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Research paper

Bird use of grain fields and implications for habitat management at airports

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ABSTRACT

Airport properties often include agricultural land cover that can attract wildlife species hazardous to aircraft, despite recommendations against row crops near air operations areas. However, few studies have directly quantified bird use of corn, wheat, and soybean fields relative to bird-aircraft collision (strike) hazard levels to support land cover recommendations. Therefore, we compared bird use among corn, wheat and soybean fields and predicted that corn and wheat would attract bird species recognized as hazardous to aviation. We also anticipated that soybeans would pose minimal attraction to such birds. Here, hazard ranking (low to extremely high) reflects the percentage of strikes involving a species that resulted in damage to aircraft. We investigated bird use among 22 corn, wheat, and soybean fields near Oak Harbor, OH, using approximately weekly point transects from 2013 to 2014. We used generalized distance sampling models and analysis of variance using distance matrices to determine bird abundance and community responses to row crop land coverages and crop height. We observed 4331 birds of 40 species, with most birds observed in wheat fields (n = 2555 birds) and standing stubble (n = 2409 birds). Large flocks occurred more in corn and wheat fields than soybean fields, but soybean fields harbored greater cumulative hazard scores than corn, likely due to consistent detections of small, non-flocking birds in soybean fields. Crop type and height had greater influence on medium- and high-hazard level bird species than other hazard levels. Density of medium- and high-hazard level birds increased with increasing crop height in soybean and wheat fields with wheat fields having slightly greater densities than soybeans. Corn fields also had the greatest bird densities in the tallest crop height categories. Categories of very and extremely high-hazard level bird species were rarely detected, but their abundance peaked in crops 0–15 cm, similar to low-hazard level bird species. However, model selection results included null models for very and extremely high-hazard level bird species suggesting minimal effects. Overall, our results suggest that all three crop types can harbor birds hazardous to aircraft, and crop height can enhance bird use. Although not directly tested in our study, land management surrounding airports may benefit most from alternative land covers (e.g., biofuel crops), but additional research is necessary.

1. Introduction

Bird composition and abundance in agricultural fields vary throughout the production cycle following changes in food and cover availability. Newly planted fields in the USA can attract open-field, ground-nesting species such as killdeer (*Charadrius vociferus*; Basore et al., 1986; Cornell Lab of Ornithology, 2013), but lack the protective cover which increases as crops mature (Wilson et al., 1996; Chamberlain et al., 1999; Moorcroft et al., 2002; Kuzmenko, 2012). However, food availability in newly planted or stubble fields can attract myriad bird species despite cover preferences (Fernández-Juricic et al., 2004). After crops mature, cultivation practices further influence bird communities as they affect crop residue and waste grain availability (Rodenhouse and Best, 1983; Basore et al., 1986; Krapu et al., 2004) and even directly destroy nests or kill birds (Rodenhouse and Best, 1983; Frawley, 1989; Rodenhouse et al., 1993).

Food and cover use varies by crop type as well. For example, corn (*Zea mays*) comprised 45.4% of fall foods for mourning doves (*Zenaida macroura*; Chamberlain, 1965), and corn silage and grains comprised 9–16% and 21–26%, respectively, of stomach contents in European

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starlings (*Sturnus vulgaris*; Killpak and Crittenden, 1952). Snow geese (*Chen caerulescens*) select waste corn over wheat and soybeans (Frederick and Klaas, 1982). Canada goose (*Branta canadensis*) and other waterfowl have demonstrated differential field use based on waste corn density (Anteau et al., 2011). As cover, fields with standing stubble of cereal crops and oilseed were used by more granivores than fields with traditional tillage in Europe and North America (Castrale, 1985; Donald and Forrest, 1995; Chamberlain et al., 1999; Gillings et al., 2005; Kopij, 2008; Kragten and de Snoo, 2008). Sterner et al. (1984) found 28 crops that had no reports of bird use. For example, soybeans may not provide adequate structure and cover for some wildlife species and are a low-quality food for waterfowl (Krapu et al., 2004). However, the lack of reported use does not conclusively demonstrate that birds do not use those crops.

Corn and wheat are known attractants and can be used extensively by wildlife (Best et al., 1990; Krapu et al., 1995; Cerkal et al., 2009), but limited information is available comparing their use to soybeans (Blackwell and Dolbeer, 2001; Krapu et al., 2004, 2005; Galle et al., 2009). The U.S. Federal Aviation Administration (FAA) recommends against the use of airport property for agricultural production (FAA Advisory Circular 150/5200-33B) and recognizes that most, if not all, crops can attract hazardous wildlife during some phase of production (FAA, 2007). Wildlife strike risk mitigation at airports is essential for safe air operations (DeVault et al., 2013a). From 1990–2014, wildlife strikes caused 981,200 h of downtime, $631.8 million in direct costs and $76.4 million for other costs, not including lost revenue, flight cancellations, or passenger accommodations (Dolbeer et al., 2015). However, financial constraints often favor leasing airport land outside primary airport operation areas to farmers, in which case minimum distances between on-airport crops and specific airport features should be maintained (Advisory Circular 150/5300-13, Appendix A7; FAA, 2007). Among 10 small airports in Indiana, USA, land coverage of soybean (10.3%) and corn (9.5%) fields were intermediate to short grass (e.g., airport grassland; 40.2%) and runway systems (8.1%; DeVault et al., 2009). Investigating bird use of agricultural crop fields and their potential hazards could inform airport personnel of the associated wildlife strike risk of row crops adjacent to air operations areas and encourage establishment of alternative land uses, including haying, biofuel crops, native warm season grasses, and solar arrays (Blackwell et al., 2009; Martin et al., 2011, 2013; DeVault et al., 2012, 2013b, 2014).

Mature crops can also restrict bird line of sight, influencing bird predator-evasion behaviors in some species and consequently bird use (Brough and Bridgman, 1980; Conover and Kania, 1991; see also Blackwell et al., 2013, 2016). Flocking bird species in taller and denser vegetation encounter greater visual obstruction which has been observed to increase vigilance and lengthen response times to predator attacks (Devereux et al., 2004; Whittingham and Devereux, 2008). Flock sizes of European starlings can also influence their likelihood of using dense, visually-obstructive vegetation that smaller flocks and individuals may avoid (Fernández-Juricic et al., 2004). Typical airfield grassland management focuses on grass height manipulation to mitigate bird hazards in which taller, visually obstructive grass heights (i.e., obstructive to most passerines) might be less attractive to some, large-bodied bird species than short grass. Shorter grass heights also support visual detection of potential hazards (i.e., detecting hazardous animals approaching active runways). Currently, the FAA does not have a direct policy regarding grass height recommendations for wildlife hazard mitigation at airports but instead advises development of local grass-management plans incorporating airport-specific characteristics such as local hazardous species (FAA, 2009).

Most research regarding bird use and agriculture has compared bird use among conservation practices or alternative field management practices of single crop types (e.g., till vs. no-till) and seldom includes direct comparisons of bird use among traditionally managed row crop and concomitant changes in crop height. To accurately assess potential hazard risk of traditional row cropping near airports and vegetation height management, it is essential to conduct direct comparisons of bird field use and assess hazard associated with each crop type and height. Bird field use can also differ among ecological regions emphasizing the need to investigate region-specific responses for developing optimal conservation or hazard mitigation management (Whittingham and Devereux, (2008); however, we do address avian field use at this scale.

The aim of our study was to compare bird use among crops (corn, soybeans, and wheat) and crop heights that are commonly planted on and near U.S. airports, especially smaller, General Aviation airports and determine whether abundance of birds hazardous to aircraft differs among crop types and heights (DeVault et al., 2009, 2013b). Based on past research and observations, we predicted greater use of corn and wheat fields by bird species recognized as hazardous to aviation (see below) and anticipated that soybeans would pose minimal attraction to such birds. However, we also predicted declining hazard risk as each crop grew and crop height increased. The FAA Wildlife Strike Database provides extensive information about bird-aircraft collisions since 1990 (Dolbeer et al., 2015). Some information recorded per strike includes species struck, any effects on flight, recordable damage, repair costs, and number of birds struck. From this information, Dolbeer and Wright (2009) developed species-specific hazard-level categories for bird-aircraft collisions (low: $\leq 1\%$ of strikes causing damage to extremely high hazard: $\geq 40\%$ of strikes causing damage). DeVault et al. (2011) further refined hazard-level categories by ranking species according to strike history information such as percentage of total strikes that caused any level of aircraft damage, substantial damage, or that otherwise affected flights. We assigned bird species to hazard-level categories developed by Dolbeer and Wright (2009) to assist with the evaluation of wildlife strike concern among crop types and heights. We also calculated the product of each species or species-group's hazard score and count per field visit using hazard scores from DeVault et al. (2011). Then, we summed the products among species or species-group per field visit to generate a cumulative hazard metric.

2. Material and methods

2.1. Study area

We sampled 22 agricultural fields near Oak Harbor, OH from June 2013 to March 2014 (Fig. 1). Large populations of blackbirds and waterfowl have been observed in this area due to the close proximity of Lake Erie and associated marshes. For example, during fall 2013, the Ohio Department of Natural Resources counted between 1000–6000 Canada geese in the region (M. Ervin, Ohio Department of Natural Resources, unpublished data). Fields were approximately 5–25 ha ($\bar{x}$ = 12.4 ha, SE = 1.04 ha) and < 0.25–3.0 km apart ($\bar{x}$ = 1.69 km ± 0.16 km). Fields were planted in corn (n = 3), wheat (n = 8), or soybeans (n = 11) for both study years. Our initial, more balanced design was disrupted by fields not being rotated [corn to soybeans (n = 5) or soybeans to corn (n = 3)] as we anticipated during study began. We were also restricted to sampling from field edges.

2.2. Sampling methods

We observed birds about weekly (n = 42 visits) for 3 min from a single, permanent sampling point on each field's edge using one observer for all observations. We recorded all birds detected within or above each field (i.e., approximately crop height), their distance from the observer (ocular estimate), species, flock or group size (count), detection type (visual or aural), and time of detection (Buckland et al., 2001). Numerous factors can affect field use by birds such as condition or energetic state, and food and cover resources. We assumed crop type represented food resources. Despite crop height indicating food availability with regards to crop maturity, such as stubble harboring greater waste grain food resources than actively growing crops, we used crop

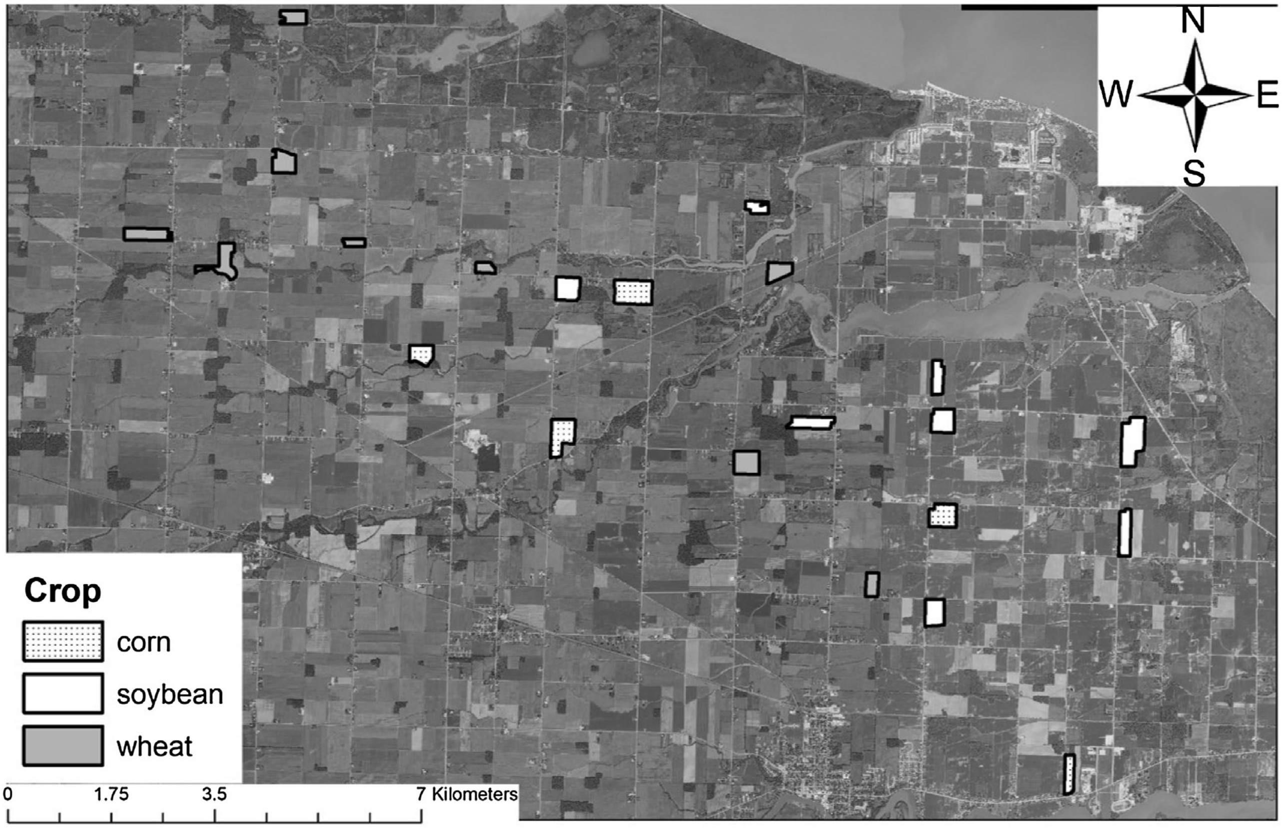

Fig. 1. Site distribution map of 22 agricultural fields sampled for birds using point transects near Oak Harbor, OH, from June 2013 to March 2014.

height, however, to primarily represent cover resources. We measured vegetation height during each visit (cm) but represented crop stubble as a qualitative variable. We then developed two crop-height classifications to investigate bird use between crop heights, one representing past research regarding typical airfield grassland management approaches (e.g., airport grassland height) and the second based on hypotheses regarding bird predator avoidance behaviors (e.g., bird eye height; sensu Blackwell et al., 2013). We developed the airport grassland-height classification from literature documenting bird use in and around airports (height bins: 0–15 cm (Mead and Carter, 1973; Brough and Bridgman, 1980; Buckley and McCarthy, 1994; Seamans et al., 1999, 2007); > 15–25 cm (Mead and Carter, 1973; Brough and Bridgman, 1980; Transport Canada, 1994; Dekker and Zee, 1996; Barras et al., 2000; Washburn and Seamans, 2004; Seamans et al., 2007); > 25–45 cm (Seamans et al., 1999); > 45 cm (Buckley and McCarthy, 1994; considered "unmanaged" grass by Barras et al., 2000)). To represent the FAA's recommendation and bird predator avoidance behaviors as they pertain to increasing crop height, we categorized measured heights based on average body lengths of observed ground foraging bird species, with bird lengths obtained from the Cornell Lab of Ornithology (2013). Although bird length may only be a proxy for eye height, it was readily available and provides a metric for comparison. Finally, we retained our stubble height category for each height classification approach.

2.3. Analysis

We investigated bird abundance responses to crop type and height using the generalized distance sampling model of Royle et al. (2004) and Chandler et al. (2011) with the "gdistsamp" function of R package unmarked (R Core Team, 2015). Generalized distance sampling models expand upon distance sampling analyses by not only allowing for inference about population densities of unmarked individuals but also accounting for temporary emigration and imperfect detection. We used month as our primary time period and calculated average crop height by month before segregating crop heights by height classification (see previous paragraph). To ensure crop height responses were driven by bird crop height selection and not seasonality of bird behavior, we checked linear and non-linear correlation between crop height and month using Pearson's product-moment correlation with the "cor.test" function and generalized additive models with "gam" function in R package stats (R Core Team, 2015). Linear relationships were weak ($r = 0.0961$), but a non-linear trend was significant (t-value = 19.53, $P < 0.001$, $R^2 = 0.214$) with increasing crop height from April through August, then decreasing until January. However, this pattern does not reflect bird seasonal patterns of migration and nesting, suggesting that any crop-height effects would result from bird crop-height selection. We categorized bird species by hazard level (Dolbeer and Wright, 2009) which also increased detections per response variable (i.e., observations of individual birds or flocks) and developed time-series covariates for crop type and height for estimating abundance to account for monthly changes. We assumed detection among species within hazard level would be similar because hazard level typically increases with bird body size and flocking behavior (DeVault et al., 2011). Due to low detections (< 30 detections), we combined bird detections in 'very high' and 'extremely high' bird hazard levels (Dolbeer and Wright, 2009). We developed models of all combinations of abundance covariates per hazard category and a model with no covariates. We evaluated all models using Akaike's Information Criterion adjusted for small sample sizes (AIC_c), ΔAIC_c values, Akaike weights, and evidence ratios (Burnham and Anderson, 2002). We used AIC_c model selection to determine the best starting point among half-normal, hazard rate, and uniform key functions and applied the appropriate key function to remaining models (Thomas et al., 2010). Because crop height might affect detection, we tested the effects of month and crop height on bird availability and detection, respectively, in the global model and retained these covariates if model fit improved. We tested data dispersion using results of a Poisson generalized linear model with crop type and height as primary factors with the "dispersiontest" function in R package AER. When data were overdispersed, we used a Negative Binomial mixture, but otherwise used a Poisson mixture. Because crop height classifications were dependent on the same measured variable (e.g., crop height), we developed two model sets per hazard category, one set for each height classification. We summed model weights of predictor variables to assess their relative importance (Burnham and Anderson, 2002). We generated model-averaged hazard level density estimates (lambda) and their 95% confidence intervals for each predictor variable based on the entire set of models using the "predict" function in unmarked (Burnham and Anderson, 2002). We used model averaging among all candidate models due to model selection uncertainty and our interest in understanding the influence of each predictor variable on bird field use.

We conducted an analysis of variance using distance matrices (ADONIS) to further investigate bird community responses among crop types and height classifications (Anderson, 2001; Ott and Longnecker, 2010) and as an alternate support for distance analysis. Using ADONIS, we partitioned sources of variation while fitting linear models to distance with permutation tests as pseudo-*F* ratios (Anderson, 2001). We accounted for repeated measures of each field (strata = field) and tested homogeneity of group spread, similar to homogeneity of variance for analysis of variance assumption. using function "betadisper" in R package vegan. We created a species abundance matrix organized by site, month, crop type and each height classification. We investigated interactions of crop type and height using 999 permutations and Bray-Curtis distances (Oksanen, 2014; R Core Team, 2015). We used Bonferroni correction for all ADONIS with an *a priori* significance level of significance of $\alpha = 0.05$ (Ott and Longnecker, 2010).

We used cumulative hazard score; species richness; and Shannon's diversity to further interpret bird community differences. We calculated relative hazard score per visit (i.e., point transect) as the sum of each detected species' count multiplied by the species' respective hazard score. Then, we summed the products among species or species-group per field visit to generate a cumulative hazard metric. We used species-specific hazard scores to develop a quantitative index of hazard by field risk, not pooling species detections by hazard category. Respective hazard scores were derived from strike report information recorded in the Federal Aviation Administration's Wildlife Strike Database which extend Dolbeer and Wright's (2009) categories by considering percentage of total strikes that caused any level of aircraft damage or substantial damage or strikes that affected flights. We assigned each species a hazard score based on DeVault et al. (2011) and applied sparrows' hazard score to unidentified small bird species.

3. Results

We observed 4331 birds of 40 species among soybean, wheat, and corn fields with most birds in wheat fields ($n = 2555$ birds) and standing stubble of all crops ($n = 2409$ birds). Of these species, body lengths of 22 ground foragers suggested 3 crop height bins of 0–15 cm, > 15–32 cm, and > 32 cm, similar to airport grassland height bins (Table 1). The > 45 cm height category of airport grassland research height classification only occurred for corn, limiting comparisons among crops but also offering insight to potential tall crop attraction. Our most extreme observations occurred in wheat and corn fields. Flocks of 600 common grackles, 400, 230 and 126 European starlings, and over 100 red-winged blackbirds were observed in wheat fields during September and October. In August and September, tall corn (> 45 cm) fields had flocks of over 300 red-winged blackbirds or barn swallows. Corn and wheat crops also averaged greater group sizes (corn = 19.65 birds, $\sigma = 65.51$, wheat = 13.44 birds, $\sigma = 59.91$, soybean = 3.12 birds, $\sigma = 7.69$).

Crop type and height had greater influence on medium and high hazard level bird species than other hazard levels despite crop height classification (Tables 2 and 3). Density of medium and high hazard level birds increased with increasing crop height in soybean and wheat fields with wheat fields having slightly greater densities than soybeans when crop height was based on bird length categories (Table 4). Medium and high hazard level bird densities among grass management crop height classification were greatest in the tallest height category for each crop in addition to slightly greater densities when crops were 0–15 cm tall compared to stubble and > 25–45 cm crops (Tables 4 and 5). Crop-height only models for low-hazard level birds were nearly 4 times stronger than second-ranked models of crop-type and height models or crop type only for bird length and grass-management-height classifications, respectively. Whereas, very and extremely high hazard-level birds were rarely detected, but their abundance peaked in crops 0–15 cm, similar to low hazard-level birds. However, model selection results included null models for very and extremely high hazard-level bird species suggesting minimal effects.

Table 1
Body lengths of ground foraging bird species observed within effective distance radii of the observer during point transects of corn, soybean, and wheat fields near Oak Harbor, OH, visited weekly from June 2013–March 2014. Number of detections represents how many observations included at least 1 bird per species, not the number of species observed, within effective distance radii of the observer. Hazard levels per species were developed based on the percentage of recorded strikes with aircraft causing damage (Dolbeer and Wright, 2009very high (20% ≤ x < 40% of strikes causing damage) and extremely high (≥40% strikes causing damage) hazard levels were combined for analysis (e.g., VE High)).

Species	Hazard Level	Number of Detections	Body Length (cm)	
			Range	Average
American goldfinch	Low	1	11–13	12.0
American pipit	Low	1	14–17	15.5
American robin	High	27	20–28	24.0
Brown-headed cowbird	Low	1	19–22	20.5
Bobolink	Low	1	15–21	18.0
Canada goose	Extremely High	1	76–110	93.0
Chipping sparrow	Low	2	12–15	13.5
Common grackle	High	25	28–34	31.0
Eastern bluebird	Low	1	16–21	18.5
Eastern meadowlark	Low	1	19–26	22.5
European starling	Medium	15	20–23	21.5
Field sparrow	Low	1	12–15	13.5
Horned lark	Low	167	16–20	18.0
House sparrow	Medium	5	15–17	16.0
Indigo bunting	Low	1	12–13	12.5
Inca dove	Low	2	18–23	20.5
Killdeer	Low	75	20–28	24.0
Lapland longspur	Low	2	15–16	15.5
Mourning dove	Medium	12	23–34	28.5
Red-winged blackbird	Medium	90	17–23	20.0
Savannah sparrow	Low	6	11–15	13.0
Song sparrow	Low	7	12–17	14.5

Bird communities differed among crops (airport grassland $F_{2,231} = 3.12$, P-value ≤ 0.001, bird length $F_{2,232} = 3.94$, P-value ≤ 0.001) and crop heights (airport grassland $F_{4,231} = 5.93$, P-value ≤ 0.001, bird length $F_{3,232} = 6.70$, P-value ≤ 0.001). Although differences occurred within most pairwise comparisons, minimal variance was explained by any model (partial $R^2 < 0.10$, Table 6). According to additional bird community characteristics, diversity metrics and cumulative hazard score increased from corn to wheat (Table 7). Diversity metrics were greater in 0–15 cm crops than other crop heights but biased low (Fig. 2), and greater cumulative hazard scores occurred in crops > 32–45 cm than shorter crops or tall corn (> 45 cm, Fig. 2).

Table 2
Model selection results regarding distance analysis of bird hazard category responses to crop type and height categories from point transects conducted near Oak Harbor, OH, June 2013–March 2014. Crop height categories were based on bird line-of-sight of 22 ground foraging species.

Hazard Category	Model[a]	k	AICc	ΔAICc	AICc Weight	Cumulative Weight	Log-Likelihood	Evidence Ratio
Low	~Crop_Height; ~1; ~Crop_Height	11	1776.55	0.00	0.73	0.73	−876.61	1.00
	~Crop_Type + Crop_Height; ~1; ~Crop_Height	13	1779.18	2.62	0.20	0.93	−875.66	3.71
	~Crop_Type; ~1; ~Crop_Height	10	1782.29	5.73	0.04	0.97	−880.59	17.57
	~1; ~1; ~Crop_Height	8	1783.20	6.65	0.03	1.00	−883.24	27.79
Medium	~Crop_Type + Crop_Height; ~Month; ~Crop_Height	14	696.26	0.00	0.85	0.85	−333.05	1.00
	~Crop_Height; ~Month; ~Crop_Height	12	699.68	3.42	0.15	1.00	−337.05	5.53
	~Crop_Type; ~Month; ~Crop_Height	11	709.67	13.41	0.00	1.00	−343.17	816.56
	~1; ~Month; ~Crop_Height	9	715.09	18.83	0.00	1.00	−348.09	12245.11
High	~Crop_Height; ~Month; ~Crop_Height	12	437.15	0.00	0.89	0.89	−205.78	1.00
	~Crop_Type + Crop_Height; ~Month; ~Crop_Height	14	441.35	4.19	0.11	1.00	−205.60	8.14
	~1; ~Month; ~Crop_Height	8	453.51	16.36	0.00	1.00	−218.40	3563.43
	~Crop_Type; ~Month; ~Crop_Height	10	456.15	19.00	0.00	1.00	−217.52	13371.90
VE High	~Crop_Height; ~Month; ~Crop_Height	12	328.39	0.00	0.59	0.59	−151.40	1.00
	~1; ~Month; ~Crop_Height	9	329.94	1.55	0.27	0.86	−155.52	2.17
	~Crop_Type; ~Month; ~Crop_Height	11	332.56	4.17	0.07	0.94	−154.61	8.03
	~Crop_Type + Crop_Height; ~Month; ~Crop_Height	14	332.81	4.41	0.06	1.00	−151.33	9.09

[a] Detection models are displayed as 3 right-sided formulas for abundance, availability, and detection covariates.

Table 3
Model selection results regarding distance analysis of bird hazard category responses to crop type and height categories from point transects conducted near Oak Harbor, OH, June 2013-March 2014. Crop-height categories were based on past studies regarding airfield grassland management.

Hazard Category	Model[a]	k	AICc	ΔAICc	AICc Weight	Cumulative Weight	Log-Likelihood	Evidence Ratio
Low	~Crop_Height, ~1, ~Crop_Height	13	1783.05	0.00	0.60	0.60	−877.60	1.00
	~Crop_Type, ~1, ~Crop_Height	11	1785.65	2.60	0.16	0.76	−881.16	3.67
	~Crop_Type + Crop_Height, ~1, ~Crop_Height	15	1786.07	3.03	0.13	0.90	−876.80	4.54
	~1, ~1, ~Crop_Height	9	1786.56	3.51	0.10	1.00	−883.83	5.78
Medium	~Crop_Type + Crop_Height, ~1, ~Crop_Height	15	699.63	0.00	0.97	0.97	−333.58	1.00
	~Crop_Height, ~1, ~Crop_Height	13	706.70	7.07	0.03	1.00	−339.42	34.30
	~Crop_Type, ~1, ~Crop_Height	11	718.83	19.21	0.00	1.00	−347.75	14804.78
	~1, ~1, ~Crop_Height	9	723.87	24.25	0.00	1.00	−352.49	184046.73
High	~Crop_Height, ~Month, ~Crop_Height	14	433.54	0.00	0.66	0.66	−201.69	1.00
	~Crop_Type + Crop_Height, ~Month, ~Crop_Height	16	434.87	1.33	0.34	1.00	−200.02	1.94
	~1, ~Month, ~Crop_Height	10	445.38	11.84	0.00	1.00	−212.14	371.74
	~Crop_Type, ~Month, ~Crop_Height	12	448.32	14.78	0.00	1.00	−211.37	1623.02
VE High	~1, ~1, ~1	3	426.99	0.00	0.43	0.43	−210.44	1.00
	~Crop_Height, ~1, ~1	7	427.24	0.25	0.38	0.82	−206.34	1.13
	~Crop_Type, ~1, ~1	5	429.53	2.53	0.12	0.94	−209.62	3.55
	~Crop_Type + Crop_Height, ~Month, ~Crop_Height	9	430.96	3.97	0.06	1.00	−206.03	7.27

[a] Detection models are displayed as 3 right-sided formulas for abundance, availability, and detection covariates.

Table 4
Density estimates and 95% confidence intervals (CI) for bird species observed using point transects among agricultural fields near Oak Harbor, OH, June 2013–March 2014. Crop height classification was based on lengths of 22 observed ground foragers. Birds were categorized by hazard categories (see text for methods).

		Hazard Category							
		Low		Medium		High		VE High	
Crop	Height	$\bar{x}$	CI	$\bar{x}$	CI	$\bar{x}$	CI	$\bar{x}$	CI
corn	Stubble	0.249	0.166–0.377	0.013	0.004–0.058	0.017	0.005 –0.064	0.014	0.004–0.053
	0–15 cm	0.413	0.262–0.660	0.046	0.011–0.225	0.086	0.026–0.322	0.058	0.016–0.248
	> 15–32 cm	0.254	0.151–0.433	0.068	0.020–0.299	0.119	0.038–0.416	0.022	0.006–0.112
	> 32 cm	0.125	0.060–0.263	0.085	0.031–0.235	0.154	0.049–0.482	0.012	0.003–0.086
soybean	Stubble	0.277	0.195–0.393	0.020	0.009–0.042	0.017	0.005–0.055	0.016	0.005–0.048
	0–15 cm	0.456	0.305–0.684	0.069	0.031–0.156	0.085	0.028–0.262	0.060	0.019–0.194
	> 15–32 cm	0.283	0.177–0.453	0.099	0.044–0.223	0.117	0.040–0.342	0.024	0.007–0.095
	> 32 cm	0.143	0.070–0.300	0.133	0.027–0.680	0.152	0.045–0.549	0.013	0.003–0.094
wheat	Stubble	0.266	0.185–0.383	0.047	0.022–0.098	0.018	0.006–0.057	0.015	0.005–0.046
	0–15 cm	0.439	0.289–0.667	0.166	0.065–0.423	0.089	0.028–0.278	0.058	0.017–0.198
	> 15–32 cm	0.271	0.168–0.439	0.225	0.115–0.440	0.122	0.042–0.356	0.023	0.006–0.089
	> 32 cm	–	–	–	–	–	–	–	–

Table 5
Density estimates and 95% confidence intervals (CI) for bird species observed using point transects among agricultural fields near Oak Harbor, OH, June 2013–March 2014. Crop height classification was based on past research investigating bird response to airport grassland management. Birds were categorized by hazard categories (see text in methods.

		Hazard Category							
		Low		Medium		High		VE High	
Crop	Height	$\bar{x}$	CI	$\bar{x}$	CI	$\bar{x}$	CI	$\bar{x}$	CI
corn	Stubble	0.244	0.162–0.373	0.001	0.000–8.209E + 13	0.010	0.003–1.048E + 65	0.020	0.007–0.070
	0–15 cm	0.385	0.244–0.615	0.002	0.001–2.784E + 14	0.051	0.016–5.031E + 65	0.050	0.015–0.204
	> 15–25 cm	0.255	0.140–0.473	0.001	0.000–1.934E + 14	0.046	0.012–5.040E + 65	0.017	0.005–0.096
	> 25–45 cm	–	–	–	–	–	–	–	–
	> 45 cm	0.135	0.064–0.299	0.132	0.045–0.386	0.221	0.068–0.721	0.020	0.005–0.130
soybean	Stubble	0.282	0.200–0.398	0.023	0.011–0.048	0.017	0.005–0.057	0.023	0.008–0.066
	0–15 cm	0.434	0.293–0.645	0.076	0.034–0.170	0.087	0.027–0.275	0.056	0.019–0.167
	> 15–25 cm	0.293	0.173–0.505	0.053	0.017–0.160	0.082	0.020–0.328	0.021	0.007–0.093
	> 25–45 cm	0.256	0.154–0.433	0.123	0.049–0.308	0.107	0.031–0.375	0.035	0.010–0.144
	> 45 cm	–	–	–	–	–	–	–	–
wheat	Stubble	0.271	0.189–0.390	0.049	0.024–0.103	0.019	0.006–0.064	0.021	0.007–0.062
	0–15 cm	0.420	0.279–0.634	0.167	0.067–0.417	0.094	0.028–0.316	0.051	0.016–0.164
	> 15–25 cm	0.283	0.162–0.500	0.115	0.035–0.376	0.090	0.020–0.399	0.019	0.006–0.089
	> 25–45 cm	0.246	0.146–0.419	0.268	0.132–0.545	0.116	0.035–0.390	0.032	0.009–0.126
	> 45 cm	–	–	–	–	–	–	–	–

Table 6
Bird community responses to 3 crops and 2 crop-height classifications (bird body length and airport-based research on bird use of different grass heights) from weekly point transects conducted near Oak Harbor, OH, June 2013–March 2014.

Comparison	df	SS[a]	MSE[b2]	*F*	Partial R[b]	*P-value*[c]
Corn vs. Soybean	2	2.487	1.243	2.894	0.022	0.001
Corn vs. Wheat	2	2.487	1.243	2.894	0.022	0.001
Soybean vs. Wheat	2	2.487	1.243	2.894	0.022	0.001
Stubble vs. 0–15 cm	2	7.215	3.608	8.781	0.064	0.001
Stubble vs. > 15–25 cm	2	5.195	2.598	6.202	0.046	0.001
Stubble vs. > 25–45 cm	2	6.614	3.307	8.003	0.059	0.001
Stubble vs. > 45 cm	2	5.817	2.908	6.985	0.052	0.001
0–15 cm vs. > 15–25 cm	2	1.913	0.956	2.214	0.017	0.004
0–15 cm vs. > 25–45 cm	2	4.523	2.261	5.365	0.040	0.001
0–15 cm vs. > 45 cm	2	2.946	1.473	3.444	0.026	0.001
> 15–25 cm vs. > 25–45 cm	2	5.428	2.714	6.494	0.048	0.001
> 15–25 cm vs. > 45 cm	2	3.835	1.918	4.520	0.034	0.001
> 25–45 cm vs. > 45 cm	2	6.809	3.405	8.254	0.061	0.001
Stubble vs. 0–15 cm	2	7.215	3.608	8.781	0.064	0.001
Stubble vs. > 15–32 cm	2	5.543	2.771	6.638	0.049	0.001
Stubble vs. > 32 cm	2	5.801	2.901	6.965	0.052	0.001
0–15 cm vs. > 15–32 cm	2	3.892	1.946	4.589	0.035	0.001
0–15 cm vs. > 32 cm	2	3.232	1.616	3.788	0.029	0.001
> 15–32 cm vs. < 32 cm	2	7.025	3.513	8.534	0.063	0.001

[a] Sum of Squares (SS).
[b] Mean Square Error (MSE).
[c] Bonferoni-corrected $\alpha = 0.0026$.

Table 7
Diversity metrics among crops and crop-height classifications by visit of observed bird communities in agricultural fields near Oak Harbor, OH, June 2013 – March 2014. Crop heights were classified by past airport grassland literature and bird body lengths.

	Species Richness		Shannon's Diversity		Cumulative Hazard Score	
	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Crops						
Corn	0.43	0.07	0.04	0.02	77.61	49.93
Soybean	0.53	0.05	0.08	0.01	122.83	37.25
Wheat	0.72	0.07	0.12	0.02	245.52	80.64
Crop Height						
Stubble[a,b]	1.34	0.06	0.16	0.03	170.27	54.08
0–15 cm[a,b]	1.68	0.12	0.34	0.06	148.68	88.71
> 15–32 cm[a]	1.54	0.11	0.25	0.05	132.40	46.48
> 32 cm[a]	1.25	0.09	0.14	0.05	251.25	159.66
> 15–25 cm[b]	1.27	0.11	0.13	0.05	90.20	42.46
> 25–45 cm[b]	1.67	0.15	0.30	0.06	240.31	105.83
> 45 cm[b]	1.32	0.11	0.17	0.06	110.63	86.42

[a] Crop height classification based on body lengths of observed ground foraging bird species.
[b] Crop height classification based on grass heights investigated in airport-based research regarding bird use of grass areas.

4. Discussion

Corn, wheat, and soybean fields can harbor birds hazardous to aircraft, and crop height can influence bird use. Corn and wheat fields harbored the most extreme observations regarding flock sizes of hazardous species, but soybean fields were intermediate among corn and wheat fields for cumulative hazard score. Crop type and height can interact to affect bird abundance (see Blackwell et al., 2016), especially for medium and high hazard-level bird species, and increasing crop height harbored greater bird densities. Even soybean fields demonstrated bird densities intermediate to corn and wheat fields when crop heights peaked.

The most common species observed among crop fields, European starlings ($n = 530$ individuals) and red-winged blackbirds ($n = 171$ individuals), were more abundant in wheat stubble and are known to feed on wheat in addition to corn (Dolbeer et al., 1978; Williams and Jackson, 1981; Linz et al., 2007). Though current harvest methods reduce waste grain (food) availability (Krapu et al., 2004), starlings and blackbirds used standing stubble fields most, likely because of food availability (Gliem et al., 1990; Blackwell et al., 2013). We did not measure food availability, but instead used crop height as an index of available cover. European starlings tend to prefer short vegetation (13 cm), but larger flocks; as observed in standing stubble and during late summer, suggest managing for visual obstruction alone would not deter starling use (Fernández-Juricic et al., 2004; Blackwell et al., 2013).

Growing or harvested soybean fields are generally used less by geese, red-winged blackbirds, northern pintails (*Anas acuta*), Sandhill cranes (*Gus canadensis*), and multiple songbirds than wheat or corn fields (Blackwell and Dolbeer, 2001; Krapu et al., 2004, 2005; Galle et al., 2009). Galle et al. (2009) also observed fewer blackbirds in soybean fields and attributed differences to soybean digestibility (Dabbert and Martin, 1994) and lack of protective cover after harvest

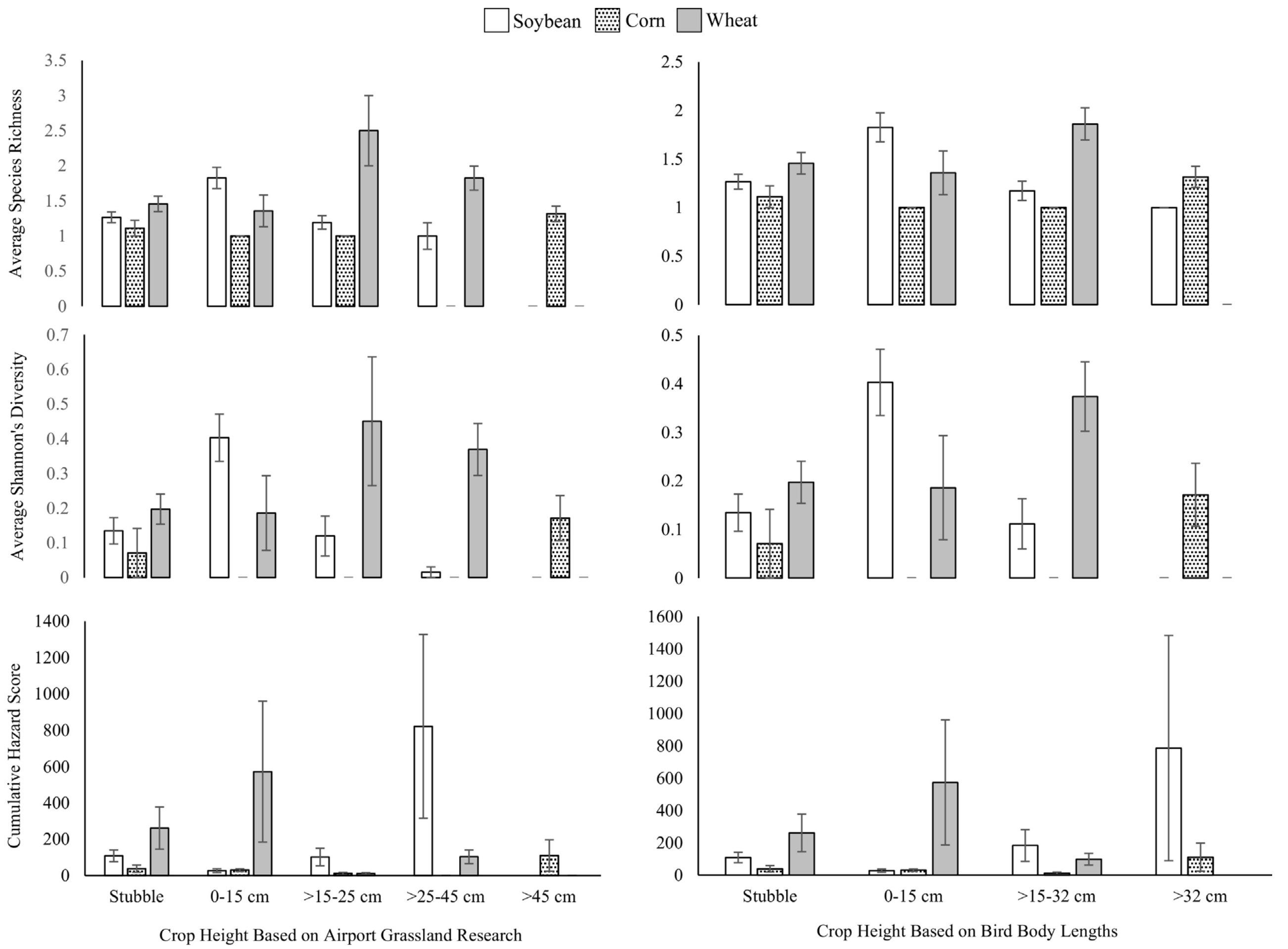

Fig. 2. Average species richness, Shannon's diversity, and cumulative bird hazard scores among crop heights of bird communities in agricultural fields near Oak Harbor, OH, June 2013 to March 2014 observed using point transects. Crop-height bins were derived from airport-based research regarding airport grassland management for bird strike mitigation or bird body lengths.

(Castrale, 1985). However, cumulative hazard scores for soybean fields were greater than corn fields, a possible result of consistent, multiple detections of horned lark (*Eremophila alpestris*, $n = 85$ detections) and killdeer ($n = 42$ detections), low hazard-level species.

Birds did not demonstrate field avoidance due to crop heights greater than their line-of-sight. Increasing crop height from 0 to 45 cm corresponded to increasing abundance of medium and high hazard-level birds. Average measured crop height (i.e., all non-stubble crop heights, $\bar{x} = 47.8$ cm, $\sigma = 56.7$) was greater than lengths of most ground foragers except Canada goose ($\bar{x} = 93.0$ cm), supporting past research that tall vegetation management is not a panacea for reducing bird use in and around airports, especially when food is available (Fernández-Juricic et al., 2004; Seamans et al., 2007; Blackwell et al., 2013). For example, migrants including blackbirds and waterfowl often use corn fields as stopovers to forage during fall or spring migration (Krapu et al., 2004; Sawin et al., 2006), whereas breeding birds may focus on cover availability or alternative food such as insects (Blackwell et al., 2013). However; crop heights > 45 cm only occurred in corn fields.

Corn is often considered attractive to many bird species hazardous to aircraft, especially when waste grain is available (Best et al., 1990; Best, 2001; Krapu et al., 2004). But, greater cumulative hazard scores were more frequent in growing fields despite crop type (crops > 25 cm height), field conditions that often have less available waste grain than standing stubble (Krapu et al., 2004). We observed similar species in corn fields as those designated as occasional or residents by Best et al. (1990) during the breeding season. Low- and medium-hazard species (e.g., killdeer, horned larks, mourning doves, red-winged blackbirds) have been observed nesting in corn and soybean fields (Best, 1986; Best et al., 1990; Jorgensen et al., 2009; VanBeek et al., 2014). Substantial nesting habitat loss in Ohio for many facultative grassland bird species over the past century may elevate the importance of alternative, lower quality nesting habitat such as row crop fields (Peterjohn, 1989). Crop height's effect on bird use may also diminish as more nesting birds seek visually-obstructive cover in alternative habitats such as corn, wheat or soybean fields, and are less selective among similar vegetation types (Brough and Bridgman, 1980; Conover and Kania, 1991). Hence, some row crops could continue to attract birds hazardous to aircraft throughout the year despite crop height.

Six of our 10 most commonly detected bird species were insectivores and contributed most to cumulative hazard ranking. European starlings ranked 40th among 66 bird species involved in wildlife strikes based on percentage of total strikes causing any level of damage; or an effect on flight; tied 47th of 77 when bird and mammal species were combined (DeVault et al., 2011). With the exception of "blackbirds" (65 g), only larger-bodied birds and mammals ranked higher (European starlings = 82 g; DeVault et al., 2011). However, European starlings and blackbirds have contributed to at least 4940 strikes (1990–2014), with damage reported in 206 strikes, negative effects on flight for 262 strikes, with 33% of strikes involving multiple birds, and with costs totaling $8,533,151 (Dolbeer et al., 2015).

Nearly a quarter of all bird strikes ($\bar{x} = 24.6\%$, $\sigma = 18.9\%$) evaluated by DeVault et al. (2011) involved multiple birds (36.1% of strikes with birds ≤82 g and 19.6% of strikes with birds > 82 g), and the greatest aerial catastrophe (e.g.; 62 human fatalities) also involved a flock of 200 European starlings in 1960 (Dolbeer, 2013). Smaller birds ($\leq$82 g) account for ~2000 fewer bird strikes than larger birds ($>$82 g); but aircraft often encounter multiple smaller birds ($\bar{x}$ = 36.1%, σ = 20.5% vs. $\bar{x}$ = 19.6%, σ = 15.7%; DeVault et al., 2011). Therefore, smaller flocking birds could pose greater future wildlife strike risk (e.g., frequency of strikes, damage, costly downtown of damaged aircraft) despite only 9% of all bird strikes typically causing damage (Dolbeer et al., 2015). Row crops around air operations areas, especially corn or wheat crops, could increase this strike risk.

For example, flocking behavior contributes less to hazard scores than body mass (DeVault et al., 2011), but small-bodied ($<$1 kg), flocking birds could pose greater wildlife strike risk as populations increase and concentrate within urban areas such as airport landscapes (Linz et al., 2007). European starlings, red-winged blackbirds, killdeer, and common grackles were the most frequent species observed during visits with greater than 100 cumulative hazard rate. We observed average flock sizes for European starlings, blackbirds, and grackles of 82, 47, and 16, respectively, with 2 killdeer ever observed together. Red-winged blackbird flocks can shift from small groups of breeding birds in summer to million plus winter communal roosts with other species (Yasukawa and Searcy, 1995). Communal roosts of starlings and common grackles peak from June to November, often exceeding 2000 birds (Caccamise et al., 1983). From these communal centers, starlings have been observed dispersing up to 50 miles to foraging areas such as row crop fields (Hamilton Iii and Gilbert, 1969) and even establish diurnal activity centers (Morrison and Caccamise, 1990). As urban dwellers, European starlings, red-winged blackbirds and common grackles will likely continue to thrive on airports and in surrounding urban settings occupying air and ground space in and around air operations (Linz et al., 2007). Agricultural crops could exacerbate the likelihood of their presence and consequent damage potential by increasing the attractiveness of airport areas as diurnal activity centers during late summer and early fall (Dolbeer, 1990; Morrison and Caccamise, 1990). The largest flocks observed in this study occurred in corn and wheat fields and were mostly small-bodied species (e.g., European starlings, common grackles, and red-winged blackbirds). Average group size (e.g., birds observed in groups, not separate individuals) was also 4–6 times greater in corn and wheat fields, respectively, than soybean fields. Therefore, despite greater cumulative hazard scores in soybean fields than corn fields, presence of larger flocks in corn and wheat fields is of greater concern for aircraft safety than non-flocking nesting birds in soybean fields.

5. Conclusions

Though larger-bodied animals often rank as greater threats to aircraft, smaller flocking birds can be equally hazardous (Dolbeer, 2013). Smaller birds typically cause less damage or chance of damage, but increasing population densities around and within air operation areas could substantially increase the frequency of strikes with smaller birds. Airports within the northern, Midwest region seeking alternative revenue sources for outlying property should be wary of row crops, especially corn and wheat, considering surrounding landscapes will continue to have an effect on local bird use and flocking behavior (e.g., communal roosting sites, crop types in surrounding agricultural fields, e.g., Fischl and Caccamise, 1985). However, more research is needed throughout the region among different species contexts and landscape matrices. Concomitant observations of row crops, airport grasslands and alternative land coverages (e.g., native warm season grasses, biofuel crops) could help inform airports of optimal land management approaches to mitigate wildlife strikes (Martin et al., 2011, 2013).

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