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Research Paper

Civil airports from a landscape perspective: A multi-scale approach with implications for reducing bird strikes

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ABSTRACT

Collisions between birds and aircraft are a global problem that jeopardizes human safety and causes economic losses. Although landscape features have been suggested as one of a number of factors contributing to bird strikes, no evidence exists to support this suggestion. We investigated the effects of landscape structure on the adverse effect (AE) bird strike rate at 98 civil airports in the United States. The number of reported AE bird strikes was standardized by air carrier movements between 2009 and 2015. Land use structure and composition were quantified within 3, 8, and 13 km radii extents from airports. We predicted large amounts and close arrangements of aquatic habitat, open space, and high landscape diversity would positively influence the AE strike rate based on the habitat requirements of many species hazardous to aviation. The rate of AE bird strikes was positively influenced by large areas and close proximity of wetlands, water, and cultivated crops at the 8- and 13-km extents. Within 3 km of an airport, increasing landscape diversity and the amount of crop area increased the strike rate. We conclude that landscape structure and composition are predictors of the AE bird strike rate at multiple spatial scales. Our results can be used to promote collaborative management among wildlife professionals, airport planners, and landowners near airports to create an environment with a lower probability of an AE bird strike. Specific priorities are to minimize the area of crops, especially corn, and increase the distances between patches of open water.

1. Introduction

By the early 1900s, the majority of the Earth's land surface had been converted from its original state to a human modified landscape (Ellis, Klein Goldewijk, Siebert, Lightman, & Ramankutty, 2010; Sanderson et al., 2002). Human population growth fueled this landscape conversion by increasing agricultural areas and urban developments beyond the industrial revolution (Goldewijk, 2001). These land use conversions alter wildlife communities along an urban-rural gradient, and benefit generalist and invasive species in the form of increased edge habitat, abundance of human-provided resources, and landscape heterogeneity (Hansen et al., 2005; McKinney, 2002; Melbourne et al., 2007).

Ubiquitous within current human-developed landscapes are airports, which require large amounts of space; upwards of 3306 km^2 of grassland are estimated to be contained at 2915 airports in the USA (DeVault et al., 2012). Airports are generally located on the fringes of the urban-rural interfaces (DeVault et al., 2012). These locations are close enough to city centers to fulfill their transportation needs, and yet far enough away from the backyards of city residences, thus creating a buffer from this locally unwanted land use (Wexler, 1996). Airports contain large amounts of impervious surface (harboring earth worms, an important avian food source), storm water drainage ponds that are used by a variety of waterfowl, and agricultural crop areas that are maintained for extra revenue, but all are major wildlife attractants (Blackwell, Schafer, Helon, & Linnell, 2008; DeVault, Kubel, Rhodes, & Dolbeer, 2009; Seamans, Blackwell, Bernhardt, & Potter, 2015). Furthermore, the landscape surrounding the airport will be managed differently in terms of vegetation height and deterrents for wildlife, thereby enhancing the attractiveness of the airport to wildlife (Martin et al., 2011). Given these landscape properties, airports may attract wildlife which can result in wildlife-aircraft collisions (Blackwell, DeVault, Fernández-Juricic, & Dolbeer, 2009; Blackwell, Felstul, &

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Seamans, 2013; DeVault, Begier, et al., 2013). Collisions between wildlife and aircraft, hereafter referred to as strikes, have had dire consequences including 258 human lives lost since 1988 and substantial aircraft damage (Dolbeer, Wright, Weller, Anderson, & Begier, 2015). In 2015 alone, 13,797 wildlife strikes were reported to the United States of America's Federal Aviation Administration (FAA) National Wildlife Strike Database (FAA, 2016). Over $229 million USD of direct and indirect losses from bird strikes were estimated in 2015 in the U.S. (Dolbeer et al., 2015).

Manipulations of known wildlife attractants paired with wildlife dispersal, repellents, and population management may effectively reduce damaging bird strikes occurring within the airport boundaries (DeVault, Blackwell, & Belant, 2013). However, the effectiveness of these techniques are limited to areas close to the ground and are not suitable once the aircraft is beyond the airport boundary and airborne because of the lack of airport control beyond its fence line. In recent years, the number of damaging strikes that occur outside airport boundaries (> 152 m above ground level [AGL] and > 1.5 miles from runways) has increased (Dolbeer, 2011; Dolbeer, Wright, Weller, & Begier, 2014). In 2012, more damaging bird strikes were reported away from, rather than in, the airport environment for the first time (Dolbeer et al., 2014). One infamous example is the forced landing of Flight 1549 in the Hudson River, New York, USA in 2009. The aircraft departed from LaGuardia Airport (KLGA) and collided with a flock of Canada geese (*Branta canadensis*) at approximately 884 m AGL, 8 km from the airport (Marra et al., 2009). An analysis of the species composition of birds involved in off-airport strikes found that waterbirds (cormorants, ducks, geese, and gulls) and raptors (including vultures) were most likely to cause damage when struck and were commonly involved in bird-aircraft collisions (DeVault, Blackwell, Seamans, & Belant, 2016).

Bird strike mitigation methods for off-airport strikes include predictive 3-D probability models (Rutledge, Moorman, Washburn, & Deperno, 2015; Walter et al., 2012), avian radar (Gauthreaux & Schmidt, 2013; Gerringer, Lima, & DeVault, 2016), and adjustments to aircraft lighting systems that can alert birds sooner to approaching aircraft (Blackwell et al., 2012; Dolbeer & Barnes, 2017; Doppler, Blackwell, DeVault, & Fernández-Juricic, 2015). Additional recommendations include minimum separation distances between the airport and specific wildlife attractants based on reviews of strike databases (DeVault, Blackwell, et al., 2013; Dolbeer, 2006). The International Civil Aviation Organization (ICAO) recommends a minimum separation distance of 13 km (Dolbeer, 2006; International Civil Aviation Organization, 2002), whereas the U.S. FAA recommends a minimum separation distance of 3 km for airports servicing turbine-powered aircraft (FAA Advisory Circular 150/5200-33B, FAA, 2007). The FAA further recommends against land uses within 8 km of airports if they have the potential to attract hazardous birds (e.g. Canada goose) into the approach and departure corridors of aircraft (FAA & Hazardous wildlife attractants on or near airports, 2007). Furthermore, the FAA advises airports that attractants even beyond 8 km from the airport should be managed if they draw birds into approach and departure corridors.

Although several studies have investigated the influence of specific habitat attractants on bird use in the context of bird strikes (e.g., Iglay et al., 2017; Schmidt, Washburn, Devault, Seamans, & Schmidt, 2013; Washburn, 2012), only one study has investigated the influence of the comprehensive landscape on bird use (Coccon et al., 2015). The latter study found that agricultural fields, wetlands, and urban areas contributed most to bird use near the airport; however, the study included only two airports and failed to replicate the results at the second airport (Coccon et al., 2015). A landscape analysis must include more than just area, because it is reflecting just one of the landscape processes at work (Marzluff, 2001; McKinney, 2002).

Along the rural-urban gradient, land use varies which creates edge habitat and habitat isolation (Hansen et al., 2005; McKinney, 2002). As distances between preferred land uses increase, habitat specialists relocate and habitat generalists begin to dominate and increase the chances of finding these species in this habitat (Marzluff et al., 2001). Many species commonly struck by aircraft prefer turf grass over mature grassland and could be considered habitat generalists (Blackwell, Seamens, et al., 2013; McKinney, 2002). Therefore, to understand the role of the landscape matrix on the strike rate, landscape processes associated with fragmentation and arrangement of land uses must be investigated.

Our objective was to determine if landscape features, especially those associated with species generalists, on and off airport property, have an effect on the adverse effect (AE) strike rate (i.e. damaging and negative effect-on-flight strikes). More specifically, we used a multi-scale (3, 8, and 13 km inclusive buffers) approach to investigate the synergistic effects created by different land uses on the bird strike rate with aircraft at multiple airports with similar air carrier movements. We predicted that: 1) the AE strike rate would be influenced by land use composition and structure quantified for the airport property and beyond because of the surrounding landscape matrix and land use characteristics of fragmentation that are favored by the generalist species commonly involved in bird strikes (Blackwell, Seamens, et al., 2013; DeVault et al., 2016); 2) the influence of landscape variables on the AE strike rate would differ at the three spatial scales because of different bird and aircraft movements and land use variability; 3) as distance between wildlife attractant patches increases, the amount of time the animal resides in the patch, and thus the AE strike rate, would decrease (Brown, 1988); 4) as edge habitat of wildlife attractant patches increases, so would the abundance of generalist species that are involved in AE strikes (Whitcomb et al., 1981); and 5) overall landscape diversity would lead to increases in the AE strike rate because of an increase in suitable habitats for avian generalists (Huston, 1994; Whitcomb et al., 1981).

2. Methods

2.1. Study area

As of February 2017, there were 474 Part 139 certificated airports located within the conterminous U.S. (FAA, 2017a). Part 139 certificated airports serve air carrier aircraft with more than 30 seats, agree to maintain certain operational/safety standards, and create a Wildlife Hazard Management Plan (FAA, 2015). A Part 139 airport usually includes a fence around the property for security and the FAA has certain restrictions over agricultural production around the airport (FAA & Hazardous wildlife attractants on or near airports, 2007). John F. Kennedy International Airport in New York City, USA, is an example of a Part 139 airport. The number of itinerant air carrier movements per airport per annum was tallied using the FAA terminal area forecast (TAF) from 2009 to 2015 (FAA, 2017b). For this study, only Part 139 air carrier movements and strikes were considered. A total of 102 Part 139 airports had more than 10,000 mean air carrier movements per annum from 2009 to 2015. Two airports reported no AE bird strikes; these airports were removed from the analysis for statistical purposes. We have the highest confidence in the reporting of AE strikes at Part 139 airports with a high number of air carrier movements, hence we focused on airports that satisfied this criteria (Dolbeer, 2015). Two airports were removed because of their close proximity to Mexico, as land use GIS rasters were only available for the U.S. Therefore, 98 Part 139 airports (Fig. 1) were used in the analysis.

2.2. Bird strike data

Wildlife strike data were obtained from the FAA National Wildlife Strike Database (FAA, 2016). Bird strikes reported to the FAA strike database are submitted primarily using a standard form (FAA Form 5200–7), and reviewed for quality control (Dolbeer et al., 2015). Although strike reporting is largely voluntary in the U.S., between 2009