Avian Hazard Advisory System (AHAS): An Evaluation of AHAS Accuracy as a Predictive Tool in Bird Strike Risk Assessment for Civil Aviation

Inger Catherine Oyoko
Avian Hazard Advisory System (AHAS): An Evaluation of AHAS

Accuracy as a Predictive Tool in Bird Strike Risk Assessment for Civil Aviation

by

Inger Catherine Oyoko

Bachelor of Science in Aviation
Aeronautical Science
Florida Institute of Technology
2005

A thesis submitted to the College of Aeronautics at Florida Institute of Technology, in partial fulfillment of the requirements for the degree of

Master of Science
In
Applied Aviation Safety

Melbourne, Florida
December, 2011
We the undersigned committee hereby approve the attached thesis

Avian Hazard Advisory System (AHAS): An Evaluation of AHAS Accuracy as a Predictive Tool in Bird Strike Risk Assessment for Civil Aviation

By
Inger Catherine Oyoko

John E. Deaton Ph.D.
Professor & Director of Research
Human Factors Committee Chair

Gordon Patterson Ph.D.
Professor
Humanities Committee Member

Tom Utley Ph.D.
Associate Professor
Meteorology Committee Member

Korhan Oyman
Associate Dean
College of Aeronautics
Abstract

Avian Hazard Advisory System (AHAS): An Evaluation of AHAS

Accuracy as a Predictive Tool in Bird Strike Risk Assessment for Civil Aviation

by

Inger Catherine Oyoko

Committee Chair: John E. Deaton, Ph.D.

The problem of bird strikes began when human aviators made their first ventures in flight and joined birds in an already crowded environment. In the decades following these first flights, the bird strike problem has resulted in numerous fatalities and millions of dollars worth of damaged or destroyed aircraft in both civil and military aviation. The problem has been further exacerbated by the technological leaps in the aviation industry such as the increase in the number of aircraft and engines on an aircraft, the introduction of the jet engine, and also faster, quieter, more efficient engine design making aircraft harder to detect.

In this thesis, the Avian Hazard Advisory System was evaluated as a possible bird strike risk assessment tool to mitigate the increasing bird strike problem. Data were collected from the FAA’s Wildlife Strike Database and statistical and descriptive analyses performed to determine the efficacy of the AHAS system. If proven to be a useful tool in bird strike predictions, the AHAS system would be a valuable tool to pilots, dispatchers and airport personnel, increase safety by aiding in better decision making during the flight planning process.
# TABLE OF CONTENTS

CHAPTER 1: INTRODUCTION .................................................................................. 1
  Significant Bird Strike Accidents ........................................................................ 1
  The Bird Avoidance Model (BAM) and the Avian Hazard Advisory System (AHAS) ........ 4
  Research Question ............................................................................................ 6
  Significance of the Study ..................................................................................... 8

CHAPTER 2: LITERATURE REVIEW .................................................................. 9
  Types of Avian Radar Currently in Use ................................................................. 14

CHAPTER 3: METHODOLOGY .......................................................................... 19
  Data Sampling ................................................................................................... 19
  Research Design ................................................................................................. 21
  Data Analysis ..................................................................................................... 21
  Chi-Square Analysis .......................................................................................... 22
  Descriptive Analyses ......................................................................................... 22

CHAPTER 4: RESULTS AND DISCUSSION ......................................................... 24
  Chi-Square Test Results ..................................................................................... 24
  Nighttime Bias .................................................................................................. 25
  Descriptive Analyses ......................................................................................... 27

CHAPTER 5: CONCLUSION .............................................................................. 34
  Current Problems with Avian Radar .................................................................. 35
  Future Development .......................................................................................... 36

REFERENCES ...................................................................................................... 37

Appendix A ........................................................................................................ 40

AHAS risk prediction for Austin-Bergstrom Airport (TX) dawn, 2/24/98 ..................... 40
AHAS risk prediction for John F. Kennedy Airport (NY), nighttime, 12/10/95.......................... 41
AHAS risk prediction for Orlando-Sanford Airport (FL), daytime, 1/27/07.............................. 42
AHAS risk prediction for Lorain County Regional Airport (OH), dusk, 9/1/05 ......................... 43
LIST OF FIGURES

Figure 1: Summary of AHAS Risk Assessment ................................................................. 24
Figure 2: Frequency of bird species accident involvement ........................................ 28
Figure 3: Frequency of Accidents by Phase of Flight .................................................. 29
Figure 4: Bird strike frequency by U.S. State ............................................................... 31
Figure 5: Bird strike frequency by time of day ......................................................... 32
CHAPTER 1: INTRODUCTION

Significant Bird Strike Accidents

Birds took to the skies “nearly 150 million years ago” (Metscher, Coyne & Reardon, 2007), human’s first venture in the air was just over 100 years ago. Humans are the new animal in the system and, as we would expect from adding a new variable, there have been problems with wildlife strikes since the beginning of aviation (Metscher et al., p. 38). The skies were already crowded and the addition of human aviators only made the situation worse. The problem of bird strikes (or from the birds’ perspective “human strikes”) by powered aircraft was first documented on September 7, 1908 when Orville Wright was demonstrating their progress by flying complete circles near Dayton, Ohio (Thorpe, 2003). The bird, assumed to have been a red-winged blackbird, was the only casualty (Metscher et al.).

Seven years later in April, 1912, a pilot named Calbraith Rodgers lost control of his aircraft when he struck a gull while flying in Long Beach, California. Rodgers was pinned under his aircraft and drowned, becoming the first documented fatality resulting from a bird strike (Metscher et al. 2007). In the early days of powered flight, these incidents were rare: aircraft were still few in number, and moved slowly, and pilots were adept at avoiding possible collisions, or in the event of a collision, sustained little damage (Metscher et al.). Since that time aircraft have been developed which are larger, faster and fly more frequently with increasing passenger loads. As a result, bird strike occurrences have increased dramatically
and are a major concern because they cost the transport industry and the military millions of dollars annually in repairs and lost revenue, as well as posing a serious threat to passenger safety (Linnell, Conover & Ohashi, 1996).

By 1960 nearly fifty years after the first bird strike fatality, aircraft collisions with birds had become substantial. In March, 1960, a Lockheed Electra turbo-prop ingested European starlings into all four engines during takeoff from Boston Logan Airport (MA). The plane crashed into Boston Harbor, killing 62 people. Following this accident, the Federal Aviation Administration (FAA) initiated action to develop minimum bird ingestion standards for turbine-powered engines (International Bird Strike Committee, 2008). Thirteen years later in February, 1973, a Lear 24 jet departing from Atlanta’s Peachtree-DeKalb Airport struck a flock of brown-headed cowbirds attracted to a nearby trash transfer station. Engine failure resulted and the aircraft crashed, killing eight people and seriously injuring one person on the ground (IBSC, 2008). In November 1990, during takeoff at Michiana Regional Airport (IN), a BA-31 multi-engine turbo-prop aircraft flew through a flock of mourning doves. Several birds were ingested in both engines and takeoff was aborted. Both engines were destroyed and the cost of repairs was $1 million and time out of service was 60 hours (IBSC).

In June 1995, an Air France Concorde, at about 10 feet AGL while landing at John F. Kennedy International Airport (NY), ingested one or two Canada geese into the number 3 engine. The engine suffered an uncontained failure. Shrapnel from the number 3 engine destroyed the number 4 engine and cut several hydraulic
lines and control cables. The pilot was able to land the plane safely but the runway was closed for several hours. Damage to the Concorde was estimated at over $7 million. The French Aviation Authority sued the Port Authority of New York and New Jersey and eventually settled out of court for $5.3 million (IBSC, 2008).

According to the International Bird Strike Committee there is inconsistency in techniques to manage wildlife strike risk on airports; “This inconsistency has arisen in part because the habitat types, the wildlife species present, and the levels of risk caused by wildlife vary widely among airports. The precise techniques that are successful at one site might not work at another. The situation is further aggravated by the differences in resources available at each airport and the attitudes of airport managers and air carriers” (Cleary, 2007 ¶ 1).

Bird and other wildlife (primarily deer and coyotes) strikes to aircraft annually cause an estimated $600 million in damage to U.S. civil and military aviation (BSCUSA, 2005). Furthermore, these strikes put the lives of aircraft crew members and their passengers at risk: over 195 people have been killed worldwide as a result of wildlife strikes since 1988 (BSCUSA). Within the United States there was no one forum where information or concerns dealing with this problem could be addressed, leading to the formation of Bird Strike Committee USA (BSCUSA) in 1991 (BSCUSA).

The IBSC is a voluntary association of representatives from organizations who aim to improve commercial, military, and private aviation flight safety, by sharing knowledge and understanding concerning the reduction of the frequency
and risk of collisions between aircraft, birds and other wildlife (IBSC, 2009). Representatives from IBSC are associate members of Bird Strike Committee USA (BSCUSA), which was formed to facilitate exchange of information, promote collection and analysis of accurate wildlife-strike hazards, development of new technologies to reduce wildlife hazards, professionalism in airport wildlife-management programs through training and advocacy, and act as a liaison to similar organizations in other countries (BSCUSA, 2005). BSCUSA is directed by an eight-person steering committee comprised of two members each from the FAA, US Department of Agriculture, US Department of Defense and the aviation industry Wildlife Hazards Working Group (BSCUSA).

My goal is to investigate risk assessment techniques for potential bird strikes at major airports in the U.S. The recent US Airways flight 1549 crash into the Hudson River on January 15, 2009 makes this research project especially timely.

**The Bird Avoidance Model (BAM) and the Avian Hazard Advisory System (AHAS)**

Two systems are currently being used for estimating wildlife strike hazard: the U.S. Air Force's Bird Avoidance Model (BAM), and the Avian Research Laboratory's Avian Hazard Advisory System (AHAS). These tools provide information regarding bird strike risk, and allow pilots to make informed decisions about their flight routes with regards to wildlife strike risk (FAA, 2008). The BAM is a historical archive of bird information, taking data from more than 10,000
locations over the past 30 years. This database includes over 50 different bird species and incorporates information on bird populations and distributions with environmental and geographic information to arrive at bird strike risk estimates for a selected route, biweekly period, and time of day (FAA).

AHAS is a dynamic version of the BAM was created to provide Air Force pilots and flight scheduler/planners with a near real-time tool for making informed decisions when selecting flight routes. AHAS utilizes current weather data from the National Weather Service (NWS) and calculates the risk of large birds species present, based upon relationships found between behavior, weather and strike rate with each species (Merritt, Kelly, White & Donalds, 1999). It was created in an effort to protect human lives and equipment during air operations throughout the contiguous U.S. (USAHAS, 2009). AHAS is used by the Department of Defense and is available to the general public through an internet application (USAHAS).

The AHAS provides the user with a standardized measure of bird strike risk for low level routes where risk is defined as the number of strikes multiplied by the bird(s) body mass (Merritt et.al. 1999). AHAS calculates risk by measuring the number of bird strikes in a particular area, and the average mass of the birds from the FAA database. AHAS incorporates weather radar data from Next Generation Radar (NEXRAD) Weather Surveillance Radar 88-Doppler (WSR-88D), historical information (BAM) and predictive models to determine current bird activity.
NEXRAD is very sensitive but it cannot differentiate between birds (which can be considered bags of water clothed in feathers) or the same volume of water distributed as precipitation (Merritt et.al. 1999). Rain tends to have both vertical and horizontal distribution, sometimes 20,000-30,000 feet up and over many square miles on the ground. Large movements of birds tend to lack any significant vertical distribution. By data processing it is possible to remove much of the weather returns from the radar data due to the vertical distribution of the precipitation and leave the bird returns (Merritt et.al.). This technique was developed for AHAS as a means to turn on and off the risk levels presented in the U.S. BAM in near real-time (20-35 minute delay), this eliminates the need to identify the type of bird target on the radar. The logic used is that if bird activity is detected by NEXRAD in an area where hazardous bird activity is expected by the U.S. BAM then the area is designated as hazardous by AHAS (Merritt et.al. 1999).

**Research Question**

How accurate is the AHAS as a predictive tool in bird strike risk assessment? For the AHAS system to be useful it would have to predict bird strike risk correctly at least 85% of the time. The AHAS system has to take into account variables such as changing weather patterns and the accompanying changes in bird behavior and therefore cannot realistically predict risk at 97-99.9% accuracy. For this study it is hypothesized that the AHAS system will correctly predict risk 85% of the time. This aim of this study is to determine AHAS accuracy by examining major bird strike related accidents from 1990 - 2009; where ‘major’ is defined as an
accident resulting in loss of life or substantial cost of repair/damage to the aircraft or total loss of the aircraft. The FAA classifies bird strike related damage as ‘substantial’ when the aircraft is destroyed or incurs damage or structural failure that adversely affects the structural strength, performance or flight characteristics of the aircraft and that normally requires major repair or replacement of the affected component (Dolbeer, 2006). These damage codes and descriptions are used by the FAA and were adopted from the International Civil Aviation Organization (ICAO) Bird Strike System (U.S. Department of Transportation, 2008):

- Minor – the aircraft can be rendered airworthy by simple repairs and replacements and an extensive inspection is not necessary
- Uncertain – the aircraft was damaged but details as to the extent of the damage are lacking
- Substantial – the aircraft is destroyed or incurs damage or structural failure that adversely affects the structural strength, performance or flight characteristics of the aircraft and that normally requires major repair or replacement of the affected component (specifically excluded are bent fairings or cowlings, small dents or puncture holes in the skin, damage to wingtips, antenna, tires or brakes; and engine blade damage not requiring blade replacement)
- Destroyed – the damages sustained make it inadvisable to restore the aircraft to an airworthy condition
Significance of the Study

This study could lead to recommendations for improvements on AHAS and also determine the viability of using AHAS as a predictive tool during the flight planning stages of civilian flight. If the AHAS system is working and proven to be accurate in predicting bird strike risk, the use of AHAS for flight planning purposes would not only aid pilots in making informed decisions when selecting flight routes, but would also increase safety, reduce the cost associated with repairs to damaged aircraft and ultimately save lives.

Currently, not all areas of the U.S. are included in the Digital Aeronautical Flight Information File (DAFIF) which is a set of files that contain data on airports, navigational aids (NAVAIDS), waypoints, special use airspace and other facts relevant to flying in the entire world. For civilian airports, the FAA would have to get involved in AHAS for these areas to be included (USAHAS, 2009), and if AHAS proves to be accurate in its predictions then it would be worthwhile, in the interest of safety, for the FAA to promote AHAS as a flight planning tool to all pilots and dispatchers countrywide.
CHAPTER 2: LITERATURE REVIEW

The civil and military aviation communities agree that the threat to human safety from aircraft collisions with wildlife is increasing. Wildlife aircraft collisions is a subject the general public and many scientists and wildlife biologists know little about (Dolbeer, 2009). It is important that this problem be explored because globally wildlife strikes have killed more than 219 people, and destroyed over 200 aircraft since 1988 (Wright & Dolbeer, 2009). Wildlife collisions with aircraft has been an ongoing problem that was brought to the fore in the aftermath of the highly-publicized ditching of US Airways Flight 1549 in the Hudson River on January 15, 2009. At least one Canada goose was ingested into each engine of the Airbus A320 after its departure from LaGuardia Airport, New York (NTSB, 2009). In the past four decades there has been a dramatic increase in populations of large bird species in North America contributing to the increased threat of wildlife strikes (Dolbeer, 2009).

In June, 1969, the very polluted Cuyohuga River in Cleveland, Ohio, caught fire and burned the docks near the outlet into Lake Eerie. This highly-publicized event was a major catalyst in stirring the environmental protection and clean-up movement between 1969 and 1972. The result was Congress enacted environmental legislation and programs; the Clean Water Act, Endangered Species Act and the establishment of the National Environmental Protection Agency (NEPA) (Dolbeer, 2009). The National Wildlife Refuge System was expanded, Earth Day was established and environmental education programs were developed for schools nationwide, developing a strong environmental awareness among the
public (Dolbeer, 2009). These actions to protect the environment are directly related to the dramatic increases in populations of most of the large bird species in North America (Dolbeer & Eschenfelder, 2003).

Dolbeer and Eschenfelder (2003) found that 36 of the approximately 650 bird species that nest in North America have average body masses greater than 4 lbs; of the 31 species for which population trend data were available, 24 (77%) showed population increases for the past 40 years. More importantly, 13 of the 14 largest (greater than 3.6 kg/8 lbs body mass) birds species have significantly increased in population (Dolbeer & Eschenfelder, 2003). Approximately 294 strikes with birds greater than 4lbs caused substantial damage to civil aircraft in the U.S. between 1990-2002. Intensifying the problem is the advances in technology making aircraft engines quieter and less obvious to birds; therefore an environment exists where the avian population is rapidly increasing and the number of quieter air traffic is increasing (Dolbeer, 2009).

Passenger enplanements in the U.S. increased from about 310 million in 1980 to 749 million in 2007 (3.3% per year), and commercial air traffic increased from about 18 million aircraft movements to 28 million in 2007 (1.8% per year Federal Aviation Administration, 2008). Commercial air traffic in the U.S. is expected to continue growing at 2% per year to over 36 million movements by 2020. Commercial carriers are replacing their older three- or four-engine aircraft with quieter and more efficient, twin-engine aircraft (FAA, 2008). In 1969, 75% of the 2,100 U.S. passenger aircraft had three or four engines, in 2005 the U.S.
passenger fleet had grown to 8,200 aircraft (Department of Transportation, 2007), with 10% having three or four engines (Cleary & Dolbeer, 2005). The reduction in redundancy increases the probability of hazardous situations resulting from aircraft collisions with wildlife, especially flocks of birds (Wright & Dolbeer, 2008).

The increase in large-bird populations is especially problematic because aircraft components are not tested or certified for birds weighing greater than 3.6kg, most components are tested for 1.8 kg birds maximum, and more alarming, the requirements to pass the test are that the engine can be shut down safety and the damage contained within the engine casing (FAA, 2001). The engines of Flight 1549 Airbus 320, both of which lost power after ingesting geese, performed exactly as they were certified to perform (Dolbeer, 2009). Dolbeer & Eshcenfelder (2003) suggest that airworthiness standards be reevaluated to address the threat posed by increasing populations of large flocking birds.

The Air Combat Command (ACC) Bird Hazard Working Group (BHWG), together with Geo-Marine Inc. developed the AHAS system to use NEXRAD weather data, weather forecasts, and known bird distributions to detect bird hazards to military aircraft conducting high speed, low altitude training, and provide aircrews with hazard advisories (Merritt et.al. 1999). The AHAS system was designed to pinpoint actual bird movement to enable more effective risk management than is possible using historic BAM data alone (Merritt et.al. 1999).

Following a risk assessment of bird strikes during low altitude training conducted by Geo-Marine and HQ ACC in 1997, risk was defined as number of
strikes multiplied by bird body mass. The results of the assessment showed that 94% of the risk came from 11 groups of birds (Merritt et al. 1999):

1. Turkey Vulture
2. Red-Tailed Hawk
3. Snow and Canada Geese
4. Ducks (Mallards and Pintails)
5. Golden and Bald Eagles
6. Black Vulture
7. Herring Gull
8. Sandhill Crane
9. White Pelican
10. Tundra Swan
11. Double Crested Cormorants

These became priority species for risk management by the ACC. The AHAS system is a dynamic version of US BAM and is therefore more accurate at forecasting bird migratory and soaring activity (Merritt et al. 1999). In addition to using historic BAM data, AHAS takes current weather data from the National Weather Service (NWS) and calculates the risk large bird species present, based on relationships found between behavior, weather and strike rate with each species (Merritt et al. 1999). Standard meteorological calculations are used to determine thermal depth and strength that gives Red-tailed Hawks the energy to soar over their territories, and Turkey Vultures the altitude to cover long distances when searching for food (Merritt et al. 1999). Integrating weather data allows the AHAS system to determine when birds will begin migration allowing for more stable and predictable results than from statistical methods alone (Merritt et al. 1999).

The test results from the ACC show that AHAS can predict bird conditions 24 hours in advance. These 24-hour predictions are less restrictive than the US
BAM because for example, AHAS forecasts recognize that birds do not migrate with strong headwinds or soar without thermals, AHAS forecasts may therefore identify higher risks than predicted from the historical US BAM data (Merritt et al. 1999).

A case in point is the DC-9 operated by USA Jet Airlines accident at Kansas City, Missouri. The DC-9 (N195US) was operating at night and on final approach to Kansas International Airport when it encountered a flock of large birds (NTSB, 2001). During the encounter the captain reported that a flock of Snow geese was suddenly illuminated in the aircraft lights, engulfing them from below, flying into the aircraft. The birds did not hit the windshields but it became immediately apparent that they had flown into the engines (NTSB, 2001). The Automated Terminal Information System (ATIS) broadcast included a note warning pilots about migratory bird activity in the vicinity of the airport. In the Airport Information section of the subsequent accident report, airport remarks listed for Kansas City International Airport in the Airport/Facilities Directory, North Central U.S., covering Missouri had an advisory for Waterfowl on and in the vicinity of the airport from October 1 to December 15, and April 1 to May 30 (NTSB, 2001).

The predictions of bird activity at the airport were corroborated by National Weather Service (NWS) radar display information to determine the likelihood of biological targets in the area during the time when the bird strike occurred. The NWS radar information showed a wide area of returns consistent with northerly
migration of birds (NTSB, 2001). Following the NTSB investigation, along with other accidents involving bird strikes, the NTSB’s first recommendation to the FAA was to “evaluate the potential for using Avian Hazard Advisory System (AHAS) technology for bird strike reduction in civil aviation, and if found feasible, implement such a system in high-risk areas, such as major hub airports, and along migratory bird routes, nationwide” (NTSB, 2001). At the request of the NTSB Geo-Marine Inc., the operator of AHAS was asked to assess the level of bird activity in the vicinity of the Kansas City International Airport on March 4, 1999, around the time of the encounter. Geo-Marine Inc. retrieved data from NEXRAD archive tapes from the WSR-88D radar, and compared with NWS information to determine the probability of biological targets in the area when the bird strike occurred. Analysis of the data confirmed the NWS radar returns indicating a large-scale migration consistent with northerly migration of birds (NTSB, 2001). AHAS is one of the six technologies that have come to the fore in the past decade that has demonstrated success as an avian radar detection system (Litt, 2006).

**Types of Avian Radar Currently in Use**

Accipiter Avian Radar (Sicom Systems Ltd.), Geo-Marine Inc. Mobile Avian Radar System (MARS), MERLIN Bird Strike Avoidance Radar System and Raptor Radar (DeTect Inc.), BIRDRAD (Clemson University Radar Ornithology Laboratory) and EchoTrack System (EchoTrack Inc.) are avian radar systems in the U.S. that focus more on avian detection in the airport terminal environment (Litt, 2006). Accipiter Avian Radar has been operational since 2004 and is currently used
by the U.S. Navy, the U.S. Department of Agriculture Wildlife Services
(USDA/WS), the New York State Police and the U.S. Department of Homeland
Security. Accipiter Avian Radar’s strength lies in its ability to update targets very
near real-time (2.5 seconds), unlimited and continuous recording capacity, high
speed playback for visual review of bird activity and statistical and historical
overlays for interpretation of correlation between bird behavior and underlying
geography (Litt, 2006). Geo-Marine’s MARS system uses commercial marine-band
radars and proprietary software for avian detection and runs 24 hours continuously
recording data (Litt, 2006).

Using two central components: TracScan S-band and VerCat X-band
MARS is capable of detecting flocks of small birds at a range of four nautical miles
(nm) and single birds at ranges between one and two nm. The MARS system is
able to detect birds at altitudes ranging from 5000 – 8000 feet and report size,
speed, heading and position data (Litt, 2006). The Bird Strike Avoidance Radar
System (MERLIN) developed by DeTect Inc. entered the market in 2003 and also
uses marine-band radar for avian detection with ranges of up to six nm around an
airport, and altitudes of up to 15,000 feet (Litt, 2006).

DeTect’s Merlin system enables air traffic control (ATC), airport operations
and bird-control units to monitor high-risk areas during severe weather. The system
can be controlled and data reviewed remotely via an internet interface, with the
option for audible and/or visual alerts via pager, cell-phone, or workstation when
high risk conditions are detected. MERLIN also has the capability to record bird
track data including size, speed, bearing and altitude to a Geographical Information System (GIS) database (Litt, 2006). DeTect’s Raptor Radar is an internet-based, large-scale, commercial aviation advisory system. Raptor Radar, like AHAS, uses the U.S. NEXRAD radar network to provide near real-time, airports specific bird density levels but no en route bird density information. Avian density imagery is available in color-coded formats within 10-50 nm range views allowing bird control units and ATC to view regional and local bird activity (Litt, 2006). The Clemson University Radar Ornithology Laboratory (CUROL) developed its first BIRDRAD in 1998 with funding from the Department of Defense Legacy Resource Management Program (Litt, 2006).

First deployed at Howard Air Force Base in Panama, BIRDRAD detected dense movements of migrating hawks and vultures within six nm. Enhancements to BIRDRAD by CUROL were made in 1999 and 2001, the new black box version allowed for high definition imaging software to enable capture of any radar image as a .bmp file. In 2005 an upgrade from BIRDRAD to eBIRDRAD was made and the unit is now being used in the Bird-Aircraft Strike Hazard (BASH) program at Patuxent River Naval Air Station (Litt, 2006). Echo Track is a marine band radar system widely used in Alberta and Ontario, Canada to monitor locations and altitudes of flight paths in a volume of airspace that is three miles in diameter and up to 4800 feet high (Litt, 2006). Echo Track is mostly used by wildlife personnel and wind farm developers to reduce the risk of collision of birds and bats with wind
turbines. A computerized console allows for real-time monitoring and the system is also automated for unlimited sampling (Litt, 2006).

A webinar (an online instruction session that uses the Internet Web as a real time presentation format along with audio channels (via web or telephone) that allow participants to listen and possibly interact with the session. Webinars allow people to participate in information or training sessions from anywhere that has Internet and audio access) was held in March, 2009 entitled “Effective Airport-Airline Partnerships for Birdstrike Prevention,” and the focus was on bird strike prevention in the terminal airport environment. Arguments were made for employment of airport specific avian radar, and the findings of Wright and Dolbeer (2008) can be used to support the argument; of the 80,000 bird strikes occurring between 1990 and 1997, about 60% occurred when the aircraft was at a height of 100 feet or less above ground level (AGL), and 92% occurred at or below 3,000 feet AGL. Less than 2% of bird strikes occurred above 10,000 feet AGL with the record height for a reported bird strike with civil aircraft in the U.S. being 32,500 feet AGL. Corroborating the findings of Metsher et.al., (2007), Wright and Dolbeer (2008) found that gulls (20%), doves/pigeons (14%), raptors (13%) and waterfowl (9%) were the most frequently struck bird groups.

Cleary and Dolbeer (2005) assert that airport managers need to assess the wildlife hazards at their airports under the guidance of professional biologists trained in wildlife management. The FAA Form 5200-7, Bird/Other Wildlife Strike Report became available in April, 2001 and is the primary means of bird strike
reporting with the options of paper or electronic reporting (Wright & Dolbeer, 2008). Bird strike reporting has improved in the aviation community; the number of strikes annually reported more than quadrupled from 1,759 in 1990, to 7,666 in 2007. Cleary and Dolbeer attribute the improvement in bird strike reporting to an increasing awareness of the wildlife strike issue, an increase in aircraft operations, an increase in populations of hazardous wildlife species, and an increase in the number of strikes.

Technology offers several possible avenues to mitigate the risk of bird strikes without adverse effects on the ecological balance. With at least five avian radar detection systems available, most of which are suited to the airport terminal environment, AHAS is the primary avian radar system that provides the aviation community with en route bird strike risk analysis data. While the airport terminal environment is also a high risk area for bird strikes during migratory seasons, AHAS provides the aviation community and especially transient air traffic the opportunity to plan ahead and get a bigger pre-flight picture of bird distributions across the U.S.

The subsequent chapter describes the method for assessing the accuracy and usefulness of the AHAS system; along with the data sources and data collection method. The research design is described and the data analysis procedures that will be used to determine the accuracy and usefulness of the AHAS system.
CHAPTER 3: METHODOLOGY

Data Sampling

The IBSC has bird strike reports dating back to 1912, but because the data presented covers only up to 2002 (Thorpe, 2003), only the FAA Wildlife Strike Database will be used as it presents extensive and current data and covers civil
aircraft operations in the United States only. The IBSC data naturally includes United States and international bird strike events (Thorpe). Drawing from the FAA’s Wildlife Strike Database, January, 1990 – December, 2009, an excerpt from the data; (a ‘major’ accident) is shown (Wright, 2009):

Table 1: Summary of Report No. 19901105058689C from the FAA Wildlife Strike Database

<table>
<thead>
<tr>
<th>Date:</th>
<th>05 November 1990</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aircraft:</td>
<td>BAE Jetstream 31</td>
</tr>
<tr>
<td>Airport:</td>
<td>Michiana Regional (IN)</td>
</tr>
<tr>
<td>Phase of Flight:</td>
<td>Takeoff run</td>
</tr>
<tr>
<td>Effect on Flight:</td>
<td>Aborted takeoff, engine shut down</td>
</tr>
<tr>
<td>Damage:</td>
<td>Engines, propellers</td>
</tr>
<tr>
<td>Wildlife Species:</td>
<td>Dove</td>
</tr>
<tr>
<td>Comments from Report:</td>
<td>Doves were ingested in both engines. Engines were destroyed. Time out of service 2 ½ days. Cost of repairs estimated at $1 million.</td>
</tr>
</tbody>
</table>

Data prior to 1990 has been excluded from this study because when the USDA/WS, took over management of the FAA database, it was necessary to verify each record that was in the system with a hard copy. The records for 1989 had been disposed of so there would have been a gap in the data if the wildlife strike reports selected began with data from the 1980's. There are records prior to 1990 but they are not available for that reason (Wright, 2009).
Research Design

By obtaining the exact location and if possible, flight path, of the 150 selected accidents, AHAS will be used to predict the risk of bird strikes at the respective locations and/or flight paths. If AHAS accurately predicts bird strike hazards where bird strikes are known to have occurred, this study will show what percentage of the time AHAS correctly predicted bird strikes, and the safety implications for using AHAS as a predictive tool during the flight planning stage.

The AHAS displays risk data using color codes representing three risk levels; low, moderate and severe, represented by the colors green, beige and red respectively. The risk levels describe three predicted risk classes - low, moderate, and severe, which are based upon the bird mass in ounces per square kilometer (USAHAS, 2009). In other words, the risk levels represent the amount of birds (bird mass) in a kilometer squared spatial area. The "Moderate Zone" indicates a risk ratio that is 57-708 times the risk of the "Low Zone", while the "Severe Zone" indicates a risk ratio that is 2,503-38,647 times the risk of the "Low Zone." The risk values are derived using a logarithmic scale for the risk surfaces (USAHAS).

Data Analysis

For this study, descriptive analyses will be used to examine AHAS accuracy when all 150 known major accidents are run through the AHAS system. Ideally AHAS should predict a risk level of ‘Moderate’ or ‘Severe’ in all of the locations where these 150 accidents have occurred. The AHAS risk categories are based on bird mass per square kilometer of spatial area. The scale used to calibrate these risk categories is logarithmic and therefore the difference in risk categories is quite
significant; a risk category of ‘moderate’ means a risk 57-708 times that of a ‘low’ risk category and a risk category of ‘severe’ indicates a risk level 2,503-38,647 times that of a ‘low’ risk level.

**Chi-Square Analysis**

A Chi-Square Goodness of Fit test will be used to illustrate the difference in frequencies and since the 150 events are confirmed major accidents, the AHAS system should predict at least a risk level of ‘moderate’ for all 150 accidents for the system to be considered a useful predictive tool.

Data were collected from the FAA’s Wildlife Strike Database. The hypotheses for the Chi-Square analysis include the following:

\[ H_0: \text{The AHAS system will not predict a bird strike risk level of ‘moderate’ or ‘severe’ in 128 of the 150 selected accidents} \]

\[ H_1: \text{The AHAS system will predict bird strike risk level of ‘moderate’ or ‘severe’ in 128 of the 150 selected accidents} \]

For this analysis, the significance level (\( \alpha \)) is 0.05. Using the sample data, a Chi-Square Goodness of Fit procedure will be used to test the hypothesis.

The sample size \( n = 150 \) which represents the number of accidents caused by bird strikes.

**Descriptive Analyses**

Descriptive analyses will also be conducted to describe the relationship between the bird strike accidents and the species of bird involved, and the bird strike accidents and the phase of flight at which the accident occurred. FAA
wildlife biologists have presented data on bird strikes in the US that show 60% of all 79,972 bird strikes occurring from 1990-2007 happened during the landing (descent, approach, or landing roll) and 37% occurred during the take-off and climb phase of flight (Wright & Dolbeer, 2008). Using the selected accidents the relationship between the number of accidents and the phase of flight at which the accident occurred will be investigated.

Wright and Dolbeer (2008) also showed that bird species were reported or identified in only 26% of the 79,972 bird strikes. Gulls (20%), doves/pigeons (14%), raptors (13%) and waterfowl (9%) were the most frequently struck bird groups. Gulls were involved in 2.4 times more strikes than waterfowl (7,021 and 2,956 respectively). Waterfowl, however, were involved in strikes that caused the most damage (1,326 or 31% of all damaging strikes in which the bird type was identified) that were gulls (1,119 or 26% of all damaging strikes in which the bird type was identified). Gulls were responsible for the greatest number of bird strikes (895 or 27%) that had a negative effect-on-flight (Wright & Dolbeer). Using the selected accidents the relationship between number of accidents and the bird type involved will be investigated.
CHAPTER 4: RESULTS AND DISCUSSION

Chi-Square Test Results

A comparison of the frequencies of the three risk assessment categories - low = 38, moderate = 112 and severe = 0, was conducted to determine if a statistically significant difference existed between the groups. With alpha (α) = .05, a Chi-Square test for Goodness of Fit on these frequencies was statistically significant; \( \chi^2 (2, N=150) = 129.76 \ p < .001 \). This indicates there was a significant difference between the three different risk assessment categories. A greater number of bird strike predictions were observed in the moderate risk assessment category.

![AHAS Risk Predictions](image)

Figure 1. Summary of AHAS Risk Assessment

If the AHAS system had correctly predicted all events, all 150 accidents would have been represented in the ‘moderate’ or ‘severe’ risk categories. The AHAS
system predicted a risk of ‘moderate’ in only 75% of the accident events; therefore, we fail to reject the null hypothesis and conclude that the AHAS system will not predict a bird strike risk level of ‘moderate’ or ‘severe’ in 128 or 85% of the 150 selected accidents.

The AHAS system predicted a ‘low’ risk in 38 of the 150 accident events and ‘moderate’ in 112. These results indicate the AHAS system accurately predicted a risk level of ‘moderate’ 75% of the time where major accidents actually occurred. Therefore, 25% of pilots, dispatchers, and airport personnel who would typically be expected to use the AHAS as a predictive tool would have erroneously received risk predictions lower than ‘moderate’.

**Nighttime Bias**

When the data were analyzed by time of day it was found that 38 of the 150 major accidents (25%) occurred at night. Of the 38 nighttime events the AHAS system incorrectly predicted a risk level of ‘low’ in 30 of the 38 nighttime events. Nighttime events therefore accounted for nearly 80% of the inaccuracies in the AHAS system.

From this analysis it is apparent that the AHAS system has a ‘nighttime bias.’ This ‘nighttime bias’ may have been built into the system because the designers applied the assumption that birds do not fly at night, and major accidents due to bird strikes which occurred at night may have been deemed outliers during the system’s design. Another possibility is, the AHAS system was borne of the Bird Avoidance Model (BAM). This model is based on historical bird strike data that the
US Air Force integrated into the Geographical Information System (GIS) as a key tool for analysis of bird strike risk during low level maneuvers (USAHAS, 2009). The seven nighttime accidents that were accurately predicted by AHAS as having a risk of ‘moderate’ were a result of collisions with Snow or Canada geese (six events). Collisions with geese accounted for approximately half of all 37 nighttime events. In one of the nighttime events, in which the risk was not accurately predicted, the bird species was not identified.

An analysis of nighttime events by season revealed that 19 of the 38 events occurred in the fall; six in the winter, 11 in the spring and two in the summer. The higher frequencies in the fall and spring coincide with the fall and spring migration. The Cornell Laboratory of Ornithology shows migratory geese populations for the years 2005 through 2010 were at their peak from March 8th to April 15th and from October 1st to November 1st (CornellLab, 2011). The single nighttime accident that occurred in the summer involved a Black-crowned Night Heron, the most widespread heron in the world, and is most active at dusk and at night (CornellLab).

The 95 bird strike accidents occurring during the day were also analyzed. Of the 95 day time events, only 7 were wrongly predicted in the ‘low’ risk category, so in comparison to the nighttime events the AHAS system predicted bird strike risk at 93% accuracy during the day. Therefore, in the absence of the nighttime bias, the AHAS system actually predicts risk at approximately 93% accuracy during the day, and the nighttime bias accounts for 20% (30) of the
erroneous risk predictions in the 150 events, where the total erroneous predictions are 25% (38) of the 150 events. It can be concluded, therefore, that the AHAS system surpasses the hypothesized accuracy of 85%, but only if the events being analyzed occurred during the day.

**Descriptive Analyses**

An analysis of the relationship between the bird strike accidents and the bird species involved was conducted and the results are displayed in Figure 2.

Following a risk assessment conducted by the Geo-Marine (developers of Accipiter Avian Radar) and USAF HQ Air Combat Command in 1997, of bird strikes during low altitude training, risk was defined as the number of strikes multiplied by bird body mass. The results of the assessment showed that 94% of the risk came from 11 groups of birds:

1. Turkey Vulture
2. Red-Tailed Hawk
3. Snow and Canada Geese
4. Ducks (Mallards and Pintails)
5. Golden and Bald Eagles
6. Black Vulture
7. Herring Gull
8. Sandhill Crane
9. White Pelican
10. Tundra Swan
11. Double Crested Cormorants

The criteria for the selection of these 11 species were rapid population growth and flight behavior in addition to the large body mass of these birds (Merritt et.al. 1999).
From the results displayed in Figure 2, the findings support those of Merritt et.al in 1999 as to the type of birds most frequently involved in bird strike events. Of the 150 bird strike events studied, the species of bird was identified in 132 events. In 18 of the events, the species was not identified. Of the 41 bird species identified in the 132 events, five of the six species with the highest accident involvements were on the list of the 11 species identified by Merritt et.al (1999). These were: Canada geese (31), Gulls (15), Snow geese (10), Red-tailed hawk (6)
and Mallards (5). European starlings were involved in six events and ranked fourth overall in frequency of bird strikes; however this species was not mentioned as a high risk species in the Merritt study.

An analysis of bird strike events with respect to phase of flight was also conducted. An FAA wildlife biology study of bird strike frequency with respect to phase of flight indicated that of the 79,972 bird strikes which occurred from 1990 – 2007, 60% occurred during the landing phase (descent, approach, or landing roll). The study further indicated that 37% of the bird strikes occurred during the take-off and climb-out phase of flight (Wright & Dolbeer, 2008). Using the 150 bird strike events in this study the relationship between the frequency of bird strikes and the phase of flight was investigated. Results of this analysis are indicated in Figure 3.

![Frequency of Accidents by Phase of Flight](image)

Figure 3. Frequency of Accidents by Phase of Flight
The findings in this study do not mirror the findings of Wright and Dolbeer (2008). In the 150 accidents analyzed, 73% occurred during the climb and takeoff phase as opposed to the 37% indicated in the Wright & Dolbeer study. The 150 bird events study indicated 27% of the events occurred during the approach/descent/landing phase as opposed to the 60% found in the Wright & Dolbeer study. The differences in the results of this study and the Wright & Dolbeer study may be due to the significantly smaller sample size of 150 bird strikes, compared to the 79,792 events used in the Wright & Dolbeer study. Another potential explanation for the differences in frequency of occurrence may be due to the fact that Wright & Dolbeer, using the FAA study, included all bird strike occurrences while the 150 sample group includes only bird strike events that resulted in ‘major’ accidents where ‘major’ is defined as an accident resulting in loss of life or substantial cost of repair/damage to the aircraft or total loss of the aircraft (Dolbeer, 2006).

A state by state analysis of the 150 bird strike events was conducted to determine the relationship between accident occurrence and geographic location. All selected accidents occurred in the United States. California had the largest number of bird strikes (18), followed by Ohio (11), Texas (11), Illinois (9), New York (8), New Jersey (8), Florida (8), Pennsylvania (6), Colorado (5), Michigan (5), Missouri (5), Oregon (5) and Tennessee (5). This analysis is depicted in Figure 4. The only states without major accidents in this study were Connecticut.

These results are in agreement with the findings reported by Wright & Dolbeer in the FAA National Wildlife Strike Database Serial Report 14. The FAA data were collected from all 50 states, from some US territories and from foreign countries where US-registered aircraft were involved. Of the 79,972 bird strikes reported for the 18-year period, the states with the highest occurrences of bird strikes were: California (6,920), Texas (5,317), Florida (5,178), and New York (4,333). Twenty-one other states had over 1,000 bird strikes, and bird strikes were reported at 1,418 airports in the US (Wright & Dolbeer, 2008).

![Bird Strike Frequency by State](image)

Figure 4. Bird strike frequency by US state
An analysis of bird strikes occurrences based on time of day revealed that most bird strikes (63%) occurred during the day, 25% occurred at night, 7% at dusk, and 5% at dawn. These findings correspond to the Wright & Dolbeer study findings for the 18 year period from 1990-2007. Wright and Dolbeer (2008) discovered that of the 52,768 bird strikes in which the time of day was reported 62% occurred during the day, 28% at night, 5% at dusk and 4% at dawn. The results are depicted in Figure 5.

![Bird Strike Occurrence by Time of Day](image)

Figure 5. Bird strike frequency by time of day

The American Meteorological Society (2000) defines these four times of day as follows:
Dawn – The first light visible in the sky before sunrise or the time of that appearance

Day – the period from midnight to midnight; local civil time or civil day, for the purpose of this study however, day is the period of daylight within a 24 hour time span

Dusk – the part of morning or evening twilight between complete darkness and civil twilight, in other words, dusk is the evening counterpart of dawn

Night - The period of darkness in each twenty-four hours; the time from sunset to sunrise

For all of the descriptive analyses it should be noted that the data presented from the FAA Wildlife Report (Wright & Dolbeer, 2008) is presented to provide a broader perspective on the trends being analyzed. The data in this study and data presented by the FAA cannot be compared because the FAA report shows trends from data that includes all the bird strike accidents – both minor and major, with all damage levels included, whereas this study uses only a subset of 150 accidents that are all categorized as major, where the damage to the aircraft was either substantial or the aircraft were destroyed.
CHAPTER 5: CONCLUSION

The civil and military aviation communities both agree that the bird strike problem poses a threat to human health and safety. Some of the factors contributing to the increasing problem are marked increases in bird populations, a major increase in air traffic over the past decades and technological advances in aviation. Many populations of bird species involved in bird strikes have increased in recent decades and have adapted to living in urban areas including airports. From 1980-2006 the resident Canada goose population has in the US and Canada has increased at a rate of 7.3% per year (Wright & Dolbeer, 2008). Other species previously identified as posing the highest risk of bird strikes to aviators have also shown significant annual rates of growth; Bald eagles (5%), Wild turkeys (13%), Turkey vultures (2.3%), American white pelicans (4.3%), Double-crested cormorants (4.9%), and Sandhill cranes (4.7%). Thirteen of the 14 bird species in North America with average body masses greater than eight pounds have shown significant increases in population over the past three decades (Dolbeer & Eschenfelder, 2003).

Simultaneous increases in air traffic in the past three decades have accompanied the increase in large bird populations in North America. Passenger enplanements in the US increased from about 310 million in 1980 to 749 million in 2007 (approximately 3% per year). Commercial air traffic increased from about 18 million aircraft movements in 1980 to over 28 million in 2007, and is expected to
continue growing at about 2% per year to about 36 million aircraft movements in 2020 (Wright & Dolbeer, 2008).

Technological advances have further exacerbated the bird strike problem in North America. Commercial air carriers have been replacing their older three or four-engine aircraft with more efficient, quieter two-engine aircraft. In 1969 75% of the 2,100 US passenger aircraft had three or four engines. In 2005 the US passenger fleet had grown to about 8,200 aircraft and only about 10% of them have three of four engines (Cleary & Dolbeer, 2005). The reduced number of engines and also the quieter more efficient engines make it difficult for birds to detect and avoid aircraft (Wright & Dolbeer, 2008).

**Current Problems with Avian Radar**

The United States Air Force (USAF) Institute for Information and Technology Applications cites technical challenges, communication, policy and funding as problems in the development of avian radar. The development of real-time predictive bird presence models is in its infancy; the AHAS system has progressed from giving forecast updates ever 25-30 minutes to every 10 minutes, but is still not able to provide real time bird strike risk analyses. The ability to communicate warnings following detection of bird hazards, so that airport staff can focus on bird dispersal efforts has not been developed. Beyond airport property the ability to communicate useful real-time warnings is virtually nonexistent (DeFusco, Hovan, Harper & Heppard, 2005). Policy coordination for bird avoidance procedures is incomplete. Policy organizations, decision makers and users are
poorly informed or unaware of potential solutions and the range of procedures and
bird avoidance techniques are incompletely defined. Sustained program funding for
long-term research, development and integration of a bird strike advisory system
does not currently exist, further slowing down the progress in development of a
real-time bird strike hazard advisory system (DeFusco et. al., 2005).

**Future Development**

Systems such as the USAF's Bird Avoidance Model (BAM) and the AHAS
system as well as the technological advancements of radar and communications
systems have made progress in addressing the problem of bird strikes. It has been
argued, however, that further advancements could be made if the current
competitive efforts could be consolidated in a single cooperative effort (DeFusco
et. al., 2005). A strategic plan to consolidate the US and Canadian military and civil
efforts in order to develop the North American Bird Strike Advisory System is the
initial step. If implemented the plan will be the first step leading to the realization
of the North American Bird Strike Advisory System that will help protect aviators
and their equipment from the deadly and costly effects of bird strikes, (DeFusco et.
al.). The North American Bird Strike Advisory System will be similar in
appearance to the US and Canadian national weather information systems. Real-
time information and predictions will be available on user-friendly, web-based
maps at North American, national, regional and local levels. During the system's
development process consultations with the international community will be
maintained to ensure global compatibility and standardization (DeFusco et. al.).
REFERENCES


37


Appendix A

AHAS risk prediction for Austin-Bergstrom Airport (TX) dawn, 2/24/98
AHAS risk prediction for John F. Kennedy Airport (NY), nighttime, 12/10/95
AHAS risk prediction for Orlando-Sanford Airport (FL), daytime, 1/27/07
AHAS risk prediction for Lorain County Regional Airport (OH), dusk, 9/1/05