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Role of near-miss bird strikes in assessing hazards

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Abstract: Management of problem wildlife within the airfield environment is a difficult job. Today's Bird–Animal Aircraft Strike Hazard (BASH) program managers require as much information as possible to accomplish their tasks. Bird censuses and actual bird-strike events in and around the air operations area are used to make airfield management decisions and to assess the risk of bird hazards to aircraft. Both types of information are sampled rather sparsely. Avian radar is now being used as a new tool to provide continuous sampling of bird activity that significantly supplements visual censuses. The measure of risk used today is commonly expressed as the ratio of the number of bird strikes per 100,000 flying hours. While important, this measure of risk is relatively insensitive to improvements in safety measures that do not result in dramatically fewer bird strikes. Stated differently, a reduction in safety or an increase in risk (which reflects an increased likelihood of bird strikes occurring) is not anticipated, but, rather, it is calculated after the fact when increases in bird strikes have been experienced. As a result, BASH managers are at a disadvantage because they can respond only after bird strikes occur. To address this deficiency, we introduce a new method for assessing risk that is based on near-miss events that complements risk calculations based on reported bird strikes. Recent advances in commercially available, digital avian tracking radars enabled biologists to automatically monitor and assess near-miss events. Near-miss events occur much more frequently than bird strikes. A combined dataset of bird strikes and near-misses provides BASH managers with a more responsive metric to evaluate the success of their program over time than by using only the bird-strike dataset.

Key words: avian, aircraft, aviation safety, BASH, bird strike, radar, hazard airfield management, human–wildlife conflicts, near-miss

Birds pose a threat to aviation safety and cost air carriers and insurance companies approximately $2 billion each year (Dolbeer and Wright 2008). More than 60% of these collisions occur within the confines of airfields (Dolbeer and Wright 2008), where airfield managers can reduce the chances of a strike by making the air operations area habitat unattractive to birds (Bernhards et al. 2009, Linnell et al. 2009) and by harassing or removing individual birds that remain despite airfield manipulations (Ball 2009). On a given airfield, bird strikes are infrequent, irregular, and underreported (Linnell et al. 1999). Visual monitoring techniques (e.g., bird censuses) currently are used to provide information on the community of birds present on the airfield and how those communities change over time. Visual monitoring, however, provides limited information on bird-strike threats. Given that bird strikes continue to be grossly underreported and that relationships between bird censuses and management actions have not been robustly examined, the ability of airfield wildlife managers to receive timely feedback on the status of management actions designed to reduce bird hazards is limited (Dale 2009, Dolbeer and Wright 2009).

A technique or metric is needed that is more sensitive to changes in safety or threat-level to aircraft than actual bird-strike events but that also is still biologically and statistically related to the frequency of bird-strikes. In this paper we propose a new metric, the Near-Miss Event (NME) index, that can serve the function of detecting changes in the probability of a bird-strike before a change in bird-strike frequency occurs. Near-miss is a term developed by NASA's Aviation Safety Reporting System to indicate 2 aircraft passing within 150 m of one another (FAA 2008*a*). In this paper, it refers to near collisions of aircraft and wildlife. We have limited the distance between aircraft and wildlife to 50 m.

As a part of the Integration and Validation of Networked Avian Radars Project (Klope and Brand 2007) under the U. S. Department of the Defense, tens of thousands of hours of avian radar data have been recorded at various airfields. These included tracking of aircraft that regularly were present within the same avian radar data. The avian radar software used in this research is capable of providing true, real-time, 3D target coordinates (latitude, longitude, altitude) for every target tracked. As birds and other flying objects (e.g., blowing seeds, insects, and large pollen) cross a given space, the radar software will represent these targets with small, individual symbols, called plots. As the radar software continues to plot these targets in succession, the software will assign a track designation to the series of plots, and the track will be represented by a different symbol (Figure 1). This new track can be designated with a unique track identification number.

During initial review and analysis of these tracks, we discovered that the radar software we use is capable of tracking and reporting near-miss events between birds and aircraft. This discovery motivated us to begin a study to characterize near-miss events and their potential for management by the Bird–Animal Aircraft Strike Hazard (BASH) program. The goal of the BASH program, which was initiated by many groups in the 1980s, is to manage wildlife and habitats on airfields to reduce the risk of wildlife strikes with aircraft.

We introduce the NME Index along with an automated process to identify near-miss events and calculate the NME Index. This process provides 3 advantages. First, it exploits the radar tracking software, which can be configured to automatically identify and extract NMEs for later tabulation and analysis, rather than requiring a trained observer to review all of the recorded track information. Second, because of the increase (or gain) in sensitivity to changes in hazardous bird conditions, the NME Index might be more responsive to changes in management practices. Third, the new index makes use of commonly available flight operations data for normalization purposes. As a result, this metric can provide a suitable tool for airfield managers to quantify the results of management actions on the airfield.

Methods

Advanced digital avian radars can detect and track birds and aircraft automatically, then save those data to a database for later analyses. Radar visualization and analytics software allow us to automate analytical processes (such as a new method to identify near-miss events), tabulate the event information, and derive a risk indicator from this near-miss information. Risk varies in both time and space; thus, we need a near-miss statistic that does the same. This statistic must be normalized to allow site-to-site comparisons. The most obvious normalization would be to divide the number of NMEs by the number of aircraft movements. When computed in this way, the spatial-temporal patterns of avian movements can be analyzed and appropriate management regimens employed.

Defining a near-miss event

The probability of a bird–aircraft collision is influenced by many factors, including evasive maneuverings by the bird and the pilot, airflow over the surface of the aircraft that may deflect the bird away, and the location of the bird from the centerline of the aircraft. A slight difference in the bird's location can transform a bird strike into a near-miss event or vice versa. The near-miss volume of an aircraft is defined as a zone surrounding an aircraft where objects entering that zone pose a significant risk of collision and can serve as an indicator of strike potential. This volume varies with aircraft speed; there is no volume behind the aircraft (assuming aircraft travel faster than birds), smaller volume to the sides, and the largest volume in front. To aid in analysis, we can simplify the near-miss volume to a sphere of radius R centered at an aircraft's center of radar reflectivity. The radius should be small enough that (1) pilots and managers would be concerned if there were a significant increase in birds in this near-miss volume and (2) a positive correlation with actual bird strikes will result. For the purposes of this paper, we set $R = 50$ m; a NME occurs whenever a bird and an aircraft pass within 50 m of one another. Currently, near midair collisions between

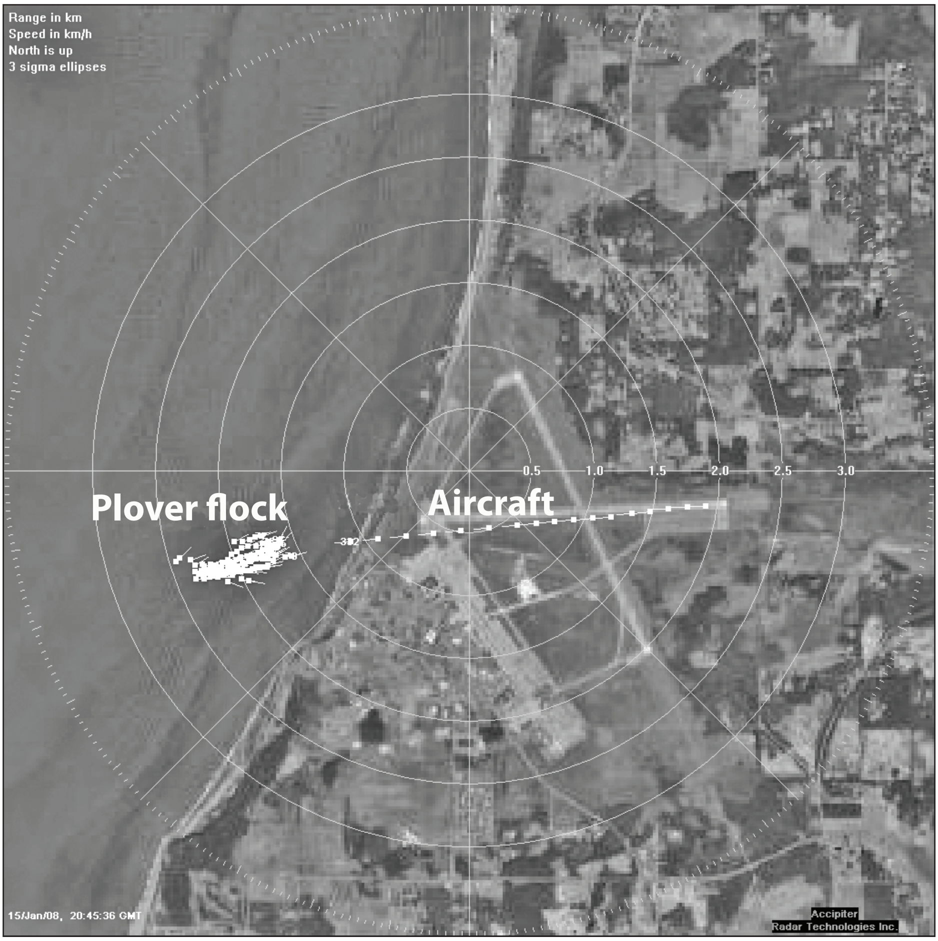

Figure 1. Near-miss event at U.S. Naval Air Station, Whidbey Island, Washington, on January 15, 2008. A Navy EA-6B Prowler aircraft conducting an exercise on Runway 25 approaches a large flock of black-bellied plovers.

aircraft, as defined by the National Aeronautics and Space Administration (NASA), are categorized as events where aircraft are <150 m from each other (FAA 2008*a*).

Data collection

This paper introduces the NME index methodology and presents some individual, illustrative examples of near misses.

Data recording. Data were obtained from radar detections and tracks recorded at the U.S. Naval Air Station, Whidbey Island, Washington (hereafter called NAS Whidbey Island), and U.S. Marine Corps Air Station, Cherry Point, North Carolina (hereafter called MCAS Cherry Point), from August 2007 to August 2008 (about 15,000 hours). Data were obtained using avian radars consisting of commercial, off-the-shelf X-band marine radar transceivers, each coupled with a dedicated Accipiter® Digital Radar Processor. The NAS Whidbey Island system employed a Furuno FR8252 radar with a 6-foot, horizontal array antenna (Figure 2), while the MCAS Cherry Point system, known as the eBirdRad configuration (Nohara et al. 2005), used a Furuno 2155BB radar with a 4° dish antenna. The returns from the Furuno radars were digitized and processed in real-time by the digital processors, with resulting detections and tracks stored locally in a database on the digital radar processor's hard drive. Details on the digital radar processor software and algorithms were provided by Weber et al. (2004) and Nohara et al. (2005).

NME extraction. Because our near-miss volume radius ($R = 50$ m) was much less than the distance an aircraft may travel between consecutive antenna revolutions (2.5 seconds), searching for those instances where a bird radar track and aircraft radar track passed within 50 m of each other would result in many NMEs being overlooked, unless the tracks were predicted to a finer temporal sampling interval than the scan time. To avoid the need to predict tracks to a finer sampling interval, we made our NME extraction procedure a 2-step process. First, using the automatic extraction capabilities of the radar software, we extracted all instances of when an aircraft and birds passed within, for example, 250 m of one another (2.5 s x 100 m/s [aircraft's speed]). We then organized these instances, along with their associated tracks and metadata, into a database for subsequent examination and filtering. Only those instances that indicated a bird or flock of birds and an aircraft passed within 50 m of one another were reported as NMEs. Each NME had a date, time-stamp, location (taken as the aircraft location at the time of the NME), aircraft track, and bird track. Location was recorded as latitude-longitude, as well as range-azimuth (in the radar scan-plane). Altitude estimates were also noted but came with associated height uncertainty as described below.

Figure 2. The radar unit installed at U.S. Naval Air Station at Whidbey Island, Washington, and used in this study.

With today's avian radar, calculating the distance between birds and aircraft (a measurement needed to identify a NME) takes some care. The vertical beam pattern of the radar antenna limited the height accuracy associated with each; it also was the driving factor in the accuracy of the distance calculation. Consider, for example, the 4° circular cross-section beam of the dish antenna used to track birds and aircraft at MCAS Cherry Point. The height uncertainty of targets tracked within this beam was about 7 m at 100 m range, 70 m at 1000 m range, and approximately 100 m at 1,500 m range. If one assumes that birds and aircraft can occupy any height within the beam with equal likelihood, then on average, only half of the NMEs occurring at 1,500 m will be for birds and aircraft within 50 m vertical separation from each other (i.e., the uncertainty). Therefore, if we confine the range over which NMEs were tabulated to be within approximately 1,500 m from the radar, we can restrict the NME bird–aircraft separation calculation to ground distances (latitude, longitude) or radar scan plane distances. As both types of location data were available in the digital radar processor-generated target tracks, calculating the separation between bird and aircraft was straightforward geometry. By placing a radar near the center of the airfield or, if >1 radar is available, at appropriate locations around the air operations area, the area over which NMEs can be reliably calculated can easily include the entire air operations areas. Future antennas with improved beam characteristics are expected to reduce the height uncertainty and will allow us to expand the region over which reliable NMEs can be calculated.

Near-miss statistics

Because each NME is associated with its location, date, and time, temporal and spatial statistics can be generated and patterns can be scrutinized. Normalizing the number of NMEs by the number of aircraft movements (i.e., take-offs and landings, or sorties) will allow creation of a NME index (NME index = number of NMEs/100,000 aircraft movements) that can be used to compare times, locations, and even airfields. These indices can be viewed at annual, seasonal, monthly, daily, and hourly scales. A baseline NME index can be generated for comparison of the efficacy of future airfield modifications. By the same token, the spatial distribution of the NME index can be depicted as an overlay on the airfield (i.e., a GIS layer). This graphical representation of the NME Index on the airfield can help identify areas with high bird-strike risks.

Automation

The identification and tabulation of NMEs and the computation of the NME index over arbitrary spatial and temporal scales can be completely automated using open, industry-standard database and networking technologies. The first step is the real-time organization of the radar tracks into a high-transaction-rate, industry-standard database or radar data server, where third-party applications can simultaneously query the server in real-time over networks using open interfaces, such as standard-query-language calls. Some existing avian radars already support this capability (Weber at al. 2005). On a regular time interval (e.g., every 15 minutes), automated scripts can search the most recent tracks for NMEs using the methods described above, and calculate cumulative NME indices. These indices follow NMEs in time, much like stock indices follow stock trading transactions. For normalized indices, access to aircraft movement databases is required during these calculations. Next, these cumulative NME indices can automatically update an NME database with its own Web service. The NME database can be hosted locally to an airport or centrally to provide a national picture. Web pages can then be hosted by a Web server and can interact with the NME web service software on the Web server to automatically provide up-to-date advisory information to end-users.

Results

The methods described in this paper and the potential benefits of using NMEs as the basis for a new and complementary risk indictor to actual bird strikes are illustrated with 2 avian radar examples. The first example is illustrated in Figure 1 and depicts a near-miss event that occurred during air operations at NAS Whidbey Island in January 2008. A Navy EA-6B Prowler aircraft was flying west through the air operations area at approximately 330 km/h as a large flock of black-bellied plovers (*Pluvialis squatarola*) approached from the adjacent Puget Sound flying to the east at approximately 80 km/h. Field personnel observed and later reviewed this NME, which avian radar system recorded. The plovers were tracked from several kilometers offshore by the avian radar, while pilots conducted their flight training unaware of the birds' presence. Figure 1 is a screen shot of the radar's display as the plovers approached the airport operations area a few seconds before the aircraft and the birds would occupy the same airspace. This was a particularly dangerous situation because of the large numbers of birds and wide frontal span (>1-km wide) of the flock. NAS Whidbey Island BASH and USDA personnel estimated the flock of plovers to be at least 1,000 birds. The plovers continued to fly directly down Runway 25, causing 3 subsequent near-misses with 2 additional aircraft in the touch-and-go pattern (i.e., a pilot's practicing repeated landings and take-offs over a short period of time). Touch-and-go is dangerous since there could be 3 or 4 aircraft in the airport flying pattern (close together), making birds a real threat. The NME illustrated in Figure 1 occurred approximately 1,500 m from the radar. The radar that captured this event has an array antenna whose vertical beam projects from the ground to 10° above the horizontal (Figure 2). The median height-separation (125 m in this example) can be calculated as half of the sum of the minimum and maximum separation values. The minimum distance would be 0, when the birds and aircraft occupy the same space (i.e., a collision) and the maximum distance would occur when the birds and aircraft are at the extremes (ground and maximum altitude of the 10° antenna beam at that range [1,500 m]). The maximum altitude (250 m) is calculated as (sin 10° × 1,500 m) following the geometric discussion above.

The second example occurred at MCAS Cherry Point, North Carolina, in November 2007 (Figure 3). Unlike the first example, this instance was found without prior knowledge of the event by playing back recorded track data and monitoring the screen. Figure 3 clearly shows a well-developed track of a flock of birds heading approximately SSW at a speed of approximately 90 km/h while an aircraft approaches from the SE at a speed of approximately 235 km/h. In this instance, the aircraft crossed the trajectory of the birds. The 4° dish antenna was used, and the crossing occurred a little more than 4.5 km from the radar. At this range, the median height-

Figure 3. Possible near-miss event at U.S. Marine Corps Air Station, Cherry Point, North Carolina, in autumn 2007. A U.S. Marine Corps aircraft on approach to Runway 32L crosses path of unidentified flock of birds heading SSW.

separation uncertainty between the flock and the aircraft is approximately 150 m.

Discussion

The NME index is a new metric that allows augmentation of bird-strike statistics. The index can be used by wildlife biologists and airfield managers to evaluate the efficacy of their airfield modifications to reduce the presence of hazardous birds in and adjacent to the flights paths of aircraft on and near the airfield. The true measure of the effectiveness of management efforts is a reduction in bird-strike frequency. However, bird strikes occur at the rate of approximately 10 per 100,000 aircraft movements (Dolbeer and Wright 2008, FAA 2008*b*) and, therefore, are of limited sensitivity for evaluating small changes in risk. Airfield managers need a metric that is more sensitive to bird strike potential and related to the actual bird strikes without having to rely only on the bird-strike rate itself. Logically, near-misses should be related to bird strikes because bird strikes represent a subset of the birds within the protection zone (near-miss + strike) of the aircraft. This assumption remains to be validated and is the next, obvious step in our work.

Both of the NME examples that we report illustrate the ability of state-of-the-art avian radars to track NMEs within and beyond the air operations area. These examples also show the advantage of using a narrower vertical-beam dish antenna as compared to a broader vertical-beam array antenna to extend the range over which NMEs can be detected. Both examples are near the range limits where we expect NME tabulation to be meaningful (i.e., where a correlation with actual bird strikes can be expected). Our 2-step, NME extraction method ensures that the 2 examples would be identified and extracted on the first pass through our data and reported as NMEs upon subsequent review. This approach will provide us with the means of varying the maximum range over which we choose to tabulate NMEs and, thus, investigate the relationship with actual bird strikes.

Risk indicator

Many characteristics of birds make them a hazardous threat to aviation. These include physical characteristics, such as avian mass and behavior (Dolbeer et al. 2000). The total mass of the bird(s) striking an aircraft constitutes a measure of the extent of the hazard. As a remote sensor, radar is well-suited to detect and monitor the biomass within a resolution cell. Greater mass, whether from a single large bird or a flock of small birds, generally has a larger reflectivity, or radar cross-section, and produces a stronger reflected signal. Advanced digital radar processors retain this information in the track structures, making radar cross section estimation possible. Furthermore, the tracks also contain the bird and aircraft dynamics information, allowing collision forces to be computed in theory. This information will allow biologists to evaluate the severity of the hazard that a near-miss event presents, in a manner analogous to categorizing the severity of bird strikes.

The NME index needs to be validated by determining how well it relates with bird-strikes through out the year. The correlation must be statistically significant not only on an annual basis, but also on seasonal and monthly scales. Looking forward, the automatic tabulation and analysis of NMEs will allow for timely advisories to aircraft controllers and members of the BASH team of changes in short-term NME statistics that might be of concern. These groups can then take the appropriate actions of alerting pilots and dispersing the offending wildlife, respectively, as necessary.

Management implications

To effectively manage a facility BASH program, the BASH program manager and aviation community must have access to all available datasets, including wildlife activity surveys, actual strike statistics, habitat maps, and now a dataset for NMEs. By utilizing all these sources of information, the BASH program manager will be better equipped to direct limited manpower and funding resources to BASH program areas that will produce the greatest results in aviation safety. This new dataset of NMEs can provide valuable information to many facility departments, including airfield tower operations, aviation operations, airfield and natural resources management, flight planning, and aviation safety.

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