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Permalink

https://escholarship.org/uc/item/0d0693xq

Journal

Proceedings of the Vertebrate Pest Conference, 31(31)

ISSN

0507-6773

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Publication Date

2024

Assessment of Bird Strike Likelihood to Refine Bird Strike Risk Models

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ABSTRACT: In its most basic form, bird strike risk is comprised of a frequency component that reflects the likelihood of a collision and a severity component that reflects the cost (monetary or otherwise) of the incident. The bird strike risk model currently used by United State Department of Agriculture (USDA) Wildlife Services to evaluate the risk posed by individual bird species at airports and establish priorities for management was developed in 2018. The model uses airport-specific data on the number of reported strikes for a species recorded in the Federal Aviation Administration (FAA)'s National Wildlife Strike Database as a measure of frequency and the species' relative hazard score as a measure of severity. The model was tested against independent data, found to perform well overall, and is being implemented widely across the United States. However, the model has limitations, including that species known to pose risk to aircraft locally, but not present in the strike record database, are not reflected as a major component of risk. Standard bird survey methodology commonly used at airports (e.g. point counts or transects) potentially can be used to complement wildlife strike records to calculate frequency or relative abundance of species. However, these methods generally focus on airport-wide population estimation and often ignore vital information that contributes to the true likelihood of a strike, such as use of runway protection zones and other critical areas, and spatial and temporal overlap with departing or approaching aircraft. As such, a more detailed understanding of space use by birds across landcovers and population fluctuations across the year is needed to accurately estimate the likelihood of bird strikes at airports. In this manuscript, we will review the extant risk model, including a discussion on its limitations. We then discuss approaches for refining our understanding of strike likelihood and briefly touch on needs for estimating probability of strike severity (cost).

KEY WORDS: bird strike, aircraft collision, damage by wildlife, public safety, wildlife management

Proceedings, 31st Vertebrate Pest Conference (R. M. Timm and D. M. Woods, Eds.)
Paper No. 38. Published December 21, 2024. 5 pp.

INTRODUCTION

Between 1990 and 2022, there were 276,846 wildlife collisions with civil aircraft reported to the United States Federal Aviation Administration (FAA); 97% of those collisions involved bird species, referred to as bird strikes (Dolbeer et al. 2023). In the decade from 2012 to 2022, bird strikes reported to the FAA increased from 10,896 to 17,190 (Dolbeer et al. 2019, Dolbeer et al. 2023). There also has been an increase of roughly 660% in yearly passengers flying since 1980, with more than 4.2 billion commercial airplane passengers embarking annually (World Bank 2019, IATA 2023). With the continual increase in global aircraft use, these negative interactions between wildlife and humans in airport landscapes becomes more relevant each year. Bird strikes result in substantial financial losses due to repair costs, flight delays, and operational disruptions for airlines and airports. Specific strike characteristics such as bird mass, number of birds, and phase of flight influence the extent of damage, and therefore related costs (Anderson et al. 2015). In 2022, annual loss in the United States civil aviation were estimated to be $385 million in direct or other monetary losses, in addition to 67,848 hours of aircraft downtime (Dolbeer et al. 2023). As bird strike events and associated negative effects progressively increase, there are growing concerns for human safety, monetary loss, and wildlife conservation (Allan 2002, Dolbeer and Eschenfelder 2002, Blackwell et al. 2009, Dolbeer and Wright 2009, DeVault et al. 2013).

Previous research has shown that 72% of bird strikes with civil aircraft occur during takeoff or landing at ≤152 meters above-ground-level (AGL) (Dolbeer et al. 2019). Consequently, there is a great need for management of hazardous bird species at lower altitudes within airport environments to reduce bird strikes (Cleary and Dolbeer 2005, DeVault et al. 2013). In the U.S., the FAA provides guidance for airport management strategies, such as the reduction or elimination of common attractants (food, water, cover) (Blackwell et al. 2006, FAA 2007, Blackwell et al. 2009, DeVault et al. 2013). Over the past 20 years, airport personnel have made appreciable progress in reducing damaging strikes by implementing a variety of management strategies through these guidelines related to wildlife hazards (Dolbeer 2011). However, prioritizing management efforts at airports is still a major challenge. To address the complex nature of an airport environment, it is arguably more proactive to mitigate high-likelihood bird strike events based on estimated risk of hazardous species (DeVault et al. 2018).

There have been several methods proposed in recent years to estimate strike risk at airports, with most methods failing to incorporate a true probability of strike (based on recorded strikes versus aircraft movements) and the associated probabilities of damage, let alone modeling that can inform likelihoods of both metrics (i.e., a quantification of factors contributing to variance in strikes and damage). Allan (2006), for example, developed a measure of risk using a frequency of strikes and an associated severity index. With data from the United Kingdom Civil Aviation Authority Bird Strike Database, Allan (2006) used a 5-year rolling average of the number of bird strikes at an airport as strike probability. The severity index was then determined by the percent of strikes that involved damage by those species. Shortly after this, Schafer et al. (2007) defined risk in an airport setting as the product of a damage metric associated with a bird strike and an index for frequency of use. Dolbeer and Wright (2009) introduced a promising metric to compare the rates (i.e., probabilities) of damaging strikes across different airports. This metric is created by standardizing the yearly count of damaging strikes per 100,000 aircraft movements and averaging this value over a 5-year period. This method offers a relative strike rate, but only for strikes classified as "damaging". To compare strikes where wildlife management within an airport has a direct effect versus outside of management efforts, Dolbeer and Begier (2012) applied this method of measurement to strikes occurring ≤457 and >457 meters AGL. Soldatini et al. (2010, 2011) created a risk measurement system for comparing between airports and modified the metric by introducing an airport-specific hazard component for a species-group, called the Group Factor. The Group Factor is based on the average mass, median flock size recorded at the airport, average number of strikes annually standardized by the total number of aircraft movements per year at the airport, and the highest ranking for species-group effect-on-flight for strikes during that year. Then, the authors multiplied the Group Factor by the average daily number of individuals for the species-group at the airport of interest for a specific month, resulting in a species-group risk estimate. Following a different approach, DeFusco et al. (2015) defined their strike risk metric categorically, using strike data and hazard rankings, without defining a specific strike risk metric.

While these previous risk models have advanced knowledge and discussion on the topic of risk in airport environments, there are notable issues with each case. Utilizing the previous five years of strike data, Allan's (2006) risk metric assumes a static value of risk. Dolbeer and Begier's (2012) method focuses only on comparing damage strikes across airports. Soldatini et al. (2010, 2011) relies on a single survey point without accounting for biases in species groups and abundances (Blackwell et al. 2013). The categorical approach of DeFusco et al. (2015) does not allow for estimating risk as a continuous probability. In the current bird strike risk model used by USDA Wildlife Services, DeVault et al. sought to estimate risk posed by individual bird species at airports, test their model against independent data, and establish priorities for management (DeVault et al. 2018; see below).

In addition, since the publication of DeVault et al. (2018), new efforts to understand strike risk and damage have incorporated observational and behavioral modeling to estimate strike probability and potential damage (Metz et al. 2021), as well as developing perspectives on strike likelihood via algebraic, Bayesian, and clustering approaches to likelihood models (Andrews et al. 2022). Metz et al. (2021) provide a novel perspective on bird position (spatial location) and overlap with aircraft movements, but their method is arguably too focused on weakly supported bird movements within a defined airspace, as opposed to utilizing avian survey data, landcover, and other factors to model seasonality of strike likelihood. Andrews et al. (2022) also move risk estimation forward in modeling strike likelihood, but the authors admittedly ignore the equally difficult aspect of estimating the likelihood of severity per strike.

Our purpose for this paper is two-fold. First, we review the extant risk model and discuss its limitations. We then discuss approaches for refining our understanding of strike likelihood and briefly touch on the needs for estimating probability of strike severity (cost).

EXTANT RISK MODEL

DeVault et al. (2018) used bird strike data from the FAA's National Wildlife Strike Database for years 2010-2015 to calculate the frequency and severity components of risk (i.e., risk = frequency × severity of event, with both components ideally represented as probabilities based a priori likelihood models, sampling, and fit of those models to the data). Here, the frequency component is not standardized by all aircraft movements and, thus, does not represent a species-specific probability of strike. As for severity, DeVault et al. (2018) calculated a relative hazard score (RHS) for each of the 79 species within their dataset following the approach used in Dolbeer et al. (2000) and DeVault et al. (2011). The RHS value is a composite variable of three criteria, providing an index for the severity portion of the risk equation. Airport-specific strike records for individual bird species in their dataset were then used to estimate the frequency component of the equation.

Using calculations from strike records of all 712 U.S. airports present in their dataset, DeVault et al. (2018) evaluated four strike risk models against independent, economic (cost) data from the National Wildlife Strike Database to determine the best fitting model. In their best-fitting model, risk is represented as RHS squared and multiplied by the number of strikes per species (Strikes) squared, forming a single, transformed independent variable. As consistent with the formulation of this metric and logically, given the basic composition of a risk metric, species with the highest risk scores were either especially high in one squared element of the model (RHS^2 or $Strikes^2$) or in both. These results not only provided a ranking of species-specific risk but highlighted the functionality of a risk metric to airport wildlife management. Specifically, airport biologists should consider more than RHS alone as a basis for prioritizing wildlife management.

To compare airport-specific risk estimates across regions, the authors chose the four airports with the most takeoffs and landings per year in the United States (Hartsfield-Jackson Atlanta International Airport (ATL), Chicago O'Hare International Airport (ORD), Dallas /Fort Worth International Airport (DFW), and Los Angeles

International Airport (LAX)) and generated risk estimates for each of these airports under their best fitting model. The results from this comparison showed similar outcomes across airports regarding the top-5 riskiest species, except for LAX. The second through fifth highest ranking species for LAX were not included in the top-5 highest risk species for the other airports. These species were also outside of the top 10 nationally, showing that high-risk species can be airport-specific. The authors contend that differences in risk across airports relates to local-level factors and, thus, that broad, across-airport risk assessments is not recommended.

While this bird strike risk model performed well when tested against independent data and is being implemented widely in the United States, it still has its own limitations. As noted, the frequency component does not reflect a true species-specific strike probability because it does not include total aircraft movements relative to aircraft movements involving strikes per species. RHS is also not representative of a true likelihood because it is a rank as opposed to a likelihood of degree of damage. Additionally, because the DeVault et al. (2018) model relies on bird strike records for the frequency component, any species present at an airport but poorly represented in bird strike records are not reflected as a major component of risk.

The authors chose to use strike data instead of survey data because strike data represent a more direct index of species strike probability (DeVault et al. 2018) and their original formulation was not airport specific. They do, however, note that while their risk estimates provide a foundation for prioritization of management, there is the potential for risk calculations to be supplemented with bias-corrected bird surveys for seasonal relative abundance and quantification of species at airports, particularly at airports with insufficient strike data because of the lack of a wildlife hazard management plan (Blackwell et al. 2013, Andersson et al. 2017). However, more research is needed to accurately quantify avian species present seasonally at an airport, their behavior as related to aircraft movements, contributions to strike likelihood and, ultimately, to risk. Current methods generally focus on airport-wide population estimation, often ignoring vital information that contributes to the true likelihood of a strike, such as the use of runway protection zones and other critical areas, and spatial and temporal overlap with departing or approaching aircraft.

SUBSEQUENT MODELING EFFORTS

Refining our understanding of strike likelihood and overall risk estimation is an ongoing effort, with various approaches explored since the publication of DeVault et al. (2018). These efforts have improved upon some of the limitations in earlier strike risk models by utilizing observational data, behavioral data, and more advanced statistical and technological methods (Andrews et al. 2022, Metz et al. 2021, Nilsson et al. 2021).

Metz et al. (2021) investigated operational bird strike prevention, expanding upon their previously developed algorithm for a bird strike advisory system by excluding the assumption of perfect bird movement predictability. Similar in concept to the Airborne Collision Avoidance System (ACAS) mandated in civil aviation, the algorithm uses protected volumes, a defined three-dimensional area, around an aircraft. If an intrusion by a bird trajectory within the protected volume is detected by the algorithm, a potential collision is predicted. In ACAS, communication between aircraft is necessary, while in this case an on-the-ground sensor, such as an avian radar system, is needed to locate birds. This algorithm is designed to focus only on birds predicted to cross over the extended center line of the runway and cause damage to the aircraft, producing an alert from the bird advisory system. While this novel approach incorporates the overlap of bird trajectory with aircraft movement to calculate bird strike risk and severity of a collision, it is lacking in its ability to incorporate realistic bird movements, which could be improved with the inclusion of more precise bird-movement data.

Importantly, current efforts to assess bird strike risk are often static risk ranking approaches, ignoring variables like season or environmental factors. Andrews et al. (2022) investigated three data-driven modelling techniques to create a more dynamic method of modelling bird strike collisions based at an airport in Brisbane, Australia. The authors explored algebraic (function approximation), Bayesian (probabilistic), and clustering (unsupervised machine learning) models to assess bird strike likelihood and evaluated models with environment and hazard species data. The authors note that the models can be used independently but are complementary and intended to be used in parallel to provide an anticipation of risk state and potentially guide airport management actions. However, as risk integrates both likelihood and severity of a collision, they also highlight that the scope of their research is focused solely on the factor of likelihood, excluding severity. Additionally, though promising, realistic use of this approach in practice at airports would necessitate routine airport specific data collection and more progress on the technological side to create a usable tool for airports.

Focusing on annual periods of high risk, Nilsson et al. (2021) incorporated publicly available radar data and community science collected bird monitoring data from eBird to map bird movements and species compositions during seasonal migration to estimate likelihood and severity of strikes. Using FAA bird strike data from three major airports in New York state, they compared historical bird strike data with their model results to show that weather radar-based estimates of migration intensity can accurately predict the probability of a bird strike. Their study revealed that 80% of the variation in annual bird strikes can be explained by the migratory movements captured on weather radar. Additionally, eBird estimates of species occurrence, coupled with species' mass and flocking propensity, was an important predictor of damaging strikes. Their results highlight the importance of seasonally changing species compositions in understanding strike risk. However, due to the data types, their study is limited to nocturnal, large movement events, and not as applicable for day-to-day risk assessment at airports.

Even with recent advances in bird strike risk modeling, it is essential to continue to build upon our understanding of bird behavior within airports and the likelihood of strikes to estimate risk. The goal of our current research is to expand on DeVault et al.'s (2018) previous methods for modeling bird strike risk and address previous caveats through the collection of detailed bird movement data, avian point count data, and landcover data at two Georgia airports, the Savannah/Hilton Head International Airport and Augusta Regional Airport.

To begin addressing the information gap on bird movement and space use of birds in airports, we are collecting fine-scale latitude, longitude, and altitude data from seven target species by way of Global Positioning Satellite (GPS) transmitters: turkey vulture (*Cathartes aura*), black vulture (*Coragyps atratus*), red-tailed hawk (*Buteo jamaicensis*), northern harrier (*Circus hudsonius*), Mississippi kite (*Ictinia mississippiensis*), American kestrel (*Falco sparverius*), and great egret (*Ardea alba*). Bias-corrected avian point count surveys are being conducted year-round at both study airports to supplement the GPS data and account for airport species presence and abundance, throughout all seasons. Environmental variables are also being collected at survey locations, such as landcover type, temperature, precipitation, wind speed, atmospheric pressure, and grass height and density.

Once our data collection is complete, we can begin the model-development process, combining species abundance data, bird airspace use, flight behavior, and land cover use for a bird occupancy model. Aircraft movements and strike data can then be integrated into the model to make predictions on overlapping presence of bird and aircraft in space and time (*sensu* Metz et al. 2021, Andrews et al. 2022). The resultant model will represent our estimate of species-specific strike likelihood (SSL).

The SSL can then be used in several ways to further our analyses. First, the SSL can be combined with revised RHS to estimate species-specific risk. These models can then be validated against relevant economic models (Altringer et al. 2021) and strike data at the study airports. The SSL for commonly struck species at our study airports can then be compared with historical strike records from the FAA's National Wildlife Strike Database to determine whether the frequency of strikes is a reliable proxy for strike likelihood.

Following model development, there will be the opportunity for airports to utilize the resultant information and more effectively prioritize management strategies for airport wildlife. Ultimately, allowing for improved human safety, reduced economic losses, and reduced loss of wildlife by more accurately quantifying risk and informing effective management decisions.

ACKNOWLEDGEMENTS

We would like to thank the University of Georgia, United States Department of Agriculture (USDA), Animal and Plant Health Inspection Service, Wildlife Services (WS), National Wildlife Research Center (NWRC), Federal Aviation Administration (FAA), WS operational program, Savannah /Hilton Head International Airport, Augusta Regional Airport, and Phinizy Swamp Nature Park. This material is based upon work supported by the Department of Energy Office of Environmental Management under Award Number DE-EM0005228 and funding to the University of Georgia Research Foundation through Agreement AP23WSNWRC00C103, Awarded / 23-7439-1649-CA, with the NWRC, and under an Interagency Agreement between WS and the Federal Aviation Administration, Contract Number 692M15-19-T-00017. Statements herein do not necessarily reflect the views or policies of the USDA or FAA.

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