that only used the observational space as a movement corridor were recorded, we did not use these data in our analyses (Buckland *et al.*, 2001). We measured the linear distance to each bird or bird flock detection (to the nearest m) using a Bushnell Elite 1500 rangefinder (Overland Park, KS). We defined a bird flock as a relatively tight aggregation of birds that moved in a similar pattern, as opposed to a loosely clumped spatial distribution of birds (Buckland *et al.*, 2001).

We pooled bird observations from all survey points within and among the NWSG areas ($n = 9$) and from all survey points within and among all airfield grassland areas ($n = 9$) and then used two data analysis methods to compare bird use between the habitat types (Bibby and Buckland, 1987; Bibby *et al.*, 2000; Thomas *et al.*, 2010). We first used a fixed radius avian point count method (Bibby *et al.*, 2000) assuming that all birds within 70 m of the center of survey points would be readily detectable (Bajema *et al.*, 2001; Buckland, 2006). These data were non normally distributed and could not be transformed satisfactorily. Therefore, we compared the number of birds observed within 70 m of the point centers between the 2 landcover types using Mann–Whitney U-tests (Zar, 1996).

We then grouped species according to similar expected detection probabilities (Appendix A1; Alldredge *et al.*, 2007) and used program DISTANCE 6.0 Release 2 (hereafter, Distance) to calculate bird density for those species/groups with at least 25 detections, the minimum number recommended for this analysis (Thomas *et al.*, 2010). Seven of the 15 species/groups did not have the minimum number of detections or contained too much variability within one or both landcover types to allow for bird density estimates using Distance analyses. For the other eight species/groups, we truncated 10% of the largest distances from each of the species/groups to exclude extra adjustment terms needed to fit a long tail to the detection function and to reduce the dependence of detection probability on cluster size (Buckland *et al.*, 2001). We grouped the remaining observations into 20 m intervals to achieve robustness in the data analysis after the examination of distance histograms revealed rounding of distances by observers (Buckland *et al.*, 2001). We employed the multiple covariates distance sampling analysis engine in Distance that allows the inclusion of covariates in addition to distance from the observation point in the detection function (Marques *et al.*, 2007). We fit multiple *a priori* models to each of the species/groups using the detection function model definitions half normal key and hazard rate key with cosine, simple polynomial, and hermite polynomial adjustment terms. We also stratified by landcover (Thomas *et al.*, 2010). Different combinations of the above functions and adjustment terms improved our accuracy of estimating species/group abundance by allowing variable fitting of the distance estimation curve. We selected the best approximating model for each of the species/groups stratified by landcover by further investigating the shape of the detection probability plots and biological plausibility of the density estimates after initial selection of competing models with Akaike's information criterion (AIC) values within two of the highest ranked model (Akaike, 1974; Buckland *et al.*, 2001; Burnham and Anderson, 2002). We compared density estimates for eight species/groups between the two landcover types using Student's *t*-tests (Zar, 1996).

Using the fixed radius avian point count data (*i.e.*, pooled bird observations from all survey points within NWSG and all airfield grassland areas, respectively) for all birds that were identified to species, we assigned each species to one of six hazard (severity) levels (*i.e.*, 'very low', 'low', 'moderate', 'high', 'very high', and 'extremely high') as defined by Dolbeer and Wright (2009). All bird species not specifically listed in Dolbeer and Wright (2009) were assigned to the 'very low' hazard level due to their small body size (<1 kg), tendency for non flocking behavior, or other factor that suggests they pose minimal hazards to aircraft (DeVault *et al.*, 2011). We compared the proportion of total birds within the hazard (severity) levels using airfield grasslands and NWSG areas using comparison of proportion tests (Zar, 1996).

SMALL MAMMALS

During Mar.–Sep. 2010, we trapped small mammals for three consecutive nights each month using Sherman live traps (Tallahassee, Florida) baited with rolled oats and peanut butter (total of seven trapping sessions for the study). Our trap transect was centered on the survey point, running south to north with 25 traps spaced 5 m apart (Pearson and Ruggiero, 2003). We identified all captured individuals to species and individually marked them via fur clipping prior to release.

We used adjusted trap success as an index of small mammal abundance. We pooled data from all NWSG and all airfield grassland areas, respectively, for each month prior to analysis. We totaled trap nights, capture events, and unavailable traps (*i.e.*, traps closed without a small mammal capture) by month and adjusted trap nights by subtracting half of a trap night for each unavailable trap from total trap nights (Nelson and Clark, 1973). We calculated adjusted trap success for small mammals by month by dividing the number of capture events by the number of adjusted trap nights standardized for 100 trap nights (Nelson and Clark, 1973). We compared trap success by month using two sample *t*-tests (Zar, 1996).

RESULTS

PLANT COMMUNITIES

During spring of 2010, the mean height of vegetation ($U = 1.71$, $P = 0.19$), plant species richness ($U = 1.00$, $P = 0.32$), and bare ground ($U = 1.82$, $P = 0.15$) were similar between NWSG and airfield grasslands areas (Table 2). In contrast NWSG areas had less total vegetative canopy cover ($U = 172.53$, $P < 0.001$) and more litter ($U = 150.70$, $P < 0.001$) than airfield grassland areas (Table 2). During fall of 2010, plant communities in NWSG areas had taller vegetation ($U = 326.95$, $P < 0.001$), higher plant species richness ($U = 80.59$, $P < 0.001$), more bare ground ($U = 114.84$, $P < 0.001$), and more litter ($U = 222.46$, $P < 0.001$) than airfield grassland areas (Table 2).

BIRDS

We conducted a total of 823 5 min bird surveys (432 in NWSG areas and 391 in airfield grasslands) during a one year period (Dec. 2009–Nov. 2010). A total of 5170 individual birds representing 51 species were observed exhibiting a behavior suggesting they were associated with the study areas. European starlings (*Sturnus vulgaris*), red-winged blackbirds (*Agelaius*

TABLE 2.—Mean (± SE) height of vegetation (cm), plant species richness (number of species/m^2), and percent cover of plant community characteristics in native warm-season grass (NWSG) adjacent to airports and airfield grasslands on 3 airports located in western Ohio, U.S.A. during spring and fall of 2010

	Spring		Fall	
	NWSG	Airfield	NWSG	Airfield
Height of vegetation (cm)	31.6 ± 1.0 a[1]	29.1 ± 0.8 a	88.7 ± 2.4 a	30.0 ± 0.8 b
Plant species richness (no. of species/m^2)	4.4 ± 0.1 a	4.0 ± 0.1 a	4.0 ± 0.1 a	3.0 ± 0.1 b
Total vegetative canopy cover (%)	54.0 ± 1.8 a	84.8 ± 1.3 b	87.3 ± 0.6 a	91.3 ± 0.7 b
Bare ground (%)	5.2 ± 0.7 a	4.6 ± 0.9 a	12.0 ± 0.9 a	5.8 ± 0.9 b
Litter (%)	48.9 ± 1.9 a	15.6 ± 0.9 b	24.9 ± 0.7 a	11.5 ± 0.5 b

[1] Means within the same row within a year and season with the same letter are not significantly different (Mann–Whitney U test; $P > 0.05$)

phoeniceus), and American goldfinches (*Carduelis tristis*) were the most abundant birds during the study, accounting for 21.8%, 9.8%, and 8.2% of the total observations, respectively.

During fixed radius avian point count surveys, we observed more ($U = 9.46$, $P = 0.002$) birds per 5 min survey using NWSG areas (3.04 ± 0.30 birds) than airfield grasslands (2.00 ± 0.17 birds). Species specific variation occurred in bird use between the two landcover types. American goldfinches, red-winged blackbirds, common yellowthroats (*Geothlypis trichas*), and bobolinks (*Dolichonyx oryzivorus*) were more abundant (all $P < 0.05$) in NWSG

TABLE 3.—Mean (± SE) number of birds observed during 5-min 70–m fixed-radius point count surveys conducted in native warm-season grassland plots (NWSG) adjacent to airports and airfield grasslands on 3 airports located in western Ohio, U.S.A., Dec. 2009-Nov. 2010

Species/group [(1)]	Mean no. of birds detected per 5-min point count (± SE)	
	NWSG	Airfield grasslands
American goldfinch	0.84 ± 0.24 a [(2)]	0.05 ± 0.02 b
Sparrows (all sparrow species)	0.75 ± 0.11 a	0.66 ± 0.07 a
field sparrow [(3)]	0.29 ± 0.04 a	0 b
song sparrow [(3)]	0.26 ± 0.03 a	0.01 ± 0.01 b
savannah sparrow [(3)]	0 a	0.37 ± 0.06 b
grasshopper sparrow [(3)]	0 a	0.14 ± 0.03 b
Red-winged blackbird	0.43 ± 0.07 a	0.20 ± 0.04 b
Eastern meadowlark	0.03 ± 0.01 a	0.17 ± 0.03 b
Bobolink	0.07 ± 0.02 a	0.02 ± 0.01 b
Common yellowthroat	0.31 ± 0.04 a	0.02 ± 0.01 b
Horned lark	0 a	0.28 ± 0.08 b
European starling	0.03 ± 0.01 a	0.04 ± 0.03 a
Swallows & swifts	0.24 ± 0.06 a	0.41 ± 0.07 b
Raptors	0.02 ± 0.01 a	0.01 ± 0.01 a
Doves & pigeons	0 a	0.06 ± 0.04 a
Total birds (all species)	3.04 ± 0.30 a	2.00 ± 0.17 b

[(1)] See Appendix A1 for group members

[(2)] Means within the same row with the same letter are not significantly different (Mann–Whitney U test; $P > 0.05$)

[(3)] This species was also included in the 'sparrows' group

TABLE 4.—Bird density estimates [1] (birds per ha) with standard errors and effective detection radius (EDR; in m) derived using Distance sampling for species/species groups at native warm season grasslands (NWSG) adjacent to airfields and airfield grasslands located on 3 airports in western Ohio, U.S.A., Dec. 2009–Nov. 2010

	NWSG		Airfield grasslands	
Species/group [2]	Density (± SE)	EDR	Density (± SE)	EDR
American goldfinch	3.02 ± 0.83 a [3]	30.3	0.18 ± 0.14 b	34.2
Sparrows	1.44 ± 0.26 a	47.5	1.11 ± 0.19 a	45.1
Red-winged blackbirds	0.52 ± 0.09 a	62.8	0.35 ± 0.18 a	63.6
Eastern meadowlark	0.03 ± 0.01 a	95.7	0.14 ± 0.02 b	113
Other icterids	0.13 ± 0.04 a	54.8	0.02 ± 0.05 b	121
Common yellowthroat	0.70 ± 0.08	39.4	NA [4]	NA
Other passerines	0.20 ± 0.05	55.9	NA	NA
Horned lark	NA	NA	0.26 ± 0.06	185.9
European starling	NA	NA	NA	NA
Turdids	0.08 ± 0.02	70.4	NA	NA
Corvids	0.01 ± 0.01 a	149.4	0.02 ± 0.01 a	185.9
Killdeer	NA	NA	0.06 ± 0.01	137.1
Swallows & swifts	0.67 ± 0.28 a	37.1	0.55 ± 0.14 a	57.8
Raptors	0.01 ± 0.01 a	178.4	0.01 ± 0.01 a	250.7
Doves & pigeons	NA	NA	0.02 ± 0.01	202.1

(1) The half-normal and hazard rate detection key function and the cosine, simple polynomial, and hermite polynomial series expansions were used to model the data in program DISTANCE 6.0 and the best-fitting model was used to estimate density

(2) See Appendix A1 for group members

(3) Means within the same row with the same letter are not significantly different (Student's t test; $P > 0.05$)

(4) Calculation of a bird density estimate was not possible because the minimum number of detections criteria was not met

than in airfield grasslands (Table 3). In contrast swallows and swifts, eastern meadowlarks (*Sturnella magna*), and horned larks (*Eremophila alpestris*) used airport grasslands more frequently (all $P < 0.05$) compared to NWSG areas (Table 3). Grasshopper sparrows (*Ammodramus savannarum*) and savannah sparrows (*Passerculus sandwichensis*) were observed only within airfield grasslands, whereas field sparrows (*Spizella pusilla*) and song sparrows (*Melospiza melodia*) used NWSG areas almost exclusively.

We were able to estimate and compare bird densities between landcover types using distance methodology for eight of the 15 species/groups (Table 4). Sample size was not adequate to reliably calculate density for the remaining seven species/groups. The densities of American goldfinches and the 'other icterids' group were higher in NWSG areas than in airfield grasslands (goldfinches: $t = 3.37$, $P < 0.001$; other icterids: $t = 2.64$, $P = 0.01$; Table 5). Conversely, Eastern meadowlark density was higher ($t = 5.59$, $P < 0.001$) within airfield grasslands compared to NWSG areas (Table 4). Density estimates of all other species/groups were similar (all $P > 0.05$) between the two landcover types.

Overall, the distribution of birds within hazard levels (as defined in Dolbeer and Wright, 2009) was relatively consistent between the two landcover types (Fig. 1). Birds in the 'low' and 'very low' hazard levels (combined) accounted for 93.9% of birds using the airfield grasslands and 97.8% of birds using the NWSG areas. The proportion of 'high' hazard level birds was higher ($z = 4.03$, $P < 0.001$) in airfield grasslands compared to NWSG areas due to

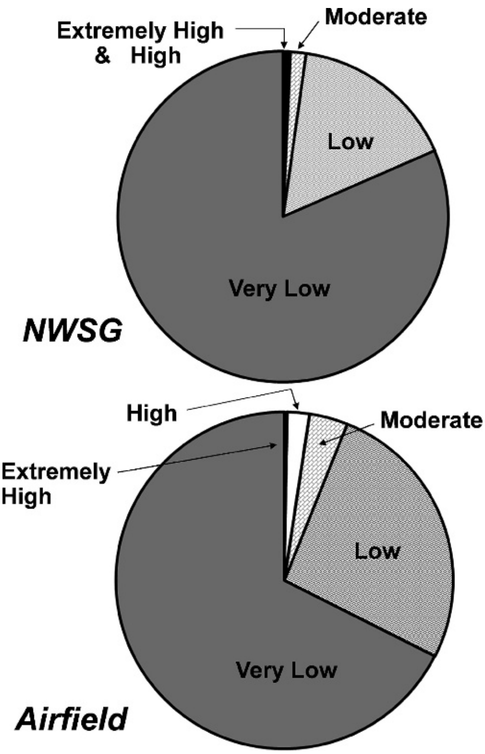

FIG. 1.—Distribution of birds categorized by species into strike hazard categories (as defined by Dolbeer and Wright, 2009) and observed at native warm season grassland plots (NWSG) adjacent to airports and airfield grasslands on 3 airports located in western Ohio, U.S.A., Dec. 2009–Nov. 2010

the presence of rock pigeons (*Columba livia*). Likewise, mourning dove (*Zenaida macroura*) use of airfield grasslands resulted in the proportion of 'moderate' hazard level birds being higher ($z = 2.99$, $P = 0.003$) in those areas compared to NWSG areas.

SMALL MAMMALS

We conducted a total of 8013 trap nights and captured individuals from 10 species of small mammal (*Blarina brevicauda, Microtus ochrogaster, Microtus pennsylvanicus, Mus musculus, Peromyscus leucopus, Peromyscus maniculatus, Sorex cinereus, Spermophilus tridecemlineatus, Tamias striatus, Zapus hudsonius*) consisting of 762 and 206 captures in NWSG and airfield grassland areas, respectively. Mean capture success (pooled across all months and species) was 19.1 $\pm$ 4.2 and 6.8 $\pm$ 1.5 small mammals/100 adjusted trap nights in NWSG and airfield grasslands, respectively. Mean capture success of small mammals was higher ($t = -2.76$, $P = 0.03$) in NWSG compared to airfield grasslands during all 6 mon (Fig. 2).

DISCUSSION

The presence and use of grassland habitats by birds are influenced by a variety of factors, including the size of grasslands, habitat characteristics of the grasslands, and land management activities (*e.g.*, mowing, prescribed burning) that occur in those habitats

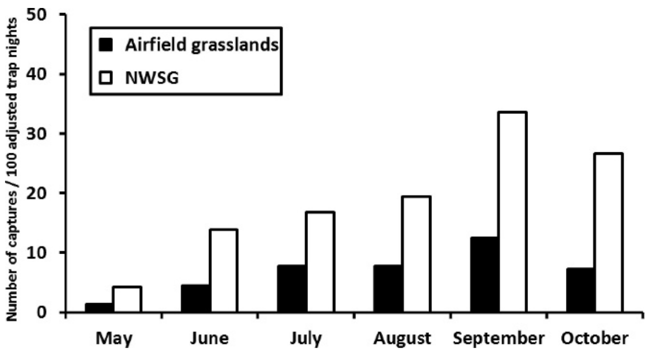

FIG. 2.—Monthly adjusted capture success (number of captures/100 adjusted trap nights) by landcover type for small mammal trapping at native warm season grassland plots (NWSG) adjacent to airports and airfield grasslands on 3 airports located in western Ohio, U.S.A., Apr. 2010–Sep. 2010

(Herkert, 1995; Norment *et al.*, 1999; Washburn and Seamans, 2007). Plant community characteristics, such as the density and structure of vegetation, have been shown to influence the use of grassland habitats by birds (Delisle and Savidge, 1997; Norment *et al.*, 1999; Fisher and Davis, 2010). In this study, differences in plant community characteristics between NWSG and airfield grassland habitats coincided with species specific patterns of bird use between the two landcover types.

In western Ohio, NWSG habitats are rare and few remnant or restored grasslands of this habitat type are present within this landscape which is comprised mostly of rowcrop agriculture. In addition the NWSG habitats that do occur are relatively small in size; the NWSG areas in this study ranged from 21 ha to 51 ha in size. American goldfinches, common yellowthroats, song sparrows, and field sparrows were found in much higher abundance or almost exclusively in the NWSG areas. These same bird species were found to be most abundant in a study examining unmanaged grassland habitats (*e.g.,* old-fields) in northcentral Ohio (Washburn and Seamans, 2007). We suspect these birds used the taller vegetation (*e.g.,* NWSG) and woody plants in the NWSG habitats to meet their specific life-history requirements, such as nesting locations, singing perches, or foraging sites (King and Savidge, 1995; Warren and Anderson, 2005).

Typical of airport situations, the airfield grasslands in this study were subjected to rigorous vegetation management (*i.e.*, mowing), resulting in plant communities that are shorter in height. Several bird species, including horned larks, grasshopper sparrows, and savannah sparrows were found exclusively in airfield grasslands. The shorter vegetation and plant community composition on the airfields were likely favorable to these birds for breeding, foraging, or meeting other specific life history needs (King and Savidge, 1995; Norment *et al.*, 1999; Ribic *et al.*, 2009). Additionally, grasshopper sparrows and savannah sparrows are area sensitive grasslands songbirds that require relatively large (>40 ha) contiguous tracts of grasslands that are intermediate in vegetation height (Herkert, 1994a, b; Vickery *et al.*, 1994; Sample *et al.*, 2003). Although airfield grasslands appear to meet the life history needs of these birds (as indicated by their presence on the airfields in this study), it is possible that airfield habitats represent a population sink for these species due to the intensive management activities (*i.e.*, mowing) that occur on airfields due to aviation safety regulations that require vegetation to be maintained at a short height in critical areas of the airfield (*e.g.,* within aircraft operating areas; Kershner and Bollinger, 1996).

Overall, the bird communities using both NWSG areas and airport grasslands were comprised of only a small proportion of birds that are considered to be of a 'moderate' to 'extremely high' hazard (severity) level (based on the analyses of Dolbeer and Wright, 2009). Although some species from these categories were observed in both landcover types [*e.g.,* turkey vultures (*Cathartes aura*)], most of the birds observed during this study (*e.g.,* American goldfinches, sparrows) pose a 'low' or 'very low' hazard to aviation safety due to their body size or behavior patterns (Dolbeer *et al.*, 2000; Dolbeer and Wright, 2009; DeVault *et al.*, 2011).

We acknowledge that wildlife damage management activities (*e.g.,* use of pyrotechnics) to disperse birds from the airfields could have reduced the use of airfield grasslands by birds. However, at all three of our study airports, minimal (*i.e.*, only periodic) wildlife control activities occurred during the study. Even so, our estimates of bird abundance and density are likely conservative on the airfields where some management activities occurred during the study.

Small mammals were substantially more abundant in NWSG areas compared to airfield grassland habitats. Mowing vegetation appears to discourage small mammal use of grasslands (Lemen and Clausen, 1984; Edge *et al.*, 1995; Seamans *et al.*, 2007). However, the abundance and density of raptors were similar between the two landcover types, suggesting raptors did not choose hunting locations based on prey density alone. Several studies have found that prey availability, rather than prey abundance, is critical to habitat use by raptors (Baker and Brooks, 1981; Bechard, 1982; Preston, 1990), because prey is more vulnerable to raptors in areas with sparser vegetation. In our study areas, NWSG grasslands had more litter in fall and spring; and higher vegetation height in fall, than airfield grasslands. We suspect the higher plant canopy cover in NWSG areas might limit prey availability to raptors and thus could offset the higher abundance of small mammals compared to airfield grasslands.

Temporal and spatial variation in plant community characteristics could influence the attractiveness of NWSG habitats to birds, as successional changes and heterogeneity across individual grassland areas have the potential to provide varying levels and types of food; and cover resources to birds using those grassland habitats. Site specific monitoring efforts should be conducted when NWSG habitats are present on or near airfields to ensure these areas do not increase the risk of bird strikes.

Although our findings suggest that NWSG areas are similar to airfield grasslands in regard to their use by birds hazardous to aviation, we recommend careful consideration when establishing or preserving NWSG in close proximity to airfields due to the limitations of our study. Bird use of grassland areas likely reflects the composition of the overall avian communities within a geographic area. For example the use of coastal prairies in Texas and Louisiana by birds that pose a 'high' hazard level to aviation might be considerably greater when compared to the NWSG areas in this study. Regardless our findings suggest that NWSG might be considered a viable land use near airfields, thereby potentially providing habitat for some grassland birds that present minimal hazards to safe aircraft operations. We believe this study provides an early step towards critical thought on alternative vegetative covers on and near airfields (DeVault *et al.*, 2012).

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APPENDIX A1.—Species/species groups (with a minimum of 25 individuals observed) detected during avian surveys and used for comparative analyses between 3 native warm-season grasslands adjacent to airfields and airfield grasslands on 3 airports in western Ohio, U.S.A., Dec. 2009–Nov. 2010

Species/group	Species in group	Latin name
AMGO	American goldfinch	*Spinus tristis*
COYE	common yellowthroat	*Geothlypis trichas*
EUST	european starling	*Sturnus vulgaris*
HOLA	horned lark	*Eremophila alpestris*
KILL	killdeer	*Charadrius vociferus*
EAME	eastern meadowlark	*Sturnella magna*
RWBL	red-winged blackbird	*Agelaius phoeniceus*
Other icterids	Baltimore oriole	*Icterus galbula*
	brown-headed cowbird	*Molothrus ater*
	bobolink	*Dolichonyx oryzivorus*
	common grackle	*Quiscalus quiscula*
	unknown blackbird	
Corvids	American crow	*Corvus brachyrhynchos*
	blue jay	*Cyanocitta cristata*
Doves & pigeons	mourning dove	*Zenaida macroura*
	rock pigeon	*Columba livia*
Raptors	American kestrel	*Falco sparverius*
	cooper's hawk	*Accipiter cooperii*
	northern harrier	*Circus cyaneus*
	red-tailed hawk	*Buteo jamaicensis*
	turkey vulture	*Cathartes aura*
	unknown hawk	

APPENDIX A1.—Continued

Species/group	Species in group	Latin name
Sparrows	American tree sparrow	*Spizella arborea*
	chipping sparrow	*Spizella passerina*
	eastern towhee	*Pipilo erythrophthalmus*
	field sparrow	*Spizella pusilla*
	grasshopper sparrow	*Ammodramus savannarum*
	lark sparrow	*Chondestes grammacus*
	savanna sparrow	*Passerculus sandwichensis*
	song sparrow	*Melospiza melodia*
	vesper sparrow	*Pooecetes gramineus*
	white-throated sparrow	*Zonotrichia albicollis*
	unknown sparrow	
Swallows & swifts	barn swallow	*Hirundo rustica*
	chimney swift	*Chaetura pelagica*
	cliff swallow	*Petrochelidon pyrrhonota*
	northern rough-winged swallow	*Stelgidopteryx serripennis*
	tree swallow	*Tachycineta bicolor*
	unknown swallow	
Turdids	American robin	*Turdus migratorius*
	eastern bluebird	*Sialia sialis*
Other passerines	cedar waxwing	*Bombycilla cedrorum*
	eastern kingbird	*Tyrannus tyrannus*
	grey catbird	*Dumetella carolinensis*
	house wren	*Troglodytes aedon*
	indigo bunting	*Passerina cyanea*
	northern mockingbird	*Mimus polyglottos*
	scarlet tanager	*Piranga olivacea*
	sedge wren	*Cistothorus platensis*
	unknown flycatcher	