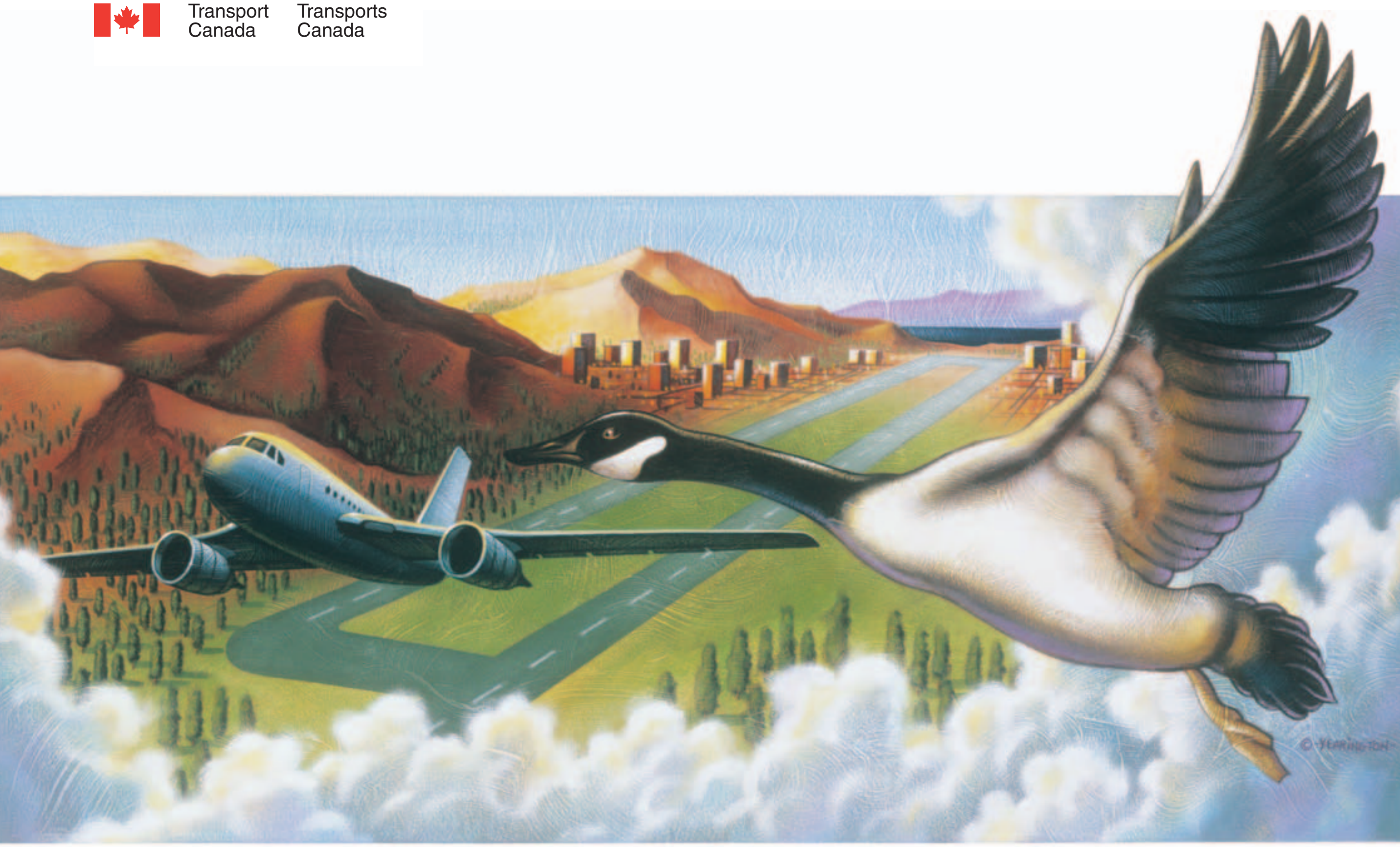
Transport Canada   Transports Canada



Sharing the Skies

An Aviation Industry Guide

to the Management of Wildlife Hazards

TP 13549 E

(03/2004)

Canada

ISBN: 0-662-36555-0

TP 13549E (Second Edition)
(03/2004)

Catalogue No. T52-4/6-2004E-PDF

Contents

Chapter 3

Chapter 4

Chapter 8

Chapter 9

Acknowledgements

Credit for this book belongs to the following people, without whose generous assistance *Sharing the Skies* would never have been completed:

Thomas Alge, Dr. John Allan, Major David Arrington, Dave Ball, Dr. Scott Barras, Nick Bartok, Jenny Bell, Dr. Hans Blokpoel, Reid Van Brabant, Bill Britt, Dr. Luit Buurma, Ed Cleary, Todd Curtis, Dr. Rolph Davis, Moyra Dhaliwal, Dr. Richard Dolbeer, Stewart Dudley, Martin Eley, Captain Paul Eschenfelder, Dave Fairbairn, Bob Grant, Dr. Edmund Hahn, Brian Hanington, Ross Harris, Iain Henderson, Laura Henze, Martyn Hexter, Ron Huizer, Capt. Sara Karcha, Adam Kelly, Terry Kelly, Art LaFlamme, Mario Larose, Harvey Layden, Eugene LeBoeuf, Hartmut Lehmkuhl, Dr. Yossi Leshem, My Luong, Red Mason, John Maxwell, Ian Martindale, Andrew McAllister, Major Kevin McCarthy, Ron Merritt, Paul McDonald, Caroline McKee, Robert O'Brien, Dr. Henri Ouellet, Dick Parker, Captain Robert Perkins, Alistair Pinos, Dr. John Richardson, Craig Richmond, Margaret Rudolph, Peter Roberts, Mark Rogers, Michael Robinson, Kristi Russell, Valerie Schmidt, Phil Scott, Gary Searing, Dr. William Seegar, Dr. John Seubert, Dr. Harlan Shannon, Jeff Short, Dr. Vic Solman, Captain Richard Sowden, Ralph Speelman, Arlo Speer, Terah Sportel, Anne Marie Taylor, Victor Thom, John Thorpe, Paul Tomlinson, Alan Tribble, Dena Warman, Darryl Watkins, Peter Watts, Heather Williams, Bonnie Wilson, Major Pete Windler, Sandra Wright, Bill Yearwood.

Special thanks are owed to Captain Richard Sowden, Dr. John Seubert and Captain Paul Eschenfelder: three individuals who made extraordinary contributions to this project.

Dedication

This book is dedicated to the memory of four close friends: Robert O'Brien, Dr. Henri Ouellet, Dr. Edmund Hahn and Roxy Labourne. All passed away well before their time, but during their lives contributed immeasurably to the management of wildlife-associated risk in the aviation industry.

Bruce MacKinnon
March 2004

Preface to the second edition

Much has changed in the world since the first edition of *Sharing the Skies* became available. In particular, the events of September 2001 had a profound impact on airports in virtually every nation. From a wildlife-management perspective, these impacts constitute fresh hazards—not of aircraft strikes against birds or mammals, but of airport owners and operators whose broader safety concerns may be eclipsed by terrorism-related security issues. (This distinction between preventing damage to life and property on the one hand (safety), and preventing acts of aggression on the other (security), is entirely my own, but seems accurate in the current climate.)

In preparing this second edition—examining emerging wildlife-management tools and techniques, reviewing facts and figures, and revisiting issues that were ongoing as we prepared the first edition—I have been reinvigorated by the conviction of airport wildlife-management teams at Canada's airports and in Transport Canada. The sheer weight of evidence, as it is revealed in this book, confirmed for me again that the risks of wildlife strikes at airports are real and growing.

More than ever, I believe that, as members of the aviation community, we must re-commit ourselves to addressing this issue. With a duty to uphold both safety and security, we must not be distracted from confronting the real risks posed by wildlife in the airport environment.

Bruce MacKinnon
March 2004
Ottawa

Foreword

While Canada's aviation system is one of the safest in the world, Transport Canada continues to look for innovative ways to achieve an even greater level of safety. In recent years, the department has devoted a great deal of effort to understanding how aviation accidents happen. Through extensive research and consultations with safety experts throughout the world, we have concluded that the most effective way to reduce aviation accidents is to adopt a systems approach to safety management—an approach that helps identify hazards, assign responsibilities among stakeholders, and reduce associated risks.

As *Sharing the Skies* so ably demonstrates, the systems approach is a crucial tool for managing hazardous interactions between wildlife and aircraft in the vicinity of airports. For example, some land-use activities near airports—such as waste-disposal sites—attract high-risk bird species and, therefore, directly impact aviation safety. Transport Canada strives for the holistic, proactive management of wildlife hazards by applying the system safety approach to engage all airport-area stakeholders, including community leaders, waste-disposal companies, farmers, airport authorities and airline operators.

Transport Canada is also developing performance-based wildlife planning and management regulations for airports—regulations that offer airport operators maximum flexibility to determine methods of compliance. In addition, and in light of research that shows a direct correlation between airspeed and bird-strike severity, other Transport Canada regulations were amended to reduce departure airspeeds to 250 knots for aircraft operations below 10,000 feet MSL (mean sea level).

I am proud to present the second edition of *Sharing the Skies*. First published in 2001, this industry guide is another crucial tool in Transport Canada's systems approach to managing safety. Sharing the Skies has been well received throughout the aviation industry. I believe this is compelling evidence not only of a growing appreciation for the risks associated with wildlife in airport environments, but also that Sharing the Skies is succeeding in raising awareness of an important safety issue.

Merlin Preuss
Director General
Civil Aviation
Transport Canada

How to Use this Book

Introduction

Sharing the Skies is a guide for everyone in the aviation community—a compendium of knowledge intended to generate both an understanding of and a reduction in the problems that arise when wildlife and aircraft interact. Whether you are a pilot, air-traffic service provider, air operator, wildlife manager, airport operator, regulator, aircraft or engine manufacturer, this book will provide you with valuable information on managing the risks associated with wildlife strikes.

You will gain the most knowledge by reading *Sharing the Skies* in its entirety; however, each chapter is written to stand alone and offer valuable specific information. We recommend all members of the aviation community read the Introduction as well as Chapters 1 and 2. The Introduction provides an overview of the nature and extent of the wildlife-strike problem. Chapter 1 will help readers develop an appreciation for both the high industry costs incurred through wildlife strikes, and the extensive liability issues associated with the problem. Chapter 2 explains the fundamental importance of the System Safety Approach in wildlife-risk management.

Sharing the Skies is not an operational manual. Readers seeking guidance on the management of individual wildlife species in airport environments are directed to such publications as Transport Canada's *Wildlife Control Procedures Manual*.

Accessing the information you need

This book is structured to both describe the wildlife-strike problem and prescribe solutions.

Chapters 1 - 7: Descriptive Overviews of Relevant Topics	
Chapter 1	Wildlife Costs
Chapter 2	Wildlife-strike Prevention and the System Safety Approach
Chapter 3	Birds

Chapters 1 - 7: Descriptive Overviews of Relevant Topics (cont'd)	
Chapter 4	Mammals
Chapter 5	The Aviation Industry
Chapter 6	Airport Operations
Chapter 7	Wildlife-strike Statistics

Chapters 8 - 12: Prescriptive Wildlife-strike Recommendations and Solutions	
Chapter 8	Airport Operators
Chapter 9	Air Traffic Service Providers
Chapter 10	Flight Crews
Chapter 11	Air Operators
Chapter 12	Engine and Airframe Manufacturers

Chapters 13 - 15: Supplementary Information and Conclusions	
Chapter 13	The military perspective on wildlife strikes
Chapter 14	An overview of new technologies that may provide solutions to wildlife-strike problems in the future
Chapter 15	Conclusions and suggestions for further efforts to reduce risks associated with wildlife strikes

Appendices A - E: Supplementary Reference Material	
Appendix A	Information on various bird-strike committees
Appendix B	Metric and Imperial conversion factors
Appendix C	How to report bird and mammal strikes
Appendix D	Aviation- and wildlife-management regulatory references
Appendix E	A list of suggested references (Bibliography)

Relevant Reading by Specific Discipline		
Segment of Aviation Community	**Understanding the Wild-strike Problem**	**Managing the Wildlife-strike Risk**
Airport Operators	Chapters 3 - 7	Chapters 8 & 14
Air Operators	Chapters 5 - 7	Chapters 9 - 11
Wildlife-management Personnel	Chapters 3 - 7	Chapter 8 & 14
Air Traffic Service Providers	Chapters 5 - 7	Chapter 9
Engine & Airframe Manufacturers	Chapters 5 - 7	Chapters 12 & 14
Pilots	Chapters 5 - 7	Chapters 9, 10 & 14

Terminology and conventions

The authors refer generally to Air Traffic Control personnel, Flight Service Specialists and Air Traffic Services personnel as ATS providers. We define a hazard as the conditions or circumstances that could lead to damage or destruction of an aircraft, or to loss of life as a result of aircraft operations. Risk is defined as the consequence of a hazard, measured in terms of likelihood and severity.

In aviation and biology, both the Imperial and Metric systems of measurement are used, therefore both systems are incorporated in this publication. Imperial and Metric conversion tables are provided in Appendix B.

Throughout the book, currency references are in Canadian dollars unless otherwise noted.

Finally, while *Sharing the Skies* gathers information from numerous sources, the authors have avoided the excessive use of footnotes and references in an effort to ensure concision and readability. Nevertheless, an exhaustive bibliography in Appendix E provides a chapter-by-chapter list of references.

Introduction

While birds, mammals and airplanes may seem to peacefully share the space at and around airports, their co-existence is burdened with extreme risk. In the case of a collision with an aircraft, a single animal has the potential to cause severe damage, leading in some cases to the loss of the aircraft, its crew and passengers.

If one were to assess the risk associated with wildlife strikes based only on the accident record of jet transport aircraft in the western world, it would be easy to conclude that related problems are negligible. And yet the closer examination of available statistics by industry professionals who are intimately involved in wildlife-hazard management provides a sobering assessment of the current wildlife-strike risk.

In this book we will demonstrate that the wildlife-strike risk is very real and demands serious consideration by the aviation industry, particularly considering the remarkable increase in the populations of some large flocking birds during the past few decades, as well as the associated increase in aircraft numbers and activity.

Aviation-industry professionals are acutely aware that the public has no tolerance for accidents involving large jet-transport aircraft. In spite of the industry's impressive safety record, the fatality/injury ratio and fatality densities associated with aviation accidents continue to capture widespread attention. The public outcry, media focus, family outrage, and ongoing litigation that will inevitably result from a wildlife-caused jet-transport accident in the western world motivates many managers to do whatever is necessary to avoid the experience.

Generally speaking, aviation-industry professionals are highly motivated, innovative and technically oriented. They are accustomed to dealing with issues that, while often extremely complex, can for the most part be addressed by engineering solutions. Finding solutions to wildlife-associated hazards, however, also requires application of the natural sciences. Only when a proper balance is struck between these two disciplines will the industry myth be dispelled that wildlife hazards are an act of God.

We believe that the risk associated with wildlife hazards, while currently under-recognized, can be managed economically and effectively. We hope that you will apply the lessons of this book and improve the management of wildlife risks within your segment of the aviation industry.

A history of bird and mammal strikes

Bird strikes have been an issue since the earliest days of manned flight. In their diaries, the pioneering Wright brothers recorded what was likely the first strike following a 4,751-metre flight over cornfields near Dayton, Ohio, on September 7, 1905. In fact, the pilot twice encountered flocks of birds during four circuits of the area. (While the Wrights did not record the species struck, it's likely Red-winged Blackbirds may have been involved; major pests during September in Ohio, these birds attack ripening corn in large flocks.)

The first recorded human fatality resulting from a bird strike occurred in 1912. Cal Rogers, the first man to fly across the United States, crashed into the ocean after a gull became jammed in his aircraft's flight controls. Since then, bird strikes have become an increasingly serious problem in both civil and military aviation, with many thousands of strikes occurring every year.

Since 1912, available data shows that more than 223 people have been killed worldwide in at least 37 bird-strike related civil-aircraft accidents. In addition, a minimum of 63 civil aircraft have been lost as a result of bird-strike related accidents. In military aviation, the number of documented serious accidents since 1950 exceeds 353, including a minimum of 165 fatalities. Experts are convinced that bird-strike statistics are vastly under-reported, and that the true numbers of accidents and fatalities are much higher. There are many reasons for this under-reporting:

- There are no consistent worldwide standards.
- Wildlife-strike reporting is not mandatory.
- Some countries are reluctant to publish such statistics out of concern for liability and negative public perception of flight safety.
- In some parts of the world, information on serious accidents is lost for a variety of reasons, including a level of media attention lower than that we are accustomed to in the western world.

To highlight the unreliable nature of data associated with bird-strike accidents, consider the April 2000 crash of an Antanov AN-8 that collided with birds on takeoff from Pepa, Congo. Few details of this accident are available, despite the death of 21 people. In some regions of the world, neither the funds nor the expertise exist to permit proper investigations.

Accidents waiting to happen

The bird-strike problem is a global one. Although the types of aircraft and species of birds involved in strike incidents vary from region to region, the population of some bird species and the number of aircraft sharing the skies is increasing everyday—in every corner of the globe.

While birds can be struck in the air or on the ground—as an aircraft takes off or lands—virtually all collisions with mammals occur on the ground, with the exception of those with bats. The number of collisions between aircraft and mammals is not nearly as large as the number of bird strikes, but given the comparatively greater weight and size of mammals, the resulting damage from a mammal strike can be serious.

A flight-safety problem that's here to stay

The risk that a multiple bird strike will result in the crash of a large airliner, while statistically low, is slowly rising and cannot be ruled out. The loss of life would be catastrophic.

Real economic losses are already mounting. Although difficult to estimate accurately, the total cost of wildlife-strike damage—according to the best available industry estimates—likely involves many millions of dollars a year for Canadian civil aviation alone.

Bird and mammal strikes will continue to be a safety issue for many reasons:

- The number of aircraft and flight movements are increasing worldwide.
- The populations of a number of high-hazard bird species are increasing.
- The populations of some mammal species are on the rise.
- Urban encroachment on airports forces birds to use the relatively safe airport environment and its associated arrival and departure paths as the only remaining open space.
- Wildlife-management procedures at airports are unlikely to succeed in keeping the airport completely free of birds and mammals.
- Detecting airborne birds in time to avoid a collision is often not feasible.

Wildlife-strike risks can be reduced

Wildlife biologists have recently become more influential at the decision-making level in the aviation industry. These experts have strenuously argued that wildlife strikes are, for the most part, not acts of God. Rather, such incidents are usually the results of careless management of either wildlife or habitat at and near airports, or are caused by inadequate timing, planning and execution of flight profiles.

There is not, nor will there ever likely be, a single solution to the wildlife-strike problem. However, this costly flight-safety dilemma is manageable to a certain extent. Through application of a system-safety approach and a coordinated effort by the aviation community, the number of fatal accidents and costly incidents can be minimized.

Careful use of state-of-the-art wildlife-management techniques and current technology to detect hazardous bird movements can provide timely information and warnings to flight crews. Enhanced bird- and mammal-impact protection of aircraft and engines can have a measurable effect on reducing the risk and associated costs—both human and financial—that bird and mammal strikes incur.

Sharing the Skies: A new look at the wildlife-strike problem

There is an abundance of literature, in many languages, dealing with the various aspects of collisions between aircraft and wildlife. This literature provides excellent sources of information but tends either to address limited aspects of the problem or concentrate on a solely biological or engineering solution. To date, no single industry publication has been written to provide a comprehensive overview of the wildlife-hazard issue.

For many years, Transport Canada has raised industry awareness of this safety problem through education. The department was involved in writing *Bird Hazards to Aircraft* (Blokpoel, 1976) and has since produced the *Wildlife Control Procedures Manual* (Transport Canada, 1994). An Internet website (www.tc.gc.ca) has also been developed, along with a series of Wildlife Bulletins, posters and videos dealing with bird-strike problems at Canadian airports.

Transport Canada recognized recently the need to publish a new, practical, comprehensive and user-friendly guide to managing wildlife hazards, prompted by the following developments:

- A recent analysis of bird- and mammal-strike statistics indicates much higher damage costs than previously estimated.
- Several recent fatal accidents have involved large, military versions of civilian jet transport aircraft.
- The recent population explosions of some high-hazard bird species.
- The increasing complexity of managing wildlife populations due to concerns expressed by wildlife conservation groups.
- The opportunity to include the latest available wildlife-strike research.
- The evolution of Transport Canada's role from operator, regulator and service provider to regulatory body.
- Privatization of the Canadian civil-aviation system has resulted in private-sector operation of airports and the air-navigation system.

Sharing the Skies presents aviation professionals with relevant and comprehensive background information on the nature and magnitude of the wildlife-strike problem. The book also describes and recommends effective strategies to reduce the risk associated with wildlife strikes.

A valuable resource for all aviation professionals

Sharing the Skies is published by Transport Canada and is written primarily as a tool for aviation professionals within Canada and the U.S., where the majority of the world's air-traffic activity takes place. However, the authors recognize that wildlife strikes occur worldwide. A great deal of excellent work has been done in Europe, Israel and other parts of the world, and we make reference to those efforts in various chapters. We trust this book will be of use and interest to a global audience.

Chapter 1

Wildlife-strike Costs and Legal Liability

Introduction

Operating costs in the aviation industry are extremely high, competition is fierce, and in most cases profit margins are small. If resources are to be devoted to the reduction of aircraft damage caused by bird- and mammal-strikes, only a sound business case will ensure the allocation of those funds. This chapter takes the first step toward building that case by explaining the variables that affect the costs of wildlife strikes.

Acknowledging that legal liability is a crucial aspect of wildlife-strike costs—particularly in the event of a complete aircraft loss that includes human fatalities—this chapter also provides a basic review of the concept of liability and how it applies to wildlife risk.

An impact-force equation

The cost of a wildlife strike is directly related to the part of the aircraft damaged and the magnitude of the damage, which is determined by the impact force created by the collision between the aircraft and bird or mammal.

A precise impact-force calculation includes impact speed, bird weight, density, dimensions and configuration, as well as angle of impact. Expressed in an equation, impact force is proportional to bird mass and the square of impact speed (see Appendix 12.1 for additional information on impact force). Applying actual figures, a 4 lb bird that strikes an aircraft traveling at 250 kts will deliver an impact force of approximately 38,000 lbs. At an airspeed of 400 kts, the force increases to 100,000 lbs.

All forward-facing parts of aircraft are at risk of being struck by birds. Aircraft undersides and landing gear are also in danger of impact during takeoff and landing, when aircraft are at higher pitch angles. Close to 75 percent of reported bird strikes, where altitude was reported, occurred within 500 feet of the ground. Mammal strikes, with the exception of those involving bats, are limited to the takeoff and landing roll phases of flight. Transport Canada data show that, where phase of flight was reported, about 90 percent of wildlife strikes occurred during the takeoff and landing.

Part Struck	% of Reported Strikes (where part identified)	Part Struck	% of Reported Strikes (where part identified)
Nose	19	Radome	4
Wings	13	Empennage	2
Engines	13	Tail	1
Fuselage	11	Lights	1
Landing gear	9	Pitot head	1
Windshield	7	All others parts	15
Propellers	4		

Table 1.1- Part of the Aircraft Struck in Bird Strikes—Canada and U.S. (1991-1999)
Note that the proportion of wildlife strikes involving engines has been gradually increasing over the past several years. This is likely due to the greater frontal areas of larger fan engines in increasing use on commercial jet airliners.

Where the aircraft are taking the hits

The most recent data from Canada and the U.S.—presented in Table 1.1—indicate that, on average, the aircraft parts struck most frequently were the nose, wing and engine.

The high costs of wildlife-damage to aircraft

A number of parameters must be considered when assessing the level of damage that might occur to a turbine engine:

- Size and weight of the bird
- Aircraft speed
- Engine type
- Diameter of the inlet
- Power setting of the engine
- Exact location of the strike on the aircraft

Let's examine how wildlife strikes affect various aircraft components:

Jet engines

Most individual small birds struck by jet engines are destroyed by the blades of the first stage and pass through the interior of the engine without causing any significant damage. A single strike by a medium-sized bird, and multiple strikes of small birds, frequently result in some engine damage. Blades in the first fan stage may be bent or deformed. Several blades may break in the event of a more serious strike by single or multiple large birds. The broken blades can be ingested into the engine, damaging subsequent engine stages, and possibly leading to complete engine failure or destruction. In a few cases, this has led to an uncontained failure of the engine.

Engine parts, expelled through the engine cowl, can also cause damage to other parts of the aircraft's systems or structure.

Two conclusions emerge from the increased use of large high-bypass ratio turbofan engines:

- The greater overall engine frontal area increases the chance of single or multiple strikes with flocking birds.
- With up to 80% of inducted air bypassing the gas-generating core of an engine, a portion of bird debris is often directed away from more vulnerable engine components.

In spite of design improvements, the net result is that these new engines suffer damage nearly as often as early generation models.

Today's jet engines are finely balanced precision machines. Ingesting a bird, no matter how small, requires an inspection at the very least. Even minor damage to the first-stage fan section can result in significant costs (USD$16,000 for a new blade in a CFM56 engine) to repair or replace the damaged fan blades. The cost to replace an engine often climbs to several million dollars. In this case, the aircraft will be out of service for a minimum of one day.

Piston, turboprop and turboshaft engines

These engines are generally less susceptible to serious damage from bird strikes. The inlet areas are substantially smaller than those of turbofan engines, and the

Photo courtesy Capt. Peter Miller, Kroger Co.

Uncontained engine damage to this Falcon 10 business jet resulted from ingestion of ducks at Lunkin Airport, January 25, 1999.

propeller or rotor blades provide some protection by deflecting bird debris away from engine intakes. Normally, mammal strikes to these types of engines do not directly result in engine damage. Damaged propeller blades, however, can bring catastrophe. With an unbalanced load, the engine can be severely damaged and may separate from its mounts.

Windshields

The results of windshield strikes range from small bloody smears to large-scale shattering. In a number of cases, when complete penetration has occurred, bird remains and windshield pieces have caused injuries and even death to crew members.

In piston-powered aircraft and helicopters, windshields are often made of a light plexiglass material that is not certified to withstand any significant impact from a bird strike. Even though these aircraft operate at lower speeds than jets, and impact forces of bird strikes are diminished, there have been numerous instances of shattered windshields and cockpit penetrations. Single-engine piston aircraft are somewhat less vulnerable to windshield strikes because of the protection provided by the engine and propeller. In the case of helicopters, the very large windshield area poses more of a risk. In addition, helicopters frequently spend a higher proportion of their total flight time at low altitudes where greater numbers of birds fly.

Windshield replacement costs can be as low as $2,000 for general-aviation aircraft, and as high as $100,000 for a large jet aircraft. Repair or replacement times can range from a few hours to several days, depending on the damage to the surrounding airframe structure.

Wing and tail structures

A strike to the leading edge of the wing or tail components can result in a dent or hole in the skin and possibly torn or crumpled metal. If the bird is sufficiently heavy or dense, and the aircraft speed high enough, the animal may penetrate far enough into the aircraft structure to damage the spar and control cables or hydraulic components. Many wing designs incorporate the use of lift augmentation devices, such as flaps or slats, on either the leading or trailing edge of the wing. These too can be damaged by a bird strike. Damage-repair costs can be negligible in the case of a small dent that requires dressing out, but staggering if significant damage occurs to critical structures or systems.

Landing gear

At first glance, aircraft landing gear appear to be very strong components capable of absorbing significant loads during landing. However, closer examination shows that the main landing gear used on today's aircraft include a number of vulnerable components such as hydraulic lines, electrical cables, solenoids and micro-switches. Rarely does a bird strike lead to significant structural damage to the undercarriage. However, in the case of mammal strikes, particularly deer, undercarriage damage can be severe. Repair costs to undercarriages range from a few hundred dollars for the replacement of damaged hydraulic lines and micro switches to over $100,000 for structural damage to the main landing-gear components.

Piper PA-44 after impact with a Black Vulture at 2000 ft AGL and 140 knots near Daytona Beach, Florida, in October 2000.

Other components

As described in Table 1.1, many other aircraft parts are damaged—with varying repair costs and times—as a result of bird and mammal strikes. These other components include radomes, landing lights and pitot tubes. Replacement costs for these parts can be thousands of dollars, and repair times range between several hours and several days.

Delayed-effect damage

One of the more sinister results of bird strikes is damage that is not immediately apparent or detected. There are documented cases in which aircraft engines struck by birds subsequently failed on later flights, despite basic visual inspections that detected no damage. Frequently, damage is not detected until the aircraft undergoes periodic inspection, and non-destructive testing is carried out on disassembled aircraft parts.

Broader cost repercussions of wildlife strikes

The total cost of a wildlife strike is the sum of the direct, indirect, ancillary, hull-loss fatality and legal liability costs.

Direct costs

The direct costs refer to those incurred in the repair or replacement of damaged parts, and include the actual cost of the parts, labour and the overhead cost associated with the labour.

Industry data on these direct repair costs are available, but limited analysis has been done to isolate wildlife-strike repair costs from other foreign object damage (FOD) costs. The under-reporting of wildlife strikes suggests that the amounts indicated in related repair-cost data will be low. Available data does indicate that repair costs resulting from wildlife strikes are significant. H. Lehmkuhl, of the insurance division of Lufthansa German Airlines, found that in the 10-year period from 1985 to 1994 the airline experienced 2,637 bird strikes, of which 807 (31%) caused damage. During the last five years of this period, the average direct cost of damaging strikes was 45,794 German Marks, or about $31,600. (Lufthansa is unique in compiling complete information on bird strikes involving its aircraft.) In the United States, the Federal Aviation Administration (FAA) reports an average direct cost for damaging strikes between 1991 and 1999 of approximately USD$90,000. These figures do not include any complete hull-loss accidents.

Indirect costs

Wildlife strikes can also generate a vast number of indirect costs for aircraft operators. Indirect costs are influenced by the extent of damage to the aircraft, distance from the operator's nearest repair base, size of the airline fleet and the operator's type of business (passenger, cargo, charter). Indirect costs can include some or all of the following:

- Fuel used and dumped during precautionary and emergency landing procedures
- Transporting replacement parts and mechanics to the site
- Accommodation and meal costs for repair crews
- Accommodation, compensation and meals for stranded passengers and flight crews
- Replacement aircraft
- Replacement flight crews
- Missed connections and re-booking passengers on alternate flights, often with other carriers
- Delaying effects on highly integrated airline schedules, particularly for airlines employing major hub-and-spoke operations
- Replacement of damaged aircraft on subsequent scheduled flights until repairs have been made
- Downtime costs of damaged aircraft
- Contractual penalties for late delivery of freight
- Lost business opportunities for delayed passengers
- Loss of passenger confidence and goodwill

The indirect costs of bird and mammal strikes are not well documented. Some of the examples listed above are not tracked by airlines. Lufthansa's H. Lehmkuhl concluded that in many—if not most—cases, the indirect costs associated with a damaging bird strike are greater than the direct costs. However, as an example of the magnitude of some of the above costs, current information shows that flight delay costs can run as high as USD$15,000 per hour. The cost to an airline of a passenger missing a long-haul transcontinental connecting flight can exceed $3,000. Data compiled by the

FAA supports the contention that indirect costs exceed the direct costs when aircraft downtime is included. In fact, it is commonly accepted within the industry that indirect costs exceed direct costs by a factor of four.

Ancillary costs

Ancillary costs are incurred by the airport owner or operator, regulatory authorities, other airport users and emergency-response agencies that must deal with the results of bird or mammal strikes. Ancillary costs include:

- Runway closures
- Airport emergency response
- Off-airport emergency response by ambulances, fire fighters, police, hospital emergency-room standby
- Runway clean-up and repairs
- Flight arrival and departure delays
- Additional fuel used by aircraft during delays
- Airport wildlife-management programs
- Off-airport search and rescue service
- Accident investigations and safety reviews
- Liability insurance
- Administration of regulatory agencies involved with bird and wildlife hazards

Ancillary costs are rarely considered in the analysis of wildlife strikes, although some estimates are available. Costs associated with flight delays have been estimated at between USD$6,000 and USD$15,000 per hour. The cost of major accident investigations such as those for TWA B747 off Long Island, New York, and the Swissair MD-11 off the coast of Nova Scotia, Canada, can exceed several million dollars.

Hull-loss and fatalities costs

Although military aircraft have not been so fortunate (see Chapter 13), there are no known recent aircraft hull-loss accidents involving large civilian passenger jets caused by wildlife strikes. Numerous close calls, however, support the concern that a catastrophic bird-strike accident may happen in the near future. The costs associated with such an accident would be astronomical. New-aircraft costs are steadily rising. In 1996, there were over 1,000 aircraft in operation or on order, valued at over USD$100 million each. A new Boeing 747-400 is valued at more than USD$250 million. Recent passenger-liability awards in the U.S. approach $2.5 million per passenger death—amounts that are not likely to decline. Applying these figures, the cost of a bird-strike accident resulting in the loss of a new B747 or similar large aircraft carrying 300-400 passengers could easily exceed USD$1 billion—costs directly associated with an accident and the resulting legal liabilities. As noted earlier, indirect and ancillary costs can also be significant. Even a fatal accident involving an older model narrow-body passenger jet such as a B737-200 or a DC-9 could easily incur costs approaching USD$100 million.

The total annual cost of bird and mammal strikes

At this time, it is not possible to accurately determine the annual cost in any major jurisdiction of bird and mammal strikes to the aviation industry. The required data are either not available or have not been assembled. Several attempts have been made to determine costs in various jurisdictions, but each attempt has shortcomings due to a lack of critical data.

Most available damage-cost information relates to airline and other multi-engine, turbine-powered, commercially operated aircraft. There is little information about damage costs for helicopters and even less concerning damage costs for general-aviation aircraft, which comprise approximately 339,000 privately registered aircraft worldwide. Available estimates of the annual damage costs from wildlife strikes are also dramatically skewed by major hull-loss accidents, which can greatly inflate damage-cost statistics for a given year. Properly documented multi-year data is needed if the industry hopes to determine true long-term average costs.

In spite of limitations, available data still provide sufficient proof that wildlife-strike costs are a significant portion of an airline's annual aircraft-operating costs. Anecdotal reports provided by executives from a failed North American start-up airline indicate that the cost associated with bird-strike damage to their fleet was a contributing cause of their failure. Recent information supplied by airline executives indicates that 40 percent of United Airlines' annual costs from FOD were incurred as a result of bird strikes. Robinson (1996) reported that one U.K. airline estimated that birds accounted for about 20 percent of FOD costs. If we estimate 30 percent across the industry as a whole, then the total cost is between USD$64 million and USD $107 million, based on estimated aviation-industry FOD costs of approximately USD$320 million per year.

Again, these are only direct costs. Aviation wildlife-management experts believe that if all other costs associated with wildlife damage are included, then a conservative estimate of the annual cost to the North American aviation industry exceeds $500 million.

Legal liability

In the past, bird strikes were often considered to be acts of God. As a result, in accidents involving bird strikes, no one could be held responsible. Thanks to the work of many natural-science professionals, the idea that wildlife cannot be managed is gradually being recognized as a myth. The behaviour patterns of some bird and mammal species adjacent to airports are reasonably predictable. These patterns can often be changed through appropriate management interventions based on the results of comprehensive wildlife studies. By declining to introduce measures to reduce the numbers of hazardous birds and mammals at and near airports, the responsible organizations and individuals expose themselves to potential liability. This is demonstrated in a brief overview of the concept of liability and the applicable Canadian legislation presented below.

Negligence and liability

The basic principle of liability depends on the proof of negligence. Parties are considered negligent when they act without due care, or when they fail to act, and a person, or persons, whom they ought to have considered, either is affected by their actions or their failure to act. Should a plaintiff prove that a defendant was negligent in their duties, then that defendant will be liable for damages incurred.

Liability has both criminal and civil classifications. The penalties for criminal liability include fines and incarceration. Civil liability penalties in Canada are limited to a requirement to make restitution for the damages incurred. However, in some jurisdictions—particularly the U.S.—civil liability also involves the levying of substantial punitive damages. As discussed earlier, damage costs in the event of a major hull loss assessed against one or more parties could exceed USD$1 billion should negligence be proven.

It's important to understand that the concepts of negligence and liability apply to all persons and business entities associated with aircraft operations including—but not limited to—airport operators, ATS providers, pilots, airport employees and airport wildlife-management contractors. Even non-aviation related industries can be affected; waste disposal contractors are an example.

Canadian law

In Canada, safe aircraft operation is governed under law by duties and responsibilities—summarized below—imposed on owners, operators and users of aircraft and airports.

Duties and responsibilities in Common Law

Common law relies on precedent, and centres on two key phrases: *duty of care* and *duty to warn*. The principles applied to determine whether duties and responsibilities have been adequately discharged are *reasonableness* and *due diligence*. A full explanation of these terms would occupy many pages, but the basic concepts are fairly simple. With respect to cases stemming from wildlife-strike incidents, reasonable care must be applied to ensure that an aircraft is operated safely; those responsible must be diligent in availing themselves of up-to-date information and technology that provides adequate warning of any hazards.

For airport operators, this means minimizing the risk of wildlife strikes to aircraft by instituting and maintaining a wildlife-management program and making flight crews aware of unmanaged wildlife risk. Similarly, ATS providers are also responsible both for warning pilots of wildlife hazards at an airport and communicating wildlife activities to airport wildlife-management personnel. Pilots are responsible for adjusting flight operations to avoid known hazards, and for advising airport operators of dangerous situations. Everyone associated with aircraft operation must show due diligence when conducting respective tasks.

Duties and responsibilities agreed and/or imposed by contracts

Contracts impose duties and responsibilities on all signatories—duties and responsibilities that can extend beyond the contracting parties. For instance, contractors providing wildlife-management services to an airport operator may also find themselves responsible for damage that occurs to aircraft operating at the airport. Airport operators are responsible for monitoring the effectiveness of the airport wildlife-management program, and must ensure that contractors meet their obligations.

Particular care must also be taken when defining contracts between airport operators and tenants. Failure to control tenant actions that create hazards may lead to liability for the airport operator should an accident occur.

Duties and responsibilities imposed by Occupiers Liability Legislation

Airports in Canada are similar to all property in that they are governed by individual provincial or territorial legislation. The Ontario Statute, *The Occupiers' Liability Act* (R.S.O. 1990, c.322), is quoted below and provides an example of the principles embodied in the act.

> 3. (1) an occupier of premises owes a duty to take such care as in all the circumstances of the case is reasonable to see that persons entering on the premises, and the property brought on the premises by those persons are reasonably safe while on the premises.
>
> (2) The duty of care provided for in subsection (1) applies whether the danger is caused by the condition of the premises or by an activity carried on the premises.

Note also that there is a clause in this legislation that states "*where an occupier has duties imposed by the legislation, they may not be restricted.*" This means a contract cannot contain disclaimer language that avoids obligations imposed by the legislation.

In applying this Act, the terms *airport owner, operator* and *user* are referred to in the legislation as *occupiers*, *invitees* and *licensees*. In the simplest terms, an airport operator is an *occupier* and the airline is an *invitee*. The fact that the airport operator collects landing fees from the airline—and has invited the airline to use the site—imposes a significant responsibility on the airport operator to manage a safe facility.

Legal-liability case studies

These case-law examples may help illustrate the concepts of civil and criminal liability as they apply to wildlife strikes:

Falcon 20 — Norwich, England 1973

On December 12, 1973, a Falcon 20 business jet with nine people on board struck Common and Black-headed Gulls just after takeoff from Norwich airport. The strike caused severe damage to both engines. One minor injury resulted from the crash, which destroyed the aircraft. The judge presiding over the case wrote that the Defendants (the airport operator) owed the Plaintiffs (the aircraft operator and occupants) the common duty of care—a duty to take such care when carrying on their activities at the airport as was reasonable in the circumstances. After weighing the considerable evidence, the Judge decided that the Defendants failed in their duty, and that there must be judgement for the Plaintiffs for damages. In other words, the airport operator failed to show due diligence in managing the airport's bird hazards.

Sabreliner — Watertown, USA 1975

On June 14, 1975, a NA265 Sabreliner twin-engine jet ingested gulls in both engines at rotation from the Watertown airport. The aircraft crashed. Both wings were torn off and a severe fire ensued. Three of the six people on board were injured and the aircraft was destroyed. The Safeco Insurance Company brought an action against the airport operator, the City of Watertown. The court maintained that the proximate cause of the crash was the failure to warn the pilot of the presence of birds. Judgement for the full value of the destroyed aircraft was entered against the airport operator.

Concorde — New York, USA 1995

An Air France Concorde struck Canada Geese while landing at John F. Kennedy International Airport on June 3, 1995. Two of the four engines on the supersonic jet caught fire and were destroyed. Air France sued the airport operator (Port Authority of NY & NJ) for the USD$6-million cost of the two engines. After significant legal costs for both sides, the parties settled on the eve of the trial for a reported USD$5.3 million. There is anecdotal information indicating that in spite of a sound wildlife-management program, the airport failed to warn the flight crew of known Canada Goose activity.

Falcon 20 — Paris, France 1995

In the fall of 1998, French authorities laid charges of involuntary manslaughter against the Paris Airport Authority and three former officers for their roles in an accident at Le Bourget airport. The charges related to the crash of a Dassault Falcon 20 business jet that struck Lapwings during takeoff from the airport on January 20, 1995. The pilot was unable to control the aircraft after the ingested birds destroyed the left engine. The aircraft crashed, killing all 10 people on board. A subsequent inquiry found that staff failed to perform routine bird-scaring operations prior to the accident. The airport authority was accused of "*negligently failing to follow normal security procedures.*" The disposition of the case is not known at this time.

Summary

In this chapter, we have attempted to build the business case that will support resource allocation and reduce the likelihood of wildlife strikes to aircraft. For the aviation industry, two key messages are clear:

- Damage associated with wildlife strikes costs millions of dollars each year.

- Courts in several jurisdictions have indicated that failure to exercise due diligence in managing wildlife hazards will result in both civil and criminal liability judgments. (Note that a number of other cases have resulted in settlements protected by non-disclosure agreements. To the best of our knowledge, no settlement or judgment has been made in favour of the defendant.)

Chapter 2

Wildlife-strike Prevention: The System Safety Approach

Using a comprehensive process that focuses on the accident to be prevented.

Introduction

The following script is not from a Hollywood work of fiction—it's real, and presents some of what happened in June 1993. As the early morning sun warmed the air, making it feel heavy after a recent rainfall, a Canadian Airlines B-737 moved along the taxiway at Calgary International Airport in preparation for takeoff. We pick up the conversation between the pilots:

" We've got a full load this morning: 110 passengers and 12,400 lbs of fuel."

" Yeah, this flight's always a full one. Let's see if we can save a few minutes and get runway 28 for takeoff."

A moment later:

" ATC says there'll be no problem with getting runway 28."

" Great. Have you noticed the number of gulls around these days?"

" Yeah, look at all those over there on Foxtrot."

With the before-takeoff checks completed and takeoff clearance received, the pilot turned on the landing lights and moved the thrust levers forward. The aircraft accelerated down the runway, a beautiful view of the Rocky Mountain foothills filling the windscreen.

" V_1."

" Roger."

" Rotate."

The aircraft lifted and then seemed to pause nose-high before the crew felt the main wheels lift from the pavement. Then the normal routine was suddenly shattered… by gulls.

The pilot-in-command later described flying into a "sea of white." He remembered loud noises, strange smells, a muffled curse, and then—as suddenly as the sky had gone white—there was clear blue sky ahead. But the aircraft was sinking; it had taken numerous serious strikes.

Both pilots watched the needle on the vertical speed indicator slowly climb. Once a positive-climb rate was established, they raised the landing gear. Then it was time to assess their situation. The left engine was surging and torching flames from its exhaust. At 400 ft AGL, they eased the left thrust lever back. The airspeed stabilized in the climb. They slowly accelerated, raised the flaps and felt the drag reduce. They banked the aircraft and started a slow, climbing turn to return to the airport. They leveled-off near 2000 ft AGL but there were increasing vibrations on the right engine—the engine that was keeping them in the air. There was no choice but to ease back on its power lever and track downwind to the landing runway.

Once around, the pilot lowered the nose and turned the aircraft to line up with the runway. The crew could see the crash trucks moving into position. Moments later, it was over—they had landed safely. The pilots cleared the runway and shut down the left engine before taxiing to the ramp.

In hindsight, it could be argued that there was a greater than normal probability of a near-catastrophe occurring that day. But it's a fair bet that the pilots of Canadian Airlines Flight 661 didn't know that. They probably didn't know there was a major gull-breeding area northeast of the airport, and that the gulls flew daily to feed at landfill sites to the southeast and northwest. Nor could they have known that the unusually wet summer had led to a number of changes in the airport wildlife-management program. The pilots didn't know that during the two hours preceding their takeoff, the airport duty manager and ATS providers had detected several large flocks of gulls in the vicinity of runways 28 and 34. The ATIS (Automatic Terminal Information Service) recording heard by the crew of Canadian Airlines Flight 661 did not include the bird-activity warning that had been on the ATIS just an hour before their departure. They would not have known that ATS providers and airport operational staff were often hampered in detecting stationary and low-flying birds because of tall grass and a lack of colour contrast in the airport's undulating terrain. And almost certainly the crew did not know their aircraft was at greater risk of a bird strike because they were the morning's first departure from runway 28, a runway where birds often settled. The application of a System Safety Approach might have ensured the crew of Flight 661 knew all these things.

The System Safety Approach

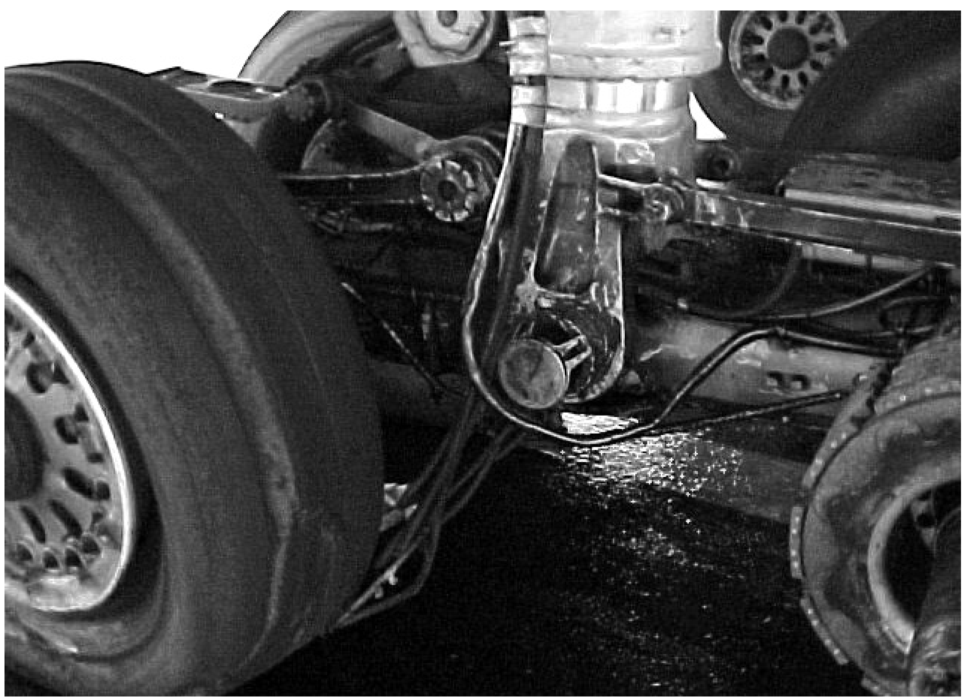
The *only* way to prevent wildlife strikes is through the careful application of a System Safety Approach—an approach that systematically and proactively involves all stakeholders.

System safety is outcome-based: to prevent an accident, the approach is used to identify all of the complex, interwoven events that can lead to an accident. Within the system, specific responsibilities are distributed among various stakeholders—responsibilities that are closely linked. As long as all stakeholders fulfill their roles, the system remains intact, and safety is ensured.

From its origins in aerospace engineering after the Second World War, system safety has been adopted by numerous and diverse industries—accepted as a best-business practice and an assurance of demonstrated due diligence in industries where failure can lead to catastrophic losses.

Wildlife strikes: a dynamic risk-management challenge

The risk of a bird or mammal strike is greatest when an aircraft is operating on the ground or in the lower altitudes, where wildlife hazards are most prevalent. The risks



January 2001 in Portland, Oregon. Damage to an MD-11 following rejected takeoff due to bird strike. The aircraft struck a gull at V_1 (167 kts). Other damage included a detached cowl and destruction of one engine.

are most serious when an aircraft is taking-off and climbing, as was the case in the Calgary occurrence. According to data from Boeing and the U.S. NTSB (National Transportation Safety Board), 50 percent of all high-speed RTOs (rejected takeoffs at speeds in excess of 120 kts) are caused by bird strikes.

When an aircraft operates at its maximum operating weight, carrying the many tons of fuel it will burn on the flight, it is close to the edge of the certified performance envelope. A bird strike on the takeoff roll just before or at V_1 forces the flight crew to make a split-second decision to reject or continue the takeoff. If the decision is to reject the takeoff, the brakes, wheels and tires will be fully tested as the crew carries out swift actions to bring the aircraft to a halt before the end of the runway. If the decision is to continue the takeoff, the crew's skills will be challenged to get airborne and climb in an aircraft that has suffered an undetermined degree of engine and airframe damage. Even when airborne, they will be operating a heavy aircraft at critical speeds, where options for maneuvering may be limited by the presence of obstructions and proximity of terrain. From a management perspective, risk is extremely high.

Applying the risk-management formula

Introduction to risk management

As Figure 2.1 indicates, there are three components associated with wildlife-strike risk management:

1. reducing the overall exposure to wildlife hazards,
2. reducing the probability of striking wildlife, and
3. reducing the severity of a wildlife strike.

When all three components are managed effectively, system safety is optimized.

Reduce exposure

The key to successful risk management—and the aim of strategic risk-management activities—is to reduce exposure to hazards whenever possible. Simply operating at altitudes where most birds do not normally fly often reduces exposure to most bird species. But some aircraft can't operate at high altitude, and all must takeoff and land. As they do, particularly over water or near urban areas, exposure to wildlife-strike hazards generally increases. The challenge is to reduce an aircraft's exposure when operating on the ground and in lower altitudes.

Birds and mammals will always be found where their physical needs are best met. If their food sources are limited and nesting locations scarce, birds and mammals will seek more hospitable habitats. For this reason, municipal authorities play an important role in reducing exposure to wildlife-strike hazards. These authorities generally influence the location and nature of landfill sites and other waste-disposal

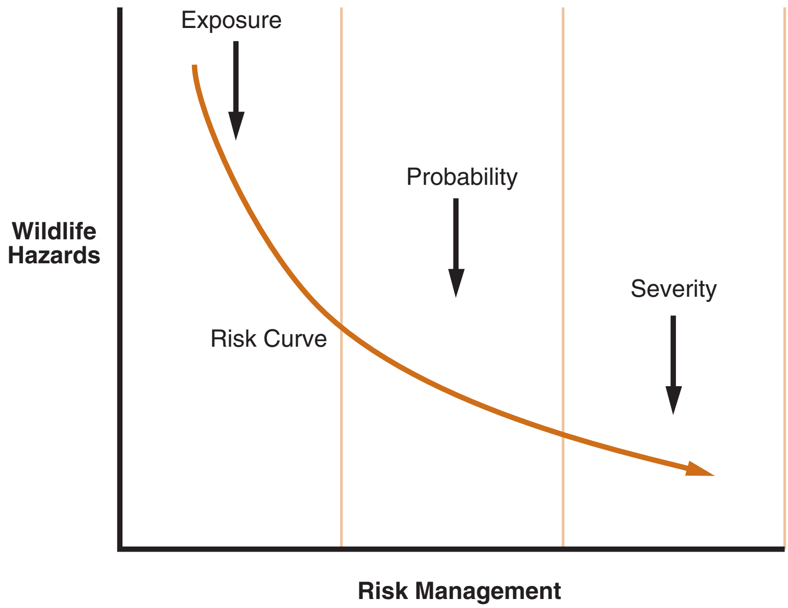


Figure 2.1 – The Risk-management Formula

facilities, influencing the activities of many hazardous bird species. By the same token, local commercial interests must also contribute to a solution; agricultural practices and food-service outlets, for example, may attract birds that otherwise would not inhabit the area. Finally, the manner in which airport operators manage habitats on airfields is critical in determining which birds and mammals will be found on or near airport lands.

Reduce probability

No matter how successful municipal authorities, local business leaders and airport operators are in discouraging hazardous wildlife species from frequenting lands near an airport, some will inevitably feed or loaf there. And so the task is to reduce the probability of strikes, which can be achieved through detection, deterrence and avoidance. These activities are tactical, and supplement previously described strategic efforts that are aimed at exposure reduction.

Airport staff, ATS providers and pilots all play an important role in the timely detection and reporting of wildlife activity in proximity to airports. Airport staff regularly and systematically patrol airport land. ATS providers scan the airport area with binoculars to locate signs of wildlife activity.

Once birds and mammals are detected, wildlife-management personnel are dispatched to directly intervene and initiate some form of active management. Other deterrent methods are more passive and may include electronic distress signals, propane cannons and chemical deterrents.

	Exposure	Probability	Severity
Airports	X	X	X
Air Traffic Service Providers		X	
Airlines		X	X
Engine Manufacturers			X
Aircraft Manufacturers			X
Pilots	X	X	X
Regulatory Bodies	X	X	X

Table 2.1 – Summary of Responsibility for Risk Management of Bird Strikes

Not surprisingly, pilots play a significant role in reducing the probability of an occurrence. Through careful observation, pilots can initiate early action to avoid collisions with wildlife. By communicating observed locations, types and numbers of birds and mammals to ATS providers, they reduce the probability of strikes to other aircraft.

By operating with landing lights illuminated, pilots provide birds and mammals with increased opportunity to see and avoid the aircraft. When operating conditions permit, pilots can plan their arrival and departure routes to avoid large concentrations of birds.

The success of these tactics relies on timely and accurate communication, a critical aspect of the system safety approach. Birds and mammals detected by pilots, airport staff and ATS providers remain a threat until the information is passed to those who can initiate some management action to prevent a strike.

Reduce severity

Although exposure- and probability-reduction efforts are bound to produce dramatic results, wildlife-strikes will inevitably occur. With that in mind, the risk-management formula's third component is reducing the severity of strike damage.

Aircraft-engine manufacturers are now developing power plants that will better withstand the impact of one or more birds. Aircraft manufacturers are producing some windscreens and other parts to deflect birds, or to absorb the energy of their impact. Airline-training programs hone pilots' skills to ensure wildlife strikes are managed confidently and competently. Pilots employ numerous defences when preparing themselves for the unexpected, including:

- availing themselves of updated information on local wildlife activity,
- heightening their awareness during high-risk flight profiles,
- remaining proficient in emergency procedures,

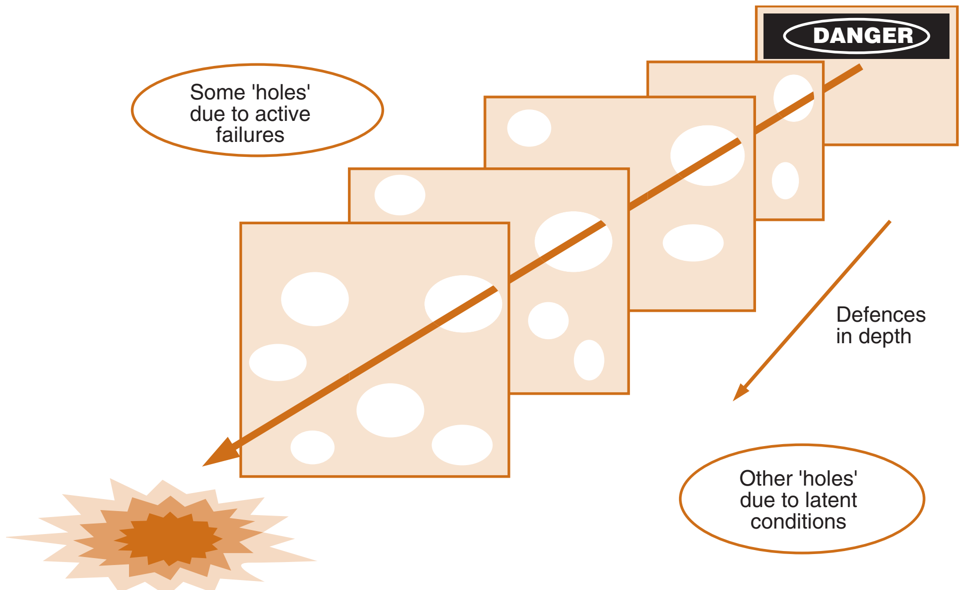


Figure 2.2 James Reason's Accident Trajectory *(Reason 1997)*

- applying heat to windscreens to make the surface more pliable in the event of a strike, and
- protecting themselves from impact debris through the use of aircraft visors and, in the case of helicopter or military pilots, by wearing helmets with visors extended.

Case Study: Amending regulations to limit airspeed

In the past, the development of air regulations has been reactive; most aviation-industry rules have been drafted in response to accidents. However, Notice of Proposed Amendment (NPA) 2002-022 to *Canadian Aviation Regulation* 602.32 marked a turning point for Transport Canada. The amendment was among the department's first attempts to apply data-driven risk-management procedures to develop air-safety regulations proactively.

Presented on February 26, 2002, the NPA proposed to eliminate the ATC practice of allowing aircraft departing from Canadian airports to exceed 250 kias (knots indicated air speed) below 10,000 feet MSL. The NPA responded to data that demonstrated populations of large flocking-bird species—which tend to migrate at relatively high altitudes—are increasing in Canada, as are damaging bird-strike events at higher altitudes.

To provide additional data in support of the amendment, TC contracted a risk analysis of the ATC practice. The resulting study, *Risk Analysis of High Speed Aircraft*

Departures Below 10,000 Feet, was the world's first holistic, system-safety examination of risks associated with high-speed departures.

The TC study applied a rigorous data-driven, risk-analysis process and determined that high-speed departures are not safe, and that NPA 2002–022 was appropriate and effective risk mitigation. Furthermore, the study demonstrated that any organization that would endorse high-speed air operations below 10,000 feet MSL, which would subject airframes and engines to conditions that exceed certification standards, would face potential liability.

The TC Canadian Aviation Regulatory Committee reviewed all data, concluded that there was a requirement to manage risks associated with collisions between large flocking birds and aircraft operating at the altitudes in question, and decided to enact NPA 2002-022 (see Appendix D).

Summary

The management of bird-strike risk is multi-tiered. As Table 2.1 illustrates, airport authorities are on the leading edge of the risk curve, poised to minimize the presence of birds and take measures to keep them away from aircraft. Airlines and aircraft manufacturers reside mainly at the other end of the risk curve, minimizing the effects once a bird or mammal strike occurs. Air-traffic service providers are positioned near the centre of the curve, detecting and communicating so that others can reduce the risk of a wildlife strike. Finally, pilots—who along with other crew members and passengers stand to benefit or lose the most—take actions that affect all three components of the risk-management curve.

Breaches in the defences

Risk-management specialists refer to aviation as a tightly coupled industry operating in a high-consequence environment. This implies that a change in risk-management procedures by one stakeholder can dramatically alter the effectiveness of risk-management initiatives by others. The bottom line is that, as a defence against wildlife strikes, risk management is a finely balanced activity involving many stakeholders in the aviation community. As experience proves, it's a balance that can be easily tipped.

In James Reason's famous Swiss-cheese model, reproduced in Figure 2.2 (Reason 1997), defences are depicted as walls separating the source of danger in the background from an accident in the foreground. Breaches of these defences are presented as holes in the walls. The model illustrates the porous nature of well established defences; even those employing the latest technological advances are not impervious. The reasons for most breaches can be understood by examining how people and organizations function in tightly coupled operations.

As the source of danger we're concerned with is wildlife strikes, the walls can be thought of as defences designed to minimize exposure to wildlife, and to reduce the probability and severity of a wildlife strike.

Imagine a situation in which an airport operator changes long-standing wildlife-management practices, or diverts funds to another part of the operation. Altering the risk-management framework could create holes in the defences of others, such as those critical to airlines operating from the airport. These new holes might align with other previously harmless airport practices. An immediate increase in wildlife strikes might be the result.

To illustrate the delicate interweaving of wildlife-strike lines of defence, let's examine a few examples which, while fictitious, could just as easily be fact. As you read, note how everyday policy and business decisions can affect the exposure, probability and severity of wildlife risks felt elsewhere. Note also that in many cases other stakeholders could effectively address the risks if they were aware of the change—and of the need to do things differently.

Cases of increased exposure

- An aircraft operator with routes concentrated over land introduces several new routes along the coast. Because of high-traffic densities, the short-flight segments are operated at low altitudes. The result is increased exposure to soaring-bird species that pose a high risk to aircraft. Though predictable, this risk might remain unidentified in the rush to introduce the new service.

- The completion of a new runway aligned 90 degrees to existing parallel runways results in the regular departure of trans-oceanic aircraft over wetlands far removed from previous aircraft operations. The result is increased exposure of passenger-carrying aircraft—operating near the performance envelope—to large flocks of waterfowl.

- A new in-flight catering business opens near the airport. The operation's garbage attracts gulls from sites several kilometers away. The result is increased exposure to flocking birds.

Cases of increased probability

- Landing lights for a specific aircraft type are in short supply, so an airline temporarily rescinds its longstanding policy that requires illuminated landing lights on aircraft operating below 10,000 feet. The airline saves money, so the change in policy is extended to all aircraft types in the company's fleet. The result is increased probability of wildlife strikes to all aircraft types operated by the company.

- At an inland airport, unusually heavy rain dilutes chemicals used at the airport to kill worms that attract hazardous bird species. The probability of bird strikes will increase until new and effective spray schedules are drafted and implemented.

- An advanced-technology engine is introduced. Its intake is significantly larger and the engine is quieter than those of previous generations. Both the increased size and reduced noise combine to increase the probability of bird strikes against aircraft equipped with these engines.

Cases of increased severity

- As a cost saving measure, a helicopter company no longer requires its pilots to use helmets and visors. Consequently, the use of this equipment gradually erodes. Pilots are therefore at greater risk of injury in the event of a bird strike. Passengers and crew are also at heightened risk, as a pilot may not be able to safely land an aircraft.

- Higher airspeeds are permitted while flying below 10,000 feet, despite power plants and airframes designed to withstand only bird strikes occurring at lower speeds. More severe damage could result from the increased energy of bird strikes.

Summary

- Change is an essential part of aviation. The system-safety challenge is to identify safety consequences before changes are introduced—consequences that can affect all stakeholders in the safety-management formula. The best-engineered system will not prevent an accident if decisions and actions unwittingly undermine risk-management efforts. Information must be shared to ensure that defences remain strong.

- Local, national and international bird-strike committees are central to risk-management efforts in the aviation industry, particularly in sharing information, knowledge and experience.

- System safety demands the exchange of accurate, relevant data regarding aircraft operations, airport operations, bird movements and bird strikes, so that risk-management strategies can be continuously improved.

Conclusion

The best-laid plans of airlines, pilots, airport operators, aircraft manufacturers, investors, scientists and policy makers can easily go awry because of a few wayward birds. This is most likely to happen when aviation-industry activities are uncoordinated, and fail to target the effective management of bird-strike risks.

The Calgary occurrence in June 1993 was not just a case of bad luck. It illustrated—with near-fatal consequences—how easily a well-defended operation can be breached. In a number of other cases, the end results were much more tragic.

Chapter 3

Birds — A Primer

Introduction

Birds are the only animals that have feathers, which evolved from reptilian scales, according to current theory. Birds are also distinguished by features that permit them to fly, such as:

- forelimbs that take the form of wings,
- the absence of teeth,
- the absence of a urinary bladder (reducing weight),
- a light and well-fused skeleton, and
- a four-chambered heart and warm blood for the high-metabolic energy demands of flight.

This chapter is a general introduction to birds: their types, numbers, distribution and general behaviour. It will provide you with a working knowledge of bird biology—knowledge that is critical in developing an aviation-industry System Safety Approach—and will help optimize related risk-management strategies. Detailed information is provided on some bird species commonly present at North American airports. For exhaustive research on the matter, we suggest you refer to publications listed in Appendix E.

In this book, we adhere to the custom of capitalizing the first letter of bird species' common names (e.g. Common Snipe and Herring Gull); species' group names are not capitalized (e.g. gulls and geese).

Bird classification or taxonomy

Taxonomy is the science of the classification of living and extinct organisms. Knowledge of taxonomy will assist in identifying birds and understanding their behaviour, since most field guides, checklists and books present species not alphabetically but in their taxonomic order. The taxonomic order of birds begins with the most primitive species and ends with what is believed to be the most recently evolved order of birds. To explain,

Illustration: Red-tailed Hawk. Weight: 2.5 lbs. A common bird at Canadian airports.

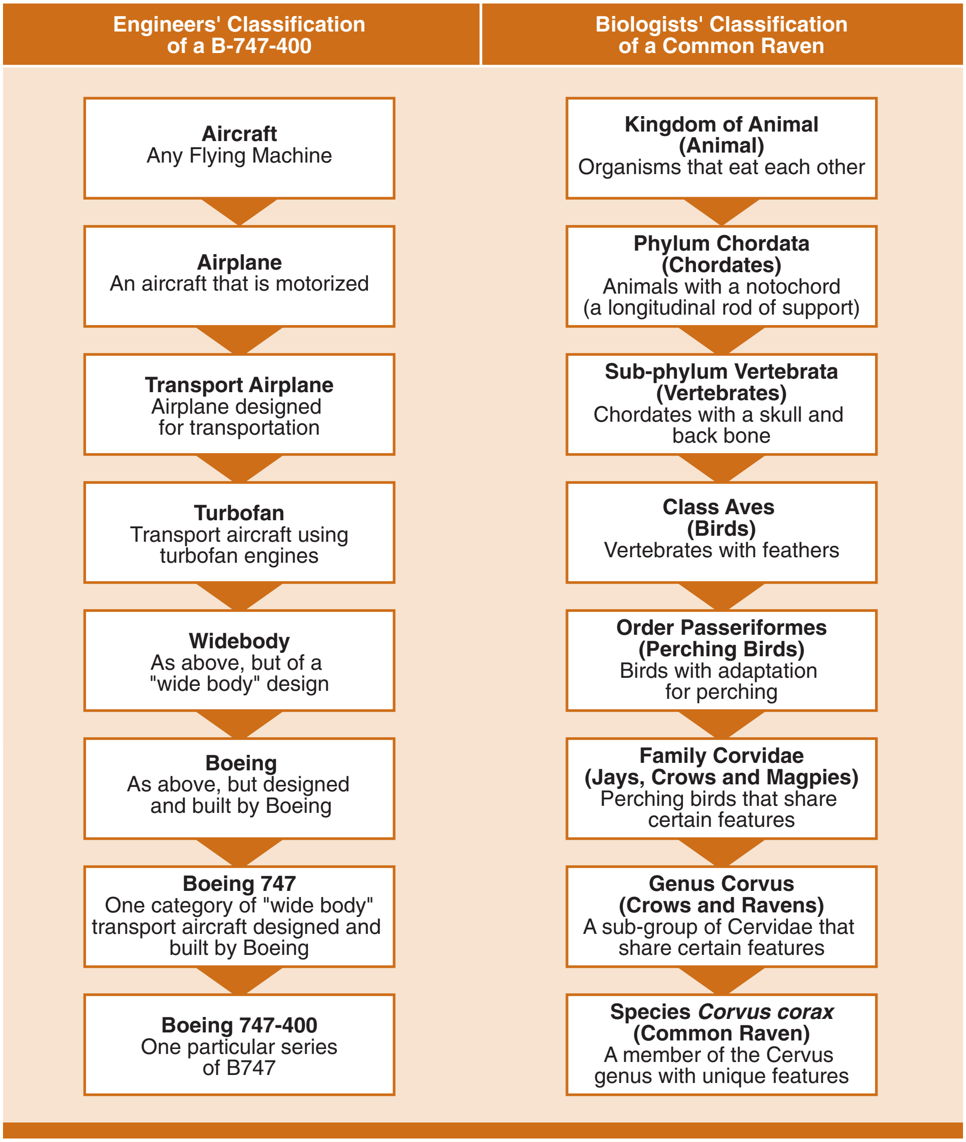


Figure 3.1 Classification of Boeing 747-400 and a Common Raven

Figure 3.1 compares the taxonomic classification of the Common Raven with that of a Boeing 747-400.

From a taxonomic perspective, the world's birds belong to the Class Aves, divided into 28 orders representing the major groupings of birds. In North America, all bird species belong to one of 20 bird orders. For example, ducks, geese and swans—which share the same features and body form—are in the order Anseriformes, while woodpeckers are in the order Piciformes. Today, more than half the world's bird species belong to the order Passeriformes. These are perching birds, represented by more than 60 families including most of the common songbirds.

Diverse and distributed species

The exact number of bird species is a topic of ongoing debate among taxonomists, with estimated totals ranging from 8,700 to 10,000 worldwide. The geographic distribution of these species varies considerably; more occupy habitats near the equator, and numbers decline near the north and south poles. The greatest numbers of species are found in Central and South America, where 3,000 species represent nearly a third of the world's bird diversity. In comparison, only 750 species are found in North America.

The geographic area inhabited by a bird species is called its breeding range. Most species that nest in northern North America are migrants. After the breeding season they travel to more southerly areas—their winter range—before returning north to breed. Therefore, we can expect different birds to populate our airports at various times throughout the year. These include:

- migrants—birds that stay temporarily during spring and fall;
- summer residents—birds that breed and raise their young on airport lands;
- winter residents—birds that spend only their winters at airports; and
- residents—birds that are present all year long.

Bird numbers and population density

Bird numbers

Even though a geographic location may support relatively few bird species, the numbers of individual birds may still be high. For example, Canada's extreme north is home to fewer species than South America, and yet the actual number of birds breeding in the far north is astounding. Many millions of waterfowl and shorebirds migrate northward to breed every year.

The total number of birds in the world has been estimated to be in the order of 100 billion. The following list provides bird-number estimates for selected regions in the Northern Hemisphere:

North America	20 billion
United States	6 billion
Germany	200 million
British Isles	180 million
Finland	64 million

Snow Goose. Weight: 6 lbs. Numerous serious incidents have resulted from aircraft colliding with Snow Geese during the fall migration in North America.

North American populations include well over 100 million ducks of all species, more than three million Snow Geese, over four million Canada Geese, as well as starlings and blackbirds estimated in the hundreds of millions.

Population density

The population density of birds—or number of birds per unit of area—varies considerably among regions and habitats. In general, greater numbers of bird species are attracted to areas offering more diverse food sources; an abundance of food leads to larger numbers of birds.

The distribution and density of birds also changes with the season. In the Northern Hemisphere, bird numbers peak in the summer—after the breeding season—and contribute to the documented annual increase in reported bird strikes in August.

During the breeding season, the concentrations of birds at nesting colonies can be spectacular. In the far north, Snow Geese breed in colonies of up to 150,000 pairs. Large sea-bird colonies comprised of thousands of nesting birds are found along both the eastern and western seaboards of Canada and the United States. Around the Great Lakes—on small islands only hectares in size—gull colonies have been documented as containing over 40,000 breeding pairs.

During migration, birds of some species funnel to and congregate at key staging areas along the flyways. As a result, relatively small areas can become the temporary home

Species	Weight (lbs)
Canada Goose	7.3-13.8
Sandhill Crane	5.4-8.2
Bald Eagle	8.0-14.1
Common Loon	7.9-9.9
Snow Goose	5.1-6.6
Great Blue Heron	4.1-6.3
Turkey Vulture	3.3
Mallard	1.6-3.5
Red-tailed Hawk	2.3-2.7
Ring-billed Gull	0.83-1.4
Rock Dove (Pigeon)	0.7-0.9
Killdeer	0.19-0.24
American Robin	0.14-0.23
European Starling	0.17-0.21
Red-winged Blackbird	0.06-.18
Snow Bunting	0.07-0.12
Horned Lark	0.07
House Sparrow	0.5-0.07
Barn Swallow	0.02-0.06

Table 3.1 Weights of Some Common North American Bird Species

to extremely high concentrations of birds, and many airports located along major bird routes suffer a distinct increase in the bird-strike rate during the fall migration period.

Bird weights and densities

Bird weights

The heavier the bird involved in a strike, the greater the potential for serious aircraft damage. For example, an aircraft flying at 250 kts and striking a Canada Goose weighing 15 lbs will be subject to an impact force of approximately 57,000 lbs (see Table 12.1).

Bird sizes cover a considerable range. A tiny hummingbird weighs no more than an ounce, while a large flightless ostrich weighs up to 300 lbs. The vast majority of birds, however, weigh less than a pound. Table 3.1 shows the range of weights for some common bird species in North America.

An examination of the chemistry and physics of flight for the largest bird species—including pelicans, swans and albatrosses—indicates that 30 to 40 lbs is the

Large flocks of starlings create significant hazards at many airports. Weight: 0.2 lbs. Density: 0.85 g/cc.

maximum weight at which birds can achieve flight. Even then, many of these species rely heavily on wind currents and updrafts to provide lift for soaring and gliding.

Although emphasis is placed on the management of larger birds at airports, small birds are also hazardous to aircraft. This is particularly true for small flocking species; simultaneous multiple strikes by these birds can equal the impact of one large bird. For example, the jet-engine ingestion of seven European Starlings is equivalent, based on weight, to that of one Ring-billed Gull.

Bird density

Recent investigations into the effects of bird ingestion by jet engines suggest that potential damage may be dictated more by the density of a bird—the ratio of bird weight to its volume—than its weight. For example, the Laughing Gull weighs only a third of the larger Herring Gull, but has a higher density—0.7 g/cc as opposed to 0.602 gm/cm^3. Perhaps this is why starlings are often referred to as 'feathered bullets.'

Bird senses

Birds are equipped with the same sense organs as humans; they generally hear, see, taste, smell and feel in the same range as we do. A number of wildlife-management devices on the market today (see Chapter 8) are said to be effective in targeting bird senses through the use of various chemicals, sounds, vibrations and visual cues. When considering such devices, follow this simple rule of thumb: if you cannot hear, feel, see or taste it, neither can birds.

Vision

Birds as a group have one of the most highly developed senses of vision in the animal kingdom. The importance of this sense is best illustrated by the larger size of a bird's eyes relative to other animal groups. For example, heads of both humans and starlings represent about one-tenth of total body weight. The starling's eye, however, represents 15 percent of its head weight, compared to less than 1 percent in humans.

The structure of a bird's eye is similar to that of a human eye. Though birds of prey and those that inhabit open country enjoy vision highly superior to that of humans, studies have shown that for the most part birds have vision that is similar to humans. Birds can see roughly as far as humans can, and are able to see near and far with equal acuity.

There is no evidence to support the theory that some birds can see polarized light, or recognize ultraviolet wavelengths to assist in migration or foraging. Birds also see in the same light-frequency range as we do. They can distinguish various tints and shades of colour.

Hearing

The sense of hearing in birds is well developed. The inner ear functions in essentially the same way as a human's. Optimum hearing occurs in the frequency range of 1 to 5 kHz. While it is believed that some bird species can detect low-frequency sound—sometimes referred to as infrasound—most birds cannot hear high-frequency sounds of 10 kHz or above. Large birds, such as waterfowl and birds of prey, cannot hear high-frequencies above 6 or 8 kHz. Songbirds are able to hear in a range of frequencies narrower than those in which a human can hear. Generally, however, if you can't hear a sound, chances are birds can't either.

Touch

For birds, the sense of touch is concentrated primarily in their feet and bills—the areas that are not feathered. Their feet detect feelings of cold, heat and pain. Many birds have a highly developed sense of touch in their bill, which they employ when capturing and manipulating food. Experiments on birds indicate they have an acute sense of taste, but they have fewer taste buds than mammals. Some bird species are insensitive to bitter, sweet, or sour tastes—a fact to consider when choosing chemical deterrents in the airport environment.

Smell

Of all senses, smell is generally the least developed in birds, although their detection and discrimination ability varies considerably. Some species have poor abilities, while others have some of the best-documented scent capabilities of any terrestrial vertebrates.

Bird behaviour

Flight characteristics, feeding habits, reproduction, social interaction, migration and predator avoidance are all aspects of bird behaviour, knowledge of which is essential when determining effective wildlife-management techniques.

Food Type	Species or Family
Flying Insects	Swallows, goatsuckers, flycatchers
Insects in trees and shrubs	Cuckoos, woodpeckers, jays, chickadees, nuthatches, thrushes, vireos, warblers, blackbirds, tanagers, finches, sparrows
Insects in grass fields and pond edges	Ducks, geese, rails, plovers, sandpipers, Common Snipes, gulls, American Kestrels, larks, crows, starlings, blackbirds
Worms	Gulls, Common Snipes, crows, robins, blackbirds, starlings
Aquatic vegetation/insects	Grebes, ducks, geese, rails
Berries	Grouse, pheasants, thrushes, thrashers, waxwings, blackbirds, starlings
Grass	Ducks, geese
Fish	Herons, cranes, osprey, eagles, terns, gulls, sea birds, kingfishers
Frogs	Herons, bitterns, cranes
Mice/voles	Cranes, gulls, accipiters, harriers, buteos, owls
Small birds	Accipiters, buteos, falcons, owls, turkey, grouse, pheasants, pigeons, doves, finches
Seeds	Sparrows, longspurs, Snow Buntings
Crops (corn, grains)	Ducks, geese, turkey, grouse, pheasants, pigeons, doves, crows, blackbirds, longspurs, Snow Buntings
Garbage	Gulls, crows, ravens, magpies, blackbirds, starlings
Carrion	Vultures, eagles, crows, ravens, magpies

Table 3.2 — Food Types and Associated Birds

Feeding

Birds are attracted by food, so knowing what they eat and controlling food availability is key to successful bird management.

Birds can be grouped into four categories based on their diets and feeding habits. Most birds are insectivores—insect feeders. The second largest group feeds on various parts of plants, including seeds and berries. Carnivores feed on animals like fish, small invertebrates, small birds and mammals. Finally, some species of birds are omnivorous—they thrive on both plants and animals.

Table 3.2 associates these groups of birds with their food sources. Use the table to determine which bird species might be attracted to your airport.

Most bird species eat a limited variety of foods; some consume only one food type such as a specific seed, fish or insect. Certain species such as gulls, crows and some waterfowl are less particular—their diets include a wide range of foods, both plant and animal. Their generalized diet allows these species to take advantage of local and seasonal foods where and when they can be found. For example, many species of gulls can switch quickly from feeding on fish at a waterfront to feeding on worms in recently plowed fields.

Most birds tend to feed individually within a territorial space or home range, from which they exclude others of the same species. When a food supply is abundant, however, birds will concentrate in large numbers and tolerate one another's presence. Some bird species are referred to as flock feeders; they routinely feed in groups made up of their own kind, or in mixed-species flocks. Among other benefits, flock feeding offers safety in numbers; with more eyes to detect predators, individual birds can spend more time feeding rather than watching for potential threats. Common flock-feeding birds include waterfowl, gulls, blackbirds, starlings, doves and pigeons. Feeding flocks can contain hundreds or thousands of birds—a severe hazard in an airport environment.

Reproduction

Bird reproduction tends to include a typical set of behaviours:

- establishment of a breeding territory,
- courtship and mate selection,
- nest building and egg laying, and
- brooding and caring for young.

Well over 80 percent of the world's birds are monogamous, forming a single mated pair during the breeding season. In North America, the vast majority of bird species breed in mated pairs and raise their young in well-established and well-defended territories. Spring is a time of territory establishment and heightened bird activity as males actively defend their territories from all challengers.

As the days grow longer, breeding begins. In North America, the primary breeding season begins in April and is usually completed by the end of July. During this period, many species attempt to rear more than one set of young; some raise as many as three broods. If eggs are lost to predators, most species will re-nest.

A diverse selection of bird species—including herons and egrets, swallows and swifts, gulls, terns and other sea birds—breed in dense colonies. Once a colony is established, adult birds and their adult offspring return to the same colony year after year—colonies that can remain active for hundreds of years.

These dense bird colonies feature individual territories no larger than the space occupied by the nest and the brooding adult. This high-nest density results in enormous congregations, sometimes populated by tens of thousands of birds, as well as colony-growth rates that can be exponential in nature. Colonies can grow from just a few birds to hundreds or thousands in a short time. As an example, a Ring-billed

Gull colony near Toronto, Canada, grew from 10 pairs to approximately 80,000 pairs in a span of only ten years. Similar dramatic growth in new colonies has been recorded elsewhere in the world.

Feeding territories are established well away from the colony; the distance birds travel between the two locations can be considerable. Round trips of 10 km or more are not unusual for many colonial species.

Needless to say, nesting colonies near airports create serious hazards. When a colony of Laughing Gulls was established near JFK International Airport in New York City, authorities had to move quickly to implement a comprehensive and aggressive wildlife-management plan that included lethal control.

Behaviour that can create aviation hazards

Bird flight

Daily and migratory flight activities are prime causes of bird strikes, so understanding when, where and how birds fly is one of the key factors in determining exposure to, and probability and severity of, the hazard they create.

Most birds flap their wings to move forward and attain lift. Smaller species fly at moderate speeds between 10 and 20 mph. Larger birds such as waterfowl can maintain flight speeds of more than 40 mph, although high speeds make significant energy demands and are generally avoided. During migration, birds take advantage of tail winds at various altitudes to significantly increase their speeds, sometimes achieving radar-detected ground speeds of more than 60 mph.

Bird-flight altitudes

The majority of day-to-day movements occur between 30 and 300 feet above ground level (AGL). Little regular activity occurs above 1,000 ft AGL, so it's not surprising that over 80 percent of reported bird strikes occur when aircraft are below that level; the vast majority of strikes are suffered below 300 ft AGL.

One of the highest altitude bird strikes on record involved a Boeing 747 that struck a large bird flying over the West African coast at 37,000 ft above sea level (ASL), but high-altitude bird activity generally occurs only during migration. At that time, birds attain greater heights either to take advantage of winds aloft or to pass over obstacles such as mountain ranges. Migrating Bar-headed Geese have been reported above the summit of Mount Everest, and typically cross the Himalayas at altitudes up to 30,000 ft ASL. A flock of swans migrating from Iceland to Western Europe was reported by a pilot at just over 27,000 ft ASL. Mallards have been reported at 21,000 ft, and Snow Geese have been reported at 20,000 ft. While the altitudes of most migrating birds tend to be much lower, documented average migration altitudes are impressive. Radar observations during peak migration movements in Europe have shown that the majority of migrants

Bald Eagle. Weight: 11 lbs. The high altitude soaring flight of raptors such as eagles and vultures puts them out of reach of most wildlife management techniques.

flew between 5,000 and 7,000 ft AGL, with a lower limit of 1,600 ft and an upper limit of 11,500 ft.

Soaring and gliding

Other bird-flight behaviours such as gliding, soaring and towering also pose a threat to aircraft. Towering is the slow circling flight that birds engage in as they harness rising parcels of warm air. Towering, soaring and gliding are often used in combination; the bird takes advantage of rising thermals of air—towering to effortlessly gain altitude—and then uses the gained altitude to soar aloft and then glide down. Soaring and gliding flight are energy-efficient behaviours typical of larger bird species—such as condors, vultures, eagles, hawks, storks, gulls and pelicans—that travel long distances as they hunt and migrate.

In bird-hazard assessment, soaring flight is important for a number of reasons:

- Towering conditions are often found at or near airports. Open and flat, airfields contain large expanses of concrete and asphalt which re-radiate stored heat, creating ideal conditions for the development of local thermals. As a result, towering birds—particularly hawks and vultures—often concentrate and circle above airfields.

- Soaring birds tend to make their daily movements at greater altitudes than other birds. During ideal thermal conditions, hunting hawks and vultures can maintain altitudes greater than 1,000 ft AGL. Soaring also permits these birds to cover more lateral distance, as the activity allows them to save energy. As a result, these species range over a much greater airspace in and around airports—vertically and horizontally—raising their profile as bird-strike hazards and putting them out of the reach of many wildlife-management techniques. Studies of gull movements to and from landfills found that flapping-flight movements occur at under 300 ft AGL—while birds are more likely to glide at altitudes over 1,300 ft. Birds save energy by towering to gain altitude over the landfill before moving off to roosting sites.

- During the migration period, large concentrations of hawks and vultures congregate in areas such as mountain ranges and coastlines—areas that offer dependable thermals and updrafts. In the late morning—along North American migration corridors—boils of hawks and kettles of vultures each containing hundreds and thousands of birds are not uncommon. Under ideal conditions, these birds can ride thermals to altitudes at which they can no longer be seen from the ground.

Daily bird activities

More than 90 percent of all bird species are *diurnal*; they remain active during the day and sleep at night. Some birds such as owls and nighthawks are *nocturnal*—primarily active at night. Peak diurnal activity usually occurs in the morning, beginning before sunrise and stretching to approximately 11:00 a.m.

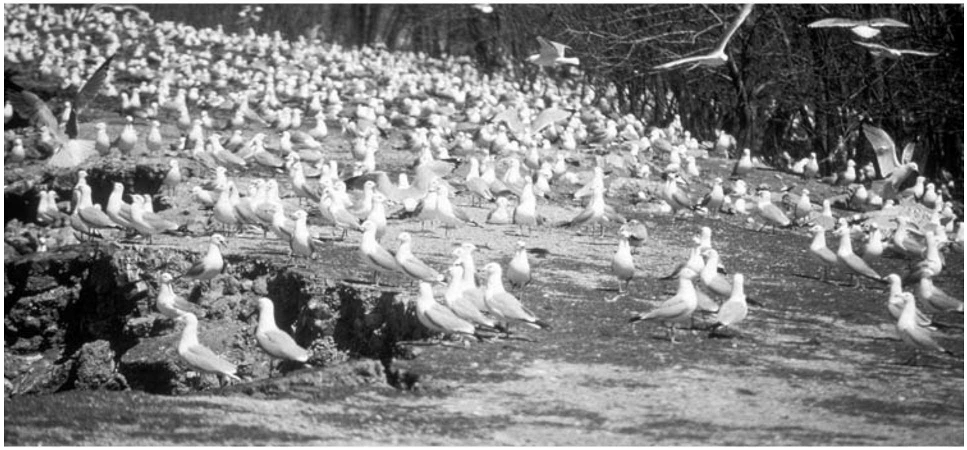

Great Horned Owl. Weight: 3.5 lbs. The nocturnal activity of birds such as owls results in bird strike rates that can be higher at night than during the day.

Unfortunately, aircraft movements at airports typically increase at these times, and bird-strike data tends to show a sudden increase starting at around 07:00 a.m. But there is also growing evidence to suggest that strikes per 10,000 aircraft movements are in fact higher at night—a reminder that wildlife management must be undertaken around the clock.

Daily bird activity is lowest at midday. There is often a second activity peak in the late afternoon and early evening when birds again move between feeding and roosting sites.

During midday, most birds spend their time resting or loafing, preening and avoiding predators. Some birds—such as gulls and waterfowl—will congregate at loafing sites where, in the safety of numbers, they rest and watch for predators. At many airports, loafing gulls are a common problem. They make regular flights from feeding sites to the airport and spend their idle time in the safe, open expanse of the airfield before moving on to their roosting site in the early evening.

The sleeping and resting activities of birds are referred to collectively as roosting. Most birds sleep throughout the night, choosing to rest alone in sheltered areas such as



Loafing gulls. Dramatic increases in some gull populations, resulting largely from poor municipal waste-management practices, has created one of the most serious North American flight-safety issues.

dense foliage, cavities or tangled undergrowth. Depending on latitude and time of year, sleep periods can vary from four to eight hours. Even when asleep, birds open their eyes every few minutes, alert to potential danger.

Following the breeding season, some birds roost communally. Flights to communal roost sites are either direct or made in stages. In most cases, the same roost and pre-roost sites are used every year. The number of birds that congregate at roost sites can be enormous. Roosting waterfowl and gulls on inland lakes often number into the thousands. Fall and winter flocks of roosting starlings, crows and blackbirds in the southern United States have been estimated in the millions; the weight of these flocks can be enough to break branches in trees in which they roost.

Daily bird activity is greatly influenced by local weather; short-term forecasting of bird movements based on weather conditions is an important aspect of an effective wildlife-management program. Birds are generally less active during extreme heat or cold, rain or snow, mist or fog. In these conditions, birds significantly limit time spent feeding and moving about. In contrast, bird activity can show a marked increase immediately before and following rain showers. The rain drives insects out of trees, and brings worms and other invertebrates above ground. A burst of feeding activity follows. After a summer rain at many airfields, runways must be cleaned—they become slick with worms and attract hundreds of birds that flock to the sudden surfeit of food. Pools that develop after rainfall also provide much needed water for drinking and bathing.

Wind speed and direction can also affect the daily movements of birds. High winds generally reduce bird movements and flight altitudes as birds hug the ground. Wind

Worms on the runway. Large numbers of worms that emerge onto runways after rain events create an attractive food source for birds such as Ring-billed Gulls.

direction can alter the time and direction of daily movements to and from roosts, feeding and loafing sites. Many bird species use different feeding and loafing sites based on local wind conditions.

On the move: bird migratory activity

The vast majority of North American bird species (60 to 80 percent, or more than five billion birds) migrate each fall to the southern U.S., Mexico—and as far as Central and South America—only to make the journey back in the spring. During these migration periods, enormous numbers of birds move across the entire North American continent. There is no question that migration periods (September to October and April to May) are times when there is great risk of a serious bird strike.

Many species of small songbirds migrate slowly on a broad front, moving a few hundred miles every few days. However, the study of waterfowl migration has identified specific flyways through which the majority of the migrating birds pass. In North America, four distinct flyways have been identified. They are the:

- Atlantic and Pacific coastlines;
- Mississippi Flyway, wherewaterfowl from the interior of Canada and the U.S. move southward along the Mississippi River Valley; and
- Central Flyway, where birds from the western interior of Canada and the U.S. follow the central prairie regions along the Rocky Mountain foothills.

Important resting and feeding sites are found along these flyways, and are home to concentrations of thousands of waterfowl.

Seasonal changes in day length cause birds to prepare for migration instinctively. The onset of favourable weather conditions is usually the trigger that sets birds on their way north. Each year, a species' arrival at and departure from a specific geographical area can occur within the same week of the same month. This predictability is crucial; knowing when high concentrations of birds will migrate allows ATS providers, wildlife-management staff and pilots to prepare for the increased numbers.

Depending on the species and type of navigation method used, migration flights occur day and night. Many species migrate at both times; however, soaring species that depend on air thermals are restricted to daytime migration. Other species use a cruise-climb strategy to gain altitude during long flights, flying higher as their fuel load decreases. The ground speed of birds varies with speed and direction of winds aloft, as well as the species' airspeed capability. Most songbirds travel at ground speeds of 20 to 30 mph. Shorebirds and waterfowl travel at 30 to 50 mph.

Weather plays a significant role in bird migration. Birds do not generally travel through rain, fog, mist, high winds or heavily overcast skies. At these times, birds remain downed until conditions improve. The best conditions for fall migration are created by strong tail winds behind cold fronts where birds will move along flyways en masse. These waves can be predicted by weather conditions, offering the opportunity to forecast bird movements over airports located within migration corridors.

Bird behaviour towards aircraft

Are birds naturally afraid of aircraft? The answer to that seemingly simple question is complex. Many factors can alter a bird’s behaviour toward aircraft including:

- bird species,
- time of year,
- weather conditions,
- age and condition of the bird, and
- the bird’s experience with aircraft and an airport environment.

To date, few scientific investigations have been undertaken to study bird reactions to aircraft. Most current information is anecdotal and has been reported by pilots and airfield staff, although research has recently been initiated to acquire a better understanding.

Evolutionary and adaptive behaviour

Through natural evolution, birds have learned to respond quickly to animals that prey upon them. Birds are genetically programmed to avoid and escape predators. Since birds have not evolved with aircraft as predators, they are not naturally programmed to be frightened by or avoid them. If aircraft did cause alarm, bird strikes would be much less of a problem.

Birds are naturally cautious of new or unfamiliar objects in their environment but, as long as these objects do not cause harm, birds also quickly habituate to them. Evidence suggests that airport birds have adapted to their surroundings, learning that aircraft are not a threat. The sight of birds feeding and loafing along busy runways—apparently oblivious to noise and movement—is a familiar one. Many involved in airport-wildlife management believe these smart airport birds are not a hazard as these animals have learned to stay out of the way. However, there is little—if any—documented evidence to suggest that this is true.

Bird behavioural responses are unpredictable

When considering bird behaviour toward aircraft, the most important thing to remember is that it is *unpredictable*. Bird behaviour varies with individual species, maturity of individual birds and any threats facing the animals.

Generally, birds that feed and loaf on airfields either ignore aircraft threats, avoid busy runways in advance of approaching aircraft, or respond with fright or panic flight as aircraft approach.

Young and migrating birds unfamiliar with airport environments seem more prone to panic flight. Adults of the same species may completely ignore aircraft. In panic flight, starlings and shorebirds form dense flocks, then undertake erratic movements that result in thick and extremely hazardous congregations of birds crossing paths of arriving and departing aircraft.

The response of birds in flight is also highly unpredictable and varies greatly by species. Typically, birds undertake simple manoeuvres to escape the path of aircraft. Gulls often attempt to out-fly aircraft rather than move away at right angles to aircraft flight paths. Hawks and eagles will occasionally attack aircraft rather than avoid them.

Gulls on runway. The biomass contained in a small flock of gulls is more than any currently operating jet engine is designed to withstand.

While straight and level aircraft flights are relatively easy for birds to anticipate, avoiding aircraft in climb-descent or turns seems to be more difficult. Recent studies indicate some birds view aircraft as immobile objects, much like trees or buildings, and attempt to turn slowly away from the threat at a perceived safe distance.

When encountering aircraft, a number of birds free-fall, folding their wings and diving. This behaviour has been documented to be common among a number of waterfowl species, but has also been noted in others. This free-fall behaviour has led the U.S. Air Force to evaluate a manoeuvre in which pilots undertake a steep climb when directly confronted with birds. It is a manoeuvre that may put the aircraft in a marginal flight profile should it strike them, can easily lead to an over-stressed airframe and, most importantly and perhaps unadvisedly, assumes consistent behaviour by the birds.

Remember: the behaviour of birds toward aircraft is highly unpredictable. Additionally, modern aircraft are more vulnerable due to higher flight speeds and larger engine inlets.. Combine these factors with significant reductions in aircraft noise levels, and it's easy to understand that birds often have little time to react. Therefore, to reduce bird-strike risks, efforts must focus on limiting the numbers of birds in and around airfields.

The dynamic nature of bird populations

In any local area or region, bird numbers and species diversity can vary considerably. Some of these variations are natural and occur annually during migration or following the breeding season. Other changes are less obvious and are often related to gradual habitat changes, to which bird species respond by altering their range or local

Urban Geese. Weight: 15 lbs. FAA/USDA data show that damage occurs to 64% of jet engiunes struck by geese. The FAA estimates that if current trends continue, the probability of a major goose-strike incident resulting in uncontrolled fire or loss of two or more engines will double in the next 10 years.

distribution. At other times, birds respond quickly to environmental changes. These rapid changes may come when birds respond to either sudden changes in important resources—such as food and nesting habitats—or to changes in predator and competitor populations. The dynamic and adaptive nature of bird populations demands that airport wildlife-management programs be equally responsive.

Landscape alteration can change the distribution, diversity and abundance of birds. In general, bird species that inhabit mature forests, wetlands and riparian habitat are now less abundant. Species that rely on open fields, scrubland and young forests are more numerous than in the past. Over the past 50 years, urban sprawl has created artificial habitats to which a number of bird species have adapted. Many of these urban species—including crows, starlings, pigeons, Canada Geese and, more recently, gulls—have shown significant increases in their populations at both local and regional levels. Species such as Canada Geese and blackbirds have adapted to feed on agriculture crops. Gull populations have boomed with the increase in both the size and number of landfills and other waste-disposal facilities in North America and Europe. Landfills have also changed wintering ranges for these species, providing reliable year-round food sources.

Direct human intervention—through species introductions and conservation efforts—has also led to increases in both the number and distribution of some bird species in North America. More than 200 species of birds have been introduced to various regions of North America with varying degrees of success. Two species—the House Sparrow and European Starling—are examples of highly successful introductions. Common and widespread, the Rock Dove is a hybrid of several feral domestic European pigeons that were released or escaped into the wild during the 1600s. More recently, the relocation of nuisance Canada Geese has become an issue. Nuisance birds captured in urban areas are released in areas still willing to accept the birds. This is of great concern when these relocated birds take refuge in proximity to airports, as small populations quickly increase and become flight-safety hazards.

Finally, in response to the loss of natural habitats—particularly wetlands—many governments and non-governmental agencies have initiated conservation efforts. Over the past 30 years, millions of acres of wetlands have been created across North America. Marsh-habitat areas that traditionally supported low numbers of waterfowl can be easily enhanced; increasing waterfowl numbers often result, rapidly propelling bird populations into the hundreds and thousands. The establishment of reserves and conservation areas can also result in a sudden rise in bird numbers. Birds are quick to find areas that provide reliable food, shelter and protection.

Readily adaptable to human environments

Though it's widely accepted that human activities—such as the destruction of natural habitats—have a significant negative impact on birds, many species have proven

Agricultural Food Sources	**Breeding Sites**
Grain crops, vegetable crops	Fence and hedgerows
Plowing and harvesting activities	Buildings, including roof tops
Crop storage and transfer areas	Bridges/piers/dykes/dams
Feed lots, manure piles	Poles/lighting structures/hydro towers
Orchards and vineyards	Quarries and borrow pits
	Reservoirs and stormwater ponds
Other Food Sources	Landfills
Landfills and waste transfer stations	Human made lakes/wetlands/impoundments
Food waste composting sites	Conservation areas/refuges/sanctuaries
Abattoirs and fish processing plants	Airports
Sewage treatment lagoons	
Fast food restaurants, malls,	**Loafing/Roosting Sites**
Fairgrounds, parks and sport facilities	Parks, parking lots, sport fields
Golf courses	Buildings ledges, roof tops
Airports	Docks/piers/dykes/dams
	Reservoirs/stormwater ponds
	Human-made lakes
	Landfills
	Golf courses
	Airports

Table 3.3 Features that are Attractive to Birds in the Human Environment

adaptable to human environments. Their presence has increased in rural, suburban and urban areas where birds find new feeding and nesting opportunities, as well as safety from predators. Table 3.3 presents some of the environments to which birds have successfully adapted.

Several common factors help identify species that are successful in exploiting human environments:

- Successful species are often generalists in regard to food requirements. Birds such as gulls, crows, House Sparrows, blackbirds and starlings feed on a variety of food items and delight in the smorgasborg provided by agriculture crops, restaurant waste and landfills.

- Flocking birds are known to take advantage of food availability that results from farming activities such as spring plowing and planting, summer haying, and fall harvest.

- Human activities have increased the availability of nesting habitat for some species of birds, providing a variety of locations suitable for nesting and rearing young.

Species	Weight (lbs)
Great Black-backed Gull	2.3-5.0
Glaucous Gull	2.4-4.0
Herring Gull	1.6-3.3
Ring-billed Gull	0.83-1.4
Iceland Gull	1.9

Table 3.4 Weights of Some North American Gull Species

These locations include buildings, bridges, quarries, sewage lagoons, storm-water ponds, piers, hedgerows, parks, malls and golf courses. It's not surprising that airports have become prime bird locations—they offer abundant food sources, water for drinking and bathing, safe open space for both feeding and resting, perching opportunities and a wide variety of nesting opportunities.

Bird species that commonly create flight-safety problems

Bird-strike data from around the world indicates that hundreds of different species of birds have been struck by aircraft. Nevertheless, a review of strike data from airports across North America consistently indicates that some species are more likely to be struck.

Gulls

- There are 45 gull species worldwide, including 23 in North America. Weights of some gull species are provided in Table 3.4. Males are on average heavier than females.

- Gulls are a common problem at many airports in North America and Europe. Where reported strikes identified the species, more than one third involved gulls.

- Factors that contribute to the gull problem include size, flocking behaviour, relatively slow flying speed and their preference for airport environments as both feeding and loafing sites.

- Gulls adapt to the human environment exceptionally well. They are quick to adjust to new food sources such as those found in agricultural sites, feed lots and landfills. Gulls also take advantage of urban food sources provided by garbage cans, fast-food restaurants and malls. The use of rooftops as gull-breeding and roosting sites appears to be spreading in heavily urbanized areas—especially in the Great Lakes area of North America.

- Gulls are food generalists. They eat a wide variety of both plant and animal foods, which are readily available at airports.

- Several North American gull species have increased steadily in number over the past 50 years, and the increase in gull numbers at landfills—particularly during the winter—is well documented.

Species	Weight (lbs)
American White Pelican	9.9-30
Mute Swan	3.2-16.5
Tundra Swan	14-21
Canada Goose (the "maxima" race)*	11.0-16+
Canada Goose (the "interior" race)*	6.8-10.4
Canada Goose (the "Canadensis" race)*	7.3-13.8
Snow Goose	5.1-6.6
Brant	1.9-4.0
American Black Duck	1.6-3.5
Mallard	1.2-3.8
Northern Pintail	1.3-2.4
Gadwall	1.4-2.3
American Widgeon	1.1-2.3

* There are several subspecies of Canada Goose; each has its own name.

Table 3.5 Weights of Some North American Waterfowl Species

- Movements among feeding, roosting and loafing sites follow well-established and predictable flight lines. Gulls consider airport environments relatively safe, and choose them as loafing or pre-roost sites. Gull flights typically occur below 300 ft AGL, yet towering behaviour is common over feeding sites. Feeding flights of over 30 km are not uncommon.

- Gulls usually breed in densely packed colonies that may comprise many thousands of birds.

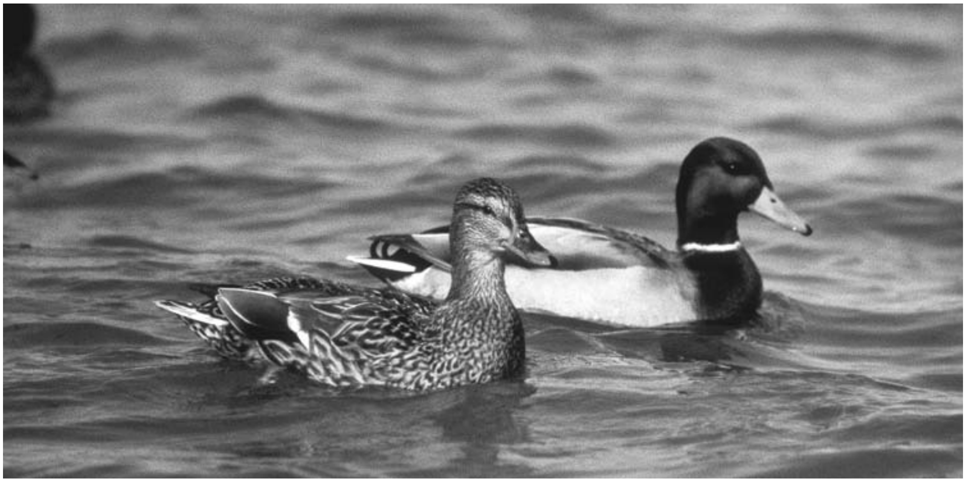
- Most gull species are migratory. In Canada, southern migration begins in late September and October and is usually completed by November. Spring migration begins in March and is usually well underway by April. Adult birds typically arrive at the breeding colonies by the end of April.

Waterfowl

- Nearly 160 species of waterfowl are found worldwide; North America is home to 62 species.

- As a group, waterfowl are among the world's largest flying birds (see Table 3.5).

- Large size combined with flocking and migration behaviour make waterfowl particularly hazardous to aircraft operations.



Mallard Ducks. Weight: 3 lbs. Many serious incidents have resulted from strikes with ducks that frequent ponds and grain stubble near airports.

- Waterfowl are attracted to common airport features such as ponds, wetlands, ditches and grass fields. Temporary ponding of water from spring snow melt and prolonged rains also attracts these birds.
- After feeding, flocks of geese and ducks commonly loaf within the confines of an airfield.
- During spring and fall migration, many thousands of waterfowl concentrate in farm fields, wetlands and nature reserves that may be located near airports, creating a significant hazard to aircraft operations.
- Recently, the numbers of some waterfowl species—Mallards and Canada Geese in particular—have increased substantially in the U.S. and Canada. Between 1985 and 1997, the North American Canada Goose population increased by 54 percent, and is now estimated at over two million birds.
- Their extended winter range into the North has been attributed to their adaptability to changing food sources and nesting locations—behavioural changes that have resulted in ever-increasing, year-round resident populations at many airports.
- Relocation programs have contributed to rising waterfowl populations, as these animals are moved to locales that offer fresh food sources and relative safety from predators.

Doves and Pigeons

- North America is home to 16 species of doves and pigeons. The majority live in the southern U.S. and Mexico. The Domestic Pigeon (Rock Dove) and Mourning Dove range widely throughout most of the U.S. and southern Canada.

Species	Weight (lbs)
Rock Dove (Pigeon)	0.7-0.9
Ringed Turtle-Dove	0.3-0.4
Mourning Dove	0.2-0.4

Table 3.6 Weights of Some North American Dove Species

- Doves and pigeons are medium-sized birds (see Table 3.6) that frequent open areas; all species of this group have adapted well to rural and urban environments.

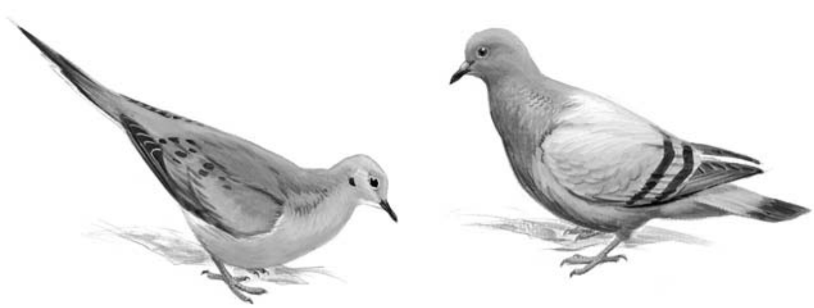
- All dove and pigeon species feed on grains, small seeds and fruits. Gregarious in nature, they feed and roost in flocks of varying size depending on time of year and location.

- The Rock Dove is commonly found in urban areas where it frequents roofs, ledges, bridges and parking garages. Like other dove species, the Rock Dove commonly feeds on seeds found in farm fields, feed lots, bird feeders, grain elevators, flour mills, railway yards and docks. During the fall and winter period, large feeding flocks gather at abundant food sources—particularly following harvests of cereal crops and grains. In cities, the Rock Dove also feeds on a variety of food items including bread, nuts, fruits, chips and French fries.

- Doves and pigeons require grit (particles of small gravel and sand) to aid in the digestion of seeds and grains.

- Airports attract doves and pigeons with food sources, water and grit found along roads, taxiways and runways—particularly during snow removal. Airfields and associated buildings and structures provide loafing and roosting areas.

- Buildings, hangars and parking garages provide nesting sites for Rock Doves, which often nest in close proximity to other breeding pairs once ideal nesting habitats are



Dove and Pigeon.

Species	Weight (lbs)
Bald Eagle	9.1-11.8
Gyrfalcon	2.1-4.4
Turkey Vulture	2.5-3.5
Red-tailed Hawk	2.3-2.7
Rough-legged Hawk	1.7-2.7
Peregrine Falcon	1.4-2.1
Northern Harrier	0.65-1.66
Broad-winged Hawk	0.93-1.1
American Kestrel	0.24-0.26

Table 3.7 Weights of Some North American Raptor Species

found. These birds can produce several broods during spring and summer breeding periods. The species can also breed during the winter period when a reliable food supply is available. Under ideal breeding conditions, Rock Dove populations can grow dramatically; a few pairs can produce hundreds of birds in a very short period of time. (See Appendix 3.1 for information on diseases associated with some common urban birds such as Rock Doves.)

Raptors

- Raptors are diurnal birds of prey that are found worldwide. There are six families of raptors inhabiting North America:

  - vultures (3 species),
  - hawks (15 species),
  - eagles (2 species),
  - kites (5 species),
  - falcons (6 species), and
  - harriers (1 species).

- Raptor species commonly found in and around North American airports include the Turkey Vulture, Red-tailed Hawk, Swainson's Hawk, Northern Harrier, Bald Eagle and American Kestrel, as well as the Rough-legged Hawk during the winter.

- Most species are attracted to open grass fields at airports—home to small mammals such as voles, ground squirrels, gophers, rabbits and hares. The abundance of prominent perching sites also makes airfields attractive. Flat open expanses provide good conditions for development of strong local thermals that enable soaring flight.

- Their large size (see Table 3.7), and high-altitude soaring and towering flight make these birds extremely hazardous to aircraft.

American Kestrel. Weight: 0.25 lbs.

- During migration, raptors prefer mountain ranges and coastlines where warm-air thermals and wind updrafts can be found. Migrating waves of raptors comprising thousands of birds can be encountered during ideal soaring and towering conditions.

- Normally, raptors are specific in their food requirements, preferring small mammals and birds. Smaller species will also feed on insects and shellfish. Vultures and eagles are commonly attracted to landfills because of their scavenging behaviour, and falcons are particularly attracted to areas that support populations of shorebirds.

- During the breeding season, individual pairs require large feeding territories and are therefore well spaced throughout their breeding range.

- With a few exceptions, both sexes have similar plumage, but immature birds can be strikingly different in colour.

- Some species have shown population declines over the past few decades and are protected under various wildlife regulations. As a result, specific identification is critical when raptor management is required.

- Turkey Vulture numbers have increased in recent years, and their habitat range now extends into southern Canada. The United States Air Force believes the greatest bird-strike risks to their aircraft are posed by Turkey Vultures.

Species	Weight (lbs)
Eastern Meadowlark	0.16-0.23
Common Grackle	0.22-0.28
European Starling	0.17-0.21
Yellow-headed Blackbird	0.09-0.19
Red-winged Blackbird	0.06-0.18
Rusty Blackbird	0.18-1.0
Brown-headed Cowbird	0.07-0.13

Table 3.8 Weights of Some North American "Blackbird" Species

Starlings and Blackbirds

- In North America, the name blackbird is often misused. It properly refers to a diverse number of species including:
  - Eastern and Western Meadowlarks,
  - Common Grackles,
  - Red-winged Blackbirds,
  - Yellow-headed Blackbirds,
  - Brewer's and Rusty Blackbirds,
  - Brown-headed Cowbirds, and sometimes
  - European Starlings and American Crows.
- Species commonly found in airport environments include Red-winged Blackbirds, Yellow-headed Blackbirds, Common Grackles, Brown-headed Cowbirds and European Starlings. As shown in Table 3.8, they are generally small in size, usually weighing less than 0.25 pounds.
- These species are significant hazards due to their flock-feeding and roosting behaviour. Based on a five-year average (1992 to 96) of reported bird strikes in the U.S., blackbirds, including starlings, were involved in 13 percent of all strikes—second only to gulls.
- All species in this group are attracted to short-grass and cash-crop fields, pastures, barn yards, feed lots, grain-storage bins and feed-transfer facilities. They eat insects, grains, seeds and fruits.
- This species is attracted to standing open water and wetland habitats commonly found at airports. The starling often nests in holes and cavities in airport buildings.

Species	Weight (lbs)
Snow Bunting	0.07-0.12
Lapland Longspur	0.05-0.07
Horned Lark	0.07

Table 3.9 Weights of Some North American Smaller Song Bird Species

- After the breeding season, these birds form large pre-migratory flocks that can include thousands of individual birds. During migration—and throughout their winter range—large concentrations of birds feed in grain fields. The number of birds that congregate in late-summer, fall and winter roosts can number into the millions.

- Starlings and blackbirds have adapted well to rural and urban human environments. Many species have extended their winter ranges by taking advantage of abundant agricultural crops throughout North America. Some species—especially starlings—have adapted to feeding at landfills, dumps and compost facilities.

Horned Larks, Snow Buntings and Lapland Longspurs

- These small (see Table 3.9), sparrow-like birds inhabit open grasslands and fields. In North America, they breed in northern Canada and Alaska.

- During the winter, large mixed-species flocks gather throughout the U.S. and southern Canada. Lapland Longspurs and Snow Buntings are the most widespread; their flocks can be made up of thousands of birds.

- During the winter, these species inhabit open fields where they feed on seeds and dry fruits. They favour fields where vegetation and seed heads are exposed above the snow, as well as plowed spaces and fields recently spread with manure. Large flocks will return repeatedly to the same fields as long as a good food supply remains available.

Horned Lark and Snow Buntings.

- Airfields are popular with these species because of seed availability. When fields are covered with deep snow, the bare grass edges of plowed runways are particularly attractive, providing a source of seeds and grit.

- The tendency of these species to move unpredictably as highly synchronized, dense flocks makes them potentially hazardous to aircraft operations.

Photo courtesy Northwest Airlines

Chapter 4

Mammals — A Primer

Introduction

As one might expect, mammals are not struck by aircraft as frequently as birds. When mammal strikes do occur, they are confined to runways—with the exception of collisions involving bats. Strikes involving mammals, however, usually inflict significant damage, since the sizes of these animals are, on the whole, greater than those of birds. Yet even small mammals inflict their share of damage; during takeoff and landing, general aviation pilots have on occasion swerved to avoid small mammals, often resulting in damaging runway excursions.

This chapter presents an introduction to mammals: their numbers, distribution and general behaviour. It will provide you with a working knowledge of mammal biology—knowledge that is critical in developing risk-management strategies. Detailed information is provided on some mammal species commonly found at North American airports. For exhaustive research on the matter, refer to publications listed in Appendix E.

Mammals have been the dominant life form for the past 65-million years. During this time, they evolved into a variety of shapes and types ranging from bats, seals, whales and deer to cats, dogs and primates. Mammals share the basic features of all vertebrates but are distinguished from birds, fish and reptiles by two fundamental characteristics: the possession of milk-producing glands—or mammae—and body hair. Other distinguishing features include well developed external ears and a pelvic girdle that permits standing, walking and running in certain species.

As in Chapter 3, we follow the custom of capitalizing the first letter of common names of mammal species (e.g., Red Fox, Coyote, and Grey Squirrel); names of groups of species are not capitalized (e.g., squirrel and deer).

Photo: This Saab 340 struck two deer while landing at a Michigan airport in April 2000. Following the strike, the engine was held in place only by oil and fuel lines.

Mammal classification or taxonomy

Mammals belong to the Class Mammalia, which is comprised of three major groups:

- egg-laying mammals such as the Duck-billed Platypus;
- mammals that give birth to embryonic young and often have a pouch, such as opossums; and
- those mammals which gestate inside the mother's body.

Only the last two groups are found in North America.

Present-day mammals are divided into 18 distinct orders, largely based on differences in gross body structure. Mammals' taxonomic order also recognizes the kind and number of teeth possessed by the various groups. In North America, there are 10 orders of mammals and more than 100 separate families.

More than 40 percent of mammals belong to the order Rodentia—or rodents—which includes more than 1,500 species. In North America, rodents make up almost 60 percent of all mammal species. Most rodents are small, secretive and go largely unnoticed.

Interestingly, bats are the second largest order of mammals in the world; their 896 species represent nearly a quarter of the world's mammals.

Mammalian diversity and distribution

Mammals have the lowest species diversity among the world's vertebrates, comprising about 3,800 species—less than half the number of bird species, and only a fraction of the number of fish species. Mammals are found throughout the seas and continents of the world. The largest concentration of mammal species is found in Central and South America, where 930 species reside. Africa is home to 860 species. In spite of North America's large landmass, this more recently formed continent is home to only 350 species, and less than 10 percent of the world's mammals.

The numbers of mammal species and individuals vary considerably around the world. For example, though the number of species in South America is high, these species are typically represented by relatively low numbers of individuals. In contrast, the number of land mammal species in Canada is low at 160, yet are represented by very large local populations. A caribou herd on its calving grounds may number into the hundreds of thousands. Similarly, local deer populations in southern Canada and throughout much of the U.S. often comprise hundreds of individuals each.

Although individual bird species in North America may be found breeding from coast to coast, mammals here tend to be much more restrictive in their distribution. Many species are restricted to specific habitats and are found only in a single province or state. For this reason, problem species at airports vary significantly from region to region.

Species	Number of Individuals
Black Bear	1
Red Fox	5-10
Raccoon	50
Striped Skunk	50-65
White-tail Jackrabbit	50-100
Deer Mouse	640-6,400
Eastern Cottontail	3,200-6,400
Woodchuck	3,200-16,000
Meadow Vole	144,000-480,000

Table 4.1 Estimated Average Population Densities of Some Common Mammals in Home-range Areas of 5 Square Miles

As a rule of thumb in North America, the number of mammals found in any local area seldom exceeds 30 species, and only a few of these present a hazard to aircraft. On the other hand, the presence of as many as 80 to 100 species of birds is not uncommon.

Mammalian numbers and population density

Mammalian numbers

The size of continental mammal populations is, for the most part, poorly documented and rarely studied. This may be attributed to the secretive nature of mammals; most are small and nocturnal, making them difficult to observe—unlike birds. Many large mammals occupy a wide home range through which they constantly move, making their detection difficult. In addition, most mammals do not migrate as birds do, and therefore cannot be counted and observed at key points along migration routes. Even so, population estimates for some larger game mammals reach impressive numbers.

In Canada, the Alberta population of Mule Deer has been estimated at more than 150,000 animals. The North American Elk population exceeds 500,000 while as many as 300,000 Moose are distributed across the continent. The population of White-tailed Deer across Canada has been estimated at approximately 2.5 million.

Mammalian population density

In any local area, mammal population densities are usually high. Many species of rodents, such as voles and mice, can reproduce at formidable rates; 6 to 8 litters of young in a single season is not uncommon. As a result, the number of voles in the grass fields around an airport can easily reach the tens of thousands. Average densities of the Meadow Vole range between 45 to 150 animals per acre. During population peaks, this figure can go as high as 400. Table 4.1 provides average home-range density estimates for a number of common mammal species.

Species	Weight (lbs)
Moose	800-1100
Elk	400-1000
Black Bear	200-600
Mule Deer	70-450
Barren Ground Caribou	150-400
White-tailed Deer	90-400
Pronghorn Antelope	70-150
Coyote	15-50
Raccoon	10-30
Red Fox	8-30
Woodchuck	5-14
European Hare	6-12
Whitetail Jackrabbit	5-10
Striped Skunk	2-5
Snowshoe Hare	3-4
Eastern Cottontail	2-4

Table 4.2 Weights of Some Common North American Mammals

Mammalian weights

The range of mammal body sizes and weights is much greater than among birds, because the vast majority of mammals live terrestrial or aquatic lives and are not restricted by the demands of flight. The North American Pygmy Shrew is the smallest mammal, with a body length of less than 2 inches and a weight of only 0.1 ounce. The largest land mammal is the African Elephant, standing as high as 11 feet and weighing up to 15,000 lbs. The largest animal on the planet is the Blue Whale, 70 to 80 feet in length and weighing up to a staggering 390,000 lbs. Apart from these extremes, the majority of mammals are smaller than the common house cat, and weigh less than a pound.

In North America, hoofed mammals and large carnivores are the largest mammals, and pose significant hazards when they roam onto active runways. Table 4.2 presents the weights of mammal species considered hazardous to aircraft in North America.

Mammalian senses

The degree to which mammals see, hear, smell and taste varies considerably. These variations are directly related to an animal's environment, way of life and role as either predator or prey.

For example, deer—constantly on the lookout for predators—have far better vision than moles, whose eyes have adapted to life in dark underground tunnels. We are all familiar with the fact that dogs have a much better sense of smell than we do—and hear sounds inaudible to the human ear. Many species have highly developed senses of hearing, smell *and* vision—unlike birds that have evolved primarily with only a keen sense of vision.

Vision

All mammals—including humans—detect light in the same spectral range. Mammals cannot see ultraviolet or infrared light. To the best of our knowledge, except for humans and other primates, mammals do not recognize colour.

The retina of the human eye is composed predominately of cone cells, responsible for sharpness of vision and detection of colour. In contrast, the retina of the non-human mammalian eye is almost entirely composed of rod cells, which register black, white and grey. While limiting colour detection, these rod cells also afford enhanced night vision—many mammals see as well at night as we do in daylight hours.

The lack of retinal cone cells in non-primate mammals results in poor visual acuity; in response, these animals have adapted to detect motion. Mammals may not detect the presence of a human provided he or she remains motionless; however, non-human mammals can detect the slightest movement—even the blinking of a human eye. Predators such as the wolf and Coyote have a visual acuity similar to humans. They have eyes that face forward, providing binocular vision for depth perception. Most prey mammals have poor vision, but are highly sensitive to the detection of movement. The bulging eyes on the sides of their heads provide primarily monocular vision throughout a range of almost 360 degrees, enabling detection of movement and danger on all sides.

Hearing

Non-primate mammals possess well-developed hearing; their inner ears are similar in both structure and function to the human ear. Human hearing is sensitive to sounds between 40 Hz and 20 kHz. Dogs and other canids—such as the Coyote and wolf—can hear frequencies as high as 30 to 40 kHz. Deer are believed to hear frequencies as high as 30 kHz. Bats, which emit sounds for echolocation of insect prey, can detect frequencies as high as 100 kHz, although it is unknown whether the detection of sound at these high frequencies constitutes hearing as we understand it.

Apart from their ability to perceive sound frequencies beyond our range of hearing, many mammals have external ears proportionately larger than those of humans. Larger ears provide significantly more reflective surface, directing sound waves to the inner ear for collection and detection of the faintest sounds. Mammals also have the ability to move their ears—often independently—to search for and track sounds.

Smell

Humans and birds *see* the world; other mammals *smell* it. Of all the senses, smell is the most highly developed in mammals. Their environment is rich with odours, informing them of the presence of danger, food and family. Studies have shown that deer cannot recognize their own fawns by sight—they rely on scent recognition. Though humans can identify hundreds of different odours, we may never appreciate the scope of other mammals' sense of smell.

In humans, the nose is associated with breathing, but for most mammals its primary function is that of olfaction, or smell. This sense detects minute amounts of chemical particles that trigger responses from chemoreceptors located in the mucus-covered epithelium membranes lining the nasal passageway.

Chemical detection occurs both inside the nose and on the nose surface—outside the nostrils. Chemicals in the air dissolve and are detected by surface receptors on this wet portion of the nose.

The keen sense of smell in mammals is truly amazing. Coyotes and wolves often locate voles under a deep layer of snow by smell alone. Deer and Bighorn Sheep also use their sense of smell to locate food under snow. Large ungulates—such as deer, Moose and Elk—do not possess sharp vision, and often depend on the detection of a predator's scent to become alerted to danger. Under ideal conditions, bloodhounds can follow a scent that is two-weeks old. Small mammals with poorly developed hearing and vision—such as voles and mice—depend almost entirely on smell to survive in their environments.

Taste

Experiments on mammals indicate they have an acute sense of taste. Like humans, mammals can detect taste only as being either sweet, sour, bitter or salty. The human ability to sense flavours is in fact more dependant on what we smell than what we think we taste. This is probably true for other mammals as well, and that may confound efforts to achieve an appealing balance between taste and smell in the development of chemically altered mammal-deterrent foods—we simply don't know what tastes good or bad to different species of mammals.

Touch

For mammals, the sense of touch is primarily concentrated in skin not covered by fur—the nose, tongue and pads of the feet. Mammals have tactile sensors located throughout their skin that detect the sensations of warmth, cold, touch, pressure and vibration. Unlike birds, the sense of touch in mammals is important to communication. Tactile stimulation such as licking, nuzzling, grooming and nipping is an important aspect of various social behaviours including mating and nurturing.

Mammalian behaviour

Collectively, mammals show a diverse and complex array of behaviours that vary with the season, time of day, environmental conditions and species.

Periods of activity

The majority of mammals are nocturnal—they are active at night. The presence of tracks and droppings are often the only clues that mammals inhabit an area. Identifying these clues and determining which mammals occupy an airport environment is critical in reducing potential hazards, since more than 60 percent of reported mammal strikes occur at night. Some mammals—including rabbits, hares and deer—are most active during the early morning and evening periods. They spend midday—and night—at rest. Other mammal species such as squirrels and large herbivores are active only during the day.

A number of factors can influence mammals' activity patterns. For example, the abundance or scarcity of food sources will extend feeding activity beyond its normal periods. In the fall, many mammals increase the time they spend feeding to build up energy reserves for winter. During mating periods, both males and females are often active for prolonged periods. Mammals tend to be less active when weather is unfavourable, although these periods of forced inactivity are often followed by marked increases in activity.

Feeding

Mammals are generally placed into four groups according to their eating habits:

1. Carnivores (meat)
2. Herbivores (vegetation)
3. Insectivores (insects)
4. Omnivores (generalists having a highly varied diet)

Approximately 80 percent of mammal species are herbivorous, living on leaves, shoots, roots, twigs, buds and seeds. Many mammals are attracted to airport environments by grass fields, and by trees and shrubs often found growing at airfield perimeters. Most herbivores feed on specific types of vegetation, so eliminating or controlling these food sources can be a primary management method. For example, deer activity can be reduced through removal of shrubs and early succession-forest habitat that provide browse. Similarly, grass-management programs that control broad-leaf cover and seed production can reduce small mammal populations.

Carnivores are the second most common group of mammals living in airport environments, and are attracted by the presence of small mammals. The presence of Coyotes and foxes indicates healthy populations of small mammals including voles, mice, rabbits and hares. In such cases, the management of prey populations is often the best means of reducing predator numbers.

Species	Home Range Size
Black Bear	80 sq. miles
Raccoon	1 sq. mile
Wolf	100 to 300 sq. miles
Coyote	50 to 100 sq. miles
Fox	1 to 4 sq. miles
Moose	1 to 2 sq. miles
White-tailed Deer	0.0625 to 0.469 sq. miles
Snowshoe Hare	0.016 sq. miles
Red Squirrel	0.003 to 0.008 sq. miles
Meadow Vole	0.0008 to 0.001 sq. miles

Table 4.3 Home Range Sizes of Some Common North American Mammals

Behaviour that can create aviation hazards

Mammal behaviour that is hazardous to aviation is sub-divided as follows:

- behaviour that creates direct and indirect threats to aviation, and
- behaviour that creates other aviation hazards in the airport environment.

Mammalian behaviour that creates direct and indirect aviation hazards

Movements

Mammals do not roam randomly; their daily activities occur within well-defined home ranges and territories. There is great variation in the size of these home ranges, which are key in determining local-population densities. Generally, the home-range size is correlated to species size; larger mammals are more mobile and require greater food resources, so they occupy more territory. Table 4.3 presents typical home-range sizes for groups of mammals sharing similar diets but with varied body size.

Home-range movements vary by species. Many carnivorous species move constantly throughout their home range in search of prey. Other species make local movements between different habitats within their home range, responding to local and seasonal changes in abundance of specific food types, or specific breeding habitat requirements. During breeding season, the search for a mate may extend a male's typical home range. Many small rodent species are amazingly static animals, moving less than a few hundred yards in the course of their daily activities.

A number of mammals, particularly larger ungulate species such as deer, undertake seasonal migrations. Knowledge of these movements helps wildlife-management personnel reduce the hazards of larger mammals. Caribou, which inhabit the far north, undertake extensive migrations between summer and winter ranges. Some herds travel thousands of miles each spring and fall. Many local White-tailed Deer populations undertake migrations to yard-up in well established and protected areas during deep-snow winters. Depending on local conditions, these movements can cover more than a hundred kilometres. A review of five-year deer-strike data in the U.S. shows 45 percent of all strikes occur in the fall, when many local deer populations are on the move to wintering areas.

Social behaviour

Mammals exhibit complex social behaviour in all aspects of their lives. Studied extensively over the past 30 years, knowledge of this behaviour forms much of the scientific literature on mammals, and provides valuable information for airport wildlife-management personnel—specifically in relation to the way individual mammals associate. Some live in small loose groups; others form well structured herds and packs, or live in highly organized colonies.

The majority of North American rodents live solitary lives within their territories. In contrast, a few species of rodents—marmots, ground squirrels and prairie dogs—are colonial and live communally in large numbers. Colonial rodents often live in dens and burrows, which members of the colony build and defend collectively. A prairie-dog town, with its complex network of burrows, tunnels and entrances, can cover several hundred acres and be inhabited by hundreds of individuals grouped into discrete blocks. Both the Columbian and Richardson's Ground Squirrel live in small colonies of 20 to 30 individuals. The large, undisturbed grass fields of airports are attractive to such colonies. Once established, these colonies can cause a number of problems at an airport, interfering with grass-management programs, chewing and damaging electrical cables, undermining runways and taxiways, and attracting both bird and mammal predators.

Ungulates, such as deer, Elk and Caribou, live in groups and herds varying from three to several hundred animals. The White-tailed Deer and Mule Deer are the most common herding species in most parts of North America. Mule Deer are typically more gregarious than White-tailed Deer. They live in small mixed-age groups of two to 20 individuals throughout the year. White-tailed Deer tend to be solitary throughout much of the summer; however, during the late fall and winter they may form large herds that number into the hundreds. In areas where food resources are limited, protected grass fields and small woodlots at airports can attract large numbers of deer. For example, Chicago's O'Hare and Toronto's Lester B. Pearson International airports are located in areas that are highly urbanized; both airports have reported deer herds of as many as 50 animals.

Regardless of their size, deer herds are significant hazards in an airport environment. Controlling this hazard is a delicate balance between passenger-safety and wildlife-conservation concerns. Increasing public awareness of the hazard posed by deer is necessary before effective management measures can be undertaken.

Mammalian behaviour that creates other aviation hazards

Gnawing

Rodents are distinguished by two pairs of specialised, chisel-like incisors used to gnaw and clip vegetation, twigs, bark and seeds. Growing throughout an animal's life, these teeth require constant use to maintain their sharpness. The front face of the tooth is harder than the back, but wears faster through gnawing, creating a sharp, chisel edge. The need to chew leads many rodents to gnaw instinctively on such hard materials as wood, plastic and even soft metals, and often poses a threat to airfield lighting cables, fixtures and to interiors of buildings and aircraft. For airports, which support large populations of small mammals, damage costs caused by gnawing can be significant.

Burrowing

Digging and burrowing behaviour—common to many mammal species—is a cause for concern in airport environments. Some mammals, such as Coyotes, foxes and wolves, dig and occupy dens solely for the purpose of rearing young. Groundhog, ground-squirrel and prairie-dog burrows provide nesting sites, shelter for sleeping and protection from predators. The den of a single groundhog can have a number of entrances and tunnels; a well-established den site may feature a tunnel system more than 45 feet in length. Ground squirrels excavate complicated multi-entrance burrows that are a maze of galleries, blind passages and chambers. These tunnel systems range between 10 and 60 feet long.

Burrowing activity threatens grass-management programs at airports, interfering with cutting blades and the wheels of cutting machinery. Burrowing can also cause the collapse of runway and taxiway shoulders.

Mammalian behaviour towards aircraft

Many factors can alter a mammal's behaviour toward aircraft including:

- mammal species,
- time of year,
- weather conditions,
- age and condition of the mammal, and
- the mammal's experience with aircraft and airport environments.

There is little scientific documentation concerning mammal behaviour towards aircraft. Anecdotal information is also lacking; many mammal/aircraft encounters occur at night when pilots are unable to observe fright-flight behaviour, for example.

Mammalian evolutionary and adaptive behaviour to aircraft

Unlike birds, most mammals are wary of human presence. This is particularly true of larger mammals such as deer, bears, wolves and Coyotes. Mammals respond with freeze behaviour when startled by noise or motion, remaining still to limit their own detection as they locate the source of danger. Flight behaviour follows as animals escape by running in straight lines away from perceived threats; they seem to know instinctively that attempting escape before a threat is identified may cause them to blunder into the source of danger itself.

Yet mammals that pose strike threats at airports are not innately afraid of aircraft or vehicles. Mammals adapt to almost any sound or motion, and quickly habituate to aircraft noise and movements. In national parks for example, deer, Moose, Elk and bears frequently forage undisturbed along busy highways and rail-lines, accustomed to the intense activity found there.

Mammalian behavioural responses are unpredictable

The behaviour of mammals toward aircraft is unpredictable; it varies with mammal species and maturity of individual animals.

Data show deer as the mammal most frequently struck at airports. Given their agility and wariness, their susceptibility seems puzzling, but startled by the noise and caught in landing lights of oncoming aircraft, deer freeze behaviour often spells their doom—before they are able to locate the source of danger and escape, aircraft overtake them. These mammals exhibit a mesmerised behaviour when looking directly into a strong light source at night; they often remain frozen for a long period of time before moving off, perhaps because the glare blinds them to motion behind the light.

Photo courtesy Brian Blackley, *Troy Messenger*

Lear 60 that was destroyed as a result of a deer strike while landing at Troy, Alabama, in January 2001.

Hunters often use tree stands to hunt White-tailed Deer, maintaining that deer do not detect movements more than three metres above the animal's line of sight. It may be that White-tailed Deer do not typically look upward to scan for danger since few natural predators attack them from above. Yet even in areas prowled by Mountain Lions—which pounce from trees and rock ledges—Mule Deer and Black-tailed Deer are more likely than White-tails to look upward in search of danger.

The dynamic nature of mammal populations

Most mammal populations remain stable at or near a habitat's carrying capacity from year to year. Apart from annual population fluctuations—high in late fall, low in early spring—dramatic shifts in mammal numbers are rare. Unlike birds, which are highly mobile and capable of moving quickly in or out of an area, mammals tend to be limited to movements within local areas in which they were born. In addition, competition between similar mammal species results in well-defined territorial boundaries, preventing establishment of new populations outside existing home ranges.

Some species of mammals show cyclic changes in population numbers. For example, the Snowshoe Hare, lemming and some species of voles undergo dramatic oscillations in population densities. These fluctuations follow a cyclic pattern over a span of years—from extreme lows to extreme highs, followed by a population crash, which usually results from either exhaustion of food resources or spread of disease. The difference between population highs and lows can be extreme. For example, studies of the Snowshoe Hare have shown population lows of one individual per square mile, and extreme highs of 3,400 individuals per square mile. Fluctuations in Meadow Vole populations occur over three- to four-year periods; densities rise from 15-45 animals per acre to peak highs of 400 animals per acre. Not surprisingly, predator populations rise and fall with those of their prey; however, predator numbers rarely reach the same dramatic highs and lows.

Other non-cyclic changes in population numbers of mammals can also occur as a direct result of either a sudden abundance or shortage of food. Populations can increase when extended periods of favourable weather lead to abundances of food. Numbers can also rise when animals are attracted to areas providing short-term availability of food. Periodic and extreme shortages of food can result in mass movements of animals; Black Bears in search of food roamed into suburban Ottawa communities during the mid-1990s after the failure of fall berry crops. In areas with significant winter snowfall, two or three consecutive mild winters can produce a dramatic rise in deer numbers, which are controlled primarily through winter mortality; with an abundance of food, fewer die.

Mammals are able to expand their ranges only when predator or competitor pressures are relaxed, or when new habitat becomes available. These changes tend to take place over large geographic areas in which scattered local populations expand gradually. For example, the Coyote expanded its range northward and eastward into Canada beginning in the early 1900s. This slow spread of the Coyote's range was directly linked to the disappearance of its predator and competitor—the wolf. As a result, the Coyote's range and numbers continue to grow in Canada. Similarly, deforestation—coupled with diminishing wolf populations—has allowed the White-tailed Deer to increase its presence throughout eastern Canada and the U.S.

Some mammals have recently increased their range and numbers as a direct result of human efforts. Large game species such as the White-tailed Deer, Elk and Moose have been subjects of introduction programs since the early 1900s. Habitat-management programs and the establishment of nature reserves and parks have greatly benefited local game-animal populations. Finally, reduced trapping activities and the elimination of some pest-management programs have drawn many species back to their historic ranges and resulted in resurgence in local-population numbers.

Mammalian adaptations to the human landscape

In North America, the vast majority of mammal species have not adapted well to the increasing presence of humans which, over the last 200 years, has resulted in significant and dramatic reductions in the numbers and distribution of some of the continent's mammals. It is sometimes difficult to credit the historic accounts of early settlers and explorers that described a coast-to-coast abundance of bears, wolves, Cougars, large game animals and fur-bearers. Displaced and exterminated by human activity, many large mammals occupy present-day ranges that are but a fraction of what they once were. Lumber and agricultural activities eliminated habitats of many species now found only in remote areas and wilderness parks. Many smaller rodents and carnivores considered a direct threat to agricultural interests were subjected to extensive and prolonged extermination programs that greatly reduced their range and population size.

Only a few mammals have proven adaptable in rural, suburban and urban environments—animals such as the park squirrel, country deer, skunk and Raccoon. Three factors have contributed to the success of some mammals in today's human landscape:

1. An increase in favourable food resources
2. An increase in suitable habitats
3. Population increases and range expansions resulting from relaxed hunting and trapping activities, and an absence of natural predators and competitors.

A number of mammals have benefited from the spread of agriculture, which has increased open country habitat and provided new sources of food. Many crops—such as grains, vegetables and fruits—provide a new and abundant food source for a number of mammals. Pastures and hay fields provide habitats for some small mammals, which were restricted historically in both their abundance and range by the dominance of forests. The rural mosaic of abandoned scrub fields, crop and pasture lands, hedgerows and woodlots provide ideal habitat for a diverse number of species including Coyote, fox, rabbit, hare, Woodchuck, vole and White-tailed Deer. Some mammals such as skunks, Raccoons, bats and squirrels have been particularly successful in exploiting the human landscape, and are now common in suburban and city environments. Some larger mammals such as deer and Coyotes have greatly benefited from removal of natural predators and competitors from the environment. In many parts of Canada and the U.S., deer and Coyotes are now often more abundant in rural and suburban areas than in their natural habitats. As their

Feature	Benefit	Mammal Species
Grain and vegetable crops	Direct food source	Rabbits, hare, squirrel, deer, Woodchuck, Raccoon
Pasture lands and hay fields	Direct food source	Rabbits, hare, ground squirrels, deer, voles
	Increase in small prey for predators	Fox, Coyote, Badger, skunk
	Increase in habitat	Voles, mice, moles, rabbit, hare, Badger, Woodchuck, ground squirrels
Mosaic of hedgerows and woodlots	Increase in habitat	Fox, Coyote, rabbits, Woodchuck Raccoon, skunk, deer
Orchards and berry farms	Direct food source	Deer, Raccoon, skunk, bear, rabbits, mice, voles
	Increase in habitat	Voles, mice, rabbits, Woodchuck, skunk
Landfills and food waste	Direct food source	Fox, Coyote, bear, skunk, Raccoon, rats, mice
Buildings	Shelter	Raccoon, skunk, mice, rats, bats, tree squirrels
Old shrub fields	Increase in habitat	Fox, Coyote, skunk, Raccoon, Woodchuck, deer, rabbit, hare, voles, mice
Reservoirs, ponds, channels and ditches	Increased habitat	Muskrat, Beaver, Raccoon
Harvested/managed forests	Increased food/habitat	Deer, Moose, Elk
Conservation/refuge areas	Increased habitat	Most mammals
Wildlife management, hunting/trapping/control programs	Reduce pressure on populations	Coyote, fox, Beaver, Muskrat, deer, hare, ground squirrels, Woodchuck, Raccoon

Table 4.4 Features in the Human Environment that are Attractive to Mammals

populations grow, many species that are no longer subjected to population control are now re-establishing themselves in rural and suburban areas.

Though mammals as a group have not exploited the human landscape as successfully as birds, some have clearly benefited—and tend to be among those species most often encountered in the airport environment (Table 4.4).

Mammals that commonly create flight-safety problems

Wildlife-strike data indicates that a number of mammal species have been struck by aircraft in North America. Some, such as deer and Coyote, are directly involved in collisions with aircraft. Others, especially voles, tend to be indirectly involved, attracting predators such as foxes, hawks and owls which may be directly involved in collisions.

The following sections present some species directly and indirectly involved in collisions.

Species involved directly in wildlife strikes

Deer

- Nearly 70 percent of all reported mammal strikes in North America involve deer, making this animal the greatest mammal hazard. More than 40 deer strikes are reported annually in North America—many resulting in significant aircraft damage.

- Of the two North American species of deer—Mule Deer and White-tailed Deer—involved in mammal strikes, the White-tailed Deer is the greater hazard due in part to its wider distribution.

- The White-tailed Deer has adapted well to the human landscape. Populations in many rural and suburban areas have increased significantly due to lack of natural predators, absence of hunting and availability of food. In some areas, populations are reaching such high densities that starvation is the primary control factor.

- Both species of deer show a tendency to migrate as much as 100 miles to winter feeding grounds in herds of varying size.

- At airports, deer are attracted by broad-leaf vegetation, grasses, and crops—particularly clover and alfalfa; they also browse on shrubs and young trees. Woodlots and forested ravines provide safe cover and resting areas. In suburban settings, airports may be home to concentrations of deer, providing the only source of food and cover.

- In rural areas, deer are attracted to grain crops, orchards, early-age deciduous woodlots and plantations of spruce and pine that provide ideal winter cover. Farming-area hedgerows are often used as corridors between feeding and resting areas.

Coyote

- Coyotes are second only to deer as the most hazardous mammal at North American airports. Between 1992 and 1996, 35 Coyote strikes were reported in the U.S.—11 percent of all those involving mammals. Coyotes are attracted to airport environments by the availability of small mammals such as voles, rabbits, hares and Woodchucks. Airfields that support Woodchuck and Badger populations also provide denning sites for Coyotes.

- Though often mistaken for wolves, Coyotes are smaller and have more slender bodies; they resemble medium-sized dogs. Over the past 50 years, this species has expanded its range throughout north-eastern U.S. and eastern Canada.

Extensively damaged Beech 1900 as a result of striking a White-tailed Deer at Latrobe, Pennsylvania, in December 1996.

- The basic social unit includes the mated pair and pups, but in winter they will form packs to hunt larger game such as deer. Coyote packs usually comprise related family members, and include 4 to 10 animals.

- The Coyote is intelligent and highly suspicious of people. It is an adaptable animal and is one of the few mammal species able to adjust to and thrive in rural and suburban environments. In settled areas, it prefers a landscape of open grasslands, woodlots, ravines and agricultural fields.

- Coyotes can be active at any time of day, but are primarily nocturnal.

- Females deliver pups in enlarged dens often originally created by Woodchucks and Badgers. The hunting territory surrounding a den may be as large as 12 miles in diameter. Females return to the same breeding territory each year.

Red Fox

- Though considered minor hazard, Red Fox are involved in some reported strikes each year in North America. They are attracted to airport environments by availability of voles, rabbits and hares. Red Fox will also feed on garbage.

- There are five species of fox in North America; the Red Fox has the widest distribution and is by far the most common. The Red Fox is relatively small—its body is not much larger than that of the average house cat.

Deer and Coyote. These are the two most frequently struck mammals in North America.

- The family is the basic social unit through at least half the year—from mating in early spring until pups disperse in late summer. After this period, animals are solitary until next mating season. Foxes usually modify abandoned Woodchuck burrows to serve as dens, but they will occasionally excavate their own.

- The Red Fox favours varied habitats in suburban and rural areas. Over the past few hundred years the species has become particularly abundant in rural areas, attracted by a mixture of small woodlots, open fields and hedgerows.

- The Red Fox is an omnivorous and opportunistic feeder and will eat almost anything it can catch. During late summer and fall, fruits, berries and insects make up the bulk of its diet. In winter, meat is its primary food. Small mammals like voles, Woodchuck, squirrels, Muskrats, rabbits and hares form its principal prey. Red Foxes will also scavenge carrion and feed at garbage dumps.

- Red Foxes are most active at night but may hunt during the late afternoon and early morning. They may travel up to five miles on a single hunting trip.

- The average fox density in agricultural areas is approximately two animals per square mile, yet Red Fox population cycles are subject to regular 8- to 10-year fluctuations in which peak densities may reach 25 animals per square mile.

Species indirectly involved

Rabbits and Hares

- Contrary to popular belief, rabbits and hares are not rodents but belong to the family Leporidae in the order Lagomorpha. Though rabbits resemble rodents (the order Rodentia), there are a number of anatomical differences that separate the two orders.

- Hares differ from rabbits in their larger body sizes, and longer ears and hind legs. Rabbit young are born naked, blind and helpless, whereas the young of hares are born with body hair, eyes open and the ability to run soon after birth.

- North America is home to 15 species of rabbit and hare. The most widely distributed and most common at airports include the Snowshoe Hare, Whitetail and Blacktail Jackrabbit and Eastern Cottontail.

- All species inhabit open fields and meadows and are common in rural landscapes. They are attracted to airfields by an abundance of field weeds and forbs. Crops such as clover and alfalfa are particularly attractive. Fencerows, shrub-covered ravines, ditches and small woodlots around airports provide excellent cover.

- Rabbits and hares are most active during early evening and morning hours, although some activity occurs at night.

- All species are extremely prolific breeders, producing three to four litters a year, four to five young per litter. Local populations can suddenly and dramatically increase. Some species—such as the Snowshoe Hare—can undergo dramatic population fluctuations. Densities can change from lows of only a few individuals per square mile to peaks of thousands per square mile in just a few years.

- Rabbits and hares are a minor hazard. Only a few strikes are reported each year in North America; however, rabbits and hares attract other animals that constitute a greater risk in airport environments—predators such as foxes, Coyotes, hawks, owls and eagles.

Squirrels

- The squirrel family is one of the largest families within the order Rodentia. This family includes common and well-known mammals such as chipmunks, Woodchucks, marmots, ground squirrels, prairie dogs and tree squirrels.

- Of the tree squirrels, the Red Squirrel, Fox Squirrel and Grey Squirrel are the most common and widespread. All species are arboreal and terrestrial and live in a variety of woodland habitats. Nests are typically located in trees but they will also use artificial structures such as poles, towers, buildings and machinery as nesting sites. They eat everything from seeds, nuts and buds to flowers and mushrooms. These species have adapted well to urban and rural environments and can be found in small woodlots, parks, hedgerows, windbreaks, and all kinds of landscape plants.

- Although there are no documented cases of aircraft collisions with either tree or ground squirrels, these mammals can become indirectly involved by attracting larger predatory birds and mammals to airport environments. Both species can also cause problems at airports by gnawing on cables and wires, and by nesting and storing food in buildings, maintenance equipment and parked aircraft. Ground squirrels' vast burrow systems can interfere with grass-maintenance operations.

- There are more than 15 species of ground squirrels, the prairie dog among them. Many species are restricted in their range, found only in parts of one province or state. Most inhabit well-drained open grass plains where they excavate elaborate networks of tunnels and many entrances. They eat leaves, seeds and crop plants.

- North America is home to five species of marmots, the largest ground-dwelling squirrels. The Woodchuck—or groundhog—is the best known, ranging across Canada and most of the eastern United States. A large Woodchuck can measure two feet in length and weigh 14 pounds. These animals inhabit well-drained fields, pastures and fencerows. Primarily grazers, they eat vegetative parts of grasses, field weeds and young field crops. Dens and burrows are large elaborate structures; piles of earth often form at the entrances.

- Woodchucks are a minor hazard—only a few strikes are reported each year in North America; however, these animals attract direct-hazard mammals and birds to airport environments. Their burrows significantly inhibit mowing operations, and can lead to the collapse of runway and taxiway shoulders. Woodchucks also gnaw wires, damaging airport communications and lighting systems. Their abandoned burrows provide denning and nesting sites for a variety of other mammal species such as foxes, Coyotes, skunks and Raccoons.

Voles

- Voles are often mistaken for field mice, but have shorter tails, smaller ears and larger, more robust bodies.

- More than 20 species of voles live in North America. Many inhabit dense grassy fields where they feed on such plant matter as leaves, stems, roots, fruits, seeds and flowers. The Meadow Vole has the widest distribution and is the species most often found in airports.

- Voles are rarely seen and are best evidenced by their extensive system of grass tunnels that measure about 1.5 inches in diameter; their grass-ball nests range in size from 6 to 8 inches in diameter.

Although not often considered a hazardous species, small mammals such as Woodchucks can undermine runways and taxiways with their burrowing activities.

- Under ideal conditions, Meadow Voles can breed year-round; populations can increase quickly. Local populations cycle over a span of three to four years, peaking at hundreds of animals per acre.

- Meadow Voles are a primary food source for many predatory species of mammals and birds. Many species of hawks and owls rely on voles for as much as 80 percent of their diets. Voles are also a staple diet of the fox and Coyote.

Beaver and Muskrat

- Beavers and Muskrats are aquatic mammals, never found far from water. Both species inhabit rivers, lakes, creeks, marshes, swamps and ditches. Though rarely directly involved in collisions with aircraft, they can be an indirect hazard.

- Through the construction of dams, beavers create lakes, ponds and wetland habitats that attract many species of hazardous wildlife, particularly waterfowl, shorebirds and raptors.

- Beaver dams can cause flooding of runways and taxiways. Their dams also raise water tables, causing frost heaves beneath runways and taxiways.

- Muskrats attract predatory mammals and raptors.

The large areas of standing water that result from beaver activity can create an attraction for hazardous birds such as waterfowl.

- As a result of tunnelling activities, beavers and Muskrats also cause problems at airports by damaging and undermining the integrity of drainage ditches and the banks of streams and creeks.

- Due to a decline in demand for fur, both species have shown dramatic population recovery in former ranges. The suburban and urban presence of these species is increasing throughout much of southern Canada and the U.S.

Chapter 5

Civil Aircraft and the Aviation Industry

Introduction

Risk posed to aircraft by wildlife-strikes is measured after determining:

1. the exposure, probability and severity of a wildlife strike,
2. the aircraft and engine type, and
3. the aircraft operating environment (See Chapter 2 and 6).

Exposure and probability relate to the environment in which a particular type of aircraft operates. Since most wildlife strikes occur during takeoff and landing phases (see Chapter 7), aircraft that frequently engage in these activities are at higher risks. Operations in and out of airports where there is little or no wildlife-management activity—such as small community airports and major airports in developing nations—are also at higher risks of incurring bird and mammal strikes.

Certification standards for particular engine and airframe components are important when determining the potential severity of damage. These standards vary with the type of aircraft and engine; critical forward-facing airframe components such as windshields, wing leading edges and empennages have different bird-impact design criteria. Turbine engines—particularly those in jet transport aircraft—are much more likely to sustain significant bird-strike damage than piston engines.

The probability and severity of wildlife strikes for various classes of aircraft can be determined through an examination of:

- current world-aircraft fleet distributions,
- projected growth patterns,
- various aircraft operating environments, and
- aircraft and engine certification standards.

Civil-aviation aircraft categories

Aircraft are divided into categories based on class of operation, and each category is sub-divided on the basis of engine type. Throughout this book, various terms are used to describe civil-aviation aircraft categories; the following sections explain how these terms were derived.

Class of operation:

Three definitions describe the different classes of civil-aviation operations:

1. commercial aviation,
2. general aviation, and
3. rotary wing aviation.

To refine scenarios of potential wildlife-risk, these three classes are subdivided, reflecting regulatory language.

Commercial aviation

Commercial aviation is defined as the "*use of an aircraft for hire or reward.*" Transport Canada has chosen to subdivide this class of operation in the following manner, based on aircraft weight and/or the number of passenger seats.

1. Aircraft of maximum takeoff weight (MTOW) of more than 19,000 lbs, or 20 or more passengers
2. Aircraft of a MTOW of less than 19,000 lbs or 10 to 19 passengers
3. Aircraft of a MTOW of less than 19,000 lbs or up to 9 passengers
4. Aircraft used for hire or reward and not meeting any of subdivisions 1 to 3.

- **Airline operations:** scheduled operations with aircraft having 50 seats or more.
- **Regional airline operations:** scheduled operations with aircraft from 10-50 seats.
- **Air-taxi operations:** scheduled operations with aircraft having up to nine seats.
- **Air-freight operations:** operations with any size aircraft carrying cargo only.
- **Charter operations:** operations with any size aircraft on non-scheduled flights.

General aviation

The International Civil Aviation Organization (ICAO) defines general aviation as "*all civil aviation operations other than scheduled air services and non-scheduled air transport operations for remuneration or hire.*" Transport Canada generally follows the ICAO approach in regulatory language, but refers to business aircraft as private-air operators. Other jurisdictions such as the U.S. include air taxi, business aircraft and aircraft employed in charter operations as part of their general-aviation regulatory language. The lack of a consistent definition makes these terms difficult to compare, which is a problem, considering the important role of these aircraft and their potential involvement in wildlife strikes. To clarify, this book relies on the following definitions:

- **General-aviation operations:** civil-aviation operations outside scheduled air services and non-scheduled air-transport operations for remuneration or hire.
- **Business-aircraft operations:** companies and individuals using aircraft in conducting business.

Rotary-wing operations

Rotary-wing aircraft—or helicopters—are defined as power-driven, heavier-than-air craft that derive lift in flight from aerodynamic reactions to one or more rotors on substantially vertical axes.

Aircraft engines in civil aviation

Aircraft-engine history

Until the 1930s, aircraft power plants were exclusively internal-combustion piston engines. These engines remain the dominant type today, since light, fixed-wing general aviation aircraft—and as many as one-third of civil helicopters—make up the bulk of the world's fleet. During the '30s, several countries began to develop gas-turbine engines. Research scientists quickly recognized their potential; gas-turbine engines offered greater power while being lighter, more efficient and requiring less maintenance than piston engines.

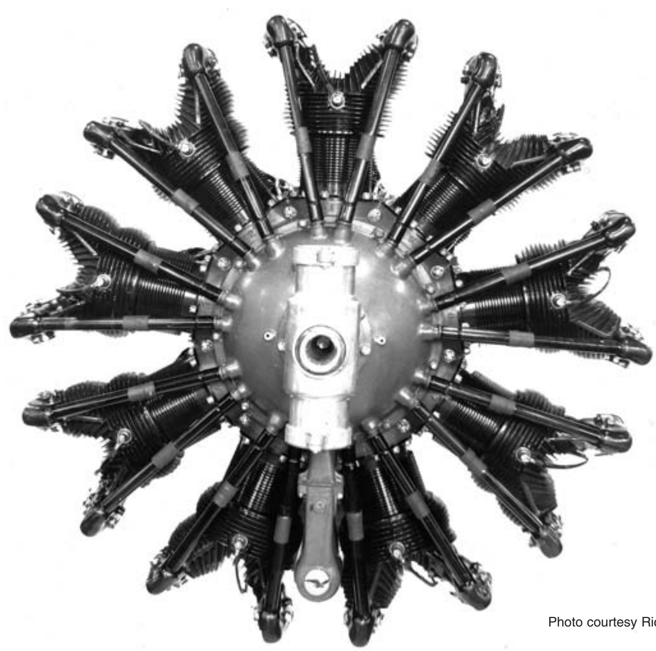


Photo courtesy Richard Parker

Figure 5.1 Radial Piston Engine

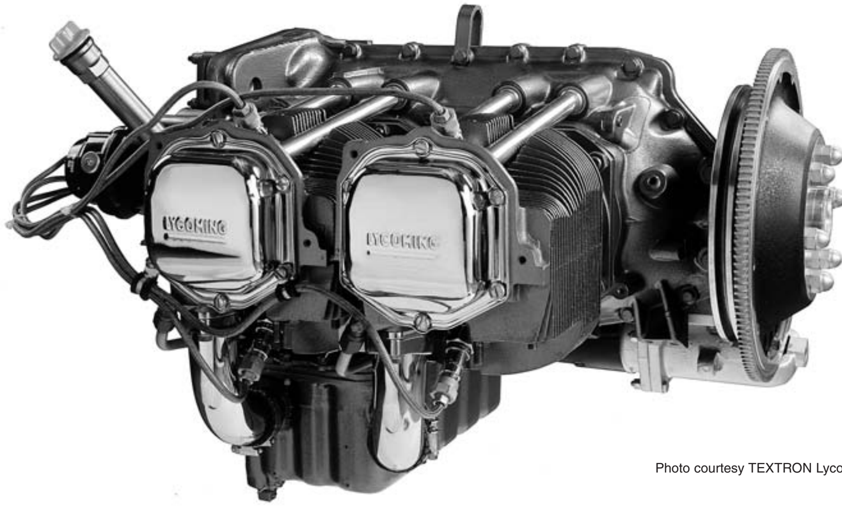


Photo courtesy TEXTRON Lycoming

Figure 5.2 Horizontally Opposed Piston Engine

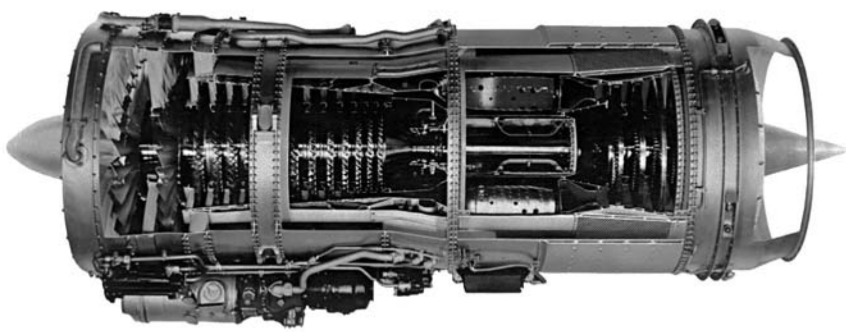


Photo courtesy Richard Parker

Figure 5.3 JT8D Jet Engine

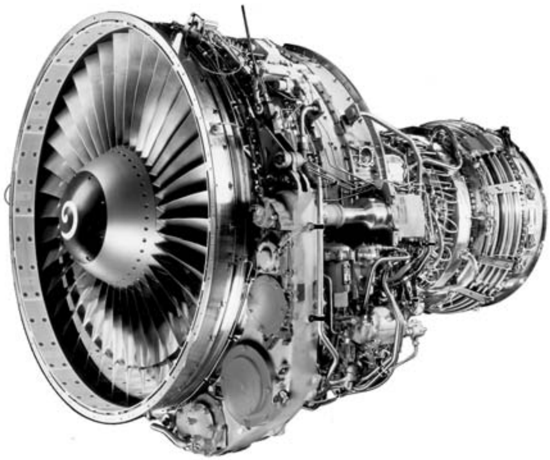


Figure 5.4 CFM56 Turbofan Jet Engine

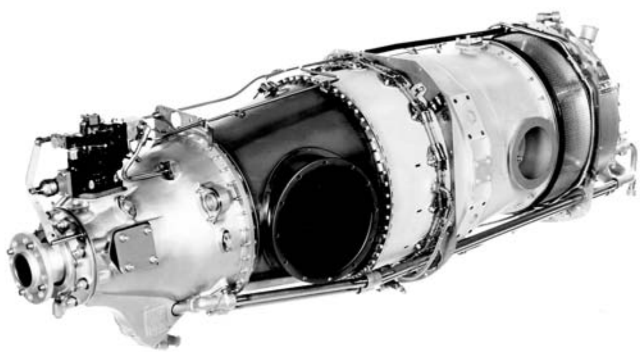


Figure 5.5 PT6 Turboprop Engine

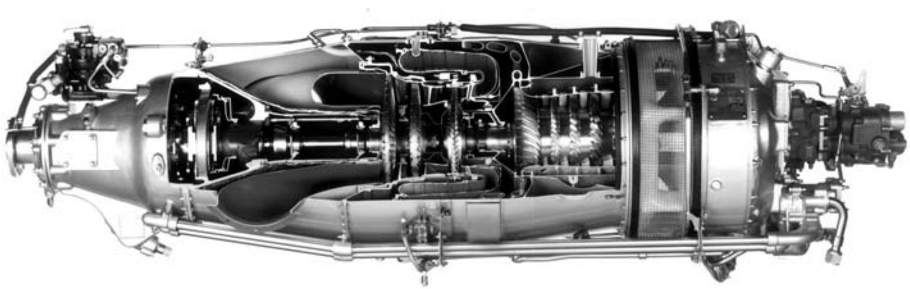


Figure 5.6 Cutaway of a Turboprop Engine

The Second World War brought the first experimental flights of prototype jet-engined aircraft, and by war's end some were in service. The first civilian jets appeared in the early '50s and included the DeHavilland Comet and the Boeing 707. Extensive research and development also applied gas-turbine technology in helicopters and corporate aircraft, as well as in aircraft serving regional airline and air-taxi operations.

Piston engines are categorized by cylinder configurations:

- **Radial engines** (Figure 5.1) feature a number of cylinders arranged around the crankshaft like spokes in a wheel. These engines are less common in North America, but are still used extensively in developing nations.

- **Horizontally opposed engines** (Figure 5.2)—commonly used on light general-aviation aircraft—are made up of cylinder pairs horizontally opposed around the crankshaft in combinations of 4, 6 or 8.

Gas turbine engines are divided into four categories:

- **Turbojets** feature a fuel-burning gas producer with an outlet nozzle that controls efflux, and produces thrust.

- **Turbofans** comprise a central gas-producing core and a fan at the front end of the engine. Driven by one or more turbine stages powered by the core, the fan compresses inlet air and passes it through the engine's main core. The bypassed air is then mixed with the core exhaust gases to produce thrust. Figure 5.3 shows a JT8D low-bypass ratio turbofan engine found on many older aircraft such as the DC9, B727 and early models of the B737. Figure 5.4 presents a CFM56 high-bypass ratio turbofan engine used on the Airbus A320 and later models of the B737.

- **Turboprops** are turbine engines that use power from one or more turbine stages to drive a propeller through a reduction gear. Figure 5.5 shows a PT6 turboprop engine commonly used on many turboprop aircraft and helicopters.

- **Turboshafts** are similar to turboprops and incorporate an output shaft powered by one or more turbine stages. These are used mainly in helicopters.

Gas turbine engines — a primer

All gas turbine engines consist of five sections, and provide either reactive thrust (jet engine) or shaft power (turboprop or helicopter). The five sections are:

1. The inlet, which guides the flow of air into the engine
2. The compressor, which condenses air
3. The combustion chambers where fuel is added to compressed air and ignited

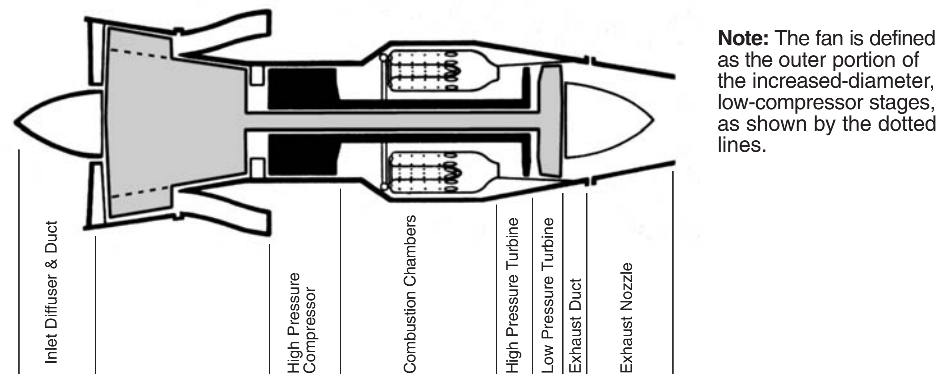


Figure 5.7 Schematic of a Turbofan Engine

4. The turbine section where energy is extracted from hot gases to drive the compressor section
5. The exhaust, which controls the outflow of gases.

The complex structure and high operating speeds of gas-turbine engines make them much more vulnerable to FOD than piston engines.

A number of different concepts and technologies are applied in the development of civil-aviation gas turbines. Air can be compressed using centrifugal or axial-flow compressors individually or in combination. For example, an initial centrifugal compressor may be supported by several axial-compressor stages. In a centrifugal compressor, intake air is expelled outwards radially from the compressor at high speed; the increased speed is converted to increased pressure. In axial-flow compressors, incoming airflow is passed between alternate rows of fixed and rotating blades; the airflow moves parallel to the engine axis and increases pressure in each successive stage. Figure 5.6 is a cutaway of a PT6, a popular Canadian turboprop engine that employs both centrifugal and axial-flow compressors.

Jet engines rely on either a single turbine or several stages of turbines at the rear of the engine; all are powered by expanding combustion gases. This energy then drives:

- the compressor and fan stages of a turbofan,
- the compressor stages and propeller of a turboprop, and
- the compressor stages and drive shaft of a turboshaft engine.

Figure 5.7 is a schematic of a typical turbofan engine.

Economic and environmental pressures have influenced gas-turbine efficiency developments since these engines first entered commercial operation. These developments continue to generate improvements in:

Engine By Year of Introduction	Bypass Ratio	Fan Diameter (Inches)	Power (Lbs. Thrust x 1000)	Aircraft Applications
Early 1960s				
P&W JT3D	1.4	53	19 –17.5	B707, DC-8
RR Conway	0.3			DC-8, VC10
P&W JT8D	1.74	54	15-21	DC-9, B727, B737, MD80
1970s				
RR RB211	4.3	74-86	42-60	L1011, B747, B757
P&W JT9D	4.8	94	46-56	B747, DC-10, B767, A300
1980s				
P&W 2037/2043	6.0	79	38-43	B757
GE CF6/50,80	4.97-5.31	93	52-60	B747, DC-10, MD11, B767
CFM56	6.0	61-72	22-31	DC-8, B737, A319/320, A340
P&W 4000 Series	4.8-5.1	94-100	50-60	B747, B767, A300, A310, MD11
IAE V2500	5.4	64	22-33	A319/320, MD90
1990s				
RR Trent 553/768	8.5	98	53-62	A330
RR Trent 875/8104	5.8	110	78-104	B777
P&W 4084/4098	5.8-6.4	112	87-98	B777
GE90	9.0	123	85-115	B777

Table 5.1 Characteristics of Jet Engines Used in Civil Aviation

- reducing fuel consumption and environmental impact,
- thrust-to-weight ratios,
- durability (including ability to cope with foreign-object ingestion),
- controlling engine-operating parameters,
- reducing noise-emission levels, and
- reducing exhaust emissions.

One comparative measure used in describing turbofan engine efficiency is bypass ratio—the ratio of air ducted around an engine core to air that passes through a core. High-bypass ratio engines generate higher thrust levels while consuming less fuel and creating less noise.

Table 5.1 describes turbofan engine types and their basic specifications, including fan diameter, bypass ratio, power output and aircraft application. The table clearly shows that since the first commercial use of jet engines in the early 1960s, maximum power output—thrust—has increased by a factor of five, and bypass ratios by a factor of six; fan diameters have more than doubled.

Bypass ratios on new engines in excess of 12:1 are now projected, and engine thrust levels of 125,000 lbs will soon be achieved. It's important to note that the first-stage fan on high-bypass ratio turbofan engines can direct bird debris from the inner portion of the engine inlet to the outer portion, allowing the debris to exit the cold section of the engine without damaging the inner core. This design feature should make these engines much more resistant to bird-strike damage. However, data indicates that the ratio between bird-strike events and damaging events involving these engines may not be much improved over earlier generation engines.

Turbine engines and bird ingestion

Jet engines have a number of noteworthy characteristics with respect to bird ingestion:

- Though conceptually simple, gas-turbine engines feature structures, components and high-rotating compressors and turbine speeds that make them particularly vulnerable to damage from ingested birds.

- The high-inlet flow rates of jet engines give them the characteristics of enormous vacuum cleaners. Not only can birds fly into these engines—they are also sucked into them.

- Turbofan engines have large frontal areas, increasing bird-strike probability.

- Large turbofan engines are used on aircraft which are not highly maneuverable and are therefore unable to take safe evasive action to avoid bird strikes.

- Modern jet engines are usually quieter than older models. Preliminary research indicates that quiet aircraft may not provide birds with sufficient time to take evasive action. Aircraft-noise reductions have been made in response to environmental and social pressures; these reductions may in fact have a negative effect on flight safety by increasing the probability of bird strikes.

- During takeoff and initial climb—and approach and landing—the speed of turbine-powered aircraft is much higher than that of light aircraft; the resulting impact force of a bird strike and the potential for damage to airframes and engines is higher as well.

- The above-noted considerations have motivated regulatory agencies and manufacturers to develop new certification standards that improve the ability of large turbofan engines to withstand bird strikes. We review progress in this area in Chapter 12.

Current aircraft fleet distribution and projected growth patterns

A basic knowledge of current and projected aircraft fleet sizes in the various classes of operation and regions of the world provides valuable insight into associated bird-

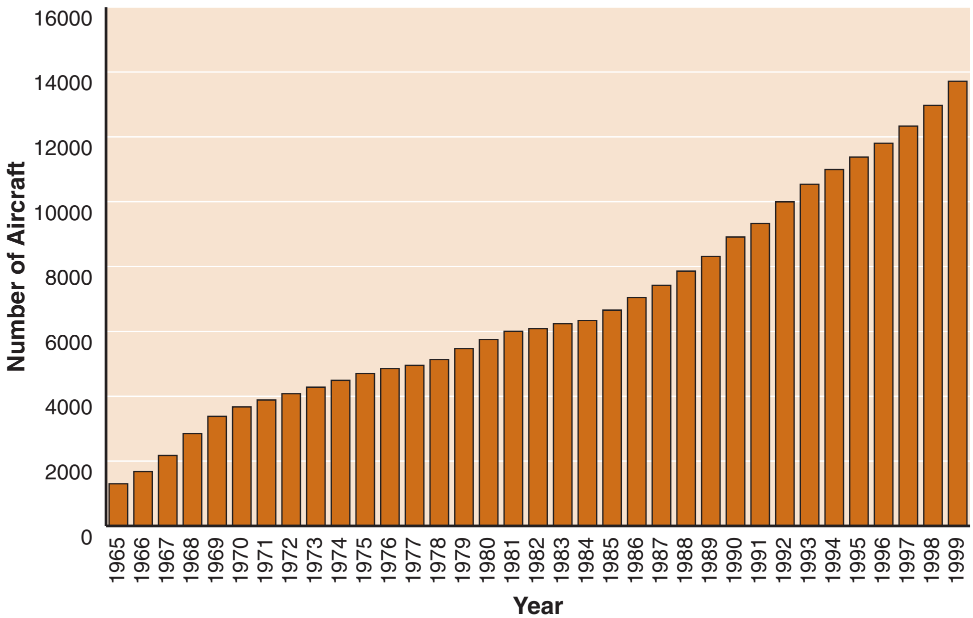


Figure 5.8 World Airline Aircraft Fleet Growth (1965 - 1999)

strike risks. Despite considerable effort during the writing of this book, complete data for all classes of operations were not available from all operators and regulatory bodies; therefore, the value of the information presented is not in its precise numbers, but in the comparative values and statistical trends.

Airline operations

Industry data show there were 13,714 aircraft with 50 or more seats in service with various civil operators in 1999. Figure 5.8 shows airline fleet growth from 1965 to 1999. Analysis of the data indicates that the world airline fleet grew at an average annual rate of 7.6 percent.

Figure 5.9 shows distribution of aircraft by operator. The chart clearly shows that in 1999 the largest portion—93 percent—was used by airlines. The geographic distribution of the 1999 aircraft fleet is shown in Figure 5.10. Data show that 46.5 percent of the total world fleet is based in North America.

Aircraft demand is driven by traffic growth, measured commonly in Revenue Passenger Kilometers (RPKs). Geographic distribution of RPKs is shown in Figure 5.11. As expected, the U.S.—at 33.6 percent—has the largest percentage of passenger traffic. RPK growth by region is shown in Figure 5.12. A comparison of projected growth by region vs. average world growth indicates that developing regions of the world—Asia, Africa and Latin America—will soon experience higher than average growth rates.

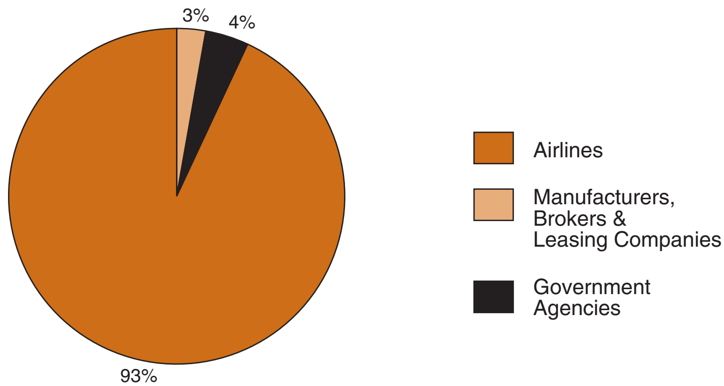


Figure 5.9 1999 World Aircraft Useage

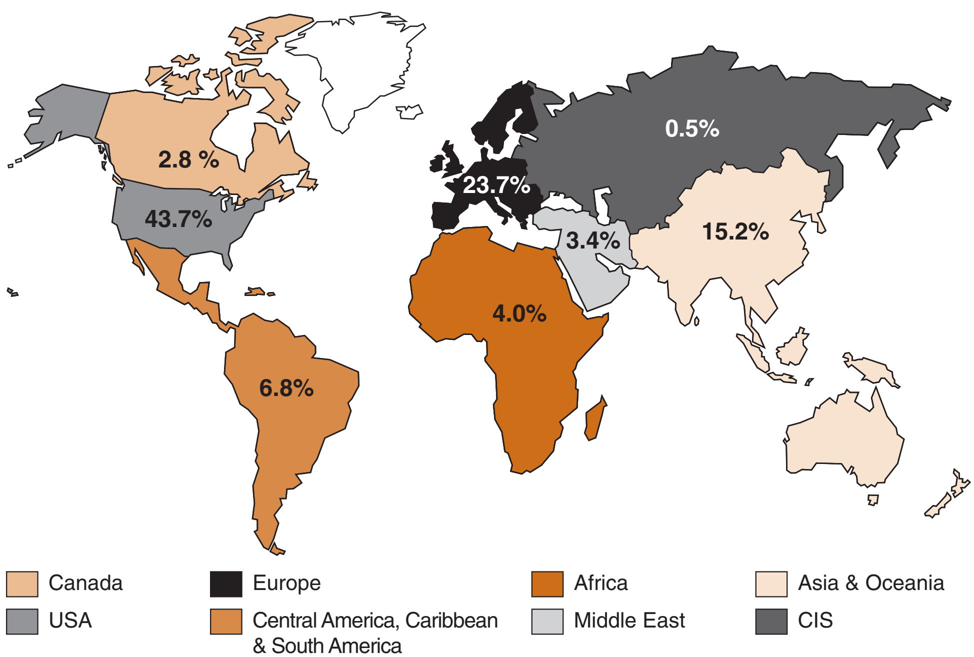


Figure 5.10 1999 World Airline Aircraft Fleet Geographic Distribution

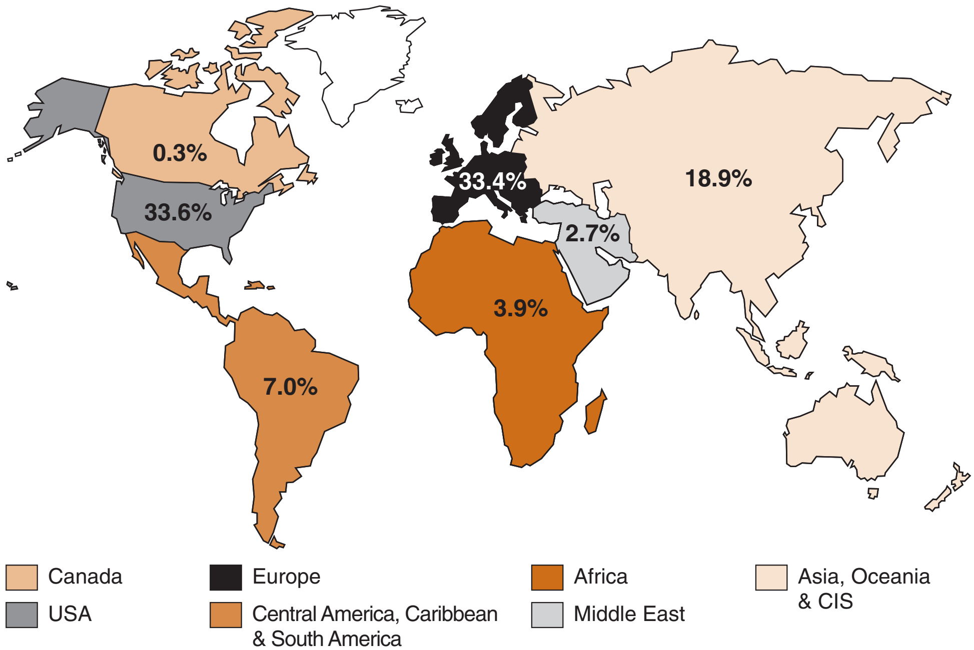


Figure 5.11 World Passenger RPK—Geographical Distribution (1998)

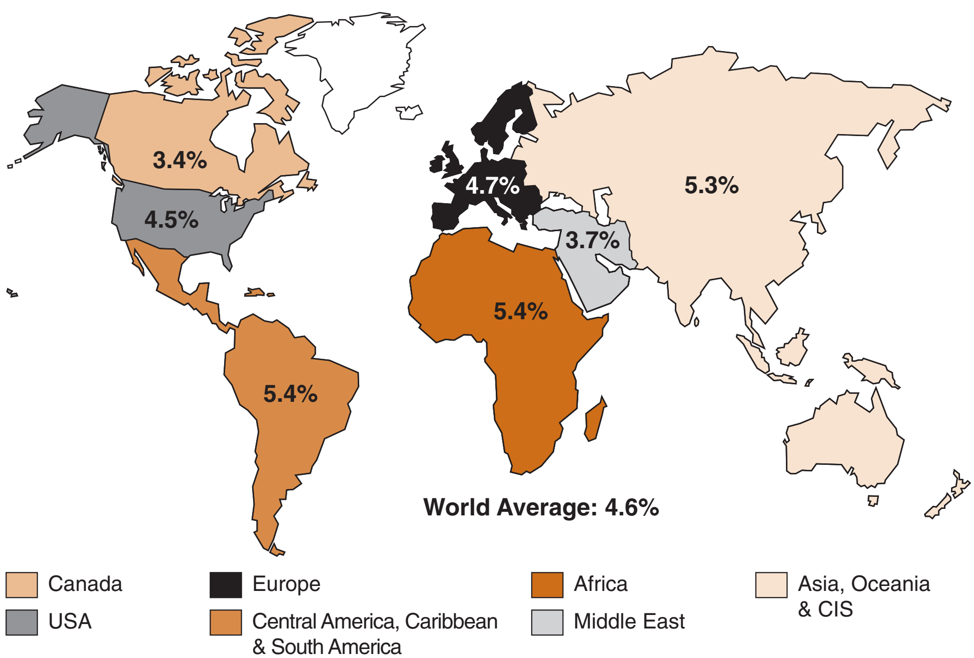


Figure 5.12 World Traffic Growth Forecast—Geographical Distribution (1998 - 2018)

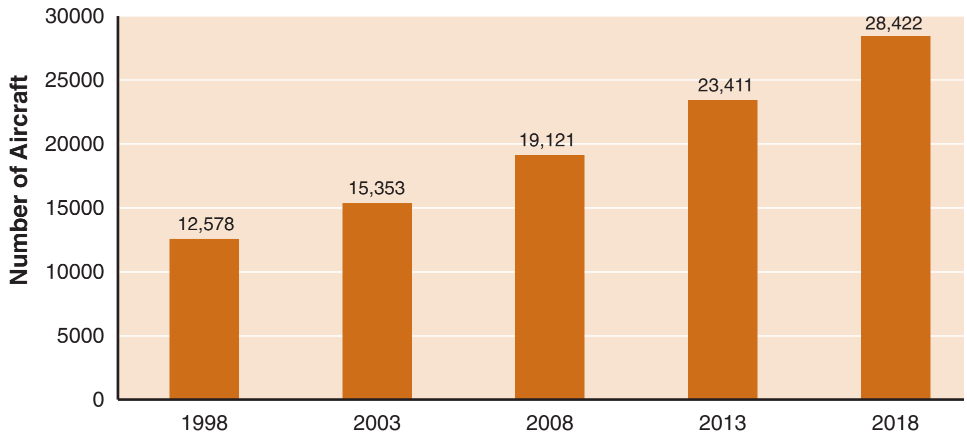


Figure 5.13 World Aircraft Fleet Growth Forecast (1998 - 2018)

Projected growth forecasts prepared by aircraft manufacturers Boeing and Airbus Industrie are similar. Both forecasts are based on similar passenger and freight growth projections. Minor differences between the Boeing and Airbus forecasts result from Boeing data including 50- to 70-seat aircraft. Boeing's forecasts were used in the following analysis to provide better comparison between classes of aircraft operation.

Figure 5.13 shows the projected fleet growth from 1998 to 2018. The average annual growth rate for the next 20 years will be nearly five percent. By 2018, the world airline fleet is expected to more than double to over 28,000 aircraft. Regional distribution of forecasted aircraft deliveries is presented in Table 5.2. While the bulk of new aircraft will be delivered to North American customers, comparison of net fleet growth by region shows that developing nations in Asia, Africa and South America will also experience very high fleet-growth rates. Currently offering few if any air travel networks—and featuring ineffective or non-existent wildlife-management programs

	1999 - 2008	2009 - 2018	1999 - 2018
Africa	203	254	457
Asia, Oceania and CIS	1664	2844	4508
Europe	2794	3221	6015
Middle East	285	270	555
Central America, Caribbean & South America	652	734	1386
North America	3304	3925	7229
Total	8902	11248	20150

Table 5.2 World Airline Aircraft Delivery Forecast Geographic Distribution (1999 - 2018)

where air-travel systems are established—developing nations are at much higher wildlife-strike risk. This risk is nearly impossible to quantify due to unreliable accident statistics and ecological data.

Of particular interest in the analysis of projected fleet growth is the fact that only 4,305 aircraft will be retired by 2018, while 20,150 new aircraft will have been delivered. Older aircraft are being retained by developing nations, or converted from passenger aircraft to freighters. In a case of economics versus safety, developing nations need air service to advance; new freight carriers worldwide must enter an intensely competitive market place. In both situations there are limited resources to purchase or lease aircraft.

The following figures show the growth forecasts for various aircraft by seat category:

Regional jets (50 - 106 seats)	Figure 5.14
Single-aisle aircraft (107 - 240 seats)	Figure 5.15
Twin-aisle aircraft (230 - 399 seats)	Figure 5.16
B747 and larger aircraft	Figure 5.17

The most significant growth will occur in the regional-jet fleet. Projections show that 50- to 106-seat aircraft will increase from 10 percent of the world fleet in 1998 to 17 percent by 2018. These aircraft are frequently used in regional or feeder-type operations, conducting many takeoffs and landings per day at both small and large airports. Regional jets have an increased probability of wildlife strikes due to high numbers of operations and limited wildlife-management programs at smaller airports.

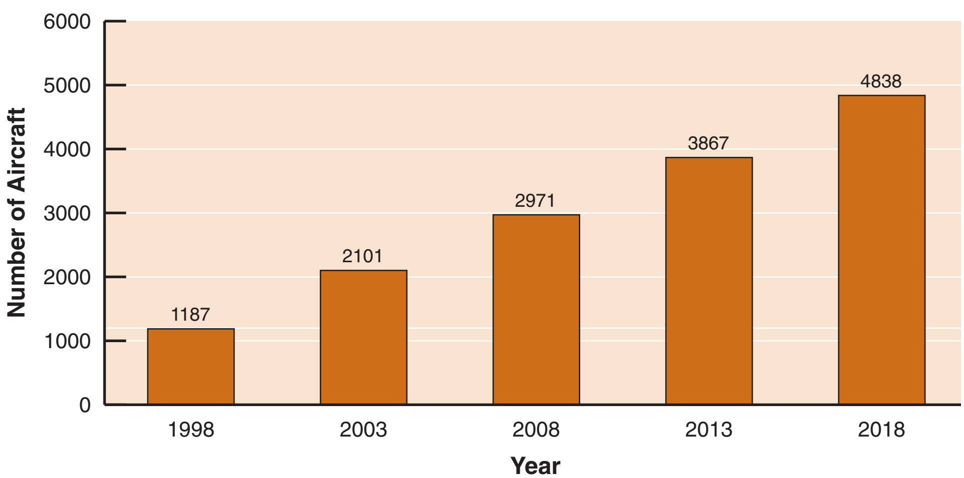


Figure 5.14 World Regional Jet Aircraft (50 - 106 Seat) Fleet Growth Forecast (1998 - 2018)

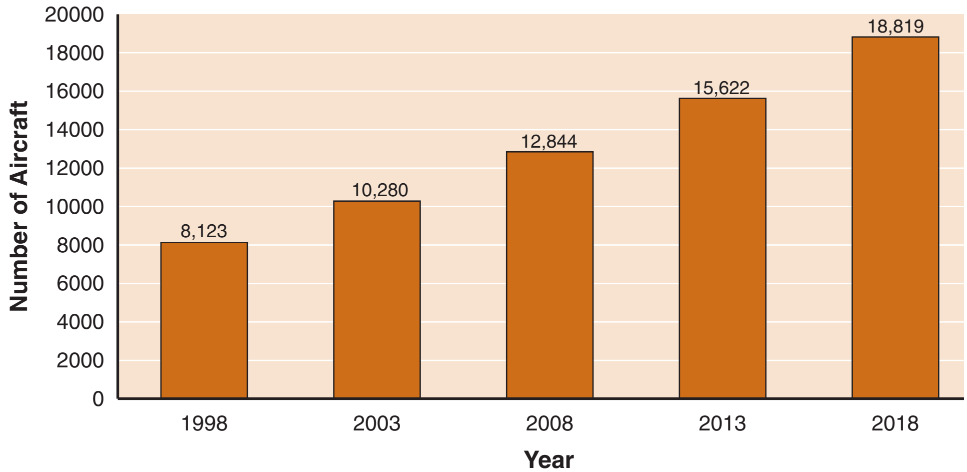


Figure 5.15 World Single Aisle Aircraft Fleet Growth Forecast (1998 - 2018)

Single-aisle aircraft fleets are also expected to grow steadily, but their percentage will remain approximately 44 percent through 2018. Employed in high-density operations feeding intercontinental hubs, these aircraft are extremely active on a daily basis and therefore face increased exposure to wildlife strikes.

Used on long-haul transcontinental and intercontinental flights, twin-aisle and larger aircraft will experience a lower growth rate. While average daily aircraft utilization is

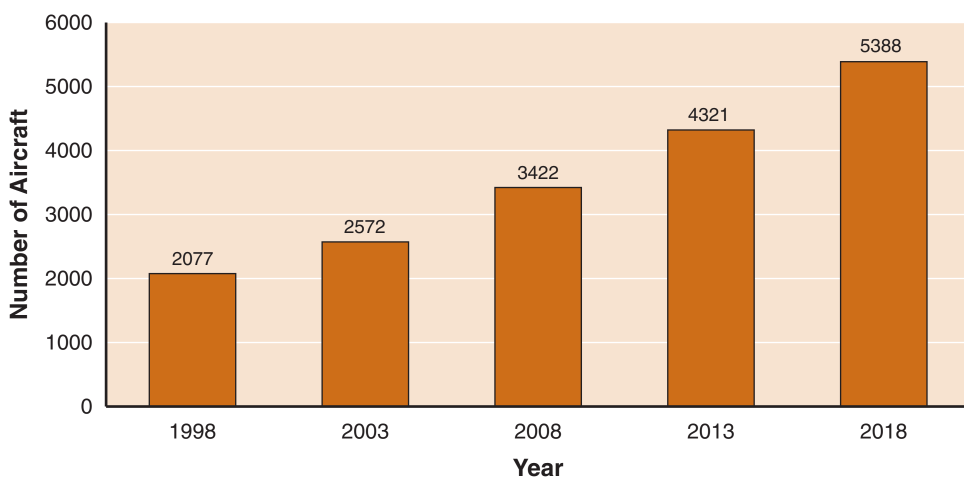


Figure 5.16 World Twin Aisle Aircraft Fleet Growth Forecast (1998 - 2018)

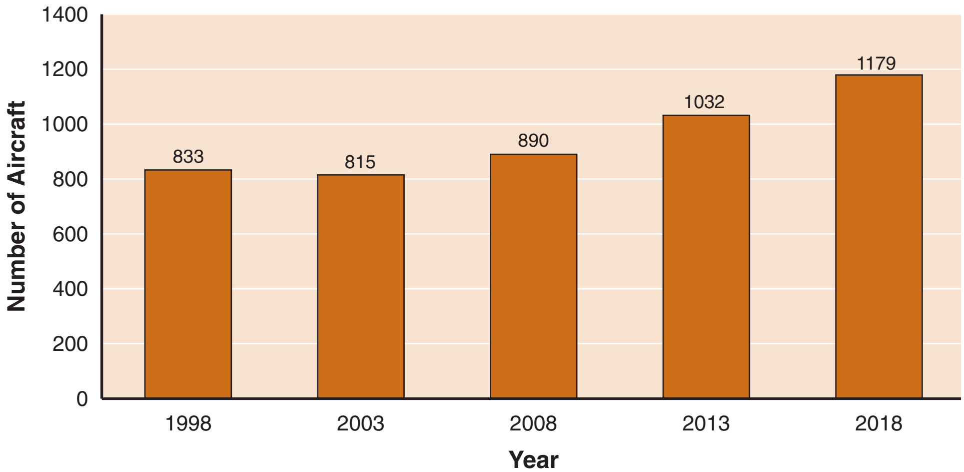


Figure 5.17 World B747 & Larger Aircraft Fleet Growth Forecast (1998 - 2018)

high, the number of takeoffs and landings is low due to long stage lengths; however, these aircraft may experience increased probability of wildlife strikes when operating at international airports located in developing nations where poor wildlife-management programs exist.

Regional airline and air-taxi operations

Information on regional airline and air-taxi operations is difficult to consolidate because of varying definitions used in many jurisdictions. The best available data are shown in Figure 5.18 and Figure 5.19. Figure 5.18 presents 1999 jet- and turboprop-fleet numbers; Figure 5.19 shows projected deliveries up to 2018. Significant growth is projected for these operations as airline hub-and-spoke operations respond to increasing demand for air service to smaller communities.

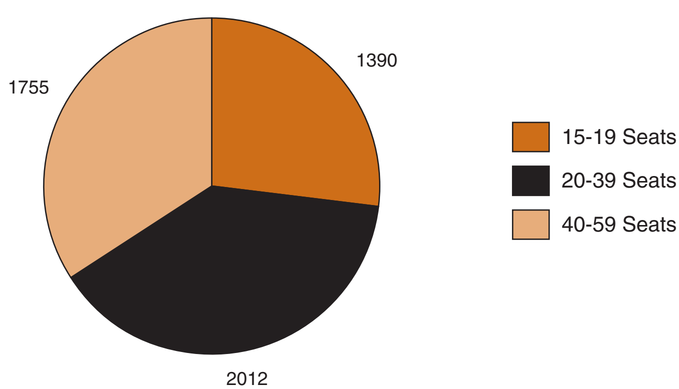


Figure 5.18 1999 World Regional Aircraft (15 - 59 Seats) Fleet

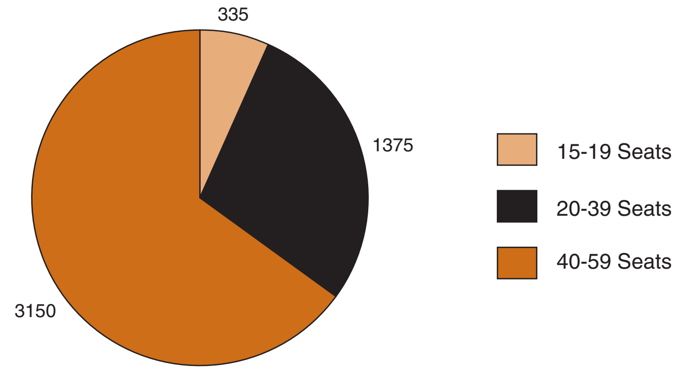


Figure 5.19 World Regional Aircraft Delivery Forecast (1998 - 2018)

Air freight operations

Strong growth in the freight-aircraft fleet is projected. Figure 5.20 shows the 20-year forecast for freighters. Industry analysts predict that 70 percent of the freighter fleet will be eventually comprised of modified passenger aircraft which will be replaced by newer models. While recycling is economical, it results in the extended operation of older aircraft that are certified to less stringent bird-strike standards.

Charter aircraft operations

Due to the wide variety of aircraft types used in charter operations and a scarcity of data, there is little to report on this class. But since all other operational classes are expected to grow, it's reasonable to assume charter operations will as well. Charter

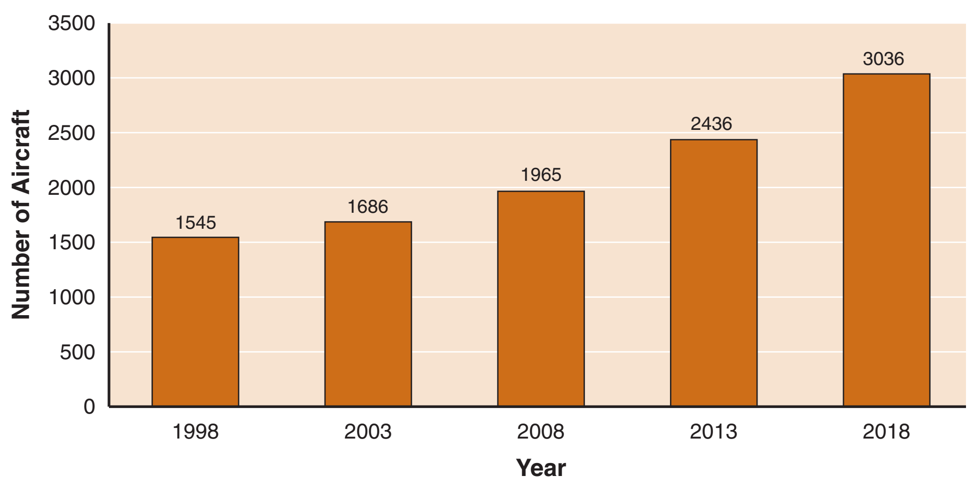


Figure 5.20 World Freighter Aircraft Fleet Growth Forecast (1998 - 2018)

services operate in developing nations and smaller airports that have limited wildlife-management programs. These sites undoubtedly present higher bird-strike risks.

General aviation operations

As described earlier, inconsistent data sources and varying jurisdictional definitions inhibit our analysis of this class. Worldwide fleet estimates of general-aviation aircraft, excluding helicopters, cover a wide range but include roughly 339,000 aircraft. Although not as precise as those for other aircraft categories, these estimates suggest that general-aviation aircraft represent the largest proportion of the world's total civil-aircraft fleet.

A few points are worth noting:

- Figure 5.21 shows the general-aviation fleet's geographic distribution; approximately 73 percent of the worldwide fleet is located in North America—10 percent in Canada, 63 percent in the United States. Canada is the second largest general-aviation operator after the United States, possessing roughly 27,000 aircraft.
- Approximately 90 percent of all general-aviation aircraft are piston powered; 75 percent are light single-engine piston-powered aircraft.
- Recreation, personal use and flight training make up 70 percent of general-aviation fleet activity.

Although the general aviation fleet is large, most aircraft are single engined and piston powered and are used approximately 135 hours per year—significantly less than commercial aircraft. Consequently, general-aviation bird-strike probability is less than in the commercial-aircraft class.

Business-aircraft operations

Corporate aircraft offer businesses the convenience of flexible scheduling, as well as access to small airports. In 1998, the total worldwide business-aircraft fleet numbered 18,850, including 9,661 jets and 9,189 turboprops. The regional distribution of business aircraft is shown in Figure 5.22. Not surprisingly, 67 percent of business aircraft are based in the U.S.

While relatively flat in the past few years, the annual growth rate is expected to reach four percent in the immediate future. Over the next ten years manufacturers forecast that 6,100 jet aircraft and 2,570 turboprop aircraft will be delivered, largely a result of increased affordability as more businesses share business aircraft—a practice referred to as fractional ownership. Fractional owners gain access to business aircraft without incurring the total cost associated with ownership.

Rotary-wing operations

Industry data indicate some 27,400 civil helicopters were in service worldwide in 1997, divided between commercial and general-aviation/aerial-work sectors. Growth

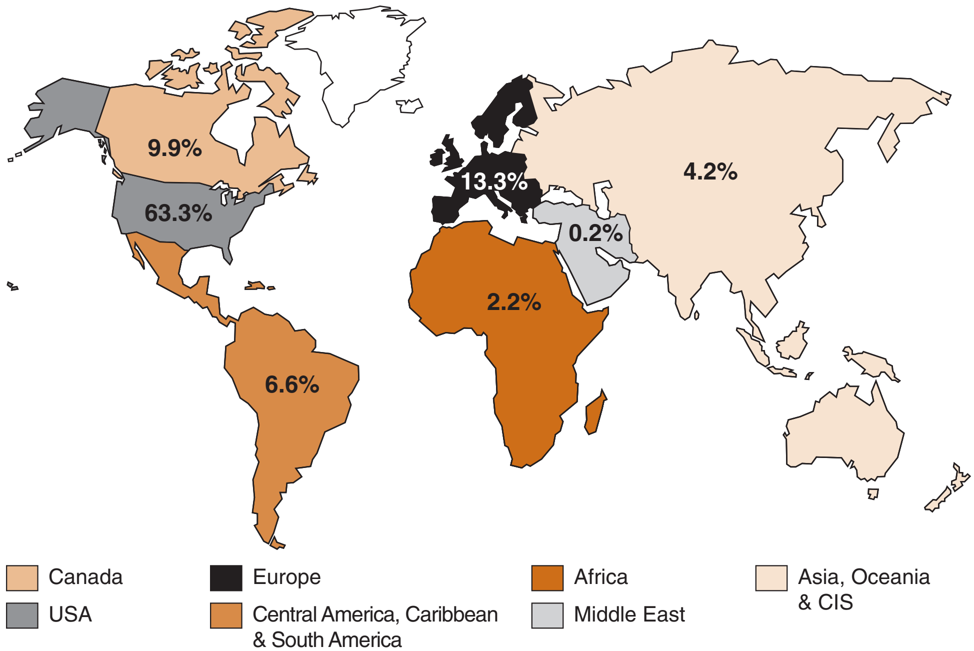


Figure 5.21 World General Aviation Aircraft Geographical Distribution (1998)

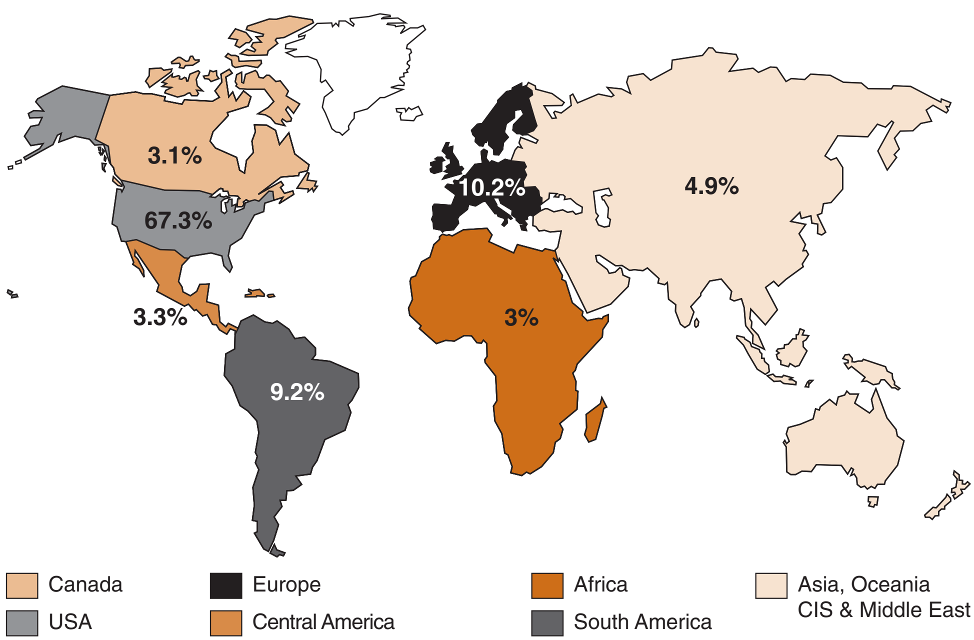


Figure 5.22 World Turbine Powered Business Aircraft Geographical Distribution (1998)

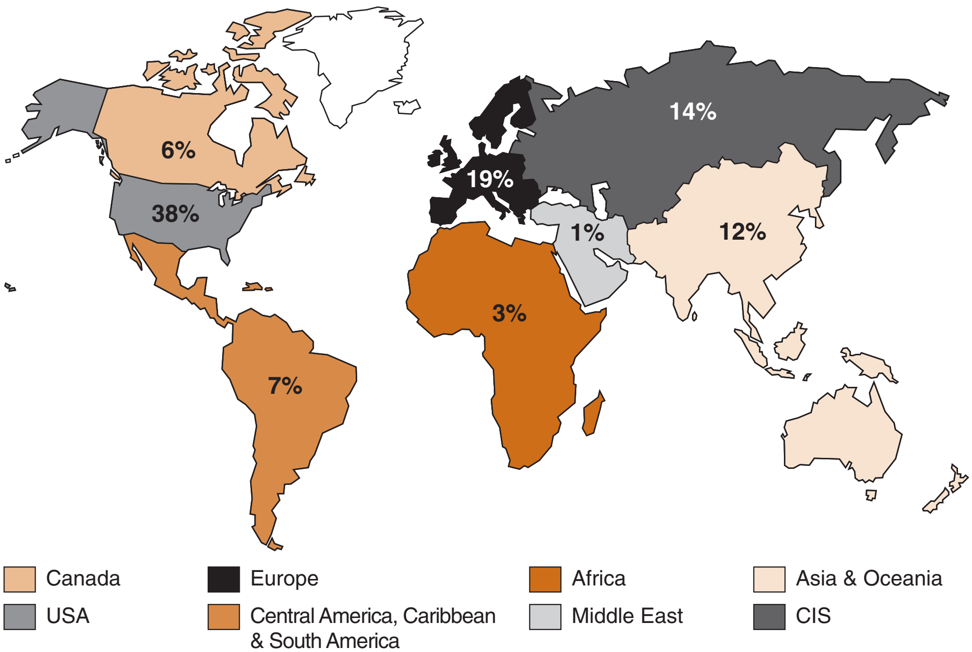


Figure 5.23 World Rotary Wing Geographic Distribution (1997)

in the numbers of these aircraft averaged about 1.6 percent per year since 1987. Figure 5.23 presents 1997 helicopter numbers by geographic region.

In the future, the rotary-wing industry is expecting average growth in the worldwide fleet of between two and three percent per year over the next few years. Based on the reported 1997 fleet, the total number of helicopters in service by 2007 will range between 33,400 and 36,800. Industry forecasts also show that most new sales over the next ten years will be divided almost equally between piston single-engine, light single-turboshaft, and light and intermediate twin helicopters.

Aviation: a *go* industry

Airline operations are complex, operating costs high and profit margins small. Time is one of the most valuable commodities, and schedules are finely tuned to ensure the peak on-time performance that instills customer confidence and improves bottom lines. Schedules are driven by market forces, and operations are constrained by infrastructure limitations such as departure and arrival slot times and available aircraft gates. Any delays—including those to accommodate wildlife-management activities or damaging events—create a domino effect that disrupts many other flights and incurs significant costs (see Chapter 1).

Airline	Destinations	Countries	Passengers (millions)	Employees	Aircraft
Aer Lingus	34	11	6	5,900	36
American Airlines	231	51	51	112,000	980
British Airways	233	96	96	63,000	321
Cathay Pacific	43	26	26	13,200	62
Finnair	70	30	30	9,000	57
Iberia	100	40	40	29,000	211
LanChile	41	17	17	9,038	45
Qantas	86	23	23	28,000	141
Oneworld Total	559	134	209	269,100	1,852

Table 5.3 Oneworld Alliance

Striving to achieve on-time performance, flight crews are constantly weighing safety and economics. During arrival and departure, cockpits are the scenes of intense activity and pressure. While flying the aircraft, flight crews complete checklists, communicate with numerous ATS providers, check flight conditions and deal with customers' needs; the ability to deal with wildlife issues is limited. Where wildlife activity is concerned, flight crews therefore rely on the vigilance of airport wildlife-management personnel and the advice of ATS providers to make informeddecisions.

Aviation: a global industry

Air travel has shrunk the globe and created the requirement to better coordinate airline operations and meet customer needs. The two major initiatives undertaken by the industry to enhance customer service are airline alliances and the development of hub airports.

Airline alliances

Alliances for the provision of services have increased dramatically in recent years. In 1996 there were almost 390 alliances in operation worldwide compared to about 280 in 1984. Alliance activities include:

- flight scheduling coordination,
- baggage handling,
- catering,
- ground services,
- maintenance,
- frequent-flyer programs, and
- airport lounges.

Increasingly, airlines engage in code sharing—a practice whereby one airline sells seats on a flight operated by another. In some cases, alliances have extended to joint pricing and selling of capacity.

Airline	Destinations	Countries	Passengers (millions)	Employees	Aircraft
AirCanada	120	26	19.2	25,800	246
Air New Zealand	48	15	6.4	9,560	79
All Nippon Airlines	62	13	43.2	14,700	142
Ansett Australia	142	5	13.4	14,900	126
Austrian Airlines	125	67	8	7,200	90
British Midland	32	12	6	6,300	60
Lufthansa	340	91	43.8	31,300	287
Mexican Airlines	50	9	7.1	6,400	54
SAS	105	31	22.2	25,800	190
Singapore Airlines	99	42	12.8	28,000	91
Thai Airways	76	35	16.3	24,100	78
United Airlines	255	26	87	100,400	600
Varig	120	20	11	17,700	87
Star Alliance Total	815	130	296	312,100	2,130

Table 5.4 Star Alliance

More complex partnerships have closely coordinated cost-sharing and marketing initiatives. Two major global airline alliances have emerged—the Oneworld Alliance and the Star Alliance. Their scope is impressive; they employ 581,200 people and operate 3,982 aircraft—30 percent of the world's current airline fleet. Table 5.3 describes Oneworld Alliance data; Table 5.4 presents the Star Alliance.

Airline hub airports

Hubs are a by-product of strategic airline-alliance developments. Passengers flow through large central airports, making more efficient use of smaller short-haul and larger long-haul aircraft. The hub-airport concept can lead to airport congestion problems, as it tends to produce cycles of traffic flow that stretch runway and gate capacity to the limit.

The time pressure created by the hub-and-spoke model is not limited to large airports; small facililites feel the stress as well. For example, the delayed departure of a DHC-8 might not otherwise be a serious cause for concern at a small local airport. However, the small airport operator understands full well that the aircraft's delayed arrival at a hub-and-spoke airport—feeding passengers to an international flight—could seriously affect schedules and incur thousands of dollars in costs due to misconnected passengers and freight.

Category of Aircraft	Airframe Component	Bird Impact Requirements
Transport Category Aircraft (FAR 25)	Entire airplane	Able to safely complete a flight after striking a 4-pound bird at design cruise speed (V_c)
	Empennage	Able to safely complete a flight after striking an 8-pound bird at design cruise speed (V_c)
	Windshield	Able to withstand impact of a 4-pound bird, without penetration, at design cruise speed (V_c)
	Airspeed indicator system	The pitot tubes must be far enough apart to avoid damage to both in a collision with a single bird
Normal Category (FAR 23) Commuter Aircraft (10 - 19 Seats)	Windshield	Able to withstand impact of a 2-pound bird at maximum approach flap speed (V_{fe})
	Air speed indicator system	The pitot tubes must be far enough apart to avoid damage to both in a collision with a single bird
Normal Category (FAR 23) Normal, Utility and Acrobatic Aircraft	All components	No requirements
Transport Category Rotorcraft (FAR 29)	Windshield	Able to continue safe flight and safe landing after impact by a 2.2 pound bird at maximum operating speed (V_{ne})
Normal Category Rotorcraft (FAR 27)	All components	No requirements

Table 5.5 Summary of FAA Airframe Bird Strike Airworthiness Requirements (Detailed information in Appendix 5.1)

Aircraft certification standards

Government regulatory organizations have reacted to the wildlife-strike problem by promoting airworthiness standards that address the ability of aircraft to safely withstand bird strikes—particularly during the critical flight phases of takeoff and climb, and approach and landing. The following list presents organizations responsible for these standards, as well as names of the regulations they enact:

United States	Federal Aviation Administration Federal Aviation Regulations (FARs)
Canada	Transport Canada Canadian Aviation Regulations (CARs)
Europe	The Joint Aviation Authorities Joint Aviation Regulations (JARs)

U.S. Federal Aviation Regulations

U.S. Federal Aviation Regulations set out a number of specific requirements pertaining to wildlife hazards. These regulations were developed as standards for the U.S. aviation industry but have since been accepted worldwide; standards promoted by other countries and other joint authorities often mirror the U.S. regulations, which are covered under five separate Parts:

FAR Part 23—Airworthiness Standards—Normal, Utility, Acrobatic and Commuter Category Airplanes;
FAR Part 25—Airworthiness Standards—Transport Category Airplanes;
FAR Part 27—Airworthiness Standards—Normal Category Rotorcraft;
FAR Part 29—Airworthiness Standards—Transport Category Rotorcraft; and,
FAR Part 33—Airworthiness Standards—Aircraft Engines.

Although these regulations address overall air-worthiness, it is forward-facing parts of airframes and engines that are most vulnerable when aircraft and wildlife collide. As such, airframe and engine requirements deserve special attention.

Airframe

Airframe issues include:

- damage tolerance and structural fatigue evaluation,
- bird-strike damage to empennage structures,
- windshields and windows, and
- airspeed-indicating systems.

The detailed and complex requirements related to airframes are included in Appendix 5.1. A summary of basic requirements is shown in Table 5.5, and indicates that Transport Category aircraft—or most commercial aircraft—face the most stringent certification requirements. In contrast, there are no bird-strike impact-resistance requirements for normal, utility and acrobatic airplanes, and limited requirements for air-taxi aircraft certified under Part 23 of the FARs. Only Transport Category helicopters have bird-strike impact-resistance requirements under Part 29, and these are minimal. Many bird species described in Chapter 3 exceed maximum bird weights used for certification tests.

Mass of Ingested Birds	Number of Ingested Birds	Bird Impact Requirements
3-ounces	Maximum of 16 birds in rapid succession	Impacts may not cause more than 25% power or thrust loss, require engine to be shut down within 5 minutes, or result in a hazardous situation
1.5 pound	Maximum of 8 birds in rapid succession	Impacts may not cause more than 25% power or thrust loss, require engine to be shut down within 5 minutes, or result in a hazardous situation
4 pound	1	Engine is not to catch fire, burst, or lose the capability to be shut down

Table 5.6 Summary of FAA FAR 33 Turbine Engine Bird Strike Airworthiness Requirements (Detailed information in Appendix 5.2)

Engines

There have been some recent changes to engine certification standards, which address damage from foreign-object ingestion, including that of birds. Aircraft and engines certified prior to the effective date of the change are grandfathered—not subject to retroactive compliance. This means that with the rare exceptions of recently certified aircraft, the current fleet is certified to the old standard.

The main requirements for most common turbine engines—with the exception of large RR Trent, P&W 4084 and GE90 turbofan engines—are shown in Table 5.6; detailed requirements applying to turbine engines installed on commercial and general-aviation aircraft are presented in Appendix 5.2.

Remember that many waterfowl and raptor species exceed the single-bird certification requirement weight of four lbs. The weights of many flocking birds experiencing high population-growth rates exceed the multiple bird-ingestion standards. In fact, to pass the individual large bird-ingestion test, the only requirement is that an engine can be "*safely shut down*"; the flocking-bird ingestion test requires an engine to produce 75-percent power and continue to run for five minutes.

Conclusion

The review of available aircraft fleet data and growth projections and airworthiness certification standards presents these key messages:

- air travel is forecast to grow steadily;
- aircraft fleets will continue to grow in size;

- growth will be higher than average among regional aircraft and single-aisle fleets carrying out many takeoffs and landings per day;
- growth will be higher than average in developing nations that have few if any airport wildlife-management programs; and
- the weights of many bird species exceed those defined in airframe and engine certification standards for current aircraft models.

The exposure to and probability of bird strikes is increasing and the potential for severe consequences following a strike is significant.

Chapter 6

Airports

Introduction

A review of wildlife-strike statistics (see Chapter 7) reveals that approximately 90 percent occur at or near airports—the battlegrounds for the war against this hazard. This chapter examines key characteristics of airports—including operating environments, certification standards and wildlife-management measures—and provides context for preventive measures described in subsequent chapters.

Airport operations and factors that influence risk

Varying in size and purpose, airports are hubs of the global transportation network—the nexus at which passengers transfer between air and surface modes of travel.

As systems, airports comprise three sub-systems (Figure 6.1) to:

- move passengers and cargo to and from airports (described at the bottom of the figure);
- prepare passengers and cargo for air transportation (described in the middle); and
- oversee the physical movement of aircraft at airports (described at the top).

The 1994 National Airports Policy (NAP) classifies airports in Canada as either:

- those in the National Airports System, including facilities in national, provincial and territorial capitals, as well as airports serving at least 200,000 passengers each year;
- local and regional airports serving fewer than 200,000 passengers each year; or
- small, remote and Arctic airports.

In Canada, the range of airport types and sizes reflects our geographic and demographic diversity. The vastness of the country explains our need for more than 1,300 registered and certified airfields; population concentrations speak to the dominance of a handful of those sites—26 Canadian airports are responsible for at least 94 percent of all the country's passenger and cargo activity. As these airfields differ, so do their exposure to risk.

Large airports are cities within cities—sprawling operations that impact significantly on local, regional and even national economies (Table 6.1). In 1997, Lester B. Pearson

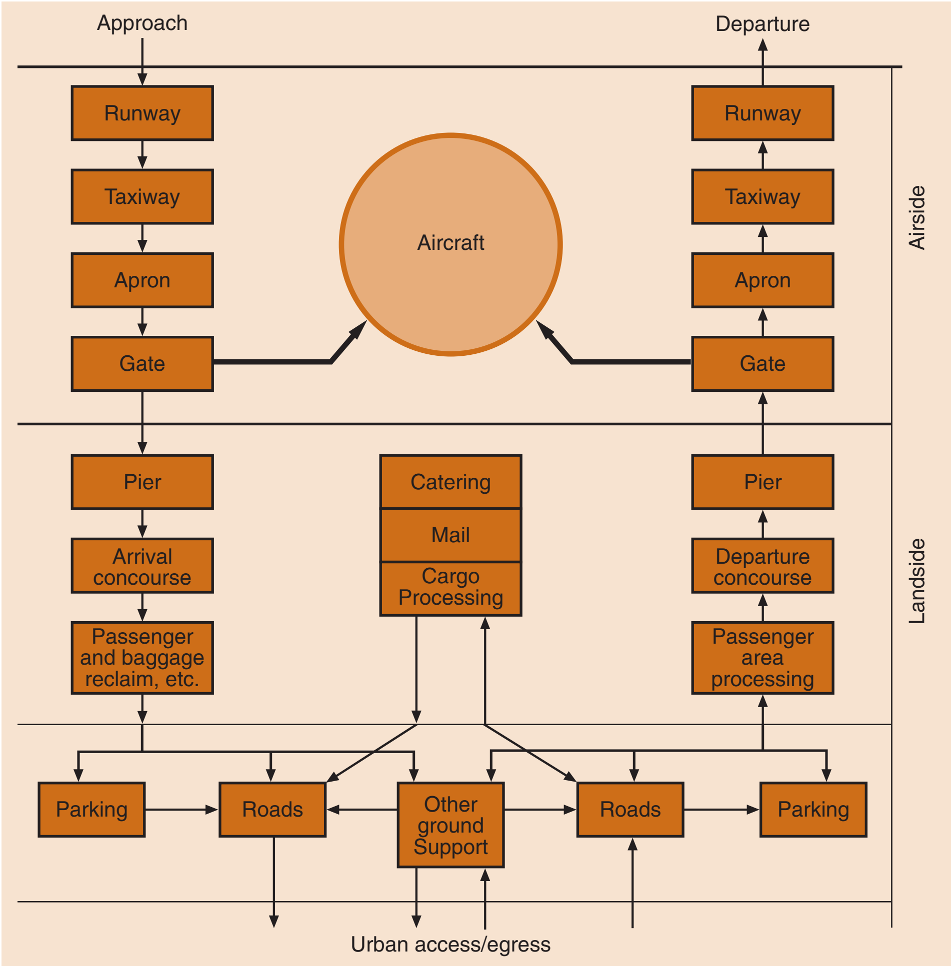


Figure 6.1 The Airport System (*Ashford, Stanton and Moore, 1997*)

International Airport created direct and indirect employment for as many as 112,000 people in the Greater Toronto Area. Heathrow, Atlanta and Chicago O'Hare boast on-site employment levels that exceed 50,000 persons each—nearly the same level of employment found in central business districts of cities of 250,000 to 500,000 people (Ashford, Stanton, Moore, 1997).

Aviation is a growth industry worldwide, and Canada is no exception—the annual growth rate has averaged 3 percent over the last 15 years. Projections indicate this rate will continue for the foreseeable future, resulting in a 50-percent increase in the number of enplaning and deplaning revenue passengers—from 82.6 million in 1998 to 124 million in 2013.

Principal Organization	Associated Organizations
Airport Operator	Regional authorities and local municipalities Federal government Provincial government Concession operators Suppliers Utilities Police Fire services Ambulance and medical services Air traffic services Meteorology
Airline	Fuel suppliers Aircraft maintentance Catering and duty free Sanitary services Other airlines and operators
Users of the airport	Cargo handlers Visitors "Meeters" and "senders"
Peripheral Stakeholders	Taxis, couriers and shippers Airport neighbour organizations Local community groups Local chambers of commerce Anti-noise groups Environmental activists Neighbourhood residents Animal Rights Groups

Table 6.1 Organizations Affected by the Operation of a Large Airport (*Adapted from Ashton, Stanton and Moore, 1997, p. 3*)

When evaluating the risk of a wildlife strike at an airport, a critical factor is the number of aircraft movements—the greater the number of aircraft movements, the higher the risk. As demonstrated in Table 6.2, some of the most dramatic increases in aircraft movements have occurred at small and mid-sized regional airports.

In 1999, the world's airlines operated 14,904 aircraft of 50 seats or more. If Industry growth projections of 5 percent per year hold true, the world fleet will nearly double to 28,422 aircraft by 2018. Annual growth projections for 50- to 106-seat regional

1999	City/Airport	% Growth in Aircraft Movements
1	Milan	184.7
2	Fresno	49.9
3	Colorado Springs	30.1
4	Washington - Dulles	22.7
5	Phoenix	20.7
6	Daytona Beach	18.7
7	Bakersfield	16.6
8	Las Vegas	15.3
9	Madrid	13.9
10	Santa Ana	12.9

Table 6.2 Fastest Growing Airports in 1999—Top 100 Movements Worldwide

aircraft are 15 percent—8 percent for twin-aisle aircraft. These aircraft will figure prominently as regional-airport flight frequencies and operations increase. As the number of aircraft movements rises, so will pressure to expand current airport facilities and develop new ones.

The impact of air-traffic growth has been felt in many ways. Privatization, while affording airports greater access to much needed capital, has also led to fundamental changes in airport operations. During the 1990s, the Government of Canada bowed out of its traditional role as an owner and operator of airports—a change that has reshaped much of the Canadian airport system. Sites that once focused solely on passenger and cargo movement are now thriving centres of commercial activity barely recognizable from traditional airports of just a decade ago, and are responsible for as much as 60 percent of an airport's total revenues.

Consider that each passenger spends an average of one hour in a terminal building before departure. Only 40 percent of this time is spent directly in preparation for enplaning; a full 60 percent of a passenger's time is free, which is key to the success of businesses that serve airports' captive audiences.

Airport commercial facilities are either operated directly by an airport authority or leased to concession operators. In either case, the business of running an airport is increasingly the business of:

- parking and renting cars,
- selling books, souvenirs and boutique items,
- reserving hotels,
- conducting banking and insurance transactions,
- offering personal services such as hair dressing, dry cleaning,
- providing business services, and
- entertaining through amusement centers, television booths and dining locations.

The quest to increase airport business performance has stimulated intense competition and resulted in airport expansion projects around the world. But this new landscape brings with it the potential for increased risk of wildlife strikes.

Any changes to a well defended, tightly coupled system can lead to the insidious and inadvertent introduction of new hazards and risks. This is particularly true with respect to wildlife strikes, where success relies on a coordinated commitment by all stakeholders. The competitive commercial dimensions of today's airports add a degree of complexity that was unknown in airport operations just a few years ago. Since the implementation of the NAP in Canada, the government department responsible—Transport Canada—is no longer directly involved in the management of airports. The effective resolution of problems—commercial and safety—rests increasingly with private-sector airport-management teams.

In light of the growing complexity in airport operations, there has been a renewed focus on traditional approaches to safety management. Airport certification processes (described later in this chapter) aim to ensure adherence to minimum levels of safety. Wildlife-management programs (described in detail in Chapter 8) are operational requirements at major airports in Canada, and are included in the Airport Operations Manuals of major airports in the U.S. and Britain.

New and less traditional methods of managing wildlife risks are also emerging. Risk-management techniques related to aviation safety at and around airports—such ascomprehensive bird-management programs developed by adjacent waste-disposal sites—are sophisticated enough to be effectively employed by policy makers and planners responsible for development of surrounding properties.

One of the more telling indications that airport risks are being managed differently is the change in the insurance structure as it relates to airport operations and businesses. Traditionally, government-operated airports were self-insured. As airport operations were transferred to the private sector, liability insurance—the risk management tool of last resort—became a necessity. Despite the potential for astronomical claims, premiums are actually relatively small—only one percent of the world's total insurance premiums are related to aviation. Premiums are influenced primarily by exposure criteria including:

- types of aircraft that frequent the airport,
- number of movements,
- services that are provided, and
- safety and claims records.

Many claims involve passengers injured in accidents within airport terminal buildings, but also include multi-million dollar engine-damage claims following FOD ingestion. Table 6.3 illustrates some losses paid by insurers for hull-loss accidents resulting from bird strikes. The amounts do not include claims for passenger injuries or death, either of which dramatically increases the scope and value of a damage claim.

Date of Loss	Location	Aircraft Type	Insured Hull Loss
November 1975	JFK, New York	DC-10	USD$25 million
April 1978	Gossellies, Belgium	Boeing 737	USD$0.8 million
July 1978	Kalamazoo, USA	Convair 580	USD$0.6 million
September 1988	Bahar Dar, Ethiopia	Boeing 737	USD$20 million*
January 1995	Le Bourget, France	Falcon 20	USD$2.3 million

* There were 35 fatalities and 21 serious injuries reported

Table 6.3 Aircraft Accidents Resulting from Bird Strikes (*Adapted from Robinson, 1996*)

As insurance issues raise the profile of risk management in airport environments, innovative modelling methods are being developed to better predict risks. These models can produce contours that plot risk levels throughout an airport environment, providing insight into third-party risk as it is affected by such factors as runway layout, traffic routing and safety-enhancement measures. For instance, changes to operations and infrastructure can be modelled before implementation to demonstrate increases and decreases in risks to households in an airport's vicinity.

Insurance costs will increasingly motivate wildlife-risk management at commercially operated airports. As Table 6.3 illustrates, both aircraft and humans have been lost over the past few decades due to bird strikes. Growth in every aspect of aviation suggests those losses will continue to plague the industry in increasing numbers.

Aerodrome or airport—what's the difference?

The terms *airport* and *aerodrome* are often used interchangeably by the aviation industry; legislation and regulation—at least in Canada—make primary use of the latter. For instance, the Canadian Aeronautics Act defines an aerodrome as:

> *"Any area of land, water (including the frozen surface thereof) or other supporting surface used, designed, prepared, equipped or set apart for use either in whole or in part for the arrival, departure movement or servicing of aircraft and includes any buildings, installations and equipment situated thereon or associated therewith."*

Aerodrome categories

There are three different categories of aerodromes, each presenting progressively different safety requirements. In order of ascending safety level, the categories are listed below:

- aerodromes (small airstrips located on private property that are neither registered nor certified),
- registered aerodromes, and
- certified aerodromes, referred to as airports.

Registered aerodromes

While listed, registered aerodromes are not certified as airports in the Canada Flight Supplement (CFS)—a publication for pilots containing operating information for registered aerodromes and airports. Registered aerodromes are not subject to ongoing inspection by Transport Canada; however, they are inspected periodically to verify compliance with Canadian Aviation Regulations (CARs) and to ensure the accuracy of information published in the CFS and the Water Aerodrome Supplement (WAS). In spite of these efforts, pilots planning to use a registered aerodrome are still expected to contact aerodrome operators to confirm CFS information is current.

Certified aerodromes

Airports are aerodromes certified under Subsection 302.03 of the CARs. Despite regulations that govern registered and non-registered aerodromes, the onus remains on a pilot to determine whether an aerodrome is safe and suitable. Regulations are in place primarily to protect those unfamiliar with an airport environment—the fare-paying public and those residing in the vicinity who could be affected by unsafe airport operations.

Aerodrome certification

Operating rules are listed in CAR III, Sub-part 1 of the Canadian Aviation Regulations (CARs), which also set forth provisions for registering an airport in both the CFS and WAS.

Certification requires an operator to maintain and operate the site in accordance with applicable Transport Canada standards listed in Transport Canada's TP 312—Aerodrome Standards and Recommended Practices. Transport Canada staff conduct regular inspections to ensure compliance.

Aerodromes in Canada must be certified when:

- they are located within the built-up area of a city or town;
- they are used by an air carrier as a main operations base, or for scheduled passenger-carrying service; or
- the Minister considers certification is in the public interest.

Exemptions are issued to:

- military aerodromes, and
- aerodromes for which the Minister has defined an equivalent level of safety.

In most countries of the world, aerodrome-certificate holders must satisfy regulating authorities that:

- airport operating areas and immediate vicinities are safe;
- airport facilities are appropriate to the operations taking place; and

Macdonald-Cartier International Airport (CYOW) Ottawa, Canada typifies the extensive and varied landscape occupied by large international airports.

- the management organization and key staff are competent and suitably qualified to provide flight-safety programming.

In most countries, including Canada, airport certification requires certificate holders to adhere to provisions of approved Airport Operations Manuals (AOMs). Often containing information on airport wildlife-management programs, AOMs integrate wildlife risks as part of the comprehensive planning and management of other operational hazards at airports.

Airport wildlife management

As 90 percent of all bird and mammal strikes occur at or near airports, the single most important contributor to reduction of associated risk is a well managed and supported science-based, wildlife-management program.

Airport operator wildlife-management responsibilities

The Aeronautics Act permits the Minister of Transport to take far-reaching action to ensure management of wildlife risks related to aircraft. Rather than exercise these powers, Transport Canada encourages various stakeholders to willingly employ control measures at and around airports.

Transport Canada recommends that aerodrome operators conduct ecological studies to assess airport wildlife hazards scientifically. If a hazard is identified, or if turbine-powered or larger fixed-wing aircraft use the facility, an Airport Wildlife Management Plan (AWMP) should be implemented.

Airport and aerodrome operators should:

- monitor and manage aerodrome-wildlife habitats and food sources that may result in hazards;
- monitor the management of off-aerodrome land use and wildlife food sources related to hazards;
- manage wildlife hazards at and near aerodromes, and implement programs to control the presence of birds and mammals; and
- conduct training programs for wildlife-management personnel.

Airport wildlife-management programs

The principal objective of an airport wildlife-management program is to implement measures that will prevent collisions between aircraft and wildlife in the vicinity of an aerodrome. As such, these programs must be a fundamental part of an airport's overall management plan—in some cases even a part of an airport's business plan. As described in Chapter 1, serious legal and financial implications can spring from the absence of comprehensive and effective airport wildlife-management programs should wildlife-related incidents occur. Chapter 8 presents airport wildlife-management programs in detail.

The airport as a component of the local ecosystem

Off-airport land management and use can contribute as much or more to the creation of wildlife hazards as those at an airport itself. With urban-growth pressures showing no signs of easing, land in the vicinity of airports—rarely prime residential locations—has become more attractive for such activities as industry, waste-disposal and agriculture. These uses are not affected by the noise and bustle generated at airports. Bitter struggles over proposed airport-vicinity land use are not uncommon; if not planned and managed properly, these developments can create a number of serious wildlife hazards.

Successful airport wildlife-management programs do not function in isolation; the airport environment is only a small part of a local ecosystem, and any changes that take place at or near an airport will likely be far reaching. Remember: among the laws that govern an ecosystem is one of Newton's—for every action there can be an equal and sometimes opposite reaction; failure to conduct appropriate ecological studies can lead to elimination of one hazard and creation of a far more serious one. Let biologists do their work, carrying out careful analysis that will inform development and implementation of effective wildlife-management measures.

The safe operation of aircraft can be seriously affected by large gull populations that benefit from poor waste-management practices near airports.

Land-use guidelines and regulations

The Aeronautics Act contains airport zoning regulations that prohibit the use of land outside an airport boundary—if that use is deemed hazardous to aircraft operations. The regulations address issues such as:

- obstacle limitation surfaces (limitations on objects which may project into areas associated with aircraft approach, departure and runway movements),
- protection of telecommunications and electronic systems,
- aircraft noise,
- restrictions to visibility,
- site protection and line-of-sight requirements, and
- bird hazards.

Transport Canada guidelines in the manual TP 1247-*Land Use in the Vicinity of Airports* are the basis for airport zoning regulations at airports across Canada. As each airport's zoning regulations are unique, so are the descriptions and scope of restricted activities. A waste-disposal clause is attached to zoning regulations at 55 of these airports, prohibiting facilities such as:

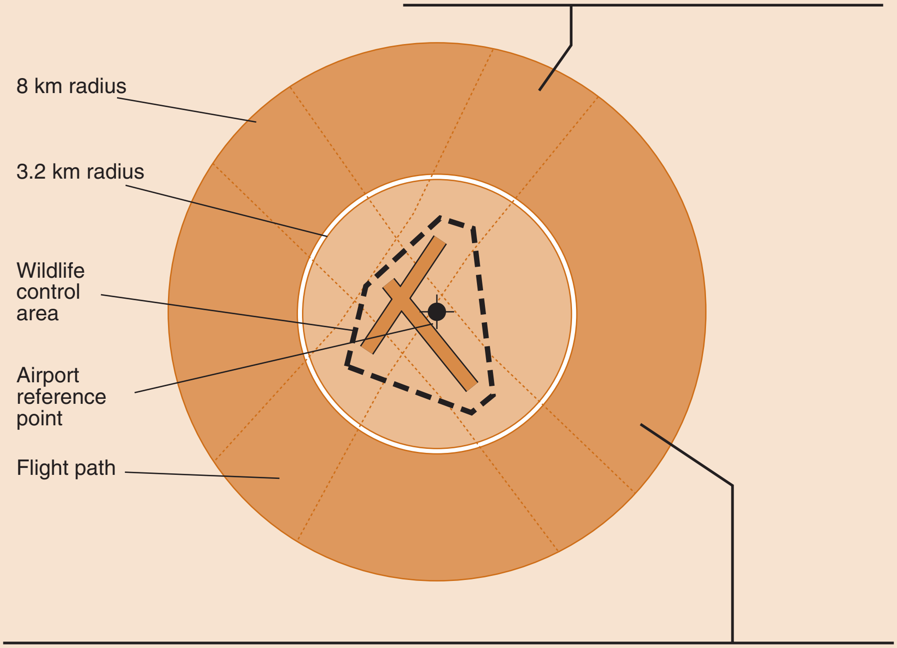
- garbage dumps,
- food-waste landfill sites,

Extremely Hazardous

Not recommended for areas within 8 km of airport reference points:

- Garbage dumps
  Food-waste landfill sites
  Coastal commercial fish-processing plants
  Crops that may attrect birds

These areas attract hazardous birds; i.e., those that pose the greatest risks to aircraft.



Moderately Hazardous

Not recommended for areas within 3.2 km of airport reference points:

- Grain crops; e.g., barley, oats, wheat (particularly Durum), corn and sunflower
  Fruit orchards; e.g., berries, cherries, grapes and apples
  Feedlots; e.g., beer-fed cattle and piggeries
  Drive-in theatres
  Migratory-waterfowl and game refuges or feeding stations
  Daytime plowing activities
  Unchecked infestations of mice and insects
  Sewage lagoons and storm-water retention ponds

These areas and practices are moderately attractive primarily to smaller birds, such as starlings, sparrows and Snow Buntings, that are not drawn from long distances to feed at airports. These birds are most hazardous during migration or when favourable feeding conditions arise, such as insect infestations, plowing or harvesting.

Some hazardous land-use practices increase the attractiveness of existing geographic features, such as open bodies of water or wetlands, which serve as nesting areas for gulls, shorebirds and waterfowl. For example, when airports lie between landfill sites (feeding areas) and natural bodies of water (nesting areas), birds will regularly fly back and forth over an airport, increasing bird-strike hazards.

Figure 6.2 Hazard Zones Adjacent to an Airport (*TC Airport Wildlife Management Bulletin No. 14*)

- coastal commercial fish-processing plants, and
- the planting of crops that may attract birds or adversely affect flight visibility within eight km of an airport-reference point.

TP1247 also notes other land-use activities not recommended within 3.2 km of an airport-reference point, as well as recommendations for alternative land use and remedial action. Especially in communities without airport zoning regulations, TP1247 provides valuable guidance in assessing due diligence on the part of those involved in land development.

Canada does not stand alone in resorting to regulatory intervention; airport vicinity land-use demand is a global issue. In the United States, the FAA issued an Advisory Circular titled *Waste Disposal Sites on or Near Airports* (AC150/5200-33), which advises against waste-disposal sites if they are:

- located within 10,000 ft of any runway end used by turbine-powered aircraft;
- located within 5,000 ft of any runway end used by piston-powered aircraft; or
- located within a five-mile radius of a runway end that attracts or sustains hazardous bird movements into or across the approach and departure paths of aircraft.

Although different in detail, the intent of the Canadian guidelines is the same as those above. Figure 6.2 lists land-use practices not recommended within distances of 3.2 and 8 km from reference points of Canadian airports.

The kind of wildlife-hazard knowledge shown above is gradually persuading all those involved in airport-vicinity land-use development—from waste-management companies to municipal governments—to adapt and apply airport wildlife-management programs in their own business practices.

Airport risk management in conflict with environmental management

Diverse and often conflicting demands are made on airport land, facilities and management. Airport authorities strive to create an efficient point of transfer for millions of passengers while at the same time relying on commercial development for revenues. On the other hand, airport operations must count aviation safety as the number-one concern. An airport's success and financial health depends on the confidence of clients and stakeholders; an error in safety management may threaten both life and the bottom line.

Airport operators can find themselves at odds with environmental regulations and local community environmental groups. Admittedly, many measures that enhance aviation safety—such as glycol-based aircraft deicing—can be detrimental to the environment if poorly managed. The same holds true in airport wildlife-management programs, which must strive to ensure safety through manipulation of wildlife habitats in accordance with applicable federal, provincial and municipal statutes.

Airport operators minimize the risks of wildlife strikes by working in harmony with local environmental groups not only to broaden the reach of airport-related wildlife-management practices, but also—and more importantly—to respect the surrounding ecosystem.

Conclusion

Airports are powerful economic engines essential to many communities. The success or failure of these enterprises depends on the level of safety and economic viability that can be achieved while maintaining a strong working relationship with surrounding stakeholders and their communities. Where wildlife strikes are concerned, safety stems from the quality of airport wildlife-management programs—programs sensitive to both the local ecosystem and environmental concerns.

Chapter 7

Bird- and Mammal-strike Statistics

Introduction

Aviation-industry decisions delicately balance safety and budgetary concerns while attempting to assess exposure to, probability of and severity of wildlife strikes. Developing effective risk-management strategies therefore relies heavily on the collection and analysis of data derived from bird- and mammal-strike statistics.

This chapter evaluates available data, and examines important trends that may help stakeholders reduce the risk of wildlife strikes.

Getting the definitions down

To ensure consistent statistics, it's important that all parties reporting wildlife strikes adhere to the same criteria. According to the Bird Strike Committee Canada, a bird strike is deemed to have occurred whenever:

- a pilot reports a bird strike;
- aircraft maintenance personnel identify damage to an aircraft as having been caused by a bird strike;
- personnel on the ground report seeing an aircraft strike one or more birds;
- bird remains—whether in whole or in part—are found on an airside pavement area or within 200 feet of a runway, unless another reason for the bird's death is identified.

Strikes against other classes of wildlife—primarily mammals—are interpreted with less formality, but embrace the spirit of definitions established for bird strikes.

The case for mandatory reporting

To ensure the highest quality of wildlife-strike statistics, it is crucial that agencies responsible for maintaining databases receive as much information as possible about every strike—even non-damaging strikes and near misses. While damage information is useful in quantifying costs to the aviation industry, non-damaging strikes and near misses are of equal statistical significance when developing a complete picture of the risk at any particular location.

Despite progress made by North America's aviation industry in reporting wildlife strikes, many continue to go incompletely reported or unreported altogether. Wildlife-management experts believe only 20 percent of all strikes are reported; reporting rates are likely lower in many developing countries where strike reporting is inconsistent or non-existent.

Strike reporting is not mandatory in most jurisdictions. Transport Canada and the FAA actively encourage reporting by aviation industry stakeholders, but currently have no regulatory authority to compel them to do so. Three additional factors contribute to the non-reporting of wildlife strikes:

- Some industry stakeholders believe strike reporting creates *information liabilities*, raising public fears about the potential for strike-related accidents.

- Stakeholders assume incorrectly that others have reported a strike.

- Pressured to meet tight on-time performance, industry personnel do not complete strike reports because of misplaced beliefs that wildlife strikes are not an important safety issue and do not have a significant economic impact on the industry.

In 1999, the NTSB recommended to the FAA (in Safety Recommendation A-99-91) that there be a requirement for "*all airplane operators to report bird strikes to the Federal Aviation Administration*." The FAA rejected the recommendation on the grounds that:

- a regulation would be difficult to enforce;

- existing reporting procedures are sufficient to monitor trends; and that

- the problem should be addressed by bird-management programs and airport-planning initiatives.

Regardless of the FAA's stance, there is ample evidence to indicate that safety would be greatly enhanced through a regulatory requirement to report all wildlife strikes.

Reporting wildlife strikes

Accurate wildlife-strike reporting requires that many industry stakeholders provide input to the data gathering process. The following sections present a brief overview of the strike-reporting process and the impact it may have on wildlife-strike statistics. A full description of the reporting process (including examples of strike-reporting forms) is contained in Appendix C—*Bird- and Mammal-strike Reporting Procedures*.

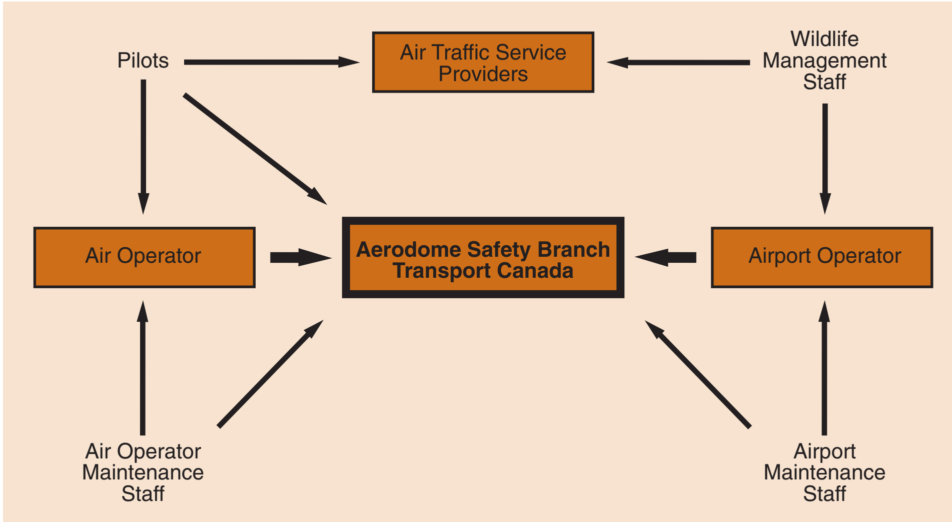


Figure 7.1 Schematic Illustrating Bird/Wildlife Reporting Functions in Canada

Who should report wildlife strikes?

Any number of stakeholders may provide either some or all of the information necessary to complete a wildlife-strike report; in fact the truth of an individual wildlife strike may only become clear once the contributions—no matter how small—of various witnesses have been gathered. The greater the amount of information gathered, the more precise the data analysis will be, enabling airport wildlife-management personnel to optimise strike-reduction strategies. The functions of and interactions between various strike-reporting stakeholders are depicted in Figure 7.1 and discussed in the following paragraphs.

Pilots report many strikes to ATS providers and may then complete strike reports for submission to Transport Canada. Commercial pilots may also report to their airlines. Pilots are often unaware of or unable to determine all the circumstances of a strike; they may be unsure of the species of bird involved, extent of the damage to the aircraft or resulting repair costs.

Air-traffic service providers may learn of a strike by radio reports from pilots or airport wildlife-management personnel. In the event of any operational impact, ATS providers must report a strike through Transport Canada's Civil Aviation Daily Occurrence Reporting System (CADORS).

Aircraft maintenance personnel occasionally discover wildlife-strike damage that may not have been previously detected during aircraft inspections.

Airlines often submit strike-report summaries directly to Transport Canada. These reports are derived from information submitted by pilots and aircraft maintenance personnel, and also include information on operational effects, aircraft damage, repair and other associated costs.

Airport maintenance and safety personnel may discover dead birds or mammals during regular FOD inspections of runways and taxiways. Unless another cause of death is evident, it is assumed that aircraft struck the animals. This strike information should be reported to an airport operator or directly to Transport Canada.

Wildlife-management personnel may find dead birds on or near runways while conducting day-to-day operations. These experts also identify struck wildlife species to supplement reports from other sources. This strike information should be reported to ATS personnel, the airport operator or directly to Transport Canada.

Airport operators should collate all airport strike data for submission to Transport Canada.

What information should be reported?

The ideal method of reporting a wildlife strike is to use the Transport Canada *Bird/Mammal Strike Report* (see Appendix C). In practice, reporters often don't have

Damage inflicted to a general aviation aircraft by a single hawk.

all the information to complete every part of the form, and yet it cannot be stressed enough that each form should be filled out to the fullest extent possible.

In reviewing U.S. and Canadian forms, its interesting to note Transport Canada's includes a box where near misses can be indicated; the corresponding FAA form does not make this provision.

The Transport Canada *Bird/Mammal Strike Report* requests the following information:

- type and time of incident,
- type of aircraft and engines involved,
- phase of flight operation,
- parts struck,
- effects on the flight,
- weather conditions,
- types and numbers of birds/mammals involved,
- specific engine damage,
- costs of the incident, and
- additional comments and remarks.

Bird identification

If bird-hazard reduction measures are to be undertaken it is essential to know:

- what species of birds are present at airports,
- what species are being struck by aircraft, and
- what species are causing damage.

Accurate identification of struck species is also becoming more important in response to liability and due-diligence issues, and in development of tools and techniques to manage species involved in strikes.

Identification of living birds

The identification of living birds is relatively straightforward but requires skill and practice. Airport and ATS personnel should be familiar with large and flocking species that frequent airfields and pose potential threats. Binoculars and modern bird guides are required; Transport Canada also distributes posters that illustrate key species found at Canadian airports. However, detailed biological studies necessary in development of effective airport wildlife-management programs require specialized and professional ornithological knowledge.

Dr. Henri Ouellet in the Canadian Museum of Nature laboratory. Dr. Ouellet developed the Keratin Electrophoresis feather identification process for Transport Canada.

Identification of bird remains

Following a bird strike, there is often little to identify a bird; remains may include a relatively intact carcass or be limited to blood smears in an engine. Investigators call on the range of identification techniques described below to determine whether a bird strike occurred and, if so, precisely what species was struck.

Comparison with museum specimens

Experienced ornithologists examine feathers by eye to determine the species or group involved; findings can be verified through comparison with specimens in a museum collection. It's estimated that 75 percent of struck birds can be identified using this technique.

Microscopic examination of feathers

Feather samples that cannot be identified by eye are examined under a microscope, where a feather's fine structure—its barbs and barbules—is revealed. Pioneered by Drs. R. C. Laybourne and C. J. Dove at the Department of Vertebrate Zoology at the Smithsonian Institution in Washington, D.C., this technique can be used to identify the family or genus of bird involved, but usually does not provide species identification.

Keratin electrophoresis

Electrophoresis is a technique whereby the biochemical structure of feathers is analyzed to identify a bird species. Feathers are made of keratin, a substance similar to human hair and fingernails; keratin proteins provide a fingerprint which is consistent within a particular species. In keratin electrophoresis, feather proteins from an unknown sample are compared with samples from known specimens—a technique developed by Dr. Henri Ouellet of the Canadian Museum of Nature with funding from Transport Canada. The Museum database contains 3,500 profiles from over 800 species of birds. Unfortunately, the service once provided by Dr. Ouellet is not available at this time.

DNA analysis

Following serious engine ingestions, only small amounts of blood or tissue may remain—just enough for DNA analysis. Using modern genetic techniques, the DNA can be amplified through polymerase chain reaction (PCR) to obtain samples large enough for analysis. The mitochondrial cytochrome "b" gene is commonly used to identify organisms based on their genes' nucleotide-coding sequence.

The Birdstrike Avoidance Team at the Central Science Laboratory (CSL) in the U.K. is developing this DNA technique for use with bird-strike samples. Comparing bird-strike material with genetic-library sequences shows that a 97- to 99-percent match efficiency is possible if the sequences are from the same or congeneric species. Birds from the same family give matches 87 to 95 percent of the time, but more distantly related species cannot be matched reliably. Dr. J. R. Allan and co-workers at the CSL estimate that this technique could become operational in the U.K. for a relatively small amount of money; a reference library of the most commonly struck families in Europe could be developed for as little as USD$15,000; each sample would cost about USD$150 to process.

Bird- and mammal-strike databases

Bird-strike statistics are maintained by civil-aviation regulatory agencies in many countries; some maintain separate military and civil-strike databases, while others maintain combined databases; however, there is no standard practice whereby these databases are combined or shared.

It falls to a database manager to ensure that multiple reports of the same strike—submitted by different sources at different times—do not skew the data. Where duplicate reports occur, each bears close scrutiny, as together they are likely to provide a better understanding of a specific incident. Careful data collation and verification is essential in maintaining accuracy of a strike database and any trend information derived from it. Once again, it's extremely important to recognize that bird strikes be recorded to the fullest extent possible. In countering the wildlife-strike problem, priorities can be defined and solutions implemented only following effective data submission, compilation and analysis.

Strike-database information is analyzed to determine a number of trends including:

- wildlife species that create problems overall and at particular locations,
- problematic times of the day and year,
- yearly strike trends by location,
- phase of flight when strikes are most likely to occur,
- types of aircraft most likely to be struck,
- parts of the aircraft most likely to be struck,
- effects of strikes on aircraft,
- percentage of strikes that are damaging and affect flight,
- costs associated with strikes, and
- altitude at which strikes occur.

Three major wildlife-strike databases are:

- the Transport Canada bird/mammal strike database,
- the United States FAA database, and
- the International Civil Aviation Organization (ICAO) database.

Many European countries also have sophisticated reporting systems and databases; however, as this book focuses on North America, discussion will be limited to the databases noted above. One further point: neither reporting parameters nor software are standardized among current databases, making exchange of data an extremely difficult and time-consuming task.

Transport Canada

The Aerodrome Safety Branch of Transport Canada maintains this country's bird/mammal-strike database. Annual summary reports of bird strikes have been published and distributed to stakeholders in essentially the same form since the early 1980s—the longest continuous series of comparable bird-strike data in existence. These reports include information on:

- strikes that occurred at Canadian sites,
- strikes to Canadian aircraft at foreign locations, and
- strikes to aircraft operated by the Department of National Defence in Canada and abroad.

It wasn't until 1997 that these reports included information on near misses and mammal strikes. Analysis of the most recent nine-year period (1991-99) indicates that there were 6,848 bird strikes in the Transport Canada database. Of those, 5,891 involved civil aircraft and 957 involved military aircraft.

U.S. Federal Aviation Administration (FAA)

In the United States, wildlife strikes are voluntarily reported to the FAA on a standard form (FAA Form 5200-7; see Appendix C). Although FAA personnel have monitored these reports since 1965 to determine general patterns of wildlife strikes, no quantitative analyses of these data were conducted until 1995. Through an interagency agreement, the U.S. Department of Agriculture's National Wildlife Research Center is now responsible for maintaining the FAA strike database and analyzing its data. Detailed annual reports are now published, providing a wealth of information. The reports are cumulative and contain data for the ten-year period from 1990 to 1999 covering 28,150 wildlife strikes—27,433 bird, 681 mammal and 36 reptile strikes.

International Civil Aviation Organization (ICAO)

As the world civil-aviation body, ICAO has maintained an international bird-strike database—the ICAO Bird Strike Information System (IBIS)—since 1980. Each member country is responsible for submitting yearly bird-strike data; ICAO analyzes the data and produces an annual report. Because reports are received from dozens of countries in as many as five languages, the production of the annual statistics usually lags by two years.

The IBIS database contains information on 89,251 bird strikes from around the world for the period 1980 to 1999 inclusive.

Major bird- and mammal-strike accident database

Apart from the compilation of bird-strike statistics is the collection of bird-strike *accident* figures. Two well-known researchers in the field have independently developed separate wildlife-strike accident databases.

John Thorpe, retired from the Civil Aviation Authority in the UK—former Chairman of the Bird Strike Committee Europe and honourary Chairman of IBSC—has compiled a worldwide database of all known serious civilian aircraft accidents involving birds. Dr. W. John Richardson of LGL Limited, Canada, has created a database of military- and civil-aircraft incidents involving birds.

Serious incidents are defined in these databases to include:

- loss of life,
- injury to occupants,
- destruction of aircraft,
- loss of or damage to more than one engine,
- damage to one engine together with ingestion in another,
- uncontained engine failure,
- fire,
- significant-sized holes (e.g., windshield, nose, radome),
- major structural damage, and
- particularly unusual features, such as complete obscuring of vision, multiple- or significant-system loss and propeller, helicopter rotor or transmission damage.

Highlights

Combining all relevant data from 1912 to 2003, birds are known to have caused 42 fatal accidents, 231 deaths, and the destruction of 80 civil aircraft. This data is undoubtedly underreported, since records from earlier years are incomplete or nonexistent. In all likelihood there have been many unreported accidents caused by birds. This is particularly possible in accidents involving small general-aviation aircraft, since investigations of these incidents are generally not as intensive as those involving commercial aircraft.

Major aircraft accidents

There are several major hull-loss accidents that are worthy of mention:

On October 4, 1960, the worst bird-strike accident to date occurred when a Lockheed Electra encountered a flock of European Starlings just after becoming airborne from Boston's Logan International Airport. Starlings fly in dense flocks of individual birds weighing about 80 grams each. Numerous birds were ingested into three of the four turboprop engines. The number-one engine had to be shut down; numbers two and four lost power. The aircraft lost speed, stalled and crashed into Boston Harbor. Of the 72 persons on board, 62 died and 9 were injured.

On November 23, 1962, a United Airlines Vickers Viscount struck a flock of Whistling (Tundra) Swans migrating at 6,000 ft above Maryland. The leading edge of the tailplane was dislodged and the aircraft became uncontrollable, crashing and killing all 17 people on board. Major movements of large flocking birds such as ducks, geese, swans and cormorants can present significant hazards to aircraft, day and night.

On November 12, 1975, at J.F.K. International Airport in New York, a remarkable accident occurred. An Overseas National Airlines DC-10-30 with 139 persons on board struck gulls at V_1 speed. The number-three engine exploded causing a severe wing fire. Takeoff was rejected and the aircraft quickly burned out. Remarkably, there were no fatalities and only 11 minor injuries, most likely due to the passengers' familiarity with emergency evacuation procedures—they were all airline employees.

On September 15, 1988, a Boeing 737-200 ingested Speckled Pigeons into both engines at liftoff from Bahar Dar—an airport 5,800 ft above sea level in Ethiopia. Both engines failed and the aircraft attempted an emergency landing in open country 10 km from the airport. Unfortunately, the aircraft struck a riverbank and burned. There were 35 fatalities and 21 injuries among the 104 passengers on board.

Major aircraft incidents

While actual hull-loss accidents are dramatic in their scope, they are far outnumbered by serious incidents in which hull losses were barely avoided—incidents that are just as important when developing risk-management strategies. Modern safety management experts recognize that risk-mitigation strategies cannot be developed through aircraft-accident statistics alone; statistically, serious accidents comprise 10 percent or less of meaningful safety data. Increasingly, the aviation industry is embracing other techniques to evaluate hazards:

- gathering safety data from other sources such as non-punitive reporting systems and incident-evaluation reports, and

- risk-analysis tools that evaluate the potential severity and potential for reoccurrence.

All serious wildlife-strike incidents need to be carefully reviewed and analyzed using an established risk-management protocol. Unfortunately, a separate database of these serious incidents does not exist at this time, nor does a risk analysis of their potential severity and reoccurrence—potential highlighted in the following examples:

On the night of January 9, 1998, a Delta Airlines B727 departed Houston, Texas. At about 6,000 feet the aircraft struck a flock of migrating Snow Geese and suffered extensive damage to all three engines, the leading-edge slats, radome and airspeed pitot tube—damage due in part to the aircraft's involvement in a trial to assess the efficiency gains of high-speed departures. The crew successfully returned to the airport and there were no injuries. However, the potential for catastrophe is clear.

On October 26, 1992, a KLM B747 landing at Calgary International Airport struck a flock of Canada Geese just before touchdown. The aircraft landed successfully and there were no injuries. The aircraft suffered major uncontained damage to the number-one engine and damage to the leading-edge slats. Multiple-bird strikes during this critical phase of flight—in close proximity to the ground—have the potential to lead to disaster.

Later sections of this chapter document the frequency of engine ingestions, rejected takeoffs, and precautionary/emergency landings that indicate just how common these close calls really are.

Analysis of bird-strike statistics in civil aviation

The following sections present analysis of bird-strike statistics collected in Canada and the U.S. between 1991 and 1999. Given that the population of the U.S. is about ten-times greater than Canada and that the U.S. has the highest per capita use of aircraft in the world, it's reasonable to assume there would be ten times more bird strikes per year in the U.S. In fact, annual reported bird strikes averaged 2,857 in the U.S. from 1991 to 1999 compared with 761 in Canada—a ratio of 3.75:1. This higher ratio may be due to the substantially higher Canadian reporting rate, the result of a longer history of concern for the problem, a more aggressive public relations program and a more formal regulatory and policy structure that—until recently—included government ownership of most airports.

When comparing strike statistics it's important to remember that data are not always representative of actual strike statistics, since many strikes go unreported. For instance, an airport with more reported strikes than another may actually have a better wildlife-management program—and therefore fewer actual strikes—than the airport with fewer reported strikes. The former airport might simply be more thorough at reporting. Numbers of strikes are also a function of the number of aircraft movements. To standardize strike statistics and enable an accurate method of annual data comparison at airports, strike rate—expressed as the number of strikes per 10,000 movements—is the measurement that's been adopted by the wildlife-strike community.

In the following analyses, the summary data—presented in tables and figures—are based on information reported in the Transport Canada and FAA summary publications. Because each strike report does not contain information on every bird-strike parameter, totals for various categories vary. For example, not all strike reports identify the type of bird struck or the part damaged, so the totals presented are only from reports that did include these data.

Phase of flight

Most bird-strike databases contain statistics noting the phase of flight during which strikes occurred. These statistics are important because each flight phase has a different level of risk. The two most critical are takeoff and landing; overall accident statistics show that most accidents occur during these two phases of flight. From a wildlife-strike perspective, an aircraft is much more vulnerable during takeoff than when landing.

At takeoff, an aircraft's engines are operating at high power settings, and the aircraft is heavier due to a full fuel load. During takeoff there is very little time—perhaps two

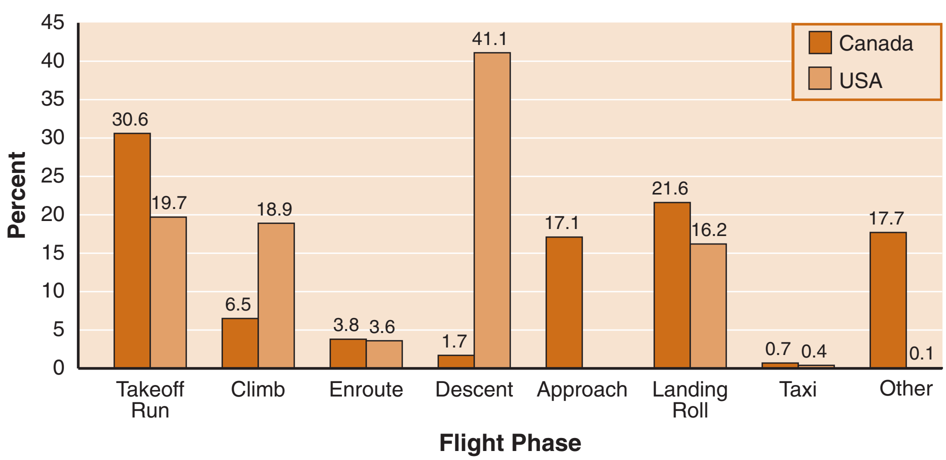


Figure 7.2 Phase of Flight at Time of Bird Strikes. Canada and U.S. (1991-1999) (Canadian data include military strikes)

to three seconds—to react to a wildlife strike, evaluate aircraft or engine damage and decide to reject takeoff or continue to fly. Successful rejected-takeoff and engine-out takeoff maneuvers require precise flying skills and good crew co-ordination, since aircraft performance under these circumstances is limited. Any multiple-system failures caused by a wildlife strike—such as loss of lift-enhancing devices or more than one engine—can render an aircraft unflyable.

There is significantly less risk involved during landing. Impact force and potential for damage are reduced because an aircraft is approaching at lower speeds, under reduced power and carrying a diminished fuel load.

The statistics on bird strikes by phase of flight for Canada and the U.S. between 1991 and 1999 are summarized in Figure 7.2. In comparing the overall statistics, the two nations are similar—37 percent of strikes in Canada occur during takeoff versus 39 percent in the U.S. However, a breakdown of the statistics reveals a different story—in Canada, 31 percent of strikes occur during the takeoff run, 6.5 percent during the climb-out. In the U.S., 20 percent of strikes occur during the takeoff run and 19 percent during the climb-out phase. The difference suggests the two databases may be using slightly different definitions of the takeoff run and the climb-out phases.

Relatively few strikes occur when aircraft are en route at higher altitudes—3.8 percent in Canada and 3.6 percent in the U.S. There are again substantial differences between Canadian and U.S. data for strikes during descent and approach—19 percent vs. 41 percent respectively—and during landing roll—22 percent vs. 16 percent. The overall figures for the landing phase are closer—41 percent in Canada and 57 percent in the U.S. Once more, definitions may vary between databases.

Altitude

Aircraft are most likely to encounter birds during takeoff and landing phases, as the majority of bird flights occur within a few hundred feet of the ground. The highest recorded strike in the FAA database involved an unidentified species of bird reportedly struck by a DC-8-62 at 39,000 ft on October 23, 1991.

Altitude (AGL)	Percent of Known Total
0	40
1-99	15
100-299	11
300-499	5
500-999	7
1000-1499	5
1500-3999	10
>4000	6

Table 7.1 Altitude of Bird Strikes in the U.S. (1991-1999)

U.S. data on bird strikes at altitudes above ground level (AGL) are summarized in Table 7.1. The figure is based on 20,893 reported strikes with known altitudes during the period 1990-1999:

- 40 percent occur while the aircraft is still on the ground—primarily during takeoff and landing roll,
- 15 percent of strikes occur between one and 99 ft above ground, and
- 16 percent occur between 100 and 499 ft AGL.

In total, 71 percent of these strikes occur on, or immediately adjacent to, airport properties. Above 500 ft, the number of bird strikes decreases proportionally as altitude increases.

Bird strikes that do occur above 500 ft AGL generally involve flocking birds, particularly migratory waterfowl that can exceed 5 kg. Multiple strikes to several parts of an aircraft are not uncommon in these incidents, creating potential for loss of more than one engine and damage to other major aircraft systems. While chances of a bird strike at altitudes above 500 ft AGL are statistically low, the potential consequences of a high-altitude bird strike may be more significant.

As this data indicates, it is imperative to reduce the numbers of birds at and around airports. This strengthens the case for both effective airport wildlife-management programs and control of sites such as bird-attracting landfills near airports (see Chapter 8).

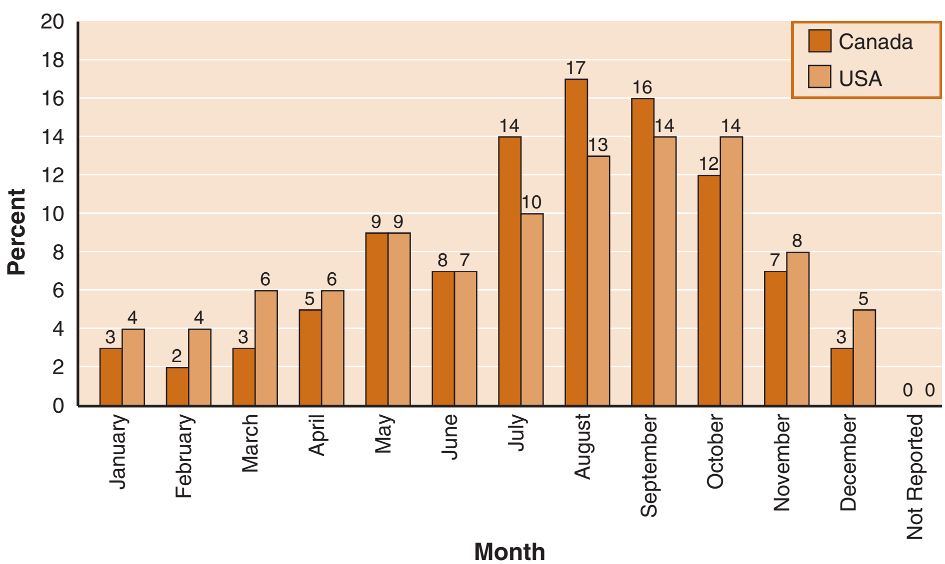


Figure 7.3 Monthly Bird Strike Distribution in Canada and the United States (1991-1999) (includes Canadian aircraft at foreign locations and Canadian military aircraft)

Time of year

The frequency of bird strikes varies with the time of year. The percentages of Canadian and U.S. strikes that occur each month are plotted in Figure 7.3 for the years 1991 to 1999. In Canada, relatively few strikes occur during winter months—two to three percent per month from December to March. The number increases in spring when migrating birds return from the south—five to nine percent per month from April to June. Peak numbers occur in summer—14 to 17 percent per month from July to September. These rates are thought to be high for two reasons: large numbers of birds are present after the nesting season—particularly naïve young birds that have no experience with aircraft—and birds begin to migrate from the far north in late summer. Fall strikes—12 percent in October and seven percent in November—mark the period when substantial numbers of birds are still present, but many migrating birds have left Canada. The significance of migratory bird strikes is important. Given the weight and numbers of birds in a flock, knowledge of migratory paths and times is critical to reduce the probability and severity of bird strikes.

The annual pattern of bird strikes in the United States is similar to that in Canada, with some exceptions. Peak strike numbers also occur from July through September—10 to 14 percent per month—but the number of winter strikes is higher at four to six percent per month from December to March. The higher winter rates reflect the large number of southern airports in the U.S. where migrant birds spend winters.

Time of day

Bird strikes occur at all hours of the day—the vast majority of Canadian strikes during daylight hours. This is not surprising, since fewer birds fly at night when fewer aircraft are flying as well. The 1999 hourly distribution of bird strikes in Canada is presented in Figure 7.4, demonstrating the substantial numbers of bird strikes occurring at all hours of the day. Small increases are evident in the morning—between

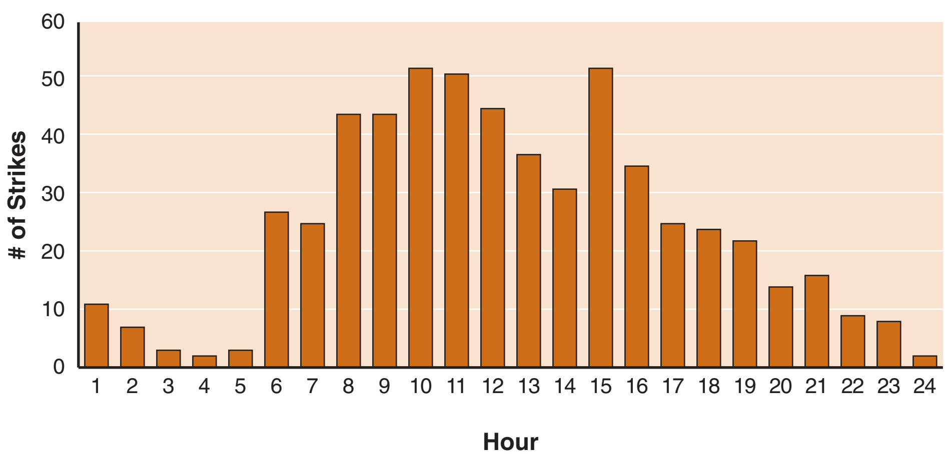


Figure 7.4 Daily Bird Strike Distribution in Canada in 1999
(includes Canadian aircraft overseas and Canadian military aircraft)

	CANADA			UNITED STATES		
Aircraft Part	Number Struck	Number Damaged	Percent Damaged	Number Struck	Number Damaged	Percent Damaged
Windshield	514	33	6.4	4,195	321	7.7
Wing/Rotor	855	113	13.2	3,030	941	31.1
Fuselage	682	31	4.5	2,665	146	5.5
Nose	750	40	5.3	3,061	235	7.7
Engine	608	96	15.8	3,887	1542	39.7
Propeller	266	12	4.5	819	92	11.2
Radome	251	32	12.7	2,645	405	15.3
Landing Gear	303	8	2.6	1,180	153	13.0
Pitot	43	29	67.4	0	0	0.0
Other	977	168	17.2	1,174	626	53.3
Total	5,249	562	10.7	22,656	4,461	19.7

Table 7.2 Aircraft Parts Most Commonly Struck and Damaged by Birds Canada and U.S. (1991-1999)

08:00 and 10:00—and early evening—15:00 through 17:00—when the numbers of scheduled flights peak.

Birds tend to be most active at dawn and dusk, but as sunrise and sunset times vary throughout the year these strike patterns are obscured. Consequently, daily strike-rate patterns revealed in the data are strongly influenced by peak aircraft-activity times. There is also variation in the temporal distribution of strikes among airports. Recent analysis also suggests that North American strike rates may in fact be higher at night.

The temporal patterns of mammal strikes are quite different than those of birds. The FAA database reported 681 mammal strikes during the 1991 to 1997 period; of the 522 mammal strikes in which time was known, 63 percent occurred at night—13 percent occurred at dawn and dusk, and only 24 percent during the day. These patterns reflect the nocturnal and crepuscular behaviour of most mammals that frequent airports in the U.S. and Canada.

Part of aircraft struck

The data presenting parts of aircraft struck by birds is partially related to type of aircraft involved and phase of flight. Data from 1991 to 1999 for Canada and the United States are summarized in Table 7.2. Overall, the fuselage, nose, radome, windshield, wing, rotor and engine are the parts most frequently struck. The numbers of strikes to windshields and engines is proportionally higher in the U.S. than Canada, although the reason is not apparent.

There is marked variation in the likelihood of a strike causing damage. The overall percentage of reported strikes causing damage is 10.7 percent in Canada and 19.7

Effect on Flight	Number of Incidents	% Total Incidents
No Effect/Continued Flight	4224	61.6
Precautionary/Forced Landing	608	8.9
Aborted Takeoff	173	2.5
Engine Ingestion	137	2.0
Engine Shutdown/Failure/Fire	30	0.4
Vision Obscured	61	0.9
Rupture Skin/Airframe	73	1.1
Other Effect	114	1.7
Unreported	1442	21.0
Totals	7002	100.0

Table 7.3 Effects of Bird Strikes on Aircraft in Canada (1991-1999)

percent in the U.S. It is not clear whether this difference is real or merely a statistical anomaly; each country uses similar aircraft and the species of hazardous birds are generally the same. It is possible that damaging strikes in the U.S. are more likely to be reported than non-damaging strikes; this would account for the apparent discrepancy between Canadian and U.S. figures.

Strikes most likely to cause damage are those involving:

- engines: 16 percent and 40 percent in Canada and the U.S. respectively,
- wings and rotors: 13 percent and 31 percent, and
- radome: 14 percent and 15 percent.

Multiple engine strikes are the most dangerous to aircraft safety; they're also the most expensive to repair.

As one might guess, mammal strikes involve different parts of aircraft than bird strikes. Overall, 607—85 percent—of the reported mammal strikes in the FAA database caused damage to various aircraft parts:

- landing gear were damaged in 63 percent of incidents: 251 occurrences in which 158 involved damage;
- propellers were damaged in 91 percent of incidents: struck 109 times and damaged 99;
- wings and rotors were struck 83 times, each resulting in damage; and
- engines were damaged 98 percent of the time: 59 cases of damage in 60 strikes.

Effect on flight

Bird strikes are of greatest concern when they cause damage and affect the flight of an aircraft. The Canadian experience from 1991 to 1999 is summarized in Table 7.3.

Aircraft Type	1991	1992	1993	1994	1995	1996	1997	1998	1999	Total
DeHavilland Dash-8	79	51	71	77	120	69	96	70	97	730
Boeing 737	115	32	62	53	54	36	61	45	38	496
DC-9/MD-80	59	30	38	46	60	47	35	15	27	357
Airbus A320	13	36	49	47	34	36	49	61	30	355
Boeing 767	27	16	22	17	31	25	8	19	11	176
Boeing 727	28	24	8	14	24	14	22	11	6	151
British Aerospace BA146	18	16	14	23	20	18	9	10	10	138
ATR 42	26	7	18	13	10	18	10	11	19	132
Fokker F28	9	0	6	6	18	17	15	16	16	103
Regional Jet CL65	0	0	0	0	11	28	27	26	1	93
Beech King Air	2	3	12	12	7	2	20	20	31	109
Canadair Challenger	11	8	9	2	6	10	0	11	8	65
Boeing 757	3	1	5	0	12	9	7	10	0	47
Boeing 747	3	5	1	10	3	8	5	11	10	56
BA Jetstream 31/41	5	3	5	7	8	0	7	12	5	52
McDonnell-Douglas DC-10	10	0	3	4	8	2	5	2	1	35

Table 7.4 Civil Aircraft Most Commonly Struck by Birds in Canada (1991-1999)

Readers should be aware that there might be more than one effect on any particular flight. In 83 percent of cases, strikes had no effect and flights continued. Precautionary landings were necessary in nine percent of reported bird strikes—many involving emergency procedures on the ground. Aborted takeoffs occurred 173 times—2.5 percent of cases.

Ingestions by engines occurred in two percent of cases, resulting in 30 engine failures, fires and precautionary engine shutdowns. Altogether, one percent of total reported strikes resulted in potentially serious engine problems.

Both Canadian and U.S. data regarding the effects on flight caused by mammal strikes differ from those involving birds. Only 36 percent of the 414 flights with full reported data proceeded without effects. Of these flights, 19 percent—79—involved rejected takeoffs, while 12 percent—49—resulted in precautionary landings.

Types of aircraft struck

All types of aircraft are susceptible to wildlife strikes, although vulnerability may differ. The types of aircraft most frequently struck in Canada are summarized in Table 7.4. The number of strikes per aircraft model is related to:

- the number of aircraft in service,
- the number of takeoffs and landings, and
- the airports used by that specific type of aircraft.

For example, the most frequently struck aircraft in Canada is the Dash-8—a short-haul aircraft that makes repeated daily takeoffs and landings at many smaller airports lacking effective wildlife-management programs.

Engine ingestions

The greatest concern regarding bird strikes to jet passenger aircraft is extensive damage and loss of power that can result when birds are ingested into engines. Unfortunately, engine manufacturers do not have access to all data on damaging events—a fact that hinders their ability to build more resilient engines. Following an examination of approximately 6,000 bird-ingestion events involving CF6 and CFM high-bypass turbofan jet engines, Tom Alge of GE Aircraft engines recommended that all bird ingestions resulting in engine damage be reported to manufacturers. Non-damaging ingestions—revealed during routine maintenance—are also not reported consistently. Alge found that of the 6,000 ingestions:

- 40 percent took place on takeoff,
- 10 percent on initial climb,
- 2 percent during cruise phase,
- 13 percent on final approach, and
- 35 percent on landing roll.

Although the frequency of ingestions was similar during departures and arrivals, departure ingestions resulted in damage at twice the rate as that incurred during arrivals.

A 1995 FAA study by Banilower and Goodall examined bird ingestions involving modern high-bypass turbofan engines used on A300, A310, A320, B747, B757, B767, DC-10 and MD-11 aircraft. Between 1989 and 1991 there were 644 ingestion events during 3,163,020 operations by 1,556 aircraft—a worldwide ingestion rate of 2.04 events per 10,000 aircraft operations. The ingestion rate in the U.S. was 0.70 per 10,000 operations compared to 2.52 ingestions per 10,000 operations in the rest of the world. During this three-year period there were 31 multiple-engine ingestion events—a rate of 9.8 per million operations. The FAA study reported that 47 percent of engines that ingested birds suffered some damage; about half of these cases involved significant damage.

The data also showed that ingestion risk fluctuates by location. Canada, the U.S. and some European and Pacific Rim countries enjoyed the lowest risks. The highest occurred at airports in Africa and some South American, Asian and European countries—locations that would gain immediate and significant benefit from effective wildlife-management programs.

Wildlife species involved in strikes

Determining which species of birds and mammals are struck adds value to the design of all aircraft components, as well as airport wildlife-management programs.

	CANADA		UNITED STATES	
Bird Group	**Total # of Strikes**	**% of Identified Strikes**	**Total # of Strikes**	**% of Identified Strikes**
Non-Passerines				
Waterfowl (i.e. ducks,geese, swans)	273	6.5	1366	11.7
Waterbirds (i.e.heron, crane, loon, coot)	37	0.9	51	0.4
Raptors	341	8.1	1320	11.4
Owls	102	2.4	250	2.1
Shorebirds	307	7.3	834	7.2
Gulls and Terns	1614	38.5	3266	28.1
Pigeons and Doves	125	3.0	1373	11.8
Gallinaceous Birds (i.e. grouse/pheasants)	27	0.6	62	0.5
Other Non-Passerines			54	0.5
Passerines (perching birds)				
Crows	65	1.6	208	1.8
Swallows	291	6.9	297	2.6
Blackbirds	20	0.5	671	5.8
Starlings	160	3.8	591	5.1
Snow Bunting	300	7.2	33	0.3
Other Passerines	528	12.6	1253	10.8
Identified Bird Totals	4190	100	11,629	100.0
Unidentified Birds Struck	2658		14,084	
Total Birds Struck	6848		25,713	

Table 7.5 Identified Bird Groups Commonly Struck in Canada and U.S. (1991-1999)

The species and numbers of strikes in Canada and the United States between 1991 and 1999 are summarized in Table 7.5. The table contains information on a total of 15,819 reported strikes. The species or group involved is identified in 61 percent of reported strikes in Canada and 45 percent in the U.S. By far, the most frequently identified group involved in strikes are gulls and terns—38.5 percent of reported strikes in Canada and 28 percent in the U.S. The overwhelming majority of these strikes involve gulls; less than one percent involve terns. Waterfowl are reported in 12 percent of U.S. strikes, but only 6.5 percent in Canada. Diurnal raptors—such as hawks, eagles and vultures—are involved in 11.4 percent of strikes in the U.S. and 8.1 percent in Canada. Pigeons and doves figure prominently in U.S. strike data—12 percent compared to only three in Canada. The U.S. has much larger dove populations, and these numbers swell in winter when Canadian doves migrate south. Overall, the passerines—perching birds—constitute 33 percent of reported Canadian strikes and 26 percent in the U.S., although figures vary among species; Blackbirds and starlings are more frequently identified in the U.S., whereas swallows and Snow Buntings are commonly struck in Canada (Table 7.5).

During the 1991 to 99 period, 152 mammal strikes were reported in Canada and 681 in the U.S. The most commonly reported species struck in Canada are:

Species/Groups	Cause Damage		Affect Flight		Aircraft Downtime		Monetary Loss	
	Number	Per Cent	Number	Per Cent	# Hours	Per Cent	Cost*	Per Cent
Gulls/Terns	581	29.8	456	32.9	19,326	20.9	11.4	19.1
Waterfowl	640	32.9	305	22.0	38,268	41.3	33.5	56.1
Raptors (incl. Owls)	334	17.1	208	15.0	24,276	26.2	8.6	14.5
Pigeons/Doves	135	6.9	141	10.2	5,578	6.0	3.8	6.4
Blackbirds/Starlings	73	3.7	91	6.6	1,240	1.3	0.7	1.1
Other Waterbirds	24	1.2	13	0.9	699	0.8	0.2	0.3
Shorebirds	85	4.4	77	5.5	2,994	3.2	1.2	2.1
Corvids (Crows, etc.)	20	1.0	18	1.3	77	0.1	0.0	0.1
Sparrows	19	1.0	36	2.6	20	0.0	0.0	0.0
Grouse/Pheasants	16	0.8	12	0.9	93	0.1	0.0	0.0
Miscellaneous	21	1.1	31	2.2	86	0.1	0.2	0.3
Total Known	1,948	100	1,388	100	92,657	100	59.6	100
Unknown Species	1,889		1,110		21,437		17.8	
Total Birds	3,837		2,498		114,094		77.4	

* in millions of U.S. dollars

Table 7.6 Identified Bird Groups Commonly Struck. Canada and U.S. (1991-1999)

- Rabbits: 24 percent,
- Striped Skunk: 13 percent,
- Coyote: 12 percent,
- Fox: 11 percent, and
- White-tailed Deer: 7 percent.

In the U.S., 65 percent of reports refer to deer—11 percent to Coyote.

Damaging strikes

The likelihood that a particular bird strike will cause aircraft damage is related to the size of bird—its weight—and its flocking behaviour, which determines how many individuals are likely to be struck. In both Canada and the U.S., gulls are the most frequently struck bird group—28 to 39 percent (Table 7.5). Gulls are involved in 30 percent of damaging bird strikes (Table 7.6). Waterfowl—primarily ducks and geese—are involved in 33 percent of damaging strikes, but only 12 percent of the overall strikes in the U.S. Raptors, including owls, are also involved in a higher percentage of damaging strikes—17 percent as opposed to 11 percent of the total number of strikes. Pigeons and doves account for 11 percent of U.S. strikes—only 6.4 percent of these cause damage. Other passerines account for 11 percent of overall strikes but less than one percent of those resulting in damage (Tables 7.5 and 7.6).

Relative costs by species

The FAA database presents information on the numbers of hours of aircraft downtime and reported costs of strike incidents. Table 7.6 illustrates how the otherwise strong influence of gull strikes appears to drop:

- waterfowl are involved in 41.3 percent of total downtime and 56 percent of damage costs,
- raptors: 26.2 percent of downtime, 14.5 percent of costs,
- gulls: 21 and 19 percent respectively, and
- pigeons and doves: six and 6.4 percent.

Hazardous species

When determining bird species that pose the greatest hazard to aircraft safety, a number of factors must be considered including:

- numbers of birds present,
- weight and density of the birds,
- flocking behaviour of the birds,
- behaviour of birds at and near an airfield, and
- their responses to aircraft.

There has been little study of the behaviour of birds in response to approaching aircraft. Based on the Canadian and American experience, it's clear that waterfowl, gulls, raptors, pigeons and doves are the most hazardous species on a continent-wide basis. This is not to say that other species or groups are not more important at specific airports.

A review of the ICAO worldwide database shows similar trends. For example, during the three-year period between 1994 and 1996 there were 743 bird-strike incidents that caused serious damage. The bird species or group was known in 419 of these cases—gulls were the leading cause of serious damage in 32 percent of incidents, followed by raptors—including owls—at 21 percent and waterfowl at 20 percent.

Conclusions

To summarize, it's important to emphasize the value of bird-strike statistics and the importance of collecting strike data—data that provides:

- a fundamental risk-analysis tool for developing strike-reduction strategies;
- a means to evaluate performance of wildlife-management strategies;
- cost information for documenting the importance of the bird-strike problem;
- justification for expenditures necessary to address the wildlife-strike problem;
- a key planning tool needed to form the basis of airport wildlife-management programs;
- data required by airframe and engine manufacturers to assist in design of safer and more bird-proof engines and airframes;
- information needed by insurance companies; and
- information needed by airport operators to demonstrate they have shown due diligence in addressing bird and mammal strike problems at their facilities.

The collection and evaluation of wildlife-strike data is a cornerstone of a safer aviation environment.

Colour Plates

Plate 1 On September 22, 1995 a 4-engine USAF E-3B AWACS crashed 43 seconds after takeoff from Elmendorf AFB, Alaska. The aircraft struck a large flock of Canada Geese that had often been observed in the area.

Plate 2 Canada Geese on the runway shortly after the September 22 AWACS crash. Twenty-four crew members died in the crash.

Plate 3 This accident involving a Cessna 441 Conquest at Fort Frances, Ontario, was the result of a gull being ingested in the intake of the #1 turboprop engine.

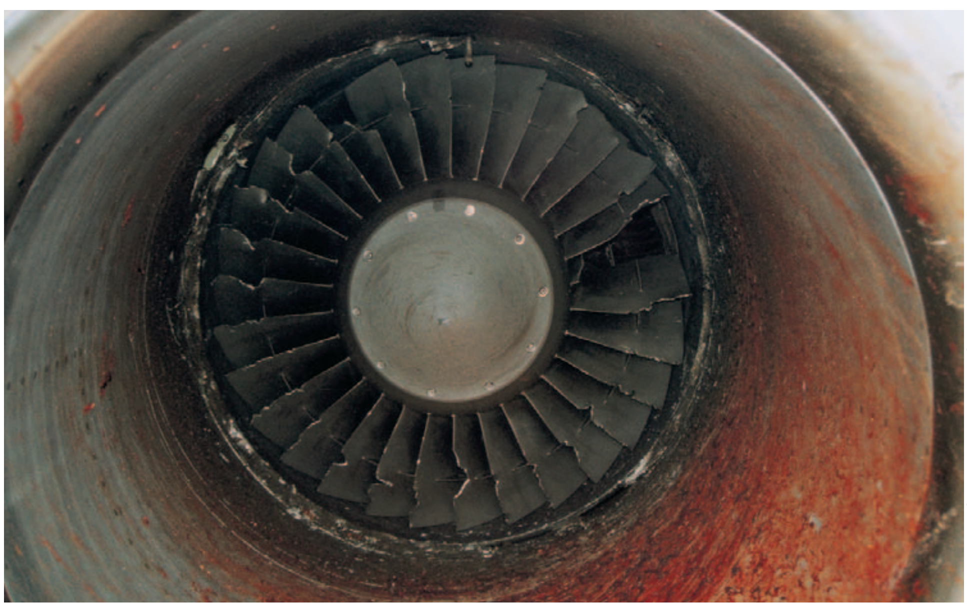


Photo courtesy Capt. Peter Miller, Kroger Co.

Plate 4 Uncontained engine failure on a Falcon 10 business jet resulting from a bird strike.

Plate 5 An impact with a Western Grebe (3 lbs) caused considerable damage to this helicopter. The bird struck the pilot in the face. (See plates 6 and 7)

Plate 6 The impact force of this incident was so severe that after striking the windshield and pilot, the bird damaged the hinges on one rear door.

Plate 7 The helmet and face-shield probably saved the life of the pilot when he was struck in the face by windshield and bird debris.

Plate 8 This is all that remains of a $200 million USAF B1-B bomber that crashed after striking an American White Pelican in Colorado. The airplane weighed 185,000 lbs, the bird 15 lbs. Three crew members died in the crash.

Plate 9 After striking a gull on takeoff from JKF International Airport on November 12, 1975, the # 3 engine on this ONA DC-10-30 exploded and caused the aircraft to burn out. The 139 passengers, who were all airline employees, safely evacuated the aircraft.

Photo: Larry MacDougal, Calgary Herald

Plate 10 The # 1 engine on this KLM B-747 suffered an uncontained failure as a result of a collision with Canada Geese while landing at Calgary International Airport. Leading edge devices were also damaged.

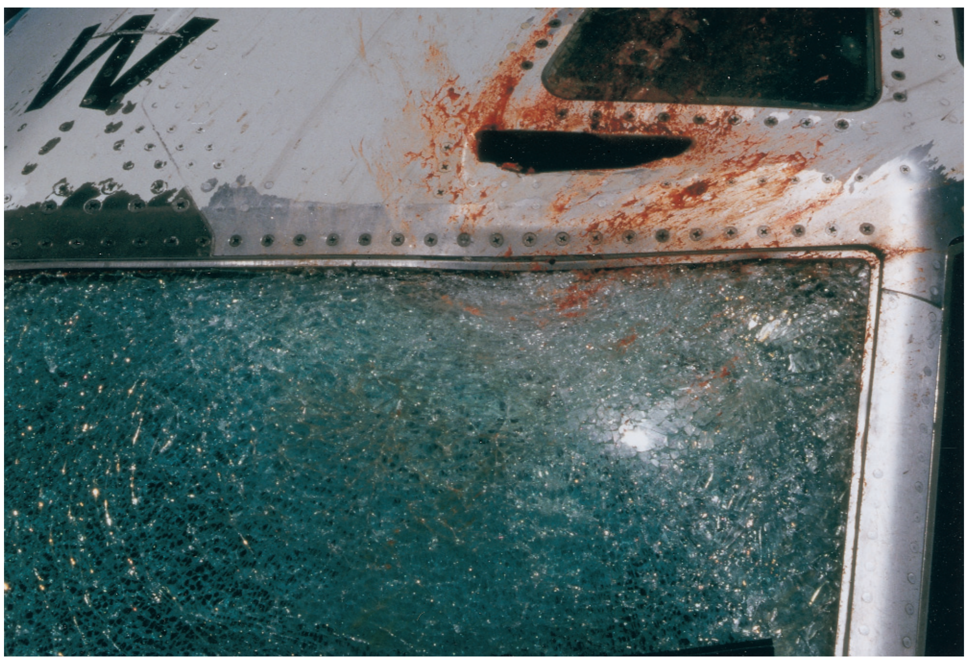


Plate 11 The windshield on this B737 was severely damaged as a result of a collision with a bird at 10,000 ft. ASL and 250 kts. The captain was injured from debris when the bird penetrated the fuselage above the windshield.

Plate 12 Severe damage to airframe components and leading edge devices is common in bird strike events. When penetrated to the spar, electrical and hydraulic systems can be affected.

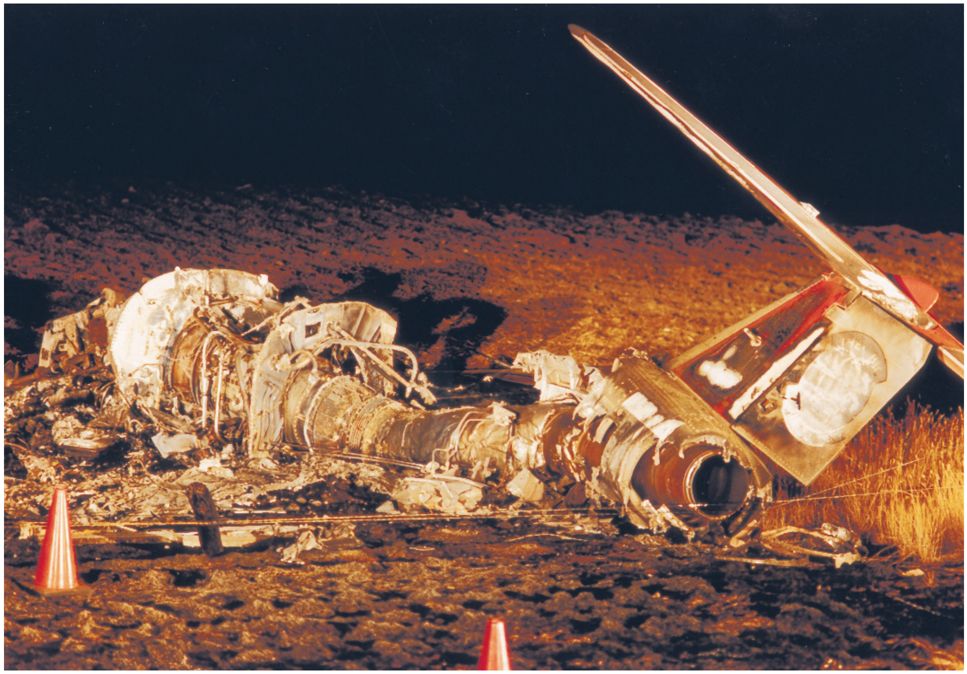


Plate 13 This RCAF CT-114 Tutor crashed during a training mission over Assiniboia on September 25,1997 after colliding with a single bird. Both crew members ejected safely.

Plate 14 When large animals are allowed access to aircraft movement areas, a high risk situation always results.

Plate 15

Plates 15 and 16 show damage to a small jet engine resulting from impact with a 3 lb Turkey Vulture.

Phase of flight: takeoff

Speed: 140kts.

The remaining engine was also damaged, but not from striking a bird. It reached an overspeed condition during recovery from the aircraft roll and the fan contacted the shroud throughout the circumference.

Plate 16 Damage to the engine included:

- Loss of nose cone
- Severence of nose cone shaft
- Loss of 10 fan blades
- Fan case damage and flange separation
- Inner shroud damage
- Sheared splines in fan hub
- Fractured fuel pump/fuel control mount flange

Plate 17 Thirty-four people died in the bird-strike related crash of this C-130H at Eindhoven AFB, Holland on July 15, 1996.

Chapter 8

Solutions — The Airport & Surroundings

"*It is the policy of Transport Canada to regard all wildlife on airports as potential hazards to airport and aircraft safety, and to site, construct, maintain, and operate the airport and its facilities in a manner that will minimize these hazards.*"

Introduction

As one might expect, activities to reduce exposure, probability and severity of wildlife strikes to aircraft are primarily undertaken at and in the vicinities of airports, where 90 percent of wildlife strikes occur. These wildlife-management efforts are focused on altering ecological processes in airport environments.

Firmly based in science, airport wildlife-management employs a variety of tools and techniques to discourage and disperse animals from the vicinity of aircraft operations. These efforts must be continually refined and updated, as no single method or product is effective over the whole range of species posing direct and indirect risks.

For detailed tactical guidance in undertaking airport-wildlife management, the authors refer you to Transport Canada's *Wildlife Control Procedures Manual*. This document examines in greater detail many of the elements discussed in this chapter.

Roles and responsibilities

The primary responsibility of the airport operator is to maintain airport safety—to develop and implement policies and programs that address problems associated with wildlife strikes.

Site-specific wildlife-management solutions

When it comes to wildlife risks, no two airports are alike; no two wildlife-management programs are alike either. Each must be site-specific, developed with input from biologists, ecologists, wildlife-management experts, regulatory bodies, airport operators and other agencies that can add value to a program. While wildlife-management efforts must focus on aircraft-movement areas and approach and departure paths regardless of an airport's size, effective programs encompass the entire airport, including buildings and structures.

At small airports, where aircraft movements are few and resources scarce, effective wildlife-management programs may involve simple runway bird-dispersal operations undertaken prior to takeoffs and landings. At large airports, however, multiple solutions are required to address the range of wildlife-management considerations; prioritization is essential, identifying species that pose the greatest hazards to aircraft operations.

Passive and active wildlife management

Effective airport wildlife-management relies on a balanced, systematic and science-driven integration of passive and active initiatives.

Passive initiatives are commonly referred to as the habitat-management components of wildlife-management programs, involving control of those airport features that attract wildlife. While these features can be reduced and modified—providing the most cost-effective means of limiting long-term wildlife-associated risks—they cannot be eliminated; animals will always be attracted to some feature at an airport, perhaps on a seasonal basis—during migratory periods, for example.

For this reason, active measures are equally important, including scaring and harassing wildlife to disperse them immediately from an area.

Passive and active initiatives work hand in hand to ensure effective wildlife management. For example, modifying large areas of suitable wildlife habitat through removal of ponds and perches will reduce the need for active management. Conversely, clearing runways of birds solely through active management techniques can be counterproductive if, for instance, passive measures have not reduced availability of food, water and shelter at other parts of the airport.

Airport wildlife management: land-use practices near airports

Airport boundaries are meaningless to wildlife, so effective airport wildlife-management programs rely on:

- knowledge of land-use activities adjacent to an airport, and
- support and participation of those who manage wildlife-attracting operations adjacent to the airport.

Past experiences have shown that on-airport control measures can be overwhelmed by large increases in gull numbers drawn to airport-area facilities such as landfills. The problem is not only one of numbers, it's also one of movement—bird-flight paths to and from these off-airport sites can intersect paths of arriving and departing aircraft. Recent studies of gull movements to and from feeding sites such as landfills have shown that gulls typically occupy airspace from 100 to 2,000 ft AGL.

Birds	Mammals
Gulls	Deer
Geese	Coyote
Swans	
Ducks	
Pelicans	
Starlings	
Shorebirds	
Raptors	
Pigeons	
Doves	
Cranes	
Herons	
Blackbirds	

Table 8.1 Common Hazardous North American Species for which Habitat Management Should be Considered a Primary Control Measure

Approaching jet aircraft, using a normal three-degree glide slope, occupy this same space for a distance of more than eight miles from the end of a runway.

Passive wildlife management: habitat management

The large open spaces typical of airports will always attract wildlife; short of creating sterile environments, it is impossible to control all species through habitat management. At the same time, modifying one habitat can create a new attractant for other species. Passive wildlife management is a delicate balancing act, and its efforts must be continually evaluated and updated.

There is, however, nothing passive about the costs of these measures—they can be high, and difficult for an airport operator to justify. For this reason, use of habitat management as a primary control measure requires careful planning and study.

The goals of habitat management

Before implementing habitat-management measures, consider carefully whether proposed modifications will achieve their goals, which should include:

- eliminating or significantly reducing numbers of problem species within an airport environment;
- not creating new attractions for species that pose either an equal or greater risk to aircraft safety; and
- reasonable implementation and maintenance costs that ensure a new habitat will remain unattractive to problem species for an extended time period.

Food Source	Habitats	Shelter & Safe Areas
Earthworms	Grass Fields	Abandoned Runways
Fish/Frogs	Drainage Ditches	Abandoned Taxiways
Insects	Hedgerows	Brush/Wooded Areas
Rodents	Marsh and Swamps	Buildings
Seed Producing Grasses or Weeds	Woodlots	Ponds/Lakes
Snails/Slugs	Scrub Lands	Roof Tops
Litter/Garbage	Riparian Vegetation	Short-grass Fields
Agricultural Crops	Nest Trees	
(grains, forage, legumes, etc.)	Raptor Perches	
	Open Bodies of Water	
	Retention Ponds	
	Temporary Ponding of Water	
	Buildings (nest & roost sites)	
	Hangars	

Table 8.2 Airport Wildlife that may be Managed through Habitat Modifications

Target species

Habitat modification is best used against species that present the greatest hazards to aircraft—species that:

- are large in size, having the greatest potential to cause an accident when struck;
- typically gather in large numbers, resulting in a higher probability of frequent or multiple strikes, and increasing the potential severity of a strike; and
- display a particular behaviour that increases strike probability, such as the propensity for gulls to loaf on runways, attracted to the warm pavement.

Table 8.1 lists wildlife species that meet these criteria.

Acquiring knowledge of airport-wildlife habitats

Effective habitat management stems from the collection of accurate and comprehensive data concerning wildlife attractants in airport environments. In some cases, these attractants will be obvious, and so well known to airport staff that little study is required; other cases may demand exhaustive long-term ecological study to identify specific habitat features that attract hazardous species.

Regardless of scope—and prior to implementation—habitat management efforts should include the following activities:

- review wildlife-strike data to identify known problem species;
- assess the probability, exposure and potential severity of incidents involving commonly struck birds and mammals;

Food Source	Management Technique
Croplands	Keep cropland more than 1,200 feet away from runways
	Re-schedule cultivating and harvesting practices that attract flocks of birds
Earthworms	Sweep worms off runways following heavy rains
	Prevent worms from crawling onto the tarmac
	Kill worms by treating the grass strips beside the runways
	Apply worm repellent along the edge of the runway
Garbage Dumps	Locate dumps at least 8 km from airport reference points
Grass Fields	Keep grass length at 10 to 15 cm (average length in Canada) to reduce loafing and feeding activity (please note that site-specific studies are required in order to determine optimum grass length)
	Maintain minimum-width short-grass aprons along runways
	Keep grass areas free of broad-leaf weeds, which attract some mammal species and provide a food source
	Spray insecticides and herbicides beside runways to eliminate seeds and insects

Table 8.3 (a) Habitat Management: Food Sources

- identify attractants such as food, water and shelter, and location of roosting, loafing and perching sites (Table 8.2 provides a list of common wildlife attractants which can be managed through habitat modification);
- obtain and review information from other relevant airport studies and experiences;
- assess seasonal presence of hazardous species (are they year-round residents or present only at specific times of the year?); and
- determine whether the habitat can be modified or eliminated.

Common habitat-management techniques

The following sections provide a brief overview of habitat-management techniques used over the past twenty years at airports across Canada, the U.S. and Europe. While each airport presents unique habitat-management challenges, these practices have generally proven effective when employed as part of a comprehensive wildlife-management plan.

Food-source habitat management

While highly effective, initiatives to reduce problem-species' food sources are sometimes overlooked for a variety of reasons:

- airports do not have equipment required to apply chemical deterrents;
- airports are reluctant to use chemicals due to cost and potential environmental harm—real or perceived;
- airports do not have easy access to specialized equipment required for large-scale cutting or removal of vegetation;

- the number of food sources at airports is considered insurmountable;
- staff are not aware that a specific food source is primarily responsible for attracting hazardous wildlife; and
- the aesthetic appeal of certain vegetation mosaics that have become traditional fixtures at many airports.

As far as the costs of these initiatives are concerned, they are far outweighed by savings that result from comprehensive wildlife-hazard reductions.

Table 8.3 (a) summarizes common habitat-management techniques used to control food sources.

Chemical control of food sources

Chemical controls must be directed only at specific food sources—to limit expenditures and minimize both the effects on non-target species and potential environmental impact. Chemical control may involve one or more of the following:

- spraying the first 30 to 40 meters of grass along the runway several times per year (Benomyl and Tersan have proven effective in the control of earthworms);
- applying rodenticides in early spring—prior to rodents' breeding cycles—to control small-mammal populations that provide food sources for raptors;
- applying insecticides throughout the year, including treatments aimed at specific species during infestation periods.

Physical methods to control food sources

Physical methods to control or remove food sources may include:

- cutting fields and vegetation to prevent seed-head development and fruit production. Cutting ground vegetation in the fall can ensure winter food sources are limited or eliminated. Similarly, trimming and removing shrubs and trees can reduce browse for ungulates, as well as berries and fruits for birds and other mammals.
- denying wildlife access to edible waste through use of well-sealed garbage receptacles. Where possible, garbage containers should be stored indoors or housed in specially designed outdoor facilities that prevent access by wildlife. Spilled waste at garbage loading areas and elsewhere should be cleaned promptly and regularly.

Leasing of airport lands for agriculture

Leases involving airside and off-airside agricultural land must be well defined and strictly monitored and controlled, ensuring the airport operator maintains the ability to manage potential wildlife hazards. Many agricultural crops provide attractive food sources; farming activities such as plowing and harvesting often create abundant, easily accessed food. Prior to leasing, it is advisable to analyze the risk posed by these activities; the revenue they generate may be outweighed by additional wildlife-management costs they incur.

Shelter/Safe Areas	Management Technique
Woodlots	Remove all undergrowth
	Thin treetops to make them less attractive as roosting sites
	Inspect trees frequently for colonies of nesting birds
Hedgerows/ Nest Trees	Cut back at least 150 m from the runway or taxiway center line
Buildings	Eliminate holes, crevices, roosting ledges and general access to buildings
	Block, cover and seal all holes, crevices and drains by using screening, concrete or brickwork
	Apply special materials to perches to keep birds away
	Slope ledges to eliminate roosting and nesting sites by using boards, plastic sheeting and concrete
	Perform routine inspections of all airside buildings and structures
	Remove old airside buildings that are no longer in use
Trees, Structures	Monitor trees around the fenced perimeter and remove if required
	Remove all large single trees as well as small clumps of trees on airside lands
Runways, Aprons & Taxiways	Carry out inspections and remove all materials that attract birds
	Put spikes on runway lights, approach lights, taxiway and apron lights to eliminate perching and nesting sites
	Spray insecticides and herbicides beside runways to eliminate seeds and insects
	Keep runways and taxiways clean

Table 8.3 (b) Habitat Management: Shelter & Safe Areas

The specific terms of lease agreements are dependent on factors such as local climate, soil conditions, cropping patterns and market values—factors that vary significantly from airport to airport. In light of this, it is impractical to provide regulations on acceptability of specific crops. It is the responsibility of the airport operator to ensure that sufficient data is available to make an informed decision regarding agricultural use of airport land.

Lease agreements should contain clauses that:

- specify types of crops grown;
- ensure that the crops selected are those least attractive to wildlife;
- specify scheduling of farming activities such as plowing, planting and harvesting to ensure that the potential for attracting wildlife is reduced;
- clearly identify harvesting methods that may be used; and
- ensure that leases or licences include an escape clause that oblige the farmer to remove or plow under crops if wildlife hazards arise.

The removal of airport vegetation—such as tree stands—eliminates roosting and nesting sites for birds, as well as shelter for mammals such as deer.

Shelter-habitat management

Shelter habitat includes safe areas where wildlife loaf, perch, roost or nest. Within the airport environment, shelter habitat can be:

- natural, including brush and woodlots, hedgerows, perch trees; and
- human, including buildings, hangars, jetways, parking garages, aircraft movement areas, signs and equipment.

Management techniques involve either removing shelter habitats from airports or altering these domains so they no longer appeal to wildlife. In most cases, wildlife shelter—once identified—can be effectively managed through little cost and effort.

Natural wildlife shelter—such as small wood lots, hedgerows and trees used for perching and roosting—should be eliminated or modified to be less inviting; this may be as simple as removing wood-lot underbrush.

Features such as abandoned buildings used by nesting birds and mammals should be demolished; abandoned taxiways and aprons—ideal loafing areas for gulls—should be scarified and revegetated.

Table 8.3 (b) summarizes techniques for removing and modifying the shelter habitats of birds and mammals.

Water-habitat management

Many bird species—particularly waterfowl and shorebirds—are attracted to water, not only to drink, but also to seek shelter and nesting sites, and a variety of available

Water Habitat	Management Technique
Open Drainage/Ditches	Increase the slope of banks to eliminate shelter areas
	Drain ditch bottoms to eliminate standing water used by birds and mammals
Water Bodies	Use herbicides and clearing techniques to limit vegetation (cattails, bushes) on the banks of all water bodies
	Set up barriers to prevent access to water using material such as nylon mesh and wires

Table 8.3 (c) Habitat Management: Water Habitats

foods. Airport water habitats vary from simple ditches and ponds to wetlands, creeks, rivers and lakes. Areas where water collects for short periods of time—after rainstorms or during spring snowmelt—can attract large numbers of birds. As a general rule, all standing water at airports should be removed or modified.

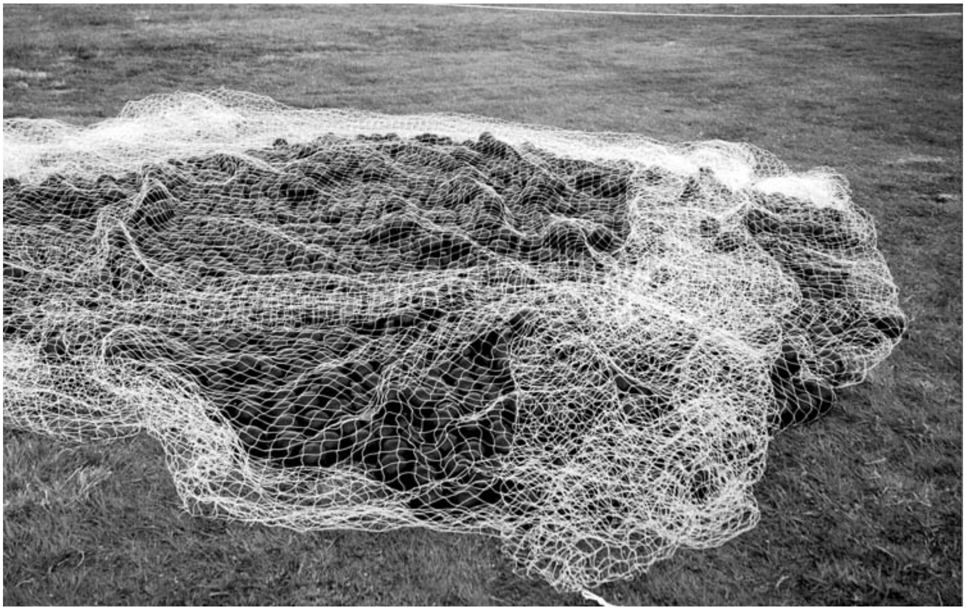
Federal, provincial and state laws that protect water-habitat areas underline the importance of co-operative partnerships between airport operators and government agencies. Significant habitat modifications are not always possible; regulatory constraints to wetland- and fish-habitat manipulation are extensive. In cases where removal or manipulation of wetlands is the only option, redress measures—such as off-site wetland or fish-habitat compensation projects—may have to be negotiated between an airport and government agencies. If removal of habitats is not possible, the management plan should allow for minimum modifications to make the areas less attractive to problem species.

Water-habitat management requires long-term permanent solutions as well as short-term measures that deal with seasonal and temporary water sources. Table 8.3 (c) provides a summary of water habitats and how they may be managed.

Large-scale, permanent measures such as those presented below are often costly due to their complexity. For this reason, airport operators may consider including these projects as long-term goals of their wildlife-management plans.

- Ineffective ditching systems that create standing water should either be re-aligned or replaced with buried drain pipes.
- Airside ponds and natural-ponding areas should be eliminated through infilling, grading and improving drainage.
- Storm-water ponds should be located in safe areas and modified so as not to attract wildlife. In recent years, a number of airports in North America have replaced typical storm-water ponds with artificial, subsurface-flow wetlands. These installations eliminate surface water and reduce wildlife habitat.

Short-term management measures either create unappealing water habitats or alter habitats to exclude specific problem species. Regular cleaning and removal of aquatic



When floated on standing water, these plastic balls prevent waterfowl and other birds from gaining access to the water.

vegetation will make ditches less attractive; ensuring these sites have deep, steep banks and regularly cut vegetation will also limit their appeal to wildlife.

A number of readily available products exclude wildlife from water habitat. The choice of product will depend on:

- the size of the area,
- the type of habitat,
- the species to be controlled, and
- the period of time wildlife must be excluded from the area.

There are four proven methods that prevent birds from either landing or swimming on water surfaces:

1. Overhead systems using metal, nylon or monofilament wire (a 2.5- to 6-metre grid will stop most gulls; a 3- to 4-metre system will stop most waterfowl)
2. Fine netting
3. Flagging tape
4. Plastic balls, which float on water, making it inaccessible to birds.

Grass management

The traditional vegetation mosaic at airports comprises large expanses of grass. Although aesthetically appealing, easy to maintain and functional—absorbing water from rain and snow-melt—grass is likely the dominant bird-attracting feature at airports. Grass fields are habitat for a number of high-risk bird species, providing safety as these birds feed, rest and breed. Given their abundance in airport environments—and the range of wildlife they host—one would expect that extensive data would be available to inform grass-management efforts. Unfortunately, this is not the case, and there is considerable debate among biologists and airport wildlife-management officers about how to manage grass spaces.

At most North American airports, significant maintenance resources are dedicated to mowing programs that keep airside grass at relatively short lengths for aesthetic purposes. In other parts of the world, however, programs that maintain long grass have proven to be effective; these measures are gradually being adopted in North America. Hazardous species such as gulls, waterfowl, starlings and lapwings use short-grass fields for feeding and as safe areas for loafing; allowing grass to grow longer serves several purposes:

- long, dense grass makes it more difficult for birds to find food such as worms and insects,
- perhaps more importantly, longer grass reduces birds' visual contact with surrounding environments and inhibits their ability to detect potential predators, and
- long grass does not provide birds the space to achieve the wing-beat needed for takeoff.

The U.S. Air Force now requires airfield grass be maintained at a height of 17 to 35 cm, and the USDA has recommended that JFK International Airport maintain mowed vegetation at a height of 15 to 25 cm. In recent years, Vancouver International Airport has undertaken an experimental program using Reed Canary Grass maintained in some areas at a height of over 75 cm. Observations in these long-grass

Grass cutting.

fields indicate that there has been a significant reduction in their use by birds. Transport Canada has traditionally recommended grass lengths in the range of 10 to 15 cm, but the recently updated *Wildlife Control Procedures Manual* includes a recommendation for site-specific studies to determine the most effective grass length.

Prior to implementation of a long-grass program, careful consideration should be given to the potential for increased collateral hazards. Long-grass fields may reduce gull and starling numbers, but may create new habitats for other species such as ground-nesting birds, and small mammals such as voles, hares and rabbits. Predator numbers may rise, including hawks, owls and Coyotes. Furthermore, the United States Department of Agriculture has gone against common knowledge and determined Canada Geese are not deterred by long grass. The key point is that no two airports have exactly the same wildlife-management challenges. Wildlife-management success results from knowledge, flexibility, and a willingness to try different solutions in addressing problems. It is essential to identify and prioritize hazardous species, and then focus efforts on the problem wildlife.

While not maintenance-free, long-grass programs are—according to some airport operators—less expensive to sustain; yet their specific cutting regimes may require new grass-cutting equipment. Cutting programs may also demand that dried cut grass be raked periodically so as not to form dense thatch. Accumulated thatch kills turf and increases plant diversity, which in turn may attract yet more wildlife species—and create potential fire hazards. The difficulties associated with cutting long grass can be partially mitigated by applying chemicals that impede growth once the required length is achieved. These habitats may also require chemical applications to reduce broad-leafed weeds, seeds and insects.

In many parts of Canada and the U.S., local soil and climate conditions will not support dense long grass. In these situations, a poor-soil approach to turf management—such as those employed at military airbases in the Netherlands—may offer a solution. Here, the low bio-productivity of the soil does not support high bird numbers. Poor-soil management refers to the hands-off practice in which weeds and other aesthetically unpleasant vegetation are permitted to take over—it's an approach worthy of consideration in arid areas, prairie regions and the more northerly regions of Canada and the U.S.

The extent of grass habitats at North American airports, and their attractiveness to high-risk species, make long-grass management programs a logical choice for reducing bird numbers. In any case, more related aviation-industry research is warranted.

Community co-ordination for off-airport habitat management

Many current airport-vicinity developments and land uses were never anticipated when most airports were first constructed—a fact that underlines the need for airport operators to have voices in land-use planning processes, partnering with municipal governments, planning authorities, business interests and the agricultural industry. The management of land near airports can have a dramatic impact on the effectiveness of wildlife-management programs.

Agriculture	**Recreational Areas**
Crops (grains, forage legumes)	Drive-in theatres
Livestock feedlots, pig farms	Golf courses
Pasture lands	Marinas
Plowing, haying, harvesting	Picnic areas
Vineyards	Outdoor restaurants
Orchards, berry farms	Beaches
	Racetracks
Food Processing	
Abattoirs	**Wildlife Concentration Areas**
Coastal fish processing plants	Wildlife refuges
Fish-waste outfall	Bird feeding stations
	Bird nesting colonies
Waste Facilities	Roosting sites
Garbage barges	Loafing sites (gulls on flat roofs, parking lots)
Garbage dumps	
Waste-transfer stations	**Natural Areas**
Landfills holding organic waste	Marshes/swamps
Compost facilities	Mud Flats/shorelines
	Bush or woodlots
Water Bodies	Hedgerows
Sewage lagoons	Riparian habitat
Sewage outfalls	
Oxidation ponds	
Stormwater retention ponds	
Reservoirs and lakes	

Table 8.4 Land Use that may Create Wildlife Hazards in the Vicinity of Airports

A good working relationship with neighbouring stakeholders is an essential first step in protecting the interests of an airport and its clients, since many community land-use planners are unfamiliar with the potential impact of off-airport land-use activities on aircraft safety. Awareness programs for key community stakeholders are particularly effective, highlighting the potential flight-safety and liability issues associated with inappropriate land use.

The Transport Canada publications *Land Use in the Vicinity of Airports* (TP1247) and *Aerodrome Standards and Recommended Practices* (TP312) provide guidelines for wildlife management outside airport boundaries, identifying land-use activities that are incompatible with the safe operation of airports and aircraft. This information is critical to both airport operators and development of effective wildlife-management programs. Table 8.4 provides a list of land-use activities deemed by Transport Canada to be incompatible with safe aircraft operations.

Solutions for land-use concerns

There are a number of available options to ensure airports enjoy a reasonable degree of protection from incompatible land-use activities:

- airport operators may implement federal airport zoning regulations and municipal by-laws that restrict specific land-use activities.
- owners of incompatible land-use facilities may reduce risks associated with their operations voluntarily, through actions that modify the location, design and procedures of risk-generating operations.

Regardless of the methods chosen, it is essential that meaningful and productive dialogue be established between an airport operator and other stakeholders in the surrounding community.

Airport zoning and land-use regulations:

Under the authority of the Aeronautics Act, Section 5.4 (2), airport zoning regulations may be enacted to prohibit land-use activities that have been identified as hazardous to aircraft operations. To date, 55 airports across Canada have waste disposal clauses contained within their zoning regulations—clauses derived from Transport Canada guidelines found in TP1247, *Land Use in the Vicinity of Airports*.

The Transport Canada guidelines identify extremely hazardous land-use that are prohibited within eight km of zoned airport reference points. These activities include:

- food-waste landfill sites,
- garbage dumps,
- coastal commercial fish-processing plants, and
- some agricultural activities that may either attract birds or adversely affect aircraft-flight visibility.

The guidelines also identify moderately hazardous land-use activities that are not recommended within 3.2 km of airport-reference points. These activities include:

- feedlots,
- specific agricultural practices,
- commercial activities such as outdoor theatres,
- managed or supplemented natural habitats,
- migratory waterfowl refuges,
- feeding stations, and
- designated mammal refuges.

Additional features not recommended within 3.2 km of airport-reference points include:

- sewage lagoons,
- manure piles,

- food waste from restaurants and picnic areas, and
- fresh tilled or plowed soil.

Distance from airport reference points should not be the only considerations. For example, many gull-movement studies have shown these birds can routinely fly more than 60 km between roosting sites and attractive food sources. Therefore, forcing a new landfill to locate outside an eight-km protected zone may do little to eliminate bird hazards if airports are anywhere between these sites. This is one of the reasons Transport Canada *Aerodrome Standards and Recommended Practices* (TP312) recommends garbage-disposal facilities—and any other food-source location—within 15 km of the end of any runway be either eliminated or prevented unless a bird-hazard study indicates that the facility is unlikely to create a problem.

Unfortunately, the provisions of TP 1247 and TP312 do not provide ironclad protection. Facilities are immune when established prior to enacting fo zoning regulations. The high costs associated with zoning can also make it an economically impractical solution. Furthermore, poorly managed facilities—such as landfills—outside a protected zone can create significant hazards due to their tendency to attract large numbers of birds, and the highly variable and unpredictable nature of some of these species.

Voluntary implementation of mitigation measures

As unused land becomes scarce, high-risk facilities are frequently located near airports. In these cases, airport operators should exert influence during the design, construction, and licencing phases of these facilities. A well-presented bird-hazard awareness program is a very useful tool in these circumstances, ensuring all stakeholders—including the responsible licencing and regulatory authorities—are aware of potential hazards that may result.

The interests of an airport and its clients can often be best served when bird-hazard studies are conducted prior to design and approval of potentially high-risk sites. Persistent and constructive interventions by the airport operator can ensure voluntary compliance with established airport safety criteria. In addition, airport operators can call on data often provided in the ecological studies, risk-analysis and management plans that these facilities may be required to provide by law.

Here are some of the criteria and conditions found in operational licences for incompatible off-airport land-use activities:

- requirement for wildlife-management programs;
- establishment of wildlife-management performance standards;
- allowance for facility-design modifications;
- allowance for modifications to facilities' operating procedures;
- establishment of appropriate habitat management at facilities;
- creation of performance bonds to ensure clean-up and compensation should facilities fail to meet their obligations; and
- authority for airport operators to inspect and monitor facilities' operations.

Effective management of a hazardous off-airport land use is possible once studies have been completed and mitigation measures identified. As always, airport managers must remain vigilant, establishing and revising procedures to ensure their efforts are appropriate and proactive in reducing the risks associated with these land uses.

Off-airport land use: three case studies

CASE STUDY 1

Voluntary implementation of mitigation measures at Winnipeg International Airport

In 1994, authorities at Winnipeg International Airport (WIA) identified a potential bird hazard associated with a proposed waste-disposal facility to be built by BFI Waste Systems under a provincial permit. Even though the site was to be located just outside the eight km bird-hazard protection zone, it was nonetheless directly under both the approach path of Runway 18 and the departure path for Runway 36.

WIA officials were concerned with the towering of gulls over the proposed site. During the planning stage, discussions took place among key stakeholders including BFI, Transport Canada, the airport operator, the airline pilots' associations and the Manitoba Ministry of Environment. These discussions led to a number of detailed studies and the implementation of voluntary mitigation measures by BFI.

These measures included:

- reducing the size of the landfill's active working face during daily operations,
- covering waste during compaction,
- replanting of disturbed soil area,
- eliminating all standing water on the site, and
- implementing an aggressive bird-management program to dissuade birds from feeding and loafing at the site.

The landfill opened in the fall of 1996 and, to date, the bird hazards associated with the site's operation appear to be well managed.

CASE STUDY 2

Coordinating land-use planning around Ottawa's MacDonald-Cartier International Airport

For a number of years, the airport operator actively informed municipal planning authorities of the unique bird-hazard issues related to land use around the airport. As a result of these efforts, the two surrounding municipalities (Gloucester and Nepean) established agreements with the airport operator to ensure that consultation would take place prior to approval of any land-use activity that might impact airport operations. The City of Nepean's official plan states that the airport manager "*will be consulted on any plans to develop new waste-disposal sites that may have implications for the airport.*"

In 1993, the City of Nepean informed the airport of plans to construct four storm-water retention ponds south of the airport as part of a strategy to control urban drainage for a new community. Initial pond designs included wetland areas and large permanent bodies of water. Following a review of the plan, the airport operator raised concerns that these ponds had the potential to increase bird activity near the airport; the largest of the ponds was poorly located with respect to a proposed parallel runway.

Through discussions between the airport operator and the City of Nepean, the parties agreed that wildlife had to be discouraged from using the ponds. As a first step, the City undertook a baseline study to determine the number and species of hazardous birds in the Ottawa area that could be attracted to the ponds. The flight paths of these birds were also determined, as was their likelihood to use the ponds. As a result, design and landscape modifications were implemented to prevent increased bird activity near the ponds.

Mitigation measures incorporated in the new design included:

- steep slopes to minimize areas of shallow water;
- strict on-site garbage management;
- fines for people found feeding birds;
- control of water-level fluctuations to reduce exposure of wet, bare soil;
- ongoing monitoring of bird populations; and
- mitigation-measure reviews and adjustments as required.

CASE STUDY 3

Innovative and environmentally sensitive solutions at Vancouver International Airport

Vancouver International Airport is located on Sea Island, a delta of alluvial sediments situated in an estuary where fresh waters of the Fraser River meet salt water of the Pacific Ocean. These unique physical characteristics provide a rich environment for many wildlife species. During peak migration periods, as many as 1.4 million birds use the Fraser River delta; more than 250,000 water birds winter in the estuary, and it is the site of the largest gathering of wintering raptors and Great Blue Herons in Canada.

When plans emerged in the early 90s to build a parallel runway at the airport, measures were taken (under the direction of a multi-agency steering committee) to assess risks associated with bird strikes. Urban development had been continuously encroaching on natural habitats of the Fraser River, and a wildlife conservation area was being considered for land immediately adjacent to the airport. Through negotiation, the conservation area was developed as compensation for habitat that would be lost to the new runway. A number of studies were conducted to ensure both the construction and establishment of the conservation area would not impede aviation safety and habitat protection. The studies included:

- an avifauna study of Sea Island and surrounding areas,
- a study analyzing interactions between aircraft and birds on Sea Island, and
- an evaluation of the effectiveness of the wildlife-management program at the airport.

A 1994 safety review concluded that ongoing modifications to the complex Sea Island ecosystem would lead to a variety of unpredictable changes in behaviour of local bird populations. The team of safety-review experts believed that these changes would create undue hazards unless a dynamic action plan was developed and aggressively pursued by:

- the airport authority,
- a number of government departments, and
- various local and national interest groups.

Recommendations focused on the need to manage the co-existence of incompatible land-use activities.

Success did not come easily, but the stakeholders resolved all issues and successfully developed a comprehensive wildlife-management plan for the Sea Island Conservation Area. In addition, the airport operator expanded the airport wildlife-management program. Independent safety reviews have been conducted regularly since 1994; the results indicate that the high risk of bird strikes in the Fraser River estuary has so far been successfully reduced thanks to the full participation of key stakeholders.

Active wildlife management: scaring and removing wildlife

Even the best habitat-management initiatives will not solve all wildlife problems at an airport. Each species has its own behaviour, habitat preferences, preferred foods, loafing and roosting habits, flocking tendencies, daily activity cycles, and times of seasonal occurrence. For these reasons, day-to-day active management interventions are a key requirement of all wildlife-management programs. Many techniques have been developed, involving scaring, harassing and removal of wildlife from specific areas within airport environment.

Active wildlife management has two specific requirements. The first—and most critical—is the need for long-term effectiveness. Techniques must be science-based and vary in presentation to reduce the likelihood of wildlife becoming familiar and comfortable with measures intended to discourage them.

Active techniques must also concentrate on keeping hazardous wildlife off airfields altogether, although moving birds and mammals from one part of an airfield to another is not an acceptable solution. The ability to control dispersal times and locations is key. For example, a potential bird hazard may be created rather than removed if birds are flushed across an active runway.

Typical problem birds that require scaring or removal include gulls, waterfowl (ducks, geese and swans), Rock Doves (pigeons), blackbirds, starlings, crows, hawks, owls, and Snow Buntings. Problem mammals include Coyotes and deer. A range of products and techniques is available to combat these groups; the challenge is to determine which measures are effective and appropriate.

Deciding which product to use

Transport Canada's *Wildlife Control Procedures Manual* TP11500 and the corresponding U.S. publication, *Wildlife Hazard Management at Airports*, provide descriptions of individual wildlife-management products and their uses, but few if any objective comparisons have been made. There is a litany of reasons for this, underlining the lack of science applied in this critical area:

- Many wildlife-management personnel have first-hand experience with wildlife control equipment and techniques, but much of their knowledge and experience remains unpublished.
- Information published so far is not easily accessible.
- Existing evaluations are subjective, in part because it is difficult to compare products and techniques due to:
  - environmental considerations:
    - availability of alternate local attractants for wildlife (e.g., other resting areas and feeding sites),
    - time of day and year and its effect on wildlife numbers and behaviour, and
    - habitat features attracting wildlife to the airport (e.g., food, water, nesting, denning or roosting).

- products that are often largely ineffective on their own—due to habituation—but can be an effective part of a multi-product approach.
- many wildlife-control products that are designed primarily for the agricultural industry. Unfortunately, airport operators often buy these products based on their proven short-term effectiveness. In the longer term, however, a product may fail through habituation.

It is crucial that all promising new active wildlife-management techniques be tested in a variety of conditions, using properly designed scientific methods, and that results are published in peer-reviewed journals.

Dispersal and deterrent products

Identified by the manner in which they deter or disperse wildlife, these products fall into the following categories:

- novelty avoidance,
- startle reaction,
- predator mimics, and
- warning signals.

Birds and mammals quickly learn to differentiate between a threat and an irritant. Most birds tend to avoid any novel stimuli—such as synthetic sounds produced electronically by noise generators—unsure as to whether or not the threat is real. Some curious animals, however, may initially investigate, creating a hazard to aircraft. Once wildlife habituate to a novelty stimulus, it loses its effectiveness, rendering it useless.

Many of the least effective products startle birds or mammals through sudden shocks or loudness. Startle devices such as gas cannons lose their effectiveness once they become an accepted part of the environment, more likely to scare passengers and airport neighbours than animals.

Wildlife-control products and techniques founded in biology—such as scarecrows and hawk kites, which mimic known threats—tend to be more effective over the long term. The period of effectiveness is related directly to the realism of a model's appearance, behaviour and sound. Birds will habituate quickly to a plastic owl model, but slowly to a stuffed owl grasping a crow that moves and calls; a live owl tethered to a post works even better. Yet birds and mammals will eventually habituate even to the best models unless presentation is occasionally supplemented—by reinforcing through the presence of a fresh kill, for example.

Similarly, warning signals that communicate the immediate or recent presence of a predator—such as distress and alarm calls, predator scents and models of dead birds—are often effective and delay habituation.

For the purposes of this book, wildlife-management products and techniques are rated as follows:

- highly recommended,
- partially recommended, and
- not recommended.

This evaluation is based on answers to three key questions;

- Is there a sound biological reason to expect a product or technique to work?
- How quickly—and to what degree—does wildlife habituate to a product or technique?
- Are measures cost-effective and practical?

Highly recommended products and techniques

elements of a successful, active airport wildlife-management program. They provide long-term effectiveness and lead to little habituation if implemented correctly, but require the frequent involvement of skilled and motivated staff.

Active management techniques may be supplemented with selected techniques from the list of partially recommended products. For example, supplementing pyrotechnics with stuffed gull models can reinforce the danger of the former. Falconry, while somewhat controversial and inappropriate in certain circumstances, can be a useful technique if properly implemented; competent and knowledgeable falconers will include other techniques in developing a rounded approach.

Partially recommended

The majority of wildlife-management products and techniques fall into this category (see Table 8.5), capable of repelling and dispersing birds and mammals, but limited in application and prone to habituation and implementation problems. These products work best when they form part of an integrated program.

This category includes several auditory, visual and chemical repellents. Birds habituate relatively quickly to gas cannons and other similar products, however the effectiveness of these products can be extended by avoiding use of automated timers—the element of surprise is critical.

The distress and alarm calls of the Phoenix Wailer® are likely to be more effective than the ultrasounds and synthetic electronic noises also broadcast by these units. Similarly, the synthetic noises produced by the AV-Alarm® hhave no basis in biology—beyond the novelty and startle avoidance reactions they create—and are susceptible to quick habituation. Bird Gard AVA®and Bird Gard ABC® are distress-call players that feature small repertoires of distress and alarm calls of a limited number of species.

Not Recommended	Limited Recommendation	Highly Recommended
High-intensity sound	Gas cannons	Pyrotechnics
Microwaves	Phoenix Wailer®	Falconry
Lasers	AV-Alarm®	Distress and alarm calls
Ultrasound	Bird Gard AVA®	Shooting
Aircraft hazing	Bird Gard ABC®	Trapping & remote release
Smoke	Scarecrows	
Magnets	Reflecting tape	
Lights	Predator models	
Dyes	Hawk kites and balloons	
Aircraft engine noise	Gull models	
Infrasound	Chemical repellents	
	Foam	
	Predator calls	
	Lure areas	
	Surfactants and water spray	
	Model aircraft	
	Poisons	
	Dogs (Border Collies)	

Table 8.5 Wildlife Management Products and Techniques—Recommendations

Most visual deterrents such as scarecrows, reflecting tape, predator models, hawk kites and balloons, and gull models are also susceptible to habituation. Chemical repellents can be effective in specific applications. These include:

- tactile, behavioural and taste aversives such as ReJeX-iT® and Flight Control®®, and
- earthworm control chemicals such as Benomyl, Tersan, and Terraclor.

Some avian feeding repellents—including Flight Control®®—show considerable promise according to reports from the United States Department of Agriculture. Predator-call playbacks and lure areas have potential in certain bird-management situations, but have been inadequately tested. Surfactants and water spray are suitable for limited applications.

Model aircraft can be successful bird-management tools, but they are labour intensive, requiring highly skilled operators. Although these devices cannot be used near active runways and taxiways, they may offer considerable promise in management of birds that soar at high altitudes above airports, such as hawks and eagles.

Not recommended

The use of high-intensity sound and microwaves is not recommended because the energy levels required are dangerous to humans, birds and other mammals. Few species of birds have the ability to detect ultrasound; those that can have not shown an avoidance reaction. Aircraft hazing and the use of smoke are not recommended because these techniques are impractical in airfield environments. Limited research conducted to date on the use of magnets, lights, dyes, aircraft engine noise and infrasound does not suggest that these products are strong candidates as bird-management tools.

Some recent research suggests that low-power, hand-held Class-II and III laser devices (see Chapter 14) may be effective dispersal tools against certain species of birds. While of the opinion that lasers have the potential to be valuable components of comprehensive bird-management programs, many knowledgeable researchers contend that more work is needed to examine the technique in greater detail. As a result, this technology is not yet recommended for bird dispersal.

New wildlife-management products appear on the market regularly, often expensive and heavily promoted. Before incurring significant costs in the purchase and installation of these products, operators should insist on independent, rigorous and unbiased testing rather than rely on the unsubstantiated claims frequently made by manufacturers.

Table 8.5 provides a summary of wildlife-management products and techniques currently available. The following paragraphs briefly explain the use of these tools.

Wildlife-removal techniques

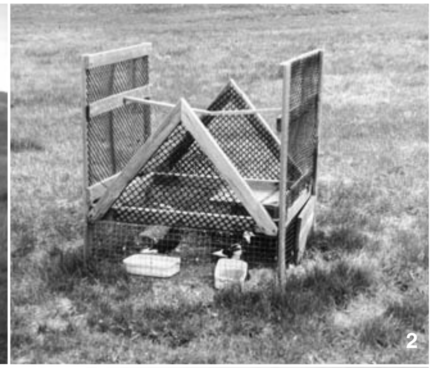
Killing and live trapping are best used in situations where specific individual birds or mammals cause persistent problems.

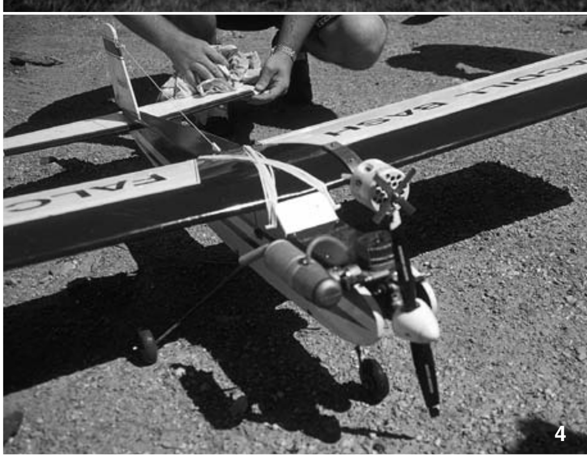
In live trapping, the animal is released at a safe distance from an airport. Though effective, this technique is labour-intensive, potentially dangerous and rarely offers immediate relief, as it may take weeks to catch problem animals.

Killing wildlife is generally an immediate and short-term solution. Though unsavoury, killing is a legitimate active-management technique, necessary on occasion and effective when committed in conjunction with other methods. Killing is usually accomplished by shooting or poisoning. When shooting is not feasible due to the proximity of aircraft and surrounding dwellings, poisoning programs must be implemented carefully, conducted by trained, licenced professionals. Proper dosage of an appropriate poison should be administered only in the location of the target species so that other wildlife are not inadvertently affected.

Summary

One point cannot be overstated: none of the techniques discussed above will work consistently over the long term unless they are applied properly by trained personnel. There is no one magic solution for active wildlife management. All successful programs are founded in science, operated by qualified staff and funded with adequate resources.



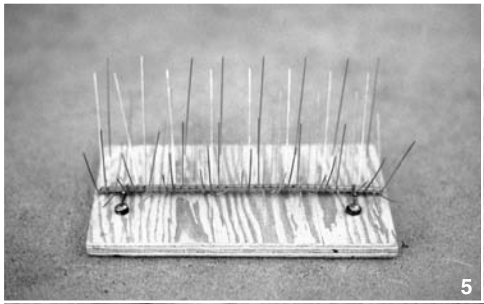


1. “Hot Foot” and other similar products discourage birds from perching on fixtures.

2. Swedish Goshawk trap

3. Propane Cannon

4. Radio controlled model airplanes can be effective as a means to disperse soaring birds at relatively high altitudes.



5. Porcupine wire is a very effective way to prevent birds from perching or nesting on fixtures.

6. Falconry can be a very effective way to disperse birds when used as part of a comprehensive active wildlife management program.

7. A variety of small mammal traps.

8. Although relatively primitive, properly applied pyrotechnic use is still one of the most effective techniques for active wildlife management.

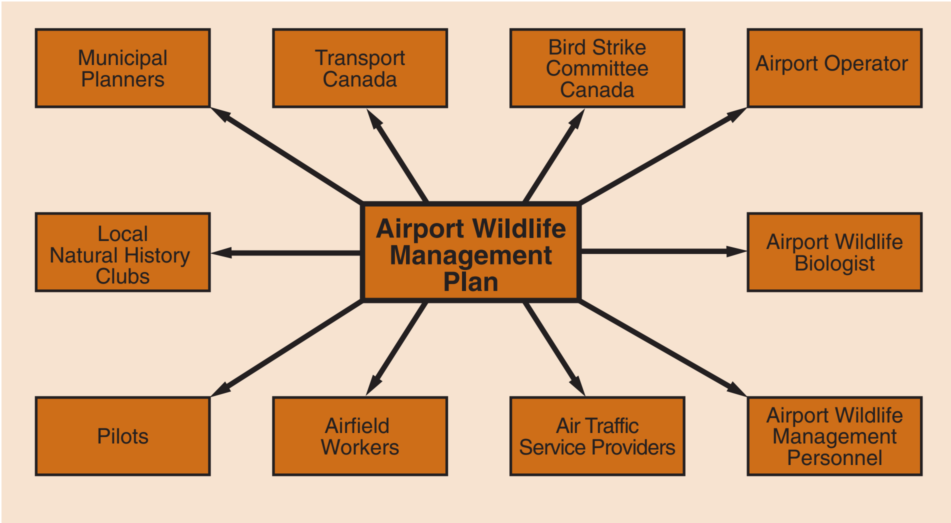


Figure 8.1 Stakeholders Who Assist in Developing, Implementing, Monitoring and Maintaining Airport Wildlife Management Plans

Airport wildlife-management plans (AWMPs)

An airport wildlife-management plan ensures wildlife problems are dealt with in a systematic and coordinated manner. A well-developed AWMP minimizes wildlife strikes, improves flight safety and reduces aircraft damage costs. These plans must have clear goals and be supported by airport policy and senior airport managers. AWMPs should also be developed in adherence with Transport Canada's policy regarding wildlife at airports—a policy in which airport operators have a clear responsibility to provide resources to ensure an AWMP is adequately developed, implemented, monitored and maintained. These resources include personnel, time, training, equipment, vehicles, licensing and permits, as well as funds, required capital and operating improvements at the airport.

Airport wildlife-management committee

The success of AWMPs is to a large extent reliant on effective airport wildlife-management committees, which assist in development, implementation and maintenance of a program. Essential as wildlife and safety-information resources, and as communication vehicles, committees should consist of representatives from:

- airport senior management teams,
- airside operations,
- airside planning,
- airside safety,
- environmental staff,
- tenants,

- ground maintenance staff,
- emergency response services (ERS),
- ATS providers,
- wildlife-management staff,
- staff or contract biologists,
- air operators who utilize an airport, and
- local land-use representatives.

Engaging a range of stakeholders

Throughout this book, emphasis has been placed on the importance of co-operative partnerships between airport and community stakeholders as part of AWMPs. All stakeholders must be recognized as invaluable resources, critical to the integrity of the System Safety Approach. Figure 8.1 identifies stakeholders who typically assist in implementation of effective AWMPs. The text below provides information on the roles and responsibilities of various stakeholders.

Bird Strike Committee Canada (BSCC)

BSCC is a national organization that provides a forum for both the exchange of information and the discussion of issues related to reduction of wildlife strikes in Canada. Permanent members include Transport Canada, the Department of National Defence, Health Canada, the Canadian Museum of Nature and the Canadian Wildlife Service. Associate members include major Canadian airlines, aviation industry associations and other interested parties. BSCC is aligned with Bird Strike Committee USA—a joint committee meets annually.

Transport Canada

This federal department is responsible for developing and enforcing regulations, standards and guidelines for the safe operation of airports. Transport Canada provides advice to airports on airport wildlife-management programs. The department also provides training and awareness materials to assist aviation industry personnel in developing and enhancing required skills and techniques to manage wildlife hazards.

Airport wildlife biologists

These scientists are responsible for the biological underpinnings of an AWMP. They oversee habitat modifications and active wildlife-management operations. In addition, wildlife biologists supervise implementation of AWMPs and report on their effectiveness to airport wildlife-management committees.

Wildlife-management personnel

These staff are responsible for daily implementation of AWMPs, ensuring airfields are clear of all hazardous wildlife through use of appropriate wildlife-management techniques. Wildlife-management personnel must be qualified to deal with all active-management equipment and techniques. In addition, these professionals should report on airport habitat management to an airport's wildlife biologist. Wildlife-strike reports and daily AWMP records are prepared and reviewed by wildlife-management personnel to determine appropriate management measures. Wildlife-management personnel communicate with local interest groups to maximize safety and ensure good relations between airports and surrounding communities.

Air traffic service (ATS) providers

ATS providers are critical links between airside workers, wildlife-management personnel and pilots. They immediately communicate observations of wildlife activity, as well as those of pilots and airfield workers, to wildlife-management personnel. ATS personnel also convey safety-critical wildlife-activity information to pilots and coordinate wildlife-management activities to maintain the safe and efficient flow of air traffic.

Airfield workers

Airfield workers include all other airport staff who have airfield access. They are responsible for reporting all wildlife activities to ATS and wildlife-management personnel. Some airfield workers are also responsible for carrying out active wildlife-management and other related wildlife management activities, such as grass-height management and habitat modification.

Pilots

Due to their unique vantage point, pilots are able to observe many wildlife activities, reporting strikes and the presence of wildlife to ATS providers and wildlife-management personnel. When appointing pilot representatives to airport wildlife-management committees, consideration should be given to all members of the community, including air-carrier, business-aircraft, helicopter and general-aviation pilots.

Airport operator

It is the responsibility of airport operators to ensure all airport staff know of potential bird hazards. Airport operators must also provide sufficient direction, information and resources for the effective implementation of AWMPs. Operators take an active role on airport wildlife-management committees, and assume direct responsibility for managing wildlife hazards and public safety. To maintain their duty of care, management must verify that all reasonable precautions are being taken to prevent wildlife strikes, and that sufficient resources are being made available to carry out mitigation measures.

Municipal planners

These professionals plan land use in the vicinity of airports and—in cases where a municipality is airport owner and operator—on the airport. Their planning initiatives must be made with due consideration for regulations, standards, guidelines and policies. Planners are in a position to influence locations, designs and operating regimes of facilities that may contribute to wildlife hazards at airports. These professionals should therefore ensure they have good working knowledge of wildlife issues, and that they avoid incompatible land uses on and near airports.

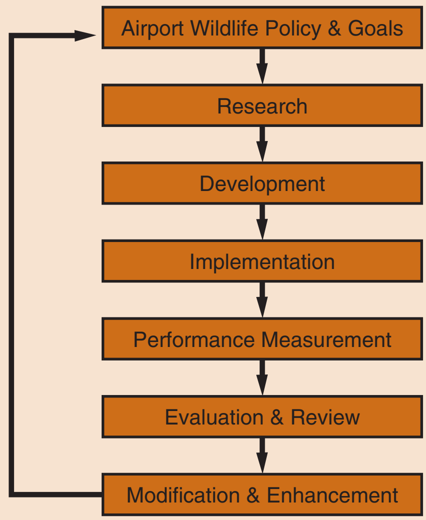


Figure 8.2 Diagram Showing the Process to Develop, Implement and Maintain an Airport Wildlife Management Plan (AWMP)

Local natural history clubs

Bird-watching groups and hunting clubs are good sources of local wildlife information. Natural history groups can often provide impressively complete bird population data from activities such as Christmas bird counts and local birders' species lists.

Government agencies

Federal, provincial and municipal governments must be involved in development and implementation of AWMPs. The resulting exchange of information will enhance the System Safety Approach and ensure an AWMP complies with applicable regulations.

Reducing wildlife hazards through the AWMP process

The overall purpose of AWMPs is to reduce wildlife hazards to aviation, so goals should be clear, realistic and as detailed as possible. Clearly defined timelines and milestones must be established along with structured audit and review processes. AWMPs should articulate wildlife-management methods and provide directions for their use.

AWMPs must define chains of authority, assign responsibilities and establish communication networks for both routine wildlife-management operations and emergency situations. These plans should also define budgets, staffing requirements, staff training and upgrading needs, equipment needs, licensing and permit requirements.

Due to the dynamic nature of airports and their surrounding ecosystems—and the changing needs of the aviation industry—AWMPs must be constantly evaluated.

Though subject to further sub-division, these seven elements form the core of AWMPs:

- airport wildlife policies and goals,
- research,
- development,
- implementation,
- performance measurement,
- evaluation and review, and
- modification and enhancement.

The process used to develop, implement and maintain an airport wildlife-management plan is illustrated schematically in Figure 8.2.

Airport wildlife policy and goals

Airport operators are responsible for developing wildlife-management policies that acknowledge:

- local wildlife problems,
- potential litigation in cases of serious wildlife strikes, and
- Transport Canada regulations, standards, policies and guidelines.

Wildlife-management goals should be clearly established in AWMPs, reflecting the commitment of senior managers to programs.

Research is crucial

Without a clear understanding of the nature and extent of potential problems, specific hazards may be missed and flight safety compromised. For this reason, successful AWMPs are based on accurate information from:

- wildlife-strike data,
- aircraft-movement statistics,
- aircraft types,
- ground maintenance procedures, and
- wildlife inventories and ecological studies.

While this information should be readily available, some data collection and analysis may be required. Airport-wildlife inventories and local bird movements are often only available following formal studies designed and supervised by biologists.

AWMPs must comply with a broad range of federal, provincial and municipal legislations. A list of Canadian and U.S. Acts and Regulations is provided in Appendix D. While not exhaustive, it introduces the variety of legislation that may pertain to AWMPs.

Developing AWMPs

As AWMPs must prioritize wildlife-management activities, wildlife-management personnel are responsible for developing the AWMP with support from airport operators.

In developing AWMPs, staff must consider both long- and short-term wildlife-management measures, since real reductions in wildlife risks at airports can only be achieved through science-based, systematic processes that combine both. Long-term measures are particularly effective in managing resident species, while short-term measures can be effective against occasional transient species. Migratory species such as geese require careful application of both long and short-term measures.

Long-term vs. short-term management measures

Long-term control measures comprise passive wildlife-management techniques such as major habitat-management projects that make the airport less attractive to wildlife. Long-term measures may require phased implementations due to resources that are either lacking or constrained, perhaps as a result of other airport development projects. The process of developing long-term measures will require coordination with tenants and other airport stakeholders. Remember, while long-term measures may in some cases be more costly and take longer to implement, they are a more effective and lasting solution.

Short-term control measures refer to active wildlife-management techniques that involve harassment, dispersal and removal techniques. AWMPs must identify the active management techniques to be employed, and how their use will be coordinated to ensure safe and efficient airfield operations.

Equipment

During development of AWMPs, equipment lists should be compiled, identifying when specific equipment is required and what permits and licences will be needed to use the equipment.

The challenge of implementation

Implementing AWMPs involves coordinated efforts by all responsible parties, and especially relies on support from senior management. Appropriate equipment and training must be made available, while awareness of all stakeholders is raised.

Training

Before an AWMP can be successfully implemented, all wildlife-management personnel must be trained to ensure they have the knowledge and skills to carry out measures described in the plan. Training also extends to other stakeholders, who can build their knowledge of wildlife-related issues through involvement in the Bird Strike Committee USA/Canada program. If management measures require federal, provincial or municipal permits—such as a Federal Firearms Possession and Acquisition License—wildlife-management personnel may be required to complete training courses to obtain them.

Building awareness

Successful AWMPs rely on an integrated System Safety Approach to assess and mitigate hazards as described in Chapter 2. To ensure success, all stakeholders must have a clear understanding of their specific roles in maintaining and enhancing flight safety—an understanding derived from awareness programs. These programs are targeted at two specific groups: the aviation community and airport neighbours.

In many cases, the aviation community is poorly informed of wildlife-hazard issues. They may not understand the value of reporting wildlife activity and incidents, or how their reports and involvement contribute to successful management of wildlife risk.

The ecosystem surrounding airports has a direct impact on the effectiveness of AWMPs. Therefore, awareness of wildlife problems must extend beyond an airport's boundaries to include local natural history groups, municipal planners, government agencies and—to a lesser extent—the general public. Community awareness programs can assist in acquisition of vital data, the ability to mitigate risks of hazardous off-airport land use and—most importantly—to dispel many myths concerning airport wildlife-management programs. When airport operators are forced to initiate lethal control over deer herds, it is much easier to accomplish related goals if meaningful dialogue has been maintained with communities.

Awareness programs are often best delivered through airport wildlife-management committees, which are composed of key stakeholders. Their contacts—and organizations they represent—can be tapped to open continuous dialogues on many issues; their support is crucial when conflict arises with opposition groups. Resource material promoting wildlife awareness is available from Transport Canada. This material includes posters, brochures, videos, wildlife-control procedures manual, bird-migration maps, bird and wildlife-strike report forms.

The value of performance measurement

Performance measurement is necessary to assess AWMPs and determine the need for enhancement or modification. Performance measurement involves routine analysis of records and periodic auditing of AWMPs by airport personnel and outside consultants.

Accurate record keeping is the foundation of any performance measurement system. Some airport operators have been reluctant to keep detailed information on wildlife activity—particularly wildlife strikes—for fear of liability in the event of an accident. There is also a perception that strike data is something of a score sheet, leading some operators to deliberately lower the number of reported wildlife incidents. It's important to remember that when proving due diligence in the event of an accident, comprehensive data are critical. Well developed, maintained and documented AWMPs—especially those demonstrating rigorous and objective data accumulation and analysis—are vital defence assets in any civil litigation.

The four main components of a comprehensive AWMP reporting system are described below.

Monitoring of wildlife and wildlife-management activities

AWMPs must include complete and accurate records of all wildlife-management activities and wildlife sightings at and near airports.

A daily log should record all wildlife management activities, noting:

- times wildlife-management activities are initiated;
- bird numbers and species;
- management techniques used and the results; and
- times when management activities conclude.

Ongoing airfield wildlife inventories should be maintained, updated, reviewed and analyzed to provide accurate and up-to-date information. These inventories help determine trends and identify species that may become hazardous. There are software tools available today which make the task of recording and analyzing wildlife-management activity much easier; the reports these programs produce are very useful for determining where changes should be made in AWMPs.

Wildlife-strike reporting and recording

Wildlife-strike reports should be maintained, reviewed and summarized to ensure the accurate current information that is critical to informing updates of AWMPs. All wildlife incidents should be reported to Transport Canada using the process described in Appendix C.

Each report should include as many details as possible. Remember that even though a form may be incomplete from one reporter, additional information may be submitted by others. When Transport Canada completes the annual summary of Bird Strikes to Canadian Aircraft, duplicate reports are used to supplement and verify information about individual episodes. Every effort is made by Transport Canada and the FAA to prevent double-counting of incident reports.

General AWMP record keeping

Other records are just as crucial to the planning process, and may include information on policies, new laws and regulations, training programs and management reviews. As always, precision and timeliness are paramount, ensuring this information demonstrates the strength and effectiveness of an AWMP in reducing liability when serious wildlife strikes occur.

Wildlife studies

Periodically, special wildlife studies may be necessary to identify changes in wildlife populations, as well as species composition in areas where extensive habitat management has been carried out. These before-and-after studies measure the success of large-scale, costly habitat modifications and identify unexpected problems and side effects.

Evaluation and review

From time to time, airport operators should carry out structured management reviews of AWMPs. While ongoing review of records is an essential component of performance measurement, periodic auditing is also valuable, evaluating:

- the goals and objectives of a plan,
- methods used to achieve goals and objectives,
- management methods used, and
- results achieved compared to defined objectives.

Auditors inspect each element of a management plan both to assess effectiveness of long- and short-term management measures and to inform ongoing improvements.

Modification and enhancement

The AWMP process is not complete until recommended modifications are applied to a wildlife-management program, whether from reporting programs or audits. Modifications are especially important if planned goals are not being met. These changes are in turn monitored to ensure big-picture changes are in fact improving AWMPs.

CASE STUDY

JFK International Airport Wildlife-management Plan

Operated by the Port Authority of New York and New Jersey, John F. Kennedy (JFK) International Airport has suffered from a serious bird-strike problem since the 1970s. Each year, there are approximately 350,000 aircraft movements at JFK, while inventories describe millions of birds—as many as 300 different species—at and near the airport. These numbers suggest—and strike data confirm—an ever-present high probability of bird strikes; at one time, JFK had the highest number of reported bird strikes in North America.

The primary goal of JFK's airport wildlife-management plan is to improve safety for all users, yet development of an AWMP was no easy task. JFK is situated next to a federally protected wildlife refuge in the region's most biologically productive environment. The Federal Aviation Administration (FAA) and United States Department of Agriculture (USDA) both played important roles in implementing an effective wildlife-management plan for JFK. The plan includes provisions for ongoing communication among the Department of the Interior, Department of Agriculture, and the airport operator to ensure that conflicting wildlife-management goals do not compromise flight safety.

A unique challenge arose at JFK in 1979 when a colony of Laughing Gulls settled into marsh habitat immediately adjacent to the airport, doubling reported bird strikes. To solve this problem, the airport operator modified the wildlife-management plan and expanded its scope. Modifications included a highly controversial lethal-control program recommended and supported by the USDA. In spite of controversy, the shooting program succeeded in reducing Laughing Gull strikes by 90 percent. The quality of the AWMP and the scientific studies that were conducted by the USDA provided justification for a bird-management program that may not have been possible otherwise.

Conclusion

It is possible to significantly reduce the number of wildlife strikes at an airport through effective wildlife management. Airport operators must ensure adequate funding and promote wildlife management as a high-priority component of broader airport-safety programs. While it is unrealistic to expect habitat management and active controls to eliminate all wildlife from airports, there is sufficient evidence to show that properly developed and implemented wildlife-management programs can effectively reduce the number of wildlife interactions with aircraft, contributing significantly to safe airport and aircraft operations. This goal can only be achieved through the firm commitments of senior management to the success of wildlife-management programs.

Photo courtesy NAV CANADA

Chapter 9

Solutions — Air Traffic Service Providers

Over 80 percent of reported bird strikes occur within the airport environment.

Introduction

If one were to liken the range of aviation professions to a hub-and-spoke airline system, Air Traffic Service (ATS) providers (departure and arrival controllers, tower and ground controllers and flight-service specialists) would form the hub. ATS providers are pivotal members of the aviation community, uniquely positioned to spearhead tactical risk-management activities associated with wildlife-hazard and strike reduction.

In constant communication with all staff operating in and around airports, these professionals:

- detect bird activity electronically on Terminal Control Unit (TCU) radar monitors;
- detect birds and mammals visually from tower cabs and FSS sites; and
- convey critical wildlife information to airside operating staff, wildlife-management personnel, pilots and other controllers operating in positive control environments.

Clearly, the vigilance of ATS providers is critical to the day-to-day prevention of bird and mammal strikes.

Roles and responsibilities

General

Controllers and flight-service specialists share a number of responsibilities in the prevention of wildlife strikes including:

- providing pilots with current information concerning wildlife activity at or near airports;
- advising pilots of possible wildlife activity;
- coordinating the use of ATIS and NOTAMs to communicate wildlife information to pilots;
- informing appropriate airport personnel about wildlife activity at airports;

- advising shift replacements about current wildlife activity on airports;
- providing options to pilots in the event of a potential wildlife-strike threat. Options include:
  - takeoff delay,
  - alternate flight profiles,
  - use of alternate runways for landing and takeoff,
  - approval of reduced aircraft operating speed, and
  - alternate routes and altitudes;
- reporting all airport wildlife incidents through the Canadian Aviation Damage Occurrence Reporting System (CADORS) and any other applicable local airport reporting procedure;
- encouraging pilots to file wildlife-strike reports after bird and mammal strikes or near misses; and
- ensuring that active wildlife-management activities pose no threat to aircraft operations.

The roles and responsibilities of ATS providers are clear in some jurisdictions, such as Canada. This country's *Manual of Operations for Air Traffic Controllers* states:

Section 164.1
Provide all aircraft that will operate in the area concerned with information concerning bird activity, including:
- size of species of birds if known;
- location;
- direction of flight; and
- altitude if known.

Section 164.2
Base bird activity information on:
- a visual observation;
- a pilot report; or
- a radar observation confirmed by:
  - a visual observation; or
  - a pilot report.

Section 164.3
You should warn an aircraft of the possibility of bird activity if you have an unconfirmed radar observation that you believe to be a flock of birds.

In the U.S., FAA Order 7110.65, 2-1-22—*The Air Traffic Controller's Handbook*—requires controllers to inform pilots of:

- the presence of bird activity,
- the location of the activity,
- the nature of the hazard (type of bird), and
- the direction in which the hazard is moving.

Controllers are also instructed to continue transmitting warnings as long as the hazard is present.

Terminal controllers

Arrival and departure controllers are key members of the bird-strike risk-management team. In spring and fall, many North American TCU positions provide front-row seats for observation of migratory bird activity. Often the first to recognize the potential hazard, terminal controllers alert flight crews:

- directly, by informing arriving and departing aircraft of the presence of high-risk wildlife activity;
- indirectly, through tower controllers who advise flight crews still on the ground; and
- through NOTAMs, informing crews of other aircraft who plan to operate at or near an airport.

This vital communication increases pilots' situational awareness and enables them to better manage flight profiles, reducing the probability and severity of wildlife strikes. As demonstrated in the following real-life scenario, quick actions of controllers in the TCU can make a vital difference in the event of a bird strike.

> Scarcely airborne out of New Orleans with a full passenger load—operating at near-maximum gross weight—a Delta Airlines MD-80 suffered numerous gull strikes. The left engine never had a chance. The right engine, though severely damaged, kept passengers and crew airborne. The captain declared an emergency and requested an immediate landing on the nearest available runway. The tower controller provided an initial vector and handed them over to Approach Control. In a unique position to gauge the evolving weather conditions, the arrival controller informed the stricken aircraft's crew that the weather had deteriorated; several aircraft had just conducted missed approaches over their intended runways. When asked about another runway—one with 100-foot lower minimums—the arrival controller responded, "*We still have rain showers to the east, but visibility looks better that way than to the south*."
>
> With windscreens obscured by bird debris and an engine incapable of powering them to an alternate airport, the aircraft broke out at minimums and made an uneventful landing—the flight lasted exactly 13 minutes. The actions of the arrival controller, the alert response of the well trained flight crew, the strength of the aircraft windscreens and the durability of the remaining damaged engine all helped avert disaster.

Tower and ground controllers

As noted in Chapter 2, tower and ground controllers are situated in the middle of the risk-management curve, strategically positioned in the system-safety network—and in the heights of tower cabs—to coordinate detection, deterrence and avoidance of wildlife strikes.


Photo courtesy NAV CANADA

Activity inside a control tower.

Tower controllers are often the first to detect wildlife activity and, using binoculars, can assess the type and size of flocking birds, their location and apparent direction of flight. Tower controllers also confirm sightings by airside staff and receive verbal pilot reports. In each case, these controllers adhere to established protocols to ensure that wildlife-management staff are advised, and that appropriate wildlife-management activity is coordinated and conducted safely. From control towers, their efforts are aimed at ensuring non-events—the avoidance of wildlife strikes.

The 1993 multiple-bird strike incident involving the B-737 at Calgary—described in Chapter 2—illustrates the important role of tower controllers.

> The Calgary controllers and airport duty manager worked hard in the early-morning hours to disperse a flock of gulls prior to the B737 occurrence. At 0537 hrs, the duty manager detected a 200- to 300-strong flock of gulls on Taxiway 'F'—north of the threshold of Runway 28. After repeated attempts—using pyrotechnics and the horns on the wildlife-management truck—the duty manager eventually succeeded in dispersing the birds; air-traffic controllers were advised that the birds had moved north, east and southeast.
>
> The 0600 hrs ATIS recording prepared by the controllers warned pilots of airport bird activity. At 0625, a large flock of gulls was seen heading north; 11 minutes later, the duty manager noted that gulls had returned to Taxiway 'F', gathering nearby. Throughout, the airport duty manager and tower controllers were in constant radio contact, coordinating bird-management tactics around landing and departing aircraft.

> A number of unrelated events led controllers to assume the bird-strike risk was diminished. At 0626 hrs, a Federal Express B-727 landed, clearing the end of runway 28. At 0637, an American Airlines MD-80 also landed on runway 28; the aircraft stopped and completed a 180-degree turn to backtrack runway 34 to the apron. Neither crew reported bird activity to controllers, nor did the airport duty manager report any further bird activity. As a result, when faced with updating the ATIS recording at 0700—a recording the crew of the Canadian Airlines B737 received a few minutes later—the controller did not include a bird advisory.
>
> The controller's ability to prevent the bird strike was undermined by a lack of information. The only aircraft to operate from runway 28 that morning had been the Federal Express B-727 and American Airlines MD-80; it was never determined whether their crews detected birds. If they did, they may have assumed that the ATIS reference to bird activity meant the tower controllers and airport authorities were aware of the bird's presence—too many assumptions by too many people.

There are important lessons to be learned from these near catastrophic events. Even though on-duty tower controllers were using binoculars to scan the area of both occurrences, none saw the birds until impact took place—when there was little more they could do.

Controllers play a key role *in advance* of strikes; they are central to the tactical prevention of these events, ensuring the best available information is conveyed, and that suitable responses are coordinated and implemented.

Flight service specialists (FSS)

Flight service specialists (FSS) work at uncontrolled airports and provide pilots with information vital to timely and well informed decision-making.

Only a few years ago, the largest aircraft to operate from uncontrolled airports were DC-3s. Today, it's not unusual for these facilities to host B-747s, heightening the role and responsibility of FSS.

Like their counterparts in control towers, FSS:

- detect and identify birds, and estimate their numbers, location and direction of movement;
- advise airport managers of the need for wildlife management; and
- relay information among pilots, airside workers and wildlife-management personnel.

Unlike tower controllers, many flight service specialists live and work in smaller communities, and are familiar with local flying conditions and regular airport users. While valuable, this knowledge can lead to assumptions, and assumptions lead to danger. Perhaps an FSS knows a certain pilot is aware of seasonal bird activity, or that another is familiar with the location of breeding grounds in the vicinity of an airport. Regardless, taking stakeholder awareness for granted immediately compromises wildlife-management system safety. Assume nothing! If employed wisely, familiarity with airport operating conditions is a boon to safety; assumed, it is a recipe for disaster. The FSS may need only to highlight the specific circumstances of bird activities on a given day.

Transient airport users in particular benefit from FSS knowledge. They can rely on these professionals for information on:

- local-wildlife movements; and
- land-use activities that attract wildlife to an airport and surrounding area, such as:
  - bird and wildlife sanctuaries,
  - landfill sites, and
  - fish-packing facilities.

Flight Service Specialists may also be able to advise pilots of dusk and dawn bird-flight paths, as well as locations of local nesting colonies.

When a bird strike does occur, FSS are often the first advised. In these cases, FSS should report all airport wildlife incidents via the Canadian Aviation Damage Occurrence Reporting System (CADORS) while adhering to any other applicable local airport procedures. FSS should also encourage pilots to report occurrences using procedures found in the Rules of the Air and Air Traffic Services Section (RAC) of Canada's Aeronautical Information Publication (A.I.P.).

Conclusion

There is little question that ATS providers are an important part of the system safety formula. Tactically, they are on the front lines in the day-to-day battle to prevent wildlife strikes, the link between people on the ground and pilots in the air. By reporting wildlife activity and strikes—and encouraging others to do the same—ATS providers ensure the scope and nature of airport wildlife hazards are better identified and understood.

Strategically, ATS managers and staff have the opportunity to participate in local and regional safety committees, and on Transport Canada's National Bird Strike Committee. At this strategic level, the exchange of knowledge among all aviation industry stakeholders is a fundamental aspect in the effort to reduce wildlife-strike risks.

Photo courtesy of Brian Losito Air Canada

Chapter 10

Solutions — Pilots

Introduction

This Chapter discusses the role pilots play as stakeholders in an airport wildlife-management plan. Information is provided to heighten awareness among pilots and to describe actions that can be taken as part of an overall strategy to reduce the risk of strikes. While the information provided here is based on well-documented best practices, this chapter is not meant to supercede any procedures contained in approved pilot's operating handbooks or aircraft operating manuals.

Pilots can reduce the probability and severity of bird and mammal strikes through prudent flight planning and the use of appropriate aircraft operating techniques. By observing and reporting wildlife movements to ATS providers and wildlife-management personnel, pilots can also help protect other aircraft operators.

Information is presented as a series of checklists comprising:

- general-pilot, flight-planning and operating principles,
- pilot-planning and operating techniques that apply to all aircraft types, and
- supplementary information that applies to specific classes of aircraft operation.

These checklists are presented in phase-of-flight order, from flight planning through to post flight. Pilots are advised to read the general checklists as well as those that apply to their specific classes of aircraft operation.

Roles and responsibilities

In Canada, the Aeronautics Act and Canadian Aviation Regulations (CARs) outline the legal responsibilities of the pilot in command of an aircraft, as well as standards for flight preparation and aircraft operation. Similar legislation exists in the United States and other jurisdictions around the world. For the purposes of outlining the applicable sections of Canadian legislation shown below, "pilot in command" is defined as the individual responsible for the operation and safety of an aircraft during flight time.

- **Pre-flight information (CAR 602.71)**
  The pilot in command of an aircraft shall, before commencing a flight, be familiar with the available information that is appropriate to the intended flight.

- **Reckless or negligent operation of aircraft (CAR 602.01)**
  No person shall operate an aircraft in such a reckless or negligent manner as to endanger or be likely to endanger the life or property of any person.

Where wildlife hazards are concerned, these regulations imply that pilots have a legal responsibility to both familiarize themselves with potential risks that may affect their flights, and operate their aircraft during all phases of flight in a manner that minimizes the probability and severity of wildlife strikes.

Pilot general flight-planning and operating principles

All pilots should plan and operate flights according to proven wildlife-strike risk-reduction techniques. The following strategies and observations apply:

1. Plan your flight to operate at the highest possible altitude; the probability of bird strikes decreases dramatically above 3,000 ft AGL, and emergency situations are more challenging at low altitudes.
2. Reducing speed also limits the severity of bird strikes—impact force increases as the square of the speed (see Chapter 12, Table 12.1).
3. Avoid planning and flying routes:
   - over areas known to attract birds, such as sanctuaries, landfill sites and fish-packing facilities;
   - along rivers and the shorelines of lakes and oceans, particularly at minimum altitude. Birds, as well as pilots, use these geographic features as navigational aids;
   - over inland waterways and shallow estuaries at minimum altitude. Large numbers of gulls, wading birds and waterfowl frequent these areas throughout the year. These species of birds may make regular flights at dawn and dusk;
   - at minimum altitude over geographical features such as offshore islands, headlands, and cliffs. These areas are frequently used as colonial nesting sites.
4. While most bird species are active primarily during the day, bear in mind that many birds such as owls and migratory waterfowl regularly fly at night.
5. Birds tend to be more active at dawn and dusk. Many species have predictable daily flight patterns; they travel to feeding sites at dawn and return to roosting sites at dusk.
6. In Canada, bird-strike risk peaks at three times throughout the year:
   - during spring migration in March and April;
   - in July and August, when many inexperienced young birds are present, and the flying abilities of adults may be impaired due to molting; and
   - during fall migration in September and October.
7. Be aware that a significant percentage of the North American Canada Goose population remains in urban areas—and therefore often in the vicinity of many airports—throughout the year.

8. On hot summer days, many bird species—such as raptors and gulls—harness thermals and soar to considerable heights.
9. Birds of prey have been reported to attack aircraft.
10. Bird size can be estimated by observing the wing-beat rate; the slower the beat, the larger the bird—and the greater the potential for damage. Remember: large and flocking birds present considerable risk to aircraft; large, flocking birds are extremely hazardous.
11. Be aware that birds may not hear quiet aircraft in time to avoid collision.
12. If you encounter birds, the most effective evasive action may be to climb above them while maintaining a safe speed. Biologists have observed that some birds break downwards when threatened. Other recent studies indicate that some birds may view aircraft as immobile objects, and turn slowly away when at a perceived safe distance.
13. If a bird strike does occur:
    - Maintain control of the aircraft. Remember that the sound of a bird strike may be disproportionately greater than the resulting damage.
    - Refer to checklists and carry out applicable emergency procedures.
    - Assess damage and its effect on aircraft landing performance.
    - Land at the nearest suitable airport.
    - Enlist the assistance of ATS providers and airport emergency personnel.
    - If structural and control-system damage is suspected, consider an aircraft controllability check prior to attempting a landing.
    - Control-surface damage and flutter are not readily apparent on fly-by-wire aircraft, which lack direct linkage from control surface to pilot. As a result, there is no physical feedback of aerodynamic flutter, while electronic control-position indicators lack sufficient fidelity to depict surface flutter.
    - If the windshield is broken or cracked, follow approved procedures contained in the pilot's operating handbook or aircraft operating manual.
    - If the windshield is penetrated, slow the aircraft to reduce wind blast. Consider the use of sunglasses or smoke goggles to protect your eyes from wind, precipitation and flying debris.
14. Following a bird or mammal strike—and before returning to the air—have the aircraft thoroughly inspected, preferably by an aircraft maintenance engineer (AME). Pay careful attention to the following:
    - Ensure the strike has not damaged or blocked the engine intake, exhaust and cooling and airflow ducts.
    - Check landing gear, brake hydraulic lines, landing-gear downlocks and any landing-gear switches.
    - If damage to the airframe or control surfaces is suspected, thorough inspections should be carried out by maintenance personnel to ensure structural integrity; minor exterior damage may disguise serious underlying structural damage.
    - Turbine engines that have suffered bird strikes deserve careful attention. In several incidents, basic visual inspections failed to reveal damage that affected subsequent flights.

Planning and operating to minimize wildlife risks

The following sections summarize pilot flight-planning and operating techniques that have proven effective in enhancing safety and reducing wildlife risk.

Planning and operating techniques for all aircraft

Many techniques that minimize wildlife risk are common to all aircraft types and classes of operation.

Flight planning

1. During the flight-planning process, review available information on potential and known bird hazards:

   - at your departure point,
   - on your flight route,
   - at the arrival airport, and
   - at any alternate airport planned for the destination or enroute.

   Bird-hazard information can be obtained from:

   - airport documentation contained in the Canada Flight Supplement (CFS) or the equivalent publication for the country of flight;
   - NOTAMs and, in some countries, specific bird-hazard information known as BIRDTAMs;
   - Rules of the Air and Air Traffic Services Section (RAC) of Canada's Aeronautical Information Publication (A.I.P.)—particularly for seasonal bird migratory routes in Canada.
   - The Avian Hazard Advisory System (AHAS) Internet website: www.ahas.com for current bird movements.

2. When planning the route, employ strategies to reduce the probability of a bird or mammal strike.

Preflight preparation

1. When approaching the aircraft, observe wildlife activity in the immediate area.
2. During preflight walk-around, be alert for signs of nesting birds in all airframe cavities and around engines. Evidence of nesting includes bird droppings and straw littered on and around the aircraft. During peak nesting season, aggressive birds can have nests partly built in the time it takes pilots to have lunch.
3. When obtaining the Automatic Terminal Information Service (ATIS) and airport information from ATS providers—or UNICOM—note any reports of bird or mammal activity.
4. If possible, heat the windshields. As noted in the pilot's operating handbook or aircraft operating manual, heat increases both windshield pliability and its ability to withstand bird impacts.
5. Prior to engine start and during pre-flight reviews of aircraft emergency procedures, consider courses of action that may be necessary following a wildlife strike.

Taxiing for takeoff

1. Takeoff is a critical phase of flight; strike statistics show that 31 percent of bird strikes and 39 percent of mammal strikes occur during this phase (see Chapter 7).
2. Be alert while taxiing for takeoff and note any bird- and mammal-activity reports by ATS providers and other operators.
3. While taxiing, report wildlife activity observed on ramps, taxiways and runways to ATS providers, UNICOM and other aircraft.
4. Be especially vigilant when operating at airports that either do not have ATS providers, or have limited hours of ATS operation. Often, these airports have no formal wildlife monitoring or management. Prior to takeoff, it may be necessary to backtrack the length of the active runway to ensure there are no birds or mammals.

Takeoff and climb

1. While rolling onto the runway, prepare yourself mentally to deal with the consequences of a bird or mammal strike during takeoff. Be aware of conditions that may affect your ability to either reject takeoff or continue flying under reduced aircraft performance. These include:
   - runway surface conditions,
   - weather, and
   - obstacles.
2. Before commencing takeoff, check the runway once more for wildlife; many birds stand on concrete and asphalt surfaces to warm themselves and to gain a clear view of approaching predators.

Photo courtesy Gordon Lawrence

In spite of the protection provided by a propeller, birds can still enter the intakes of turboprop engines, resulting in significant power loss.

3. Be aware that an aircraft taking off in front of you may frighten birds and mammals into your flight path.
4. If there is bird activity on the runway, be prepared to wait for wildlife-management personnel to clear the birds. If traffic and weather conditions permit, use another runway. Wildlife hazards should be treated like any other flight safety hazard—if any doubt exists concerning safety, delay your takeoff until conditions are right.
5. Use landing lights during takeoff. Although there is no conclusive evidence that birds see and avoid aircraft lights, limited data and anecdotal evidence suggest landing lights—particularly pulsed landing lights—make the aircraft more visible to birds and provide more time for the animals to take evasive action.
6. Aircraft weather radar are not effective as a means of warning birds, as they do not sense the low power emissions and frequencies of these units.
7. Select engine ignition on for takeoff to enhance engine flameout protection when operating turbine-powered aircraft in the presence of birds.
8. Should a bird or mammal strike occur during takeoff roll, a rejected takeoff is the safest course of action when prevailing conditions are appropriate. When safe, vacate the runway and shut down aircraft engines. Before continuing the flight, have the aircraft thoroughly inspected, preferably by an aircraft maintenance engineer (AME).
9. Be prepared to adjust your climb route to avoid birds.
10. If there is reported bird activity, plan to operate the aircraft at reduced airspeeds to minimize impact force and aircraft damage.
11. If there is an altitude band where birds are anticipated, climb through these altitudes as quickly as possible, using the manufacturer's recommended best rate of climb speed.
12. The majority of bird strikes occur below 10,000 ft AGL, so continue to use landing lights during climb until above this altitude.

Enroute

1. Listen to appropriate enroute radio frequencies to obtain up-to-date information on bird activity from ATS providers and other aircraft.
2. Report all hazardous bird movements to ATS providers and other aircraft.

Approach and landing

1. Approach and landing is a critical phase of flight. Strike statistics show that 39 percent of bird strikes and 58 percent of mammal strikes occur during approach and landing (see Chapter 7).
2. Obtain the latest bird and mammal activity information from ATS providers, ATIS, UNICOM and other aircraft.
3. Be especially vigilant when operating at airports which either do not have ATS providers, or have limited hours of ATS operation. While these airports often do not feature wildlife monitoring and management, it is nonetheless prudent to request that airport personnel inspect the runway environment to ensure it is clear of hazardous wildlife. Watch for wildlife activity throughout approach and landing.

4. Plan your descent and approach route to avoid areas that attract birds.
5. During descent and approach in areas with high bird activity, reduce airspeed to diminish the severity of potential bird strikes.
6. If bird activity is reported at particular altitudes, use a higher rate of descent—without increasing speed—to minimize exposure to potential bird strikes.
7. Wildlife hazards during approach and landing should be treated like any other flight safety hazard—if any doubt exists concerning safety, delay your landing until conditions are right.
8. If birds are encountered on approach, consider a go-around and a second approach, but only if the go-around can be initiated without striking birds after power is increased. This strategy may allow birds to disperse before your return. Please note that several bird-related incidents and fatal accidents have resulted from pilots initiating a go-around when the aircraft was in a low energy state and likely capable of a safe landing.
9. Use landing lights during approach and landing to make the aircraft more visible to birds.
10. If you encounter birds or mammals, be sure to report this activity to ATS providers, UNICOM and other aircraft.

Post-flight

1. If you've struck a bird or mammal, or suspect a strike occurred:
   - have the aircraft thoroughly inspected by an aircraft maintenance engineer (AME) prior to the next flight; and
   - if necessary, report the incident to the Transportation Safety Board of Canada.
2. Report all bird and mammal strikes to Transport Canada. In foreign countries, report to appropriate authorities. (See Appendix C for copies of reporting forms and details on the bird- and wildlife-strike reporting process.) When completing bird- and mammal-strike reports consider:
   - providing further useful information: photograph all bird remains and damage and send the photographs to Transport Canada along with the report.
   - if unable to identify the struck species, collect all remains—no matter how small—and contact Transport Canada to arrange for assistance (see Appendix C for contact information).

Commercial and business aviation: special considerations

There are specific bird-hazard concerns for pilots in commercial and business aviation:

1. The structures and engines of larger commercial and business aircraft are more capable of withstanding bird-strike impacts; they are certified to more stringent bird-strike standards than those applying to light general-aviation aircraft (see Chapter 5). However, both the probability and severity of bird strikes is increased for commercial and business aircraft due to a number of factors:
   - Operating speeds are higher, reducing the time available to observe wildlife activity and increasing potential impact force and damage should a bird strike occur.
   - The physical size of these aircraft means more airframe is exposed; an encounter with a flock of birds might lead to damage at numerous locations on the aircraft.

- These aircraft are larger and less maneuverable, making evasive action difficult.
- Aircraft size, windshield size, and cockpit location restrict visibility, limiting the ability to see birds and mammals.
- The extreme workload during critical flight phases means the flight crew has limited time in which to observe wildlife activity.
- Requests for alternate runways to avoid bird concentrations at busy airports can lead to significant delays. Similarly, commercial and business aircraft operating from busy airports are subject to tight schedule constraints; arrival and departure flexibility is limited when attempting to avoid wildlife activity.
- In the takeoff phase, commercial and business aircraft are frequently governed by published departure procedures and noise and traffic-management requirements, limiting the ability to adopt alternate flight paths to avoid areas of bird activity.
- In the approach and landing phase, constraints are similar to those for takeoff and climb. Flight profiles are governed by published approach procedures. At large airports, sequencing high volumes of traffic further restricts flight path flexibility.
- Aircraft accident statistics show a high number of accidents during rejected takeoffs among business and commercial aircraft. The decision to reject a takeoff is time-critical; the success of the manoeuvre is dependent on precise crew coordination. Multiple strikes to more than one engine are likely to result in rejected takeoffs.
- A number of bird-strike incidents have involved damage to more than one engine or aircraft system, including:
  - B737—Calgary 1993,
  - B747—Montreal 1998,
  - B727—Houston 1998.
- Given the rise in aircraft numbers—particularly of twin-engine aircraft—and the growth of the bird population, serious damage from an airborne encounter with a flock of waterfowl is a distinct possibility.

2. The following suggested operating techniques can assist in reducing the probability and severity of bird and mammal strikes involving commercial and business aircraft:
   - Prior to engine start, review emergency procedures pertinent to your aircraft type and operation. Pay particular attention to rejected-takeoff and engine-failure procedures.
   - The best way to reduce the probability of a bird strike is to maximize rate of climb on departure. Jet-engine aircraft should use the ICAO Vertical Noise Abatement Profile ‘A’ (VNAP ‘A’). The benefits are:
     - low aircraft speed (V2+10), which reduces impact force;
     - rapid climb rate to get above 3,000 ft. AGL as quickly as possible; and
     - climb-out occurs as close to the airport boundary as possible, where bird activity is managed.
   - The most effective way to reduce the severity of a bird strike is to reduce speed. Bird-impact force increases as the square of speed; doubling speed increases the impact force by a factor of four.

- Use extreme caution if accelerating above 250 kts below 10,000 ft MSL (mean sea level). (In some jurisdictions, aircraft may accelerate above 250 kts at altitudes over 3,000 ft MSL. However, *Canadian Aviation Regulations* were recently amended to limit airspeed to 250 kts or less at altitudes below 10,000 ft MSL.) These higher speeds increase the probability of a bird strike, since climb rate is reduced while accelerating, thereby increasing time spent in altitudes where birds are more likely to be present. The potential severity of a strike also rises, since impact force increases. Bird strikes above 3,000 ft AGL occur less frequently, but the majority of these strikes involve larger birds that incur frequent and significant damage.
- Use landing lights at all times when operating the aircraft below 10,000 ft AGL.

General aviation: special considerations

Pilots in this sector should consider these points:

1. The majority of general-aviation aircraft (piston single-engine aircraft) are certified under FAR 23. Airframe components in this class will withstand impacts only from the smallest of bird species (see Chapter 5).
2. Many general-aviation pilots are infrequent flyers and therefore less experienced; they may lack familiarity and not be current in handling emergency procedures. Their knowledge of the latest information on bird activity in their local flying area—or on the planned flight route—may also be limited.
3. Many general-aviation operations are from small, uncontrolled aerodromes lacking both wildlife management and available information on wildlife activity. These small aerodromes, however, may offer greater flexibility in the selection of alternate runways to avoid a wildlife hazard.
4. The following suggested operating techniques can help reduce the probability and severity of bird and mammal strikes to general-aviation aircraft.
   - Reduce aircraft speed to diminish impact force when operating in areas of bird activity;
   - For protection, be prepared to lower your head below the glareshield if a bird strike appears imminent;
   - Fly at higher altitudes to reduce the probability of a bird strike. Only one percent of reported general-aviation bird strikes occur above 2,500 ft AGL; and
   - Use landing lights during takeoff and landing to make the aircraft more visible to birds.

Rotary-wing aviation: special considerations

Rotary-wing or helicopter operations are unique in aviation and deserve particular attention in bird-hazard matters:

1. Helicopters are constantly exposed to the risk of bird strikes because:
   - The majority of helicopter flight operations are conducted at very low altitudes, typically below 500 ft AGL.
   - The pilot's concentration is focused on maintaining terrain clearance while completing the assigned task; there is little or no time available to watch for birds.

- Even during the cruise phase of flight, most helicopters remain close to the ground.
- Helicopter operating speeds are generally lower than fixed wing aircraft, but bird-strike certification standards—even for Transport Category helicopters—are not stringent (see Chapter 5).
- Helicopters are more of a disturbance to bird colonies than fixed-wing airplanes; strike risk is therefore increased when birds are flushed into the air.
- There is significant risk of birds penetrating the windshield and causing serious injury and incapacitation.


Helicopters operate in environments in which they are highly vulnerable to windshield damage from bird impacts.

2. The following suggested operating techniques can help reduce the probability and severity of bird and mammal strikes to rotary-wing aircraft:
   - Always wear a helmet with a visor. The greatest immediate danger to helicopter pilots following windshield penetrations is loss of vision from flying debris.
   - When possible, request bird-activity information daily.
   - To reduce the probability of a bird strike, fly at higher altitudes between bases and operating areas.
   - Ensure regular review of emergency procedures, particularly autorotations.
   - If a bird strike occurs, have the helicopter inspected carefully prior to the next flight, preferably by an aircraft maintenance engineer (AME). Remember that damage to main or tail rotors may not be easily detected.
3. The following suggestions may be useful when siting helipads in remote areas:
   - Helipads should not be located near waste disposal facilities such as food-waste landfills, waste-transfer stations and compost facilities, which attract large flocking birds such as gulls. Waste-disposal facilities also attract large mammals such as Black Bears and Grizzly Bears. These large predators are not only a threat to humans working around the helipad, they can also cause considerable damage to equipment and helicopters in their search for food.
   - Helipads should not be located near fish-packing and processing plants, or abattoirs. The waste from these facilities can attract large numbers of birds such as gulls.
   - Helipads should not be located near the flight paths of gulls flying between daytime feeding sites and nighttime roosting sites. During months when gulls roost on open water, regular and predictable flight paths are followed to daytime feeding sites. Many thousands of birds can follow these flight paths over several hours. Normally, these flight paths are below 500 ft AGL, so great care must be taken when manoeuvring in this airspace—especially at sunrise and sunset.

- Helipads should not be located near migratory waterfowl refuges, or in the vicinity of sites such as grain fields. During spring and fall migration, many thousands of birds can fly in these areas.
- When helipads are located near agricultural fields and orchards, remember that harvesting and plowing activities frequently attract large numbers of birds such as crows and gulls. Conducting these activities at night minimizes the risk to daytime helicopter operations.

Flight training schools: special considerations

Flight training schools play an essential role in fostering understanding among pilots about wildlife hazards. As centres of learning, they not only assist pilots in honing the skills needed to avoid and manage strikes, but these schools also disseminate vital promotional and training materials to increase awareness of wildlife-strike risks.

With respect to wildlife hazards, flight training must accomplish the following:

1. Emphasize the consequences of bird and mammal strikes by including statistical information on risks, and case studies from serious strike encounters involving different kinds of aircraft.
2. Describe problem bird and mammal species and the situations in which students are most likely to encounter hazards during training.
3. Describe the effects that single and multiple bird strikes may have on the performance of training aircraft.
4. Emphasize how normal and emergency aircraft operating procedures address the likely effects of bird and mammal strikes on an aircraft.
5. Emphasize adhering to emergency procedures in approved pilot's operating handbooks or aircraft operating manuals in the event of any unusual situation, including bird or mammal strikes.
6. Emphasize the importance of crew resource-management techniques to help pilots of large aircraft deal with unusual emergency scenarios that may follow a bird or mammal strike.
7. Emphasize that a wildlife strike during takeoff affects aircraft performance; students should not reject takeoff after reaching V_1 speed, unless the aircraft is unable to continue flight safely.
8. Train pilots in techniques that minimize the possibility of bird and mammal strikes, as well as actions that should be taken in the event of a strike:
   - Ensure that flight planning is thorough, evaluating all aspects to reduce the potential for wildlife strikes;
   - Complete a thorough pre-flight inspection of the aircraft to ensure there are no nesting birds around the engine or in airframe cavities;
   - During preflight preparation, obtain the latest wildlife-activity information from ATS providers, UNICOM and other aircraft;
   - While taxiing for takeoff, observe and report all wildlife activity;
   - Delay takeoff if birds or mammals are reported or observed on the runway;

- Avoid flying at lower altitudes in areas of high bird activity;
- Reduce aircraft speed to diminish impact force;
- If you must fly through an area heavily populated by birds; minimize climb and descent times; and
- Report all bird sightings deemed hazardous to ATS providers, UNICOM and other aircraft.

Conclusion

With critical responsibility for reducing the probability and severity of bird and mammal strikes, pilots have four important duties:

- To plan and operate all flights in ways that minimize the probability and severity of wildlife strikes.
- To stay on the lookout for birds and mammals.
- To report all wildlife activity to ATS providers, UNICOM and other aircraft.
- To file a Bird/Wildlife Strike Report with Transport Canada or other appropriate agencies following all wildlife strikes (see Appendix C for strike-reporting procedures).

Chapter 11

Solutions — Air Operators

Introduction

Whether their operations are private or commercial, whether they operate one single-engine aircraft or several hundred large jet aircraft, air operators stand to incur significant costs from fleet damage caused by wildlife strikes. Yet there are many ways the industry can reduce both the probability and severity of these strikes, including a range of actions that ensure a measurable, positive effect on companies' bottom lines. Even a ten-percent reduction in the number of damaging wildlife strikes would reduce the cost to the North American aviation industry by at least USD$50-million.

This chapter offers information on the role air operators play in reducing the likelihood and seriousness of wildlife strikes. Presented in a series of checklists, the information addresses diverse types of commercial and business-aircraft operations. As a result, some checklist items may not be applicable to all operators. The checklists apply to general flight planning and operating principles, then specific planning and operating techniques. For ease of use, the lists are presented in order of phase of flight.

Roles and responsibilities

Air operators have legal responsibilities defined in the Canadian Aviation Regulations (CARs), Part VI and VII, including:

- flight-operations procedures,
- flight-dispatch systems,
- aircraft-maintenance procedures,
- safety-management systems, and
- employee-training requirements.

For details, the CARs can be readily accessed on the Transport Canada website: www.tc.gc.ca.

Civil and criminal-code legal obligations also apply, requiring air operators to conduct business safely. Failure to meet these obligations may result in serious legal and financial consequences (See Chapter 1).

Reducing the probability and severity of wildlife strikes

There are three areas where air operators should concentrate their efforts:

- Standard Operating Procedures (SOPs),
- employee training and awareness, and
- reporting of wildlife strikes.

Standard Operating Procedures

Wildlife-hazard-specific SOPs should be developed and included in company publications, addressing the following areas:

- flight operations (pilots),
- flight dispatch (flight planning and flight following),
- aircraft maintenance, and
- ramp operations (aircraft ground handling).

Flight operations and flight dispatch

Flight operations and flight dispatch are closely related disciplines that use common SOPs. The following sections offer procedures to help reduce wildlife-strike probability and severity when included in company manuals.

General operating principles

Flight operations and dispatch wildlife-hazard SOPs should promote flight planning and aircraft-operating techniques that address the following unique aspects of commercial and business aviation:

1. Operating speeds for business and commercial aircraft are higher than for light general-aviation aircraft. Therefore, less time is available to observe wildlife. Higher speeds also increase impact force and the potential for damage in the event of a bird strike.
2. The time available to observe wildlife activity is restricted by the intense workload during critical phases of flight.
3. The physical size of these aircraft increases the likelihood that encounters with flocks of birds will lead to damage at multiple locations on the aircraft.
4. These aircraft are larger and less manoeuvrable, making it more difficult to take evasive action when birds are encountered.
5. Aircraft size, cockpit location and windshield size restrict visibility from cockpits, limiting the ability to see birds and mammals.
6. Requests for alternate runways to avoid bird concentrations at busy airports can lead to significant delays.

7. Commercial and business aircraft operating from busy airports are subject to tight schedule constraints; arrival and departure flexibility is limited when attempting to avoid wildlife activity.
8. In takeoff phase, commercial and business aircraft are frequently governed by published departure procedures and noise and traffic-management requirements, limiting the ability to adopt alternate flight paths to avoid areas of bird activity.
9. In approach and landing phase, constraints are similar to those for takeoff and climb. Flight profiles are governed by published approach procedures. At large airports, sequencing high volumes of traffic further restricts flight-path flexibility.
10. Aircraft accident statistics show a high number of accidents during rejected takeoffs among business and commercial aircraft. The decision to reject takeoff is time-critical; the success of the manoeuvre is dependent on precise crew coordination. Multiple strikes to more than one engine are likely to result in rejected takeoffs.
11. A number of bird-strike incidents have involved damage to more than one engine or aircraft system, including:
    - B737—Calgary 1993,
    - B747—Montreal 1998,
    - B727—Houston 1998.

    Given the rise in aircraft numbers—particularly of twin-engine aircraft—and growth of some bird populations, serious damage from an airborne encounter with flocks of waterfowl is a distinct possibility.
12. Rotary-wing operations are particularly challenging because:
    - The majority of helicopter flight operations are conducted at very low altitudes, typically below 500 ft AGL.
    - The pilot's concentration is focused on maintaining terrain clearance while completing the assigned task; there is little or no time available to watch for birds.
    - Even during the cruise phase of flight, most helicopters remain close to the ground.
    - Helicopter operating speeds are generally lower than fixed-wing aircraft, but bird-strike certification standards—even for Transport Category helicopters—are not stringent (see Chapter 5).
    - Helicopters are more of a disturbance to bird colonies than fixed-wing airplanes; strike risk is therefore increased when birds are flushed into the air.
    - There is significant risk of birds penetrating the windshield and causing serious injury and incapacitation.

Air operator general flight planning and operating principles

All flights should be planned and executed according to proven wildlife-strike risk reduction principles and techniques:

1. Plan your flight to operate at the highest possible altitude; the probability of bird strikes decreases dramatically above 3,000 ft AGL, and emergency situations are more challenging at low altitudes.

2. The best way to reduce the probability of a bird strike is to maximize rate of climb on departure. Jet-engine aircraft should use the ICAO Vertical Noise Abatement Profile 'A' (VNAP 'A'). The benefits are:
   - low aircraft speed (V2+10), which reduces impact force;
   - rapid climb rate to get above 3,000 ft AGL as quickly as possible; and
   - climb-out occurs as close to an airport boundary as possible, where bird activity is managed.
3. Reducing speed also limits the severity of bird strikes—impact force increases as the square of speed (see Chapter 12, Table 12.1).
4. Use extreme caution if accelerating above 250 kts below 10,000 ft MSL (mean sea level). (In some jurisdictions, aircraft may accelerate above 250 kts at altitudes over 3,000 ft MSL. However, *Canadian Aviation Regulations* were recently amended to limit airspeed to 250 kts or less at altitudes below 10,000 ft MSL.) These higher speeds increase the probability of a bird strike, since climb rate is reduced while accelerating, thereby increasing time spent in altitudes where birds are more likely to be present. The potential severity of a strike also rises, since impact force increases. Bird strikes above 3,000 AGL occur less frequently, but the majority of these strikes involve larger birds that incur frequent and significant damage.
5. Use landing lights at all times when operating aircraft below 10,000 ft AGL.
6. Avoid planning and flying routes:
   - over areas known to attract birds, such as sanctuaries, landfill sites and fish-packing facilities;
   - along rivers and the shorelines of lakes and oceans, particularly at minimum altitude. Birds, as well as pilots, use these geographic features as navigational aids;
   - over inland waterways and shallow estuaries at minimum altitude. Large numbers of gulls, wading birds and waterfowl frequent these areas throughout the year. These species of birds may make regular flights at dawn and dusk;
   - at minimum altitude over geographical features such as offshore islands, headlands, and cliffs. These areas are frequently used as colonial nesting sites.
7. The following suggested operating techniques can help reduce the probability and severity of bird and mammal strikes to rotary-wing aircraft:
   - Always wear a helmet with a visor. The greatest immediate danger to helicopter pilots following windshield penetrations is loss of vision from flying debris.
   - Ensure that flight crews regularly review emergency procedures, particularly autorotations.
   - If a bird strike occurs, have the helicopter inspected carefully prior to the next flight, preferably by an aircraft maintenance engineer (AME). Remember that damage to main or tail rotors may not be easily detected.
   - Rotary-wing aircraft are capable of accessing a range of environments, each with unique wildlife-hazard challenges. Chapter 10 includes information on establishing helipads in remote areas—information air operators may wish to include in operations manuals.
8. While most bird species are active primarily during the day, bear in mind that many birds such as owls and migratory waterfowl regularly fly at night.

9. Birds tend to be more active at dawn and dusk. Many species have predictable daily flight patterns; they travel to feeding sites at dawn and return to roosting sites at dusk.
10. In Canada, bird-strike risk peaks at three times throughout the year:
    - during spring migration in March and April;
    - in July and August, when many inexperienced young birds are present, and the flying abilities of adults may be impaired due to molting; and
    - during fall migration in September and October.
11. Be aware that a significant percentage of the North American Canada Goose population remains in urban areas—and therefore often in the vicinity of many airports—throughout the year.
12. On hot summer days, many bird species—such as raptors and gulls—harness thermals and soar to considerable heights.
13. Birds of prey have been reported to attack aircraft.
14. Bird size can be estimated by observing the wing-beat rate; the slower the beat, the larger the bird and the greater the potential for damage. Remember: large and flocking birds present considerable risk to aircraft.
15. Be aware that birds may not hear quiet aircraft in time to avoid collisions.
16. If you encounter birds, the most effective evasive action may be to climb above them while maintaining a safe speed. Biologists have observed that some birds break downwards when threatened. Other recent studies indicate that some birds may view aircraft as immobile objects, and turn slowly away when at a perceived safe distance.
17. If bird strikes occur, pilots should:
    - maintain control of the aircraft. Remember that the sound of a bird strike may be disproportionately worse than the resulting damage;
    - refer to appropriate checklists and carry out any applicable emergency procedures;
    - assess damage and its effect on aircraft landing performance;
    - land at the nearest suitable airport considering weather, facilities and emergency services;
    - enlist the assistance of ATS providers and airport emergency personnel;
    - consider an aircraft controllability check before attempting a landing if structural or control system damage is suspected;
    - remember that control-surface damage and flutter are not readily apparent on fly-by-wire aircraft, which lack direct linkage from control surface to pilot. As a result, there is no physical feedback of aerodynamic flutter, while electronic control-position indicators lack sufficient fidelity to depict surface flutter;
    - follow approved procedures contained in the pilot's operating handbook and aircraft operating manual if the windshield is broken or cracked; and
    - slow the aircraft to reduce wind blast if the windshield is penetrated. Consider the use of sunglasses or smoke goggles to protect your eyes from wind, precipitation and flying debris.
18. Following a bird or mammal strike—and before the next flight—have the aircraft thoroughly inspected according to approved company maintenance procedures.

Planning and operating techniques

Some suggested planning and operating techniques that can reduce the probability and severity of wildlife strikes, and that should be included in any air operator's Flight Operations Manual (FOM) and Aircraft Operating Manual (AOM), are listed below:

Flight planning

1. During the flight-planning process, review available information on potential and known bird hazards:

   - at your departure point,
   - on your flight route,
   - at the arrival airport, and
   - at any alternate airport planned for the destination or enroute.

   Bird-hazard information can be obtained from:

   - airport documentation contained in the Canada Flight Supplement (CFS) or the equivalent publication for the country of flight;
   - NOTAMs and, in some countries, specific bird-hazard information known as BIRDTAMs;
   - Rules of the Air and Air Traffic Services Section (RAC) of Canada's Aeronautical Information Publication (A.I.P.)—particularly for seasonal bird-migration routes in Canada;
   - The Avian Hazard Advisory System (AHAS) Internet website (www.ahas.com) for current bird movements.

2. When planning the route, employ strategies to reduce the probability of a bird or mammal strike.

Preflight preparation

1. When approaching the aircraft, pilots should take time to observe wildlife activity in the immediate area.
2. During preflight walk-around, pilots should be alert for signs of nesting birds in all airframe cavities and around the engines. Evidence of nesting includes bird droppings and straw littered on and around the aircraft. During peak nesting season, aggressive birds can have nests partly built in the time it takes pilots to have lunch.
3. When obtaining the Automatic Terminal Information Service (ATIS) and airport information from ATS providers—or UNICOM—note any reports of bird or mammal activity.
4. If possible, pilots should heat their windshields. As noted in the pilot's operating handbook and aircraft operating manual, heat increases both windshield pliability and its ability to withstand bird impacts.
5. Prior to engine start and during pre-flight reviews of aircraft-emergency procedures, flight crews should consider courses of action that may be necessary in the event of a wildlife strike.

Taxiing for takeoff

1. Takeoff is a critical phase of flight; strike statistics show that 31 percent of bird strikes and 39 percent of mammal strikes occur during this phase (see Chapter 7).
2. Pilots should be alert while taxiing for takeoff, noting any bird- and mammal-activity reports by ATS providers and other operators.
3. While taxiing, pilots should report wildlife activity observed on ramps, taxiways and runways to ATS providers, UNICOM and other aircraft.
4. Pilots must be especially vigilant when operating at airports that either do not have ATS providers, or have limited hours of ATS operation. Often, these airports have no formal wildlife monitoring or management. Prior to takeoff, it may be necessary to backtrack the length of the active runway to ensure there are no birds or mammals.

Takeoff and climb

1. As noted above, the best way to reduce the probability of a bird strike is to maximize rate of climb on departure. Jet-engine aircraft should use the ICAO Vertical Noise Abatement Profile 'A' (VNAP 'A').
2. While rolling onto the runway, pilots should prepare themselves mentally to deal with the consequences of a bird or mammal strike during takeoff. They must be aware of conditions that may affect their ability to either reject takeoff or continue flying under reduced aircraft performance. These include:
   - runway surface conditions,
   - weather, and
   - obstacles.
3. Before commencing takeoff, check the runway once more for wildlife; many birds stand on concrete and asphalt surfaces to warm themselves and to gain a clear view of approaching predators.
4. Pilots would be wise to remember that an aircraft taking off ahead of them may frighten birds and mammals into their flight path.
5. If there is bird activity on the runway, be prepared to wait for wildlife-management personnel to clear them. If traffic and weather conditions permit, pilots should use another runway. Wildlife hazards should be treated like any other flight-safety hazard—if any doubt exists concerning safety, delay takeoff until conditions are right.
6. Use landing lights during takeoff. Although there is no conclusive evidence that birds see and avoid aircraft lights, limited data and anecdotal evidence suggest that landing lights—particularly pulsed landing lights—make aircraft more visible to birds and provide more time for the animals to take evasive action.
7. Aircraft weather radar are not effective as a means of warning birds, as they do not sense the low power emissions and frequencies of these units.
8. Pilots should select engine ignition on for takeoff to enhance engine flameout protection when operating turbine-powered aircraft in the presence of birds.
9. Should a bird or mammal strike occur during takeoff roll, a rejected takeoff is the safest course of action if prevailing conditions are appropriate. When safe, vacate the runway and shut down aircraft engines. Before continuing the flight, have the aircraft thoroughly inspected, preferably by an aircraft maintenance engineer (AME).

10. Be prepared to adjust the climb route to avoid birds.
11. If there is reported bird activity, pilots should plan to operate aircraft at reduced airspeeds to minimize impact force and aircraft damage.
12. If there is an altitude band where birds are anticipated, climb through these altitudes as quickly as possible, using the manufacturer's recommended best rate-of-climb speed.
13. The majority of bird strikes occur below 10,000 ft AGL, so continue to use landing lights during climb until above this altitude.

Enroute

1. Pilots should listen to appropriate enroute radio frequencies to obtain up-to-date information on bird activity from ATS providers and other aircraft.
2. Pilots should report all hazardous bird movements to ATS providers and other aircraft.

Approach and landing

1. Approach and landing is a critical phase of flight. Strike statistics show that 39 percent of bird strikes and 58 percent of mammal strikes occur during approach and landing (see Chapter 7).
2. Pilots should obtain the latest information on any bird and mammal activity from ATS providers, ATIS, UNICOM and other aircraft.
3. Pilots must be especially vigilant when operating at airports that either do not have ATS providers, or have limited hours of ATS operation. While these airports often do not feature wildlife monitoring and management, it is nonetheless prudent to request that airport personnel inspect the runway environment to ensure it is clear of hazardous wildlife. Watch for wildlife activity throughout approach and landing.
4. Plan aircraft descent and approach routes to avoid areas that attract birds.
5. During descent and approach in areas with high bird activity, reduce airspeed to diminish the severity of potential bird strikes.
6. If bird activity is reported at particular altitudes, pilots should use a higher rate of descent—without increasing speed—to minimize exposure to potential bird strikes.
7. Wildlife hazards during approach and landing should be treated like any other flight-safety hazard—if any doubt exists concerning safety, delay landing until conditions are right.
8. If birds are encountered on approach, pilots should consider a go-around and a second approach, but only if the go-around can be initiated without striking birds after power is increased. This strategy may allow birds to disperse before the aircraft's return. Please note that several bird-related incidents and fatal accidents have resulted from pilots initiating a go-around when the aircraft was in a low energy state and likely capable of a safe landing.
9. Use landing lights during approach and landing to make the aircraft more visible to birds.
10. Pilots should report all bird and mammal activity to ATS providers, UNICOM and other aircraft.

Post-flight

1. If aircraft have struck birds or mammals, or if pilots suspect strikes may have occurred:
   - report incidents to company maintenance personnel and have aircraft thoroughly inspected prior to the next flight;
   - report incidents using approved company safety reporting systems; and
   - if required, report the incident to the Transportation Safety Board of Canada.
2. Report all bird and mammal strikes to Transport Canada. In foreign countries, report to appropriate authorities. See Appendix C for copies of reporting forms and details on bird- and wildlife-strike reporting processes. When completing bird- and mammal-strike reports consider:
   - providing further useful information: photograph all bird remains and damage and send the photographs to Transport Canada along with the report.
   - if unable to identify the struck species, collect all remains—no matter how small—and contact Transport Canada to arrange for assistance (see Appendix C for contact information).

Aircraft maintenance

Aircraft maintenance SOPs should stress:

- the importance of thorough inspections following a wildlife strike, and
- reporting details of wildlife-strike damage and repair costs to the air operator's flight-safety organization.

Maintenance inspection checklists used following wildlife strikes should:

- adhere to applicable air-operator wildlife-strike reporting procedures and ensure that the incident is reported to Transport Canada;
- ensure that strikes have not damaged
- or blocked engine intakes, exhausts, cooling and airflow ducts; and
- landing gear, brake hydraulic lines, landing-gear downlocks and any landing gear switches;
- ensure structural integrity if damage to airframe or control surfaces is suspected; minor exterior damage may disguise serious underlying structural damage;
- include close inspection of turbine engines. In several incidents, basic visual inspections failed to reveal damage that affected subsequent flights;
- note that rotary-wing aircraft are susceptible to main- or tail-rotor damage that may not be easily detected;
- encourage inclusion of additional useful information, such as damage photographs and bird remains that can be forwarded to air operators' flight-safety departments;
- in cases when struck species cannot be identified, request the collection and delivery of any bird remains—no matter how small—to air operators' flight-safety departments (see Appendix C for contact information).

Ramp operations

In addressing removal of wildlife attractants from ramp areas, ramp-operations SOPs should stress the following:

- immediate collection of all garbage—and particularly food waste—for storage in closed containers;
- secure lids for all garbage containers;
- ensuring garbage containers are kept closed;
- commitment of ramp personnel not to feed birds and mammals, nor attract them to ramp areas; and
- immediate reporting of all ramp-area wildlife activity to airport wildlife-management personnel.

Training and awareness

Through employee training and awareness, companies can foster cultures in which dangers posed by wildlife hazards are recognized and commitment can be built to reduce those hazards diligently on a daily basis.

Employee training

All employees of air operators should be trained on the risks and costs of wildlife strikes, reminding them of both the importance of company SOPs and the value of wildlife-hazard vigilance—measures critical to safety management and cost control.

Particular attention should be given to pilot training, preparing flight crews for the emergencies that often follow bird and mammal strikes. Some suggested training strategies are:

- Annual pilot briefings and recurrent training that include reviews of recent wildlife-strike incidents within the company and the industry. These sessions provide opportunities to review typical wildlife-strike scenarios and the most appropriate procedures for addressing associated hazards.
- Simulator scenarios involving aircraft-performance degradations and multiple-system damage—such as that resulting from bird strikes—impress upon pilots both the potential seriousness of strikes and the proper application of approved aircraft-operating procedures in response. In another useful simulator scenario, one crew member is incapacitated as a bird penetrates the windscreen; the remaining crew member must complete all required emergency procedures including returning to land at a suitable airport.
- Promotion of Crew Resource Management techniques (CRM) to ensure optimal use of cockpit resources in the event of a serious bird strike—particularly important when windscreen visibility is reduced as a result of a strike.

Employee awareness

While airline companies are under no specific obligation to make employees aware of problems associated with wildlife strikes, air operators are required by the CARs to disseminate safety-awareness material to employees. There are a number of practical and effective ways to communicate the wildlife risks to air-operator employees including:

- regular publication of company wildlife-strike statistics;
- posting wildlife-hazard awareness posters in strategic employee locations;
- posting special bulletins to warn pilots of newly identified wildlife hazards;
- issuing bulletins as migratory periods approach, reminding pilots of potential dangers and approved strategies to reduce the probability and severity of bird strikes;
- using company safety publications to educate employees on wildlife hazards, as well as the latest developments in equipment design and procedures that reduce risk;
- informing staff of the high costs associated with wildlife-strike damage; and
- keeping a supply of Transport Canada wildlife-hazard education materials readily available for employee review.

Wildlife-strike reporting

As discussed in Chapter 7, one of the most serious deficiencies in the effort to avert the wildlife-strike problem is a lack of comprehensive strike statistics. It is estimated that only 20 percent of wildlife strikes are reported, due in part to the lack of a regulatory requirement to do so. Air operators already have the infrastructures through which safety trends are recorded—systems ideal for capturing and analyzing wildlife-strike statistics.

Air operators should consider expanding these systems to require flight crews and maintenance personnel to report all wildlife strikes. It is also critical that this data be shared to ensure the maintenance of a comprehensive, industry-wide, wildlife-strike database. This database could be employed to identify specific trends and promote development of effective solutions that mitigate risks.

Some suggested components of a wildlife-strike safety reporting system are listed below:

- The safety-reporting system must be founded on the principle of non-punitive reporting of safety incidents.
- Safety reporting-system data that is shared with other safety professionals must be presented in an anonymous form that obscures identity of the reporter.
- Wildlife-strike data must be shared with other safety professionals such as Transport Canada and airport wildlife-management personnel.
- Wildlife-incident report forms should mirror the Transport Canada Bird/Wildlife Strike Report form to ensure correct information is reported in a uniform manner.
- Maintenance personnel should also have a means whereby they can report wildlife-strike damage to the wildlife-incident reporting system.

- The safety reporting system should include wildlife-strike damage costs.
- The safety reporting system should have a structured database that determines trends by facilitating long-term record keeping and analysis.

Conclusion

Air operators have a vested financial interest and a legal obligation to seek ways to reduce the probability and severity of wildlife strikes, focusing on:

- effective Standard Operating Procedures (SOPs);
- structured and regular employee training; and
- a robust, non-punitive safety reporting system that captures wildlife-strike data and shares it with the aviation industry in an aggregate, anonymous form.

Chapter 12

Solutions – Airframe & Engine Manufacturers

Introduction

All forward-facing aircraft parts—especially engines—are vulnerable to damage when aircraft and wildlife collide, as discussed in Chapter 7. Existing airframe- and engine-certification standards for aircraft presently in operation were described in Chapter 5. This chapter discusses advances by manufacturers and regulators in ensuring the bird worthiness of airframes and engines—improving the ability of aircraft to withstand bird and mammal strikes.

Current research and development focuses on three areas:

- certification standards,
- design and material changes to components, and
- impact testing.

Certification standards

Airframe and engine airworthiness standards are subject to periodic review. Occasionally, new data from accident reports and safety reporting systems indicates that current standards require enhancement to more closely reflect operating environments. At such times, regulatory bodies endeavour to revise the standards.

New certification standards strive to enhance safety without invoking undue economic penalties that might result from new-regulation implementation. This is one of the reasons that new standards are not applied to airframes and engines certified under old rules.

Additionally, the regulatory process is time consuming, involving exhaustive research and collaboration. Proposed rule changes are submitted to the industry for comments that are evaluated and integrated into the new or revised standards. It is not unusual for this process to take several years.

International harmonization of airworthiness requirements

As discussed in Chapter 5, there are two bodies that certify airframes and engines:

- the Federal Aviation Administration (FAA), and
- the European Joint Aviation Authority (JAA).

Generally, aircraft are certified to both FAA and JAA standards, although meeting the differences in these standards can increase both the costs to manufacturers and the length of the certification process.

In the last few years the FAA and JAA have made a concerted effort to ensure worldwide airworthiness regulations are consistent in form and substance, thereby lowering certification costs and enhancing global aviation safety.

An example of this harmonization can be found in the August 8, 1996 FAA amendments to airworthiness standards for Normal (FAR 27) and Transport Category (FAR 29) rotorcraft—amendments that improved standards for helicopter performance, systems, propulsion and airframes. These changes were also the first to incorporate bird-strike protection requirements. The proposed amendments were reviewed by a number of groups including:

- major rotorcraft manufacturers,
- Aerospace Industries Association of America, Inc.,
- Association Européene des Constructeurs de Matérial Aerospatiale,
- Helicopter Association International,
- European Joint Aviation Authorities (JAA),
- Transport Canada, and
- the United Kingdom Civil Aviation Authority.

The JAA agreed not only with the proposed FAA rule, but also the effort to harmonize certification standards and regulations in the United States and the European communities. To realize full harmonization objectives, the JAA prepared and published its own identical regulation to coincide with the final rule for Parts 27 and 29 of the FARs. The goal is to continue the harmonization process through the remainder of the regulations over the next few years.

More stringent bird-impact airworthiness requirements

One effective way to reduce the severity of wildlife strikes is to enact more stringent impact-strength requirements for airframes and engines.

Airframe airworthiness requirements modifications

Presently, there are no published proposals to enhance airframe bird-impact requirements. Yet recent analysis of bird-population and strike-incident data indicates marked increases in the number of bird strikes involving large-bird species—species that, in weight and size,

	Aircraft Speed (Knots)								
Bird Species & Weight (lbs.)	**100**	**150**	**200**	**250**	**280**	**300**	**350**	**400**	**450**
Starling 0.187 (3 ozs.)	995	2,238	3,978	6,216	7,798	8,951	12,184	15,913	20,140
Ring-billed Gull 1.5	2,775	6,244	11,100	17,343	21,756	24,974	33,993	44,399	56,193
Duck 4.0	6,078	13,676	24,314	37,990	47,655	54,706	74,461	97,255	123,088
Canada Goose 15.0	9,118	20,515	36,471	56,985	71,482	82,059	111,691	145,883	184,633

Table 12.1 Approximate Bird-impact Forces (lbs.)

exceed the current certification requirements for windshields and airframes. In many cases, strikes involving such birds have led to windshield penetrations, serious pilot injuries and significant and costly airframe damage.

Bird-population data show that the Canada Goose population in North America has increased from two million in 1990 to more than six million at the end of 1999; approximately 40 percent of the North American Canada Goose population remains in urban areas year round. Many geese weigh well over 15 lbs, and it is not unusual for individual specimens to exceed 18 lbs—sobering figures when considering that current standards for windshield impact strength are based on a *four-lb bird* hitting an aircraft at design cruise speed (V_C).

Table 12.1 shows approximate impact forces by bird weight and impact speed. Accordingly, we see that a four-lb bird striking a windshield at 300 kts generates an impact force of up to 55,000 lbs. Meanwhile, a 15-lb goose hitting a windshield at 300 kts generates an impact force of up to 82,000 lbs—a force that exceeds windshield certification standards by 200 to 300 percent (See Appendix 12.1 and 5.1).

While the data provide compelling evidence, suggesting more stringent airframe bird-impact certification standards may be required, the potential costs involved in upgrading the bird-worthiness of the current fleet of legacy aircraft would be enormous.

Modifications to airworthiness requirements

On September 14, 2000, the FAA issued revised bird-ingestion standards for jet engines (FAR 33), responding to data that define the actual bird threat encountered by jet engines in service. These standards also reflect a desire to harmonize the FAA bird-ingestion criteria with those being drafted by the JAA—standards that recognize both the capacity of new large-inlet turbine engines to ingest an increased number of birds, and the actual weights of birds being ingested.

This B737 windshield was damaged as a result of a bird strike at 10,000 ft ASL.

Bird-ingestion tests for engines certified prior to September 14, 2000, are based on large birds weighing 4 lbs, and medium flocking birds weighing 1.5 lbs. During the regulatory development process, the industry agreed that multiple strikes involving these birds must also be considered as part of the new-engine certification process. As a result, the large-bird requirement was updated to range from 4 to 8 lbs, based on information obtained from bird-weight averages recorded during the 1990 FAA Large, High Bypass Ratio Engine Study.

The FAA study also reviewed bird population data, and identified the 2.5-lb Herring Gull as a potential flocking-bird hazard at most coastal airports in the Northern Hemisphere. To confirm this suspicion, an evaluation of the observed weights of birds ingested into jet engines was carried out.

Following the review, a new certification standard was established, updating design and testing requirements for all jet-engine sizes, and enhancing bird-ingestion test requirements for large, high bypass-ratio turbofan engines. The revised standard addresses strikes by single large birds as well as those by flocks of birds, and sets out a number of parameters for assessments of engine airworthiness. The September 14, 2000, FAR 33 revised bird-ingestion engine certification standards are contained in Table 12.2.

		Original Certification Standard		Revised Certification Standard (Sep. 2000)	
Engine	**Inlet Area Sq. in.**	**Large-bird Quantity & Weight**	**Medium-bird Quantity & Weight**	**Large-bird Quantity & Weight**	**Medium-bird Quantity & Weight**
JT8D	2290	1 @ 4.0 lbs.	4 @ 1.5 lbs.	1 @ 6.05 lbs.	1 @ 2.53 lbs. plus 3 @ 1.54 lbs.
RB211	4300 - 5808	1 @ 4.0 lbs.	4 @ 1.5 lbs.	1 @ 6.05 lbs.	1 @ 2.53 lbs. plus 6 @ 1.54 lbs.
JT9D	6940	1 @ 4.0 lbs.	4 @ 1.5 lbs.	1 @ 8.03 lbs.	3 @ 2.53 lbs.
PW2037/2043	4902	1 @ 4.0 lbs.	4 @ 1.5 lbs.	1 @ 6.05 lbs.	1 @ 2.53 lbs. plus 6 @ 1.54 lbs.
CF6	6973	1 @ 4.0 lbs.	4 @ 1.5 lbs.	1 @ 8.03 lbs.	3 @ 2.53 lbs.
CFM56	2922 - 4072	1 @ 4.0 lbs.	4 @ 1.5 lbs.	1 @ 6.05 lbs.	1 @ 2.53 lbs. plus 6 @ 1.54 lbs.
V2500	3217	1 @ 4.0 lbs.	4 @ 1.5 lbs.	1 @ 6.05 lbs.	1 @ 2.53 lbs. plus 4 @ 1.54 lbs.
PW4000	6940 - 7854	1 @ 4.0 lbs.	4 @ 1.5 lbs.	1 @ 8.03 lbs.	4 @ 2.53 lbs.

Table 12.2 Original & Revised FAR 33 Engine Certification Bird Weight & Quantity Requirements for Engines Shown in Chapter 5, Table 5.1 (1)(2)(3)

(1) RR Trent 553/768/875/8104, PW4084/4098 and GE90 were voluntarily certified to revised standard and are not shown.

(2) Original small-bird ingestion certification requirements for all listed engines is 16 birds @ 0.187 lbs.

(3) Revised small-bird ingestion certification requirements for all listed engines is 16 birds @ 0.187 lbs.

Table 12.2 compares the old and new engine certification standards with respect to bird-weight requirements for engines listed in Chapter 5, Table 5.1. The large turbofan engines (RR Trent Series, P&W 4084/4098 and the GE90) are not included in this table; these engines were voluntarily tested by manufacturers to meet the new certification standards.

More recent industry data raises questions about assumptions that informed the new certification standards. The two major concerns are:

- the assumption that large-bird ingestions will only affect one engine. Strike data has shown an unusual increase in the number of strikes involving large birds to more than one engine.
- the assumption of a maximum large-bird impact speed of 200 kts. This assumption is based on speeds during approach and departure, and that aircraft are more likely to encounter large birds at the altitudes (below 500 ft) in which these phases of flight occur. In fact, many current regulations permit aircraft to undertake approaches and departures at speeds of 250 kts and greater, and these higher impact speeds could result in considerably more serious damage.

Design and material changes to airframe and engine components

Advancements in computer-assisted design and manufacturing (CAD/CAM) have led to a number of improvements in airframe and engine design. New materials—such as carbon-fiber composites—offer superior strength and reduced weight.

Developments in airframe design and materials

Efficiency motivates new airframe design work, using lighter, stronger materials to improve specific fuel consumption and aircraft range—rather than improve bird-impact strength.

Significant improvements have been made in protecting critical components such as fuel lines, flight-control cables, hydraulic lines and electrical wiring—ensuring their operation is not impaired by wildlife strikes. Relocating these components within wings and fuselages reduces the likelihood of significant damage leading to multiple system failures, and improves overall survivability of aircraft.

The development of fly-by-wire control systems was a positive step toward reducing bird-strike damage to aircraft. This approach to flight-control system design—motivated by considerable aircraft weight savings—conveys flight-deck control information through computers. The computers process a range of control parameters and distribute signals to appropriate flight-control actuators. Prior to fly-by-wire systems, control rods and cables directly connected flight decks to specific control surfaces (with or without some type of power boost).

New fly-by-wire systems reduce vulnerability of flight controls by eliminating complicated control components that run through wings, fuselage and tail surfaces. Fly-by-wire systems are also designed to incorporate multiple layers of redundancy, constructed to allow for the independent movement of individual control surfaces through back-up computer and hydraulic systems. Compensation for control-system damage is achieved by increasing control movements on surfaces unaffected by an impairment.

One disadvantage of fly-by-wire systems is that they provide no direct physical feedback from control surfaces—pilots are unable to feel any control flutter as a result of damage. Fly-by-wire flight-control systems do have electronic control-position indicators, but these instruments lack sufficient fidelity to detect aerodynamic flutter—an important indicator of the level of damage to control surfaces. If it reaches sufficient magnitude or frequency, aerodynamic flutter can ultimately lead to structural failure and loss of control.

Aircraft-transparency strength has benefited from research and development in both new materials and heating systems that help maintain the flexibility of windshields. Further research is being conducted on military aircraft, using composite materials to strengthen windshield frames. In addition, the USAF Next Generation Transparency Program is developing injection-molded frameless transparencies for fighter aircraft. Lighter than existing models, these transparencies have fewer parts, reduce changeout

Injection-molded frameless canopies which are very resistant to bird strike damage are being developed by the USAF.

time and are much more resistant to bird strikes. Positive developments from this military research will eventually be transferred into improvements in civilian-aircraft windshield construction.

Developments in engine design and materials

Developments in engine technology have been dramatic, with the high bypass-ratio turbofan becoming the engine of choice on virtually all new large commercial aircraft. The high-thrust output of these engines makes it possible to power large aircraft such as the Boeing B777 and the Airbus A330 with only two engines. The benefits include increased fuel efficiency and reduced maintenance costs compared to the three or four engines typically used in earlier generation aircraft such as the DC8, B707, L1011 and DC10.

New generation aircraft engines have been designed to meet the latest engine airworthiness certification standards. Computer design technology and advanced materials lead to fan, compressor and turbine blades that are wider and longer and improve thermodynamic efficiency. The improved structural integrity of these components has also improved their resistance to damage from bird impacts.

New aircraft engines also use advanced full-authority digital engine controls (FADEC) to optimize engine performance. FADEC provides enhanced engine-monitoring and warning systems that adjust engine parameters to maintain required thrust even when the engine has sustained damage. FADEC systems automatically select engine ignition on when engine flameout is sensed.

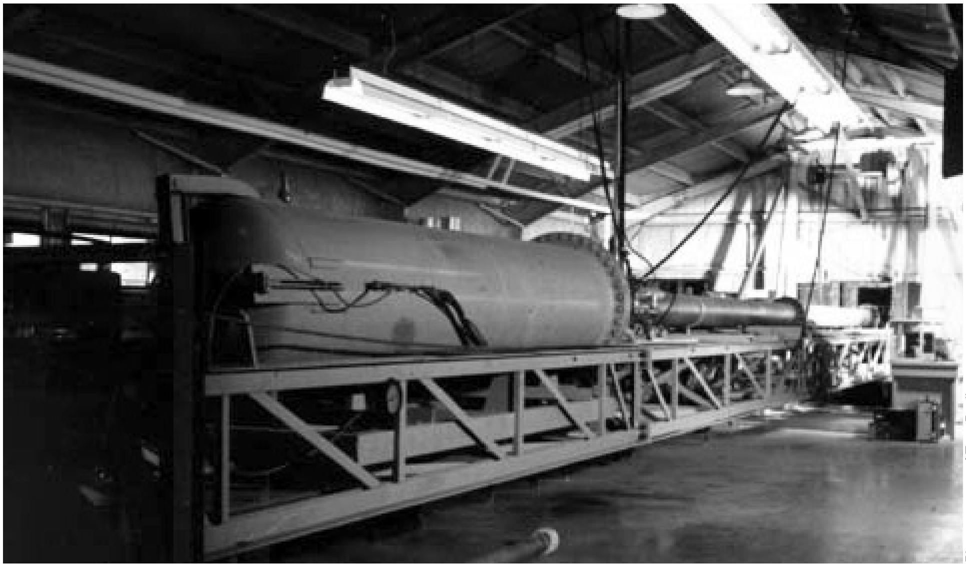


Photo courtesy of Tony Bosik

Figure 12.1 Apparatus for testing windshields and airframe components.

Bird-impact testing

Through bird-impact testing, new engines and airframes are subjected to simulated and actual bird strikes.

Aircraft windshields and airframes are tested using compressed air cannons, which direct euthanized birds against airframe components at designated speeds. The components are wired to instruments that measure impact forces and component distortion. High-speed films provide slow-motion playback, illustrating damage progression and bird trajectory after impact. Figure 12.1 shows a typical bird-impact test installation for windshields.

Engine testing begins on individual fan blades that are subjected to impact-loading tests to verify structural integrity. Euthanized birds are then fired into running engines from multi-barrel air guns. The engines are carefully monitored during both impact and a fixed-time run-on period following impact, recording engine parameters such as pressures, temperatures, accelerometer forces and strain-gauge values. Impact tests are also filmed at high speed to observe bird trajectories and engine-blade deformation. Figure 12.2 shows an example of aircraft engine bird-impact testing equipment.

Recently, airframe and engine manufacturers have investigated the use of computer simulation in modelling bird strikes. This technique will prove extremely useful during research and development, eliminating costly live testing that sometimes

Figure 12.2 Bird impact test facility for jet engines.

results in the destruction of prototype engines and windshields. Manufacturers are also examining the use of model birds for impact testing—tools that not only offer consistent density and shape and more accurate test results, but also address concerns raised by animal- welfare groups.

Conclusion

The aviation manufacturing industry strives to continuously improve product quality. In order to reduce the potential for damage from a wildlife strike, the following principles should be addressed:

- Airframe and engine manufacturers must continue to evaluate data to ensure that certification standards reflect real-life bird-strike risks.
- Manufacturers must apply design-technology and material advances to engines and airframes to improve bird-impact resistance. However, when new materials are used to achieve benefits such as weight reduction—as in composite propellers on modern turboprop transport aircraft—the industry must ensure that failure properties are properly tested.
- Manufacturers must continually evaluate and modify testing methods to ensure that they reflect actual scenarios.
- The industry should remember that although new certification standards have recently been implemented—and that newer standards are being developed—engines certified to the old rules remain the most common throughout the jet

transport fleet, and will continue to be for another generation. The increased bird-strike threat has led to improved standards only for the design and construction of future engines. This weak link in the safety chain reinforces the importance of airport bird-management efforts.

Chapter 13

Solutions — Lessons from Military Aviation Experience

Introduction

Based on the following accident statistics, it's clear that there has been and continues to be considerable and unique risks associated with bird-related accidents in military aviation settings. Please note that for the purpose of this list, serious accidents involve at least one of the following: a destroyed aircraft, an aircraft damaged beyond repair, or human fatality.

- For the period 1950 to 1999—and based on comprehensive data provided by 32 countries—there were 286 serious military aircraft accidents involving 141 fatalities.

- During the same period, there were approximately 67 serious accidents involving at least 24 fatalities in nine additional countries for which there is partial data.

- The totals for which complete or partial data exists therefore comprise a minimum of 353 serious accidents with 165 fatalities—148 aircrew and 17 people on the ground.

- Three of the 353 serious accidents involved the death of one flight-crew member as a result of windshield penetration. In each of these three accidents a second flight-crew member completed the flight. In all of the remaining 350 accidents, the aircraft were either destroyed or damaged beyond repair.

- As only one country provided complete data for the period between 1950 and 1999, one can assume that true serious-accident numbers likely exceed 353.

- Fatalities rose sharply in the decade commencing in 1990—at least 88 lives were lost. In addition, a minimum of three large four-engine military aircraft have been lost in bird-related military aviation accidents during the past 6 years. The problem appears to be growing more severe.

- Unofficial reports indicate that several additional losses have occurred in the year 2000.

Comparison of military and civilian aviation: aircraft type and role

Military transports

Military aviation bears the greatest resemblance to its civilian counterpart in the fleets of large, long-range, jet-powered transport aircraft such as those used by the United States Air Force (USAF). These aircraft include:

- the Lockheed C-141 Starlifter, a four-engine jet;
- the Lockheed C-5 Galaxy, the world's third-largest transport; and
- the new four-engine McDonnell-Douglas (now Boeing) C-17.

The Coalition of Independent States (CIS)—including Russia, and the Ukraine —employs:

- the four-engine Ilyushin Il-76 Candid;
- the four-engine Antonov AN-124 Condor, the world's second-largest transport aircraft; and
- the six-engine Antonov AN-225, the world's largest aircraft.

By far the most common military transport aircraft is the four-engine turboprop Lockheed Martin C-130 Hercules, which first saw service in 1955. Designed for short, rough landing strips close to battlefields, the C-130 continues to be popular; in 1998 there were 1,447 C-130s in the military fleets of 56 countries. New models include upgraded avionics and engines.

Photo courtesy Denis Cloutier

A C-130 Hercules, similar to the aircraft that crashed as a result of a bird strike at Eindhoven AFB in Holland on July 15, 1996; 34 lives were lost.

Photo courtesy Denis Cloutier

Boeing KC 135. This aircraft is used for air-to-air refuelling.

Tankers

Certain civilian jet transport aircraft have been adapted as tankers for military use, carrying fuel and providing in-flight refueling for fighter aircraft. The USAF—including the Air Force Reserve and the Air National Guard—flies two types of tanker aircraft:

1. the older four-engine KC-135—the precursor of the Boeing 707 passenger jet—and
2. the newer KC-10—a modified Douglas DC-10.

Other countries use converted bombers as tankers. For example, the U.K. operates BAe Victors, which have four turbofan engines, while the CIS use the twin-turbojet Tupolev Tu-16 Badger.

As tankers generally fly for long periods at high altitudes, they are susceptible to bird strikes only during takeoff and landing phases. Therefore, these aircraft are at the same level of strike risk as their civilian counterparts.

Maritime patrol, anti-submarine warfare and airborne warning-and-control aircraft

A variety of military aircraft are used for maritime patrol and anti-submarine warfare (ASW). The most common maritime patrol aircraft is the Lockheed P-3 Orion, a military version of the Lockheed Electra. The P-3 has four turboprop engines and can fly for up to 12 hours. There are an estimated 500 P-3s in use by 14 countries; the Canadian military uses a version of the P-3 called the CP-140 Aurora. The CIS equivalent of the P-3 is the four-engine turboprop Ilyushin Il-38. The Royal Navy

Photo courtesy Denis Cloutier

E-3B AWACS. The USAF has lost only one of these aircraft, and that was due to a bird strike on September 22, 1995 at Elmendorf AFB, Alaska.

flies the BAe Nimrod, a four-engine derivative of the Comet passenger jet. Several European nations use the French-built Dassault-Breguet Atlantic for maritime patrol and ASW work. These aircraft spend most of their time at relatively high altitudes when moving to and from patrol areas, but do descend to low levels (less than 500 ft) over the ocean while conducting ASW patrols.

The E-3 Sentry Airborne Warning and Control Systems (AWACS) aircraft is a derivative of the KC-135/Boeing 707, and conducts long patrols at high altitudes. Used in Europe and by NATO, the E3 circles near battlefields and acts as an airborne air-defence operations centre. In terms of bird-strike risks, the Boeing E-3 is as susceptible as many older passenger jets still flying throughout the world. The CIS equivalent of the E-3 is the Ilyushin Il-76 Mainstay, a modified version of the Il-76 four-engine Candid transport aircraft.

Bombers

The most famous bomber in operation today is the B-52 Stratofortress operated by the Strategic Air Command of the USAF. Powered by eight turbojet engines and carrying a large payload over long distances, the B-52 operates at high altitudes—above airspace regularly occupied by birds. The newer Rockwell International B-1B supersonic long-range bomber operates at extremely high speed at both high and low altitudes. In the high-altitude mode these aircraft face similar bird-strike risks as civilian jet transports, primarily during landing and takeoff; at low levels, B-1Bs are at much higher risk, especially considering their high airspeeds. The USAF Northrop B-2 stealth bomber operates mostly at moderate to high altitudes—above most birds.

Rockwell International B-1B. On September 28, 1987 a B-1B was lost in a collision with an American White Pelican while on a low-level mission in Colorado. Three crew members died.

Fighter and attack aircraft

These aircraft are unique to military aviation. They feature one or—at the most—two engines, and flight crews of one or two persons. Air-superiority fighters avoid detection by flying at extreme high and low altitudes. These aircraft also fly low to conduct attacks on ground targets, and it is during these high-speed, low-level flights that birds are most likely to be struck.

Examples of air-superiority fighters include the Grumman F-14 Tomcat flown from U.S. Navy aircraft carriers. The Tomcat is a twin-engine, twin-crew, variable-geometry wing aircraft. The USAF equivalents are variations of the McDonnell Douglas (now Boeing) F-15 Eagle—a sophisticated, twin-engine, single- or dual-seat, all-weather multiple-role air-superiority fighter. Israel, Japan and Saudi Arabia also fly the F-15 in a variety of roles. The General Dynamics (now Lockheed Martin) F-16 Falcon is a single-engine, single-seat fighter that was developed for the USAF. It is relatively inexpensive compared to other sophisticated modern fighters and is used by the military forces of 17 countries. The UK, Italy and Germany rely on the Panavia Tornado ADV, a twin-engine, variable-geometry wing, all-weather fighter.

The French-built Dassault-Breguet Mirage III is one of the most widely used fighter and attack aircraft, flown by 25 countries around the world. The McDonnell Douglas/Northrop F/A-18 Hornet is a classic dual-role fighter and attack aircraft originally developed for the U.S. Navy as a carrier-borne, single-seat, twin-engine, air-superiority and ground-attack aircraft. Known in Canada as the CF-18, the F-18 is also flown by seven other countries.

The French-built Mirage 5 is the ground-attack version of the Mirage III. A much slower ground-attack aircraft is the Fairchild Republic A-10 Thunderbolt, more

Photo courtesy Denis Cloutier

General Dynamics F-16 Falcon

commonly known as the warthog—a single-seat, twin-turbofan, subsonic aircraft. The A-10 is heavily armoured and carries massive ground-attack armament. Operating almost exclusively at low levels, A-10s are more vulnerable to bird strikes.

Military training aircraft

Military pilots in training start in relatively small, two-seat, single- or twin-engine aircraft before being streamed into aircraft more closely resembling the bombers, fighters and attack aircraft and helicopters they will eventually fly. In recent decades, jets have taken over as the advanced trainers of choice, while there has been a move to conduct initial training in single-engine turboprops. Single PT6 turboprops are featured in both the Texan II—being delivered to the USAF and Navy—and the Royal Canadian Air Force version of the same aircraft, the Harvard II. Jet trainers include the twin-engine T-37 and T-38A (U.S.), and the single-engine CT-114 Tutor (Canada) and the British Aerospace Hawk (U.K.).

Single-engine turboprop training aircraft are at lower risk of serious bird strikes. Turboprop engines are more strike resistant than jets; their air-intake path does not permit direct access by FOD to the internal working parts of the engine. These aircraft are also equipped with windscreens that are more resistant to bird strikes. While there are no records of serious bird-strike accidents involving these trainers, they've been in use for a relatively short period of time and are not deployed in as many countries as their jet counterparts.

Initial-level training aircraft are used mostly for short-range, low-altitude flights such as circuits at aerodromes. Advanced-level aircraft such as the CT-114 Tutor and T-38A are employed in a number of training scenarios involving low- and high-altitude and short- and long-range missions.

Helicopters

Many helicopter types are used for military purposes, from large, twin-engine, heavy-lift versions to light single-engine utility helicopters. Most of these machines play transport roles at altitudes of a few thousand ft AGL. In some situations, however, altitudes are lower and the bird-strike risks are increased. Some types of helicopters have been converted into helicopter gun ships that have an offensive role, such as the McDonnell Douglas AH-64A Apache—designed as an attack helicopter. The Apache is a twin-turboshaft, two-seat, all-weather attack helicopter that flies at low altitudes, often at night. Although a substantial amount of military helicopter flying is done at low levels, the speeds involved are much lower than those of fighter and attack aircraft. Therefore, bird-strike probability is high, but damage severity is usually lower.

Mission profiles

There are important differences between the routes and altitudes—commonly referred to as the mission profiles—of military and civilian aircraft; some of these profiles have been mentioned above and are discussed in more detail later in this chapter. There are also fundamental systemic differences between civilian and military flying. The majority of civilian operations carried out by vulnerable jet transport aircraft involve scheduled airline service in which commercial schedules provide a strong impetus to fly regardless of the level of bird-strike risk.

Military flight planners have much more flexibility in devising the timing and routes of training flights, routine patrols and missions. Obviously, this flexibility is greatly reduced during wartime. During peacetime, training flights can be moved from one location to another to avoid bird threats. Training flights may also be scheduled when airborne birds are less prevalent. For example, early morning training flights will reduce risks in areas where vultures and other soaring birds are the main concern. In other locations, midday training flights might reduce the risk associated with geese, gulls and ducks that are flying to and from feeding and roosting areas.

Military-fleet distribution

Each year, the journal *Aviation Week and Space Technology* publishes a compendium of aviation statistics entitled the *Aerospace Source Book*. Statistics in the 2003 edition show that 171 countries reported operating military aircraft. (Note that these numbers include many unsophisticated transport and general-aviation aircraft types used for utility purposes.)

The world's 20 largest military fleets are listed in descending order in Table 13.1. The numbers are impressive, but it should be remembered that there have been substantial reductions in the military fleets of several countries in the past few years. For example, between 1998 and 2003, the Canadian Forces' fleet was reduced from 581 to 427 aircraft.

Country	Number of Aircraft
1. U.S.A.	16,511
2. China	9,372
3. Russia	9,220
4. Ukraine	2,687
5. France	1,868
6. India	1,820
7. Japan	1,749
8. United Kingdom	1,574
9. North Korea	1,536
10. Germany	1,324
11. Italy	1,252
12. South Korea	1,249
13. Libya	1,091
14. Syria	1,053
15. Isreal	1,038
16. Iran	931
17. Egypt	927
18. Pakistan	923
19. Taiwan	891
20. Turkey	865
↓	↓
Canada	427

Table 13.1 World's Largest Military Aircraft Fleets.
Based on *Aviation Week and Space Technology, Aerospace Source Book*, January 19, 2004. The list includes all types of aircraft operated by a country's armed forces.

Military strike databases

Military wildlife-strike databases resemble those maintained in civilian aviation (see Chapter 7), and present similar challenges to analysis—notably fluctuations and inconsistencies in reporting procedures and data. Nonetheless, the authors of this book have made every effort to reconcile the variations found throughout the military databases that were examined. We acknowledge that the following sections present our subjective analysis of this information. Further information and clarity can be found in the original data referenced at the end of this book.

Canada

In Canada, the Department of National Defence (DND) collects bird-strike statistics for all Canadian military aircraft. The strike data are sent to Transport Canada where they are included in the annual report known as *Bird Strikes to Canadian Aircraft* (discussed in more detail in Chapter 7). Separate reports for civilian and military aircraft have been compiled for 15 years—1984 to 1988 and 1991 to 2000. Reports previous to

1984 did not separate military and civil aviation. Since separate reporting began, there were 2,229 reported strikes to Canadian military aircraft—an average of 171 strikes per year. The average was higher between 1984 and 1988—247 strikes per year—than during the 1991 to 1998 period—124 strikes per year. It is not clear whether this trend is related to:

- a smaller number of aircraft and reduced flying hours in recent years,
- different reporting rates in the two periods, or
- improvements to safety in the later period.

There was a steady decline in the total number of hours flown by the Canadian Armed Forces during the ten-year period from 1988 to 1997. During this time, the average number of hours flown per year was 231,162. Total hours have decreased from 294,124 in 1988 to 170,140 in 1997—a steady decline of 42 percent over the ten-year period. Over the same period, the number of recorded bird strikes declined from 290 in 1988 to 114 in 1997, a decline of 61 percent. The recorded strike rate has decreased as well—from 12.5 per 10,000 hours in 1988 to 6.7 strikes per 10,000 hours in 1997. Assuming that the reporting rate has not changed, the decline in strike rate indicates that there has been an improvement in the operations of the Canadian Armed Forces with respect to the bird-hazard issue.

United States

Through its Bird Aircraft Strike Hazard (BASH) Team, the USAF maintains a comprehensive database. During the 13-year period from 1985 to 1997, a total of 34,830 strikes were recorded—an average of 2,681 strikes per year, varying annually between 2,267 and 3,066 strikes. Strike statistics for the U.S. Navy, Marine Corps, Army and Coast Guard air services are not routinely collected and published.

Europe

The air forces of Europe submit bird-strike statistics to EURBASE, the European military bird-strike database. These statistics were summarized in a paper presented by Mr. Arie Dekker of the Royal Netherlands Air Force to the International Bird Strike Committee at its 24th meeting in Slovakia in September 1998. Although EURBASE became operational in 1990, several air forces submitted data on bird strikes that occurred prior to that date. By the end of 1997, the database contained information on 34,564 bird strikes from 17 air forces, including 1,458 records—4 percent of the total—from before 1980. The main contributors to the database are:

- Britain's Royal Air Force (11,394 strikes, 33%);
- the West German Air Force (9,000 strikes, 26%);
- the French Air Force (3,498 strikes, 10%);
- the Royal Netherlands Air Force (3,413 strikes, 10%);
- the Israeli Air Force (2,465 strikes, 7%); and
- the USAF, reporting occurrences in European air space (2,264 strikes, 7%). U.S. records were submitted for the period 1985-1992; recent U.S. statistics have not been submitted to EURBASE.

Year	Number of Strikes	Cost (USD$)
1985	2,717	5,452,151
1986	2,850	18,081,085
1987	2,732	239,343,668
1988	2,640	3,353,576
1989	3,066	24,408,483
1990	2,927	6,471,984
1991	2,752	17,656,528
1992	2,267	26,001,901
1993	2,431	13,150,533
1994	2,334	15,485,416
1995	2,632	84,582,992
1996	3,102	8,773,172
1997	2,714	9,810,083
1998	3,054	29,602,218
Total	38,218	502,173,790

Table 13.2 Costs of Bird Strikes to U.S. Air Force Aircraft

Costs associated with military bird strikes

The most complete cost estimates for damage caused by bird strikes are maintained by the USAF, and are summarized in Table 13.2. Overall identified costs were USD$502 million during the 14-year period from 1985 to 1998.

The preceding data is dominated by a strike that caused the 1987 Colorado crash of a B-1B bomber, which had a replacement cost of approximately USD$200 million at the time. The 1995 data are heavily influenced by the crash of an AWACS aircraft that struck Canada Geese on takeoff from Elmendorf Air Base in Anchorage, Alaska.

Most bird strikes do not result in damage to aircraft. Between January 1985 and February 1998, more than 95 percent of strikes (33,262 of 34,856) were reported to be non-damaging, incurring less than USD$10,000 in damage per occurrence. Damaging strikes are classified by cost:

- Class C: between USD$10,000 and USD$200,000 in damage;
- Class B: between USD$200,000 and USD$1 million in damage; and
- Class A: either USD$1 million in damage or the loss of an aircraft and/or a fatality.

Between 1985 and 1998 there were:

- 1,477 Class C events (4.2 percent),
- 59 Class B events (less than 0.1 percent), and
- 23 Class A events (less than 0.01 percent).

The costs listed in Table 13.2 are minimal; they do not include estimates of ancillary and indirect costs incurred through:

- site cleanups,
- crash investigations,
- deploying replacement aircraft,
- personnel required to complete missions delayed by bird-strike damaged aircraft, and
- legal and family compensation costs.

The total costs are for the USAF only. The aircraft associated with the U.S. Navy, U.S. Marine Corps, U.S. Army, U.S. Coast Guard—and their associated reserves—represent about 60 percent of the entire U.S. military aircraft fleet.

Given the absence of ancillary and indirect costs and the exclusion of approximately 60 percent of the military fleet, it is probably conservative to estimate that the total damage caused by birds during this 14-year period was more than one billion dollars; damage to U.S. military aircraft from bird strikes probably averaged between USD$75 million and USD$80 million per year.

The loss estimates in the previous paragraphs do not account for the deaths that accompanied some of the accidents. Between 1985 and 1998, there were 33 fatalities resulting from bird strikes to Air Force aircraft and one involving a U.S. Navy aircraft. Had the same number of aircraft been lost in civilian aviation, the number of deaths would have been significantly higher. Many military flight crews can eject from damaged aircraft—civilian flight crews cannot.

Military bird-strike accidents

As mentioned earlier, 95.4 percent of bird strikes do not cause appreciable damage to aircraft—at least in the experience of the USAF. Only strikes in the remaining 4.2 percent resulted in more than USD$10,000 damage per occurrence. Of greatest concern are bird strikes that:

- lead to fatalities,
- threaten crew safety by forcing ejections, and
- lead to the destruction of aircraft.

Dr. W. John Richardson of LGL Limited has compiled the most complete database on these types of bird-related military aviation accidents. Further information on his research can be obtained in the references at the end of this book.

European experience

Richardson's 1996 compilation included 46 years of data supplied by all major western and central European air forces, except Spain. For some countries, data was also available from navy and army air arms. Additional accident data was also recently made available from four eastern European air forces and Israel. Canadian and American losses in Europe are also relatively new additions to the compilation. Overall, the data included:

- 152 military aircraft lost in Europe,
- seven in Israel, and
- nine European aircraft lost outside the region.

Total fatalities reached 37; another 34 deaths occurred in the crash of a Belgian Air Force C-130 Hercules aircraft on July 15, 1996 (discussed later in this chapter).

Fatalities

Between 1950 and 1995, Europe's worst known bird-related accident took three civilian lives when a Belgian F-104 crashed in Germany in 1980. An East German Mi-8 helicopter crashed due to bird ingestion in 1975, resulting in three fatalities. A Royal Navy Sea King helicopter lost with 22 fatalities near the Falkland Islands on 19 May 1982 is thought to have been the victim of a bird strike, but the official cause is listed as *not positively determined* (Richardson 1996). Two aircrew died in each of at least six accidents involving either European or Israeli aircraft; 19 accidents occurred with one fatality each. Overall, there were at least 27 accidents involving between one and three fatalities, and 126 accidents with no fatalities. In the other 15 cases (14 pre-1980) it is not known whether there were any fatalities. During the period 1950 to 1995 there was one Soviet fatality in Asia and three U.S. fatalities.

Geographic distribution of accidents

The numbers of bird-related accidents involving European military aircraft are listed in Table 13.3. The numbers of accidents for each country are related to the size of the air force, the completeness of the records and the types of aircraft flown. The military of the United Kingdom shows the largest number of accidents with 58. Other significant losses occurred to the aircraft of:

- West Germany (23 bird-related accidents),
- Netherlands and East Germany (10 each),
- Sweden (9), and
- France (7).

The reported numbers grossly under-represent the situation in the CIS.

Some bird-strike accidents occur outside the borders of the operating country, including:

- 2 Belgian,
- 2 French,
- 7 West German,
- 4 Netherlands, and
- 18 British aircraft.

Since 1964, eight of the 17 known Canadian losses due to bird strikes were in Europe. At least seven U.S. aircraft have been lost to bird strikes in Europe since 1973.

Date	Location	Service	Aircraft		# Persons			Flight Phase	Time	Type of Bird Struck	Altitude		Parts Hit		
Y M D			Type	Category	Ab.	Ej.	Killed				AGL (feet)	Speed (knots)	Ws	En	Other
Belgian AF															
770926	W. Germany	AF	Mirage 5	FA 1	1	1	0	CrL	D	Pigeons, Wood	600	420	P		
800512	W. Germany	AF	TF-104	FA 1	2	2	3grnd	CrL	D	prob. birdstrike	500	450		F	
881117	Belgium	AF	F-16	FA 1	1	1	0	Cl	D	Pigeons, Wood	400	200		F	
890718	Belgium	AF	Mirage 5	FA 1	1	0	0	Ap	D	Pigeons, Wood	300	195		F	
Canadian Forces (Europe only)															
641027	France	AF	CF-104	FA 1	1	1	0	CrH	D	corvid?	2000	200	-	F	
650916	W. Germany	AF	CF-104	FA 1	1	1	0	Ap	D	unkn.	3000	300	-	F	
650916	France	AF	CF-104	FA 1	2	2	0	CrL	D	unkn.	7-1000	410	-	F	
660321	W. Germany	AF	CF-104	FA 1	1	1	0	CrL	D	unkn.	1000	410	-	F	
670718	Denmark	AF	CF-104	FA 1	1	1	0	CrL	D	gull?	300	420	-	F	N
690425	France	AF	CF-104	FA 1	1	1	0	CrL	D	large	800	420	P	-	
780818	W. Germany	AF	CF-104	FA 1	1	1	0	CrL	D	unkn.	800	420	-	F	
810316	W. Germany	AF	CF-104	FA 1	2	2	0	CrL	D	buzzard	500	510	-	F	
Czech & Slovak AF															
6_	Czechoslovakia?	AF	MiG-15	FA 1	1?		1			unkn.			P	-	
850510	Czechoslovakia	AF	MiG-21	FA 1	1	0	0	TO	D	gulls	5	135	-	I	
French AF & Navy															
900517	France	AF	Mir. 2000	FA 1	2	2	0	CrL	D	gull	500	400	S	F	
900726	Chad	AF	Mir. F1	FA 1	1	1	0	CrL	D	unkn.	300	475	-	F	A
910314	France	AF	Jaguar	FA 2	1	1	0	CrL	D	>1	500	400	S	I	
920613	Chad	AF	Jaguar	FA 2	1	1	0	Cl	D	Egrets, White	50	185		F	
960119	France	AF	Mir. 2000	FA 1	2	2	0	Ap	D	Gull, Yel.-leg.	110	135		I	
920204	France	Na	S.Etendard	FA 1	1	1	0	CrL	D	Gannet, North.	100	480	S	F	
960126	France	Na	S.Etendard	FA 1	1	1	0	CrL	D	Gull, Yel.-leg.	500	450	P	-	

Table 13.3 Serious military aviation bird-strike accidents in Europe and Israel (includes accidents in other locations that involved European aircraft). All listed accidents involved one or more of the following: destruction of the aircraft and fatalities.

Date	Location	Service	Aircraft			# Persons			Flight Phase	Time	Type of Bird Struck	Altitude		Parts Hit		
Y M D			Type	Category		Ab.	Ej.	Killed				AGL (feet)	Speed (knots)	Ws	En	Other
Germany (East) AF																
670807	E. Germany	AF	MiG-21	FA	1	1	1	0	CrH	D	unkn.	>3300	>324	-	F	
67-74	E. Germany?	AF	MiG-21	FA	1	1		1			unkn.					
720320	E. Germany	AF	MiG-21	FA	1	1	0	0	Dem	D	>1	1000	324		F	F
740417	E. Germany	AF	MiG-21	FA	1	2	2	0	Cl	D	unkn.	<3300	<324	-	F	
750428	E. Germany	AF	Mi-8	H	2	3	na	3	Hov	T	unkn.	660	0	-	F	
761002	E. Germany	AF	MiG-21	FA	1	1	0	1	Cl	D	unkn.	165	216	-	F	
770817	E. Germany	AF	MiG-21	FA	1	1	1	0	Ap	D	unkn.	330	190	-	F	
820622	E. Germany	AF	MiG-23	FA	1	1	0	0	CrH	D	ducks	2000	485		I	F
880506	E. Germany	AF	MiG-21	FA	1	1	1	1	Cl	T	ducks	65	216		F	
880805	E. Germany	AF	MiG-21	FA	1	2	2	0	CrH	D	crows	1640	270		F	
Germany (West) AF & Navy																
620411	W. Germany	AF	F-84	FA	1	1	1	0	CrL	D	buzzard	500	<450	P	-	
640805	W. Germany	AF	G-91	FA	1	1	1	0	Cl	D	pigeons	100	160		F	
670516	W. Germany	AF	F-104	FA	1	1	1	0	CrL	D	gulls	500	450	P		
691130	W. Germany	AF	F-104	FA	1	1	1	0	CrL	D	duck?	800	450	-	F	
701030	W. Germany	AF	F-104	FA	1	1	1	0	CrL	D	crow	800	450	-	F	
710907	W. Germany	AF	G-91	FA	1	1	1	0	CrH	D	gulls	1200	<450	P		
720801	W. Germany	AF	G-91	FA	1	1	1	0	CrL	D	buzzard	500	360	-	F	
760809	W. Germany	AF	G-91	FA	1	1	1	0	CrL	D	buzzard	500	360	-	F	
771007	W. Germany	AF	TF-104	FA	1	2	2	0	CrL	D	pigeons	800	450		F	
781010	France	AF	F-104	FA	1	1	1	0	CrL	D	crows	800	420		F	
810706	W. Germany	AF	F-104	FA	1	1	1	0	CrL	D	buzzard	600	450	-	F	
810817	France	AF	F-104	FA	1	1	1	0	CrL	D	buzzard?	500	450	-	F	
820421	Italy	AF	F-104	FA	1	1	1	0	CrL	D	unkn.		450	-	F	

Table 13.3 (*continued*) Serious military aviation bird-strike accidents in Europe and Israel (includes accidents in other locations that involved European aircraft). All listed accidents involved one or more of the following: destruction of the aircraft and fatalities.

Date Y M D	Location	Service	Aircraft Type	Aircraft Category		# Persons Ab.	# Persons Ej.	# Persons Killed	Flight Phase	Time	Type of Bird Struck	Altitude AGL (feet)	Speed (knots)	Parts Hit Ws	Parts Hit En	Parts Hit Other
Germany (West) AF & Navy *continued*																
820804	W. Germany	AF	F-104	FA	1	1	1	0	CrL	D	unkn.		400	-	F	
670428	W. Germany	Na	F-104	FA	1	1	1	0	CrL	D	duck?	1000	200	-	F	
760315	W. Germany	Na	F-104	FA	1	1	1	0	CrL	D	Goose, Barnacle	800	420	-	F	
770419	Denmark	Na	F-104	FA	1	1	1	0	CrL	D	gulls	300	450	P	F	
780818	W. Germany	Na	F-104	FA	1	1	1	0	CrL	D	gulls	500	400		F	
780919	Denmark	Na	F-104	FA	1	1	1	0	CrL	D	gull	200	450	-	F	
781207	W. Germany	Na	F-104	FA	1	1	1	0	CrL	D	ducks	800	480		F	
790417	W. Germany	Na	F-104	FA	1	1	1	0	CrL	D	Shelduck	800	440	-	F	
810826	Denmark	Na	F-104	FA	1	1	1	0	CrL	D	gulls	150	500		F	
850208	Denmark	Na	F-104	FA	1	1	1	0	CrL	D	gull	350	450	-	F	
Hellenic (Greek) AF																
750627	Greece	AF	F-84	FA	1	1	1	0	CrL	D	pelican	1000	320	P	I	
921007	Greece	AF	Mir. 2000	FA	1	1	1	0	Cl	D	gull	100	240		F	I
841016	Hungary	AF	MiG-21	FA	1	2	2	1	Ap	D	Goose, Bean	850	205	-	F	
Israel AF																
730219	Israel	AF	Nesher	FA	1	1	1	0	CrL	D	buzzard	300	360	-	F	
741028	Israel	AF	A-4	FA	1	1	0	1	CrL	D	Pelican, G.Wh.	400	420	P	-	
790115	Israel	AF	A-4	FA	1	1	1	0	CrL	D	medium	500	500	-	F	
791007	Israel	AF	Kfir	FA	1	1	1	0	Ap	D	Pelican, G.Wh.?	900	220	-	F	
830504	Israel	AF	A-4	FA	1	1	1	0	CrL	D	Buzzard, Honey	300	420	P	-	
881218	Israel	AF	F-16	FA	1	1	1	0	CrL	D	Eagle, Golden	300	420	-	F	
950810	Israel	AF	F-15	FA	2	2	0	2	CrL	D	storks	300	550	-	F	F

Table 13.3 (*continued*) Serious military aviation bird-strike accidents in Europe and Israel (includes accidents in other locations that involved European aircraft). All listed accidents involved one or more of the following: destruction of the aircraft and fatalities.

Date	Location	Service	Aircraft			# Persons			Flight Phase	Time	Type of Bird Struck	Altitude		Parts Hit		
Y M D			Type	Category		Ab.	Ej.	Killed				AGL (feet)	Speed (knots)	Ws	En	Other
Italian AF																
890620	Italy	AF	Tornado	FA	2	2	2	0	CrL	D	poss. birdstrike	800	225		F	
891107	Italy	AF	G-91	FA	2	1	1	0	CrL	D	unkn.	900	400	-	F	
940601	Italy	AF	MB339	T	1	2	2	0	CrH	D	swifts?	2500	250	-	F	I
Netherlands AF																
590220	Nether.	AF	Hunter	FA	1	1	1	0	Cl?		unkn.	<8000		-	F	
590915	W. Germany	AF	Hunter	FA	1	1	1	0	CrH	N	unkn.	2500		-	F	
600707	Netherlands	AF	Hunter	FA	1	1	0	0	TO	N	gulls	0	[low]		F	
610620	Netherlands	AF	F-84	FA	1	1	0	0	TO		unkn.	0	[low]			
640729	Netherlands	AF	Hunter	FA	1	1	0	0	Cl		unkn.	low		-	I	
750711	W. Germany	AF	NF-5	FA	2	1	1	1	TO		Kestrel, Eur.	0	[low]	-	F	
790301	W. Germany	AF	F-104	FA	1	1	1	0	CrH		buzzard?	>2500		-	F	
811201	W. Germany	AF	F-104	FA	1	1	0	0	CrL		Duck, Eider	4-500		-	-	W I
831004	Netherlands	AF	F-16	FA	1	1	0	1	TO		Heron, Grey	0		-	F	
900504	Netherlands	AF	NF-5	FA	2	1	1	0	T&G		Pigeon, Hom.	low		-	I	
Norwegian AF																
710809	Norway	AF	F-5	FA	2	1	0	1	CrL	D	Gull, Les.Bl.-bk.	500	3-400	P	-	
810602	Norway	AF	F-16	FA	1	1	1	0	CrH	D	Crane, Eur.	2500	450	P	-	
950504	Norway	AF	F-16	FA	1	2	2	0	Cl	D	Gull, Gr. Bl.-bk.	1100	320	-	F	
Portuguese AF																
880309	Portugal	AF	A-7	FA	1	1	1	0	CrL	D	seabird	350	360	-	F	
920429	Portugal	AF	A-7	FA	1	1	0	1	CrH	D	unkn.	2-4.5k	3-450	S	-	

Table 13.3 (*continued*) Serious military aviation bird-strike accidents in Europe and Israel (includes accidents in other locations that involved European aircraft). All listed accidents involved one or more of the following: destruction of the aircraft and fatalities.

Date	Location	Service	Aircraft			# Persons			Flight Phase	Time	Type of Bird Struck	Altitude		Parts Hit		
Y M D			Type	Category		Ab.	Ej.	Killed				AGL (feet)	Speed (knots)	Ws	En	Other
Swedish AF																
670627	Sweden	AF	Lansen	FA	1	2	0	0	Cl		gull	20	TO	-	F	
690313	Sweden	AF	Lansen	FA	1	2	2	0	CrL		large	100	430	-	F	
700531	Sweden	AF	Lansen	FA	1	2	2	2	Cl		Starlings, Eur.	35	175		F	
730416	Sweden	AF	Draken	FA	1	1		1	CrL		unkn.	165	595			
731017	Sweden	AF	Draken	FA	1	1	0	0	TO		gulls	0	165	S		
741005	Sweden	AF	Lansen	FA	1	1	1	1	CrL		unkn.	165	430	-	F	
760830	Sweden	AF	Lansen	FA	1	2	2	0	Cl		unkn.	TO	160	-	F	
770321	Sweden	AF	Viggen	FA	1	1	0	1	CrL		prob. birdstrike	~85	595	S	-	
770901	Sweden	AF	Lansen	FA	1	1	0	0	TO		small, >1	0	110			
Swiss AF																
741023	Switzerland	AF	Mirage III	FA	1	1	1	0	Cl	D	Gulls, Bl.-head.	50	190	S	F	
910812	Switzerland	AF	Hunter	FA	1	1	0	0	Dem	D	unkn.	<1650	405	-	-	W I
United Kingdom (AF, Navy, Army)																
530730	France	AF	Vampire	FA	1		0?	0?	CrL?		>1	low			I	W F
531023	UK/England	AF	Canberra	B	2	2	0?	2	Cl		>1	v.low	[low]		F	U
550226	UK/England	AF	Meteor	FA	2				CrL?		unkn.	low				
560127	UK/Scotland	AF	Vampire	FA	1	1	0	0	CrL?		unkn.	low				
560202	HongKong	AF	Vampire	FA	1	1	0	0	cir.		unkn.					
561003	UK/Scotland	AF	Hunter	FA	1	1			TO		unkn.	'TO'	[low]	-	I	
561101	UK/England	AF	Hunter	FA	1	1	0	0	CrL?		unkn.	low				
570410	UK/Wales	AF	Vampire	FA	1	2?	0?	0?	CrL?		gulls	500		-	-	W I
570522	UK/England	AF	Hunter	FA	1	1	0	0			unkn.					
570628	UK/Scotland	AF	Hunter	FA	1	1	0	0	cir.		unkn.					

Table 13.3 (*continued*) Serious military aviation bird-strike accidents in Europe and Israel (includes accidents in other locations that involved European aircraft). All listed accidents involved one or more of the following: destruction of the aircraft and fatalities.

Date Y M D	Location	Service	Aircraft Type	Aircraft Category		# Persons Ab.	# Persons Ej.	# Persons Killed	Flight Phase	Time	Type of Bird Struck	Altitude AGL (feet)	Altitude Speed (knots)	Parts Hit Ws	Parts Hit En	Parts Hit Other
United Kingdom (AF, Navy, Army) *continued*																
571114	UK/Scotland	AF	Hunter	FA	1	1	0	0	Cl		unkn.	1800	300	-	I	I
580212	UK/England	AF	Vampire	FA	1	1	0	0	TO		unkn.	'TO'	[low]			
591110	UK/England	AF	Hunter	FA	1	1	0	0	CrL?		gulls	300			I	I
591118	Aden	AF	Venom	FA	1	1					unkn.					
600329	Aden	AF	Hunter	FA	1	1	0	0	CrL	D	gull	250	400			
600507	UK/England	AF	Vampire	FA	1	1			CrL?	D	unkn.	100				
601109	W. Germ.	AF	Hunter	FA	1	1	0	0	CrL		unkn.	250	390			
610316	W. Germ.	AF	Swift	FA	1	1	0	0		D	unkn.			-	-	I
620904	UK/England	AF	Vampire	FA	1	2?	0?	0?	TO	D	gulls+plovers	0	100			
640817	HongKong	AF	Canberra	B	2				TO		Kites, Black-ear.	TO	[low]	-	I	
640930	UK/England	AF	Jet Prov.	T	1	2?	2?	0	CrL	D	large	300	190			
650714	Netherlands	AF	Canberra	B	2			2?	OvSh	D	unkn.	300	130	-	F	
660727	UK/England	AF	Jet Prov.	T	1	2?	2?	0?	CrL	D	unkn.	250	180			
681120	UK/England	AF	Canberra	B	2				TO	D	gull	TO	105	-	I	
710225	W. Germany	AF	Canberra	B	2		0?	0?	CrL	D	unkn.	100	300	S	-	N
710629	UK/England	AF	Jet Prov.	T	1	2	2	0	Ap	D	large	300	110	-	F	F
720426	UK/England	AF	Harrier	FA	1	1	1	0	CrL	D	gulls	500			F	
720504	Denmark?	AF	Harrier	FA	1	1	1	0	CrL		large	400	360	-	I	
720627	W. Germany	AF	Harrier	FA	1	1	1	0	CrL	D	Gull, Bl.-head.?	700	420	-	F	N
730709	W. Germany	AF	Harrier	FA	1	1	1	0	Cl	D	>1	20	135		F	
731012	UK/England	AF	Gnat	T	1	2	0	0	CrL	D	small, several	250	360		I	N I
740107	UK/England	AF	Jet Prov.	T	1	1+	0?	0	CrL	D	Pigeon, Wood	300	230	S	-	N
740516	W. Germany	AF	Harrier	FA	1	1	1	0	Cl	T	small	20	20	-	F	
760928	UK/England	AF	Victor	K	4		0	0	TO	D	gulls	0	145	-	-	NWF
790326	W. Germany	AF	Jaguar	FA	2	2	2	0	CrL	D	Rook	250	240	P	F	

Table 13.3 (*continued*) Serious military aviation bird-strike accidents in Europe and Israel (includes accidents in other locations that involved European aircraft). All listed accidents involved one or more of the following: destruction of the aircraft and fatalities.

Date Y M D	Location	Service	Aircraft Type	Aircraft Category		# Persons Ab.	# Persons Ej.	# Persons Killed	Flight Phase	Time	Type of Bird Struck	Altitude AGL (feet)	Altitude Speed (knots)	Parts Hit Ws	Parts Hit En	Parts Hit Other
United Kingdom (AF, Navy, Army) *continued*																
800312	UK/Wales	AF	Harrier	FA	1	1	1	0	CrL	N	buzzard	200	420	S	F	
800731	UK/England	AF	Jet Prov.	T	1	1	1	0	Cl	D	Pigeons, Hom.	400	140		F	M
801117	UK/Scotland	AF	Nimrod	P	4	20	na	2	Cl	D	Gulls, Bl-h+Com.	20	138	S	F	NWTF
810601	UK/Scotland	AF	Jaguar	FA	2	2	2	0	CrL		Gull, Bl.-head.	300	450	P	F	
810724	UK/England	AF	Jaguar	FA	2	2	2	1	CrL	D	gull	500	450	P	F	
821020	UK/England	AF	Hawk	T	1	1	1	0	Ap	D	unkn.	350	130	-	F	
830919	UK/Scotland	AF	Jaguar	FA	2	1	1	0	Ap		Lapwings	100	[low]		F	U
831121	UK/England	AF	Jet Prov.	T	1	2	2	0	CrL	T	>1	low			F	U
840815	UK/England	AF	Jet Prov.	T	1	2	0	0	Cl	D	Avoiding Birds	25	low	-	-	-
841107	UK/Wales	AF	Hawk	T	1	2	2	0	T&G	D	Lapwings	100	140	-	F	F
841129	S. Atlantic	AF	Harrier	FA	1	1	1	0	CrL		seabird, large	250	480	S	-	N
860929	UK/England	AF	Bulldog	pT	1	2	na	0	Cl	D	Avoid Sim. Birds	~250	[low]	-	-	-
890914	UK/England	AF	Tornado	FA	2	2	2	0	Cl		gulls	150	170		F	
910925	UK/England	AF	Harrier	FA	1	2	2	0	CrL	D	Gulls, Bl.-head.	250		P	-	U
930628	UK/England	AF	Harrier	FA	1	1	1	0	CrL		prob. birdstrike	low		-	-	W
580428	UK/Scotland	Na	SeaHawk	FA	1	1	0	0		D	unkn.		450	-	I	I
581028	Nigeria	Na	SeaVixen	FA	2	2	2	0	CrL	D	vulture	100	420	-	I	
621115	UK/Scotland	Na	Scimitar	FA	2	1	1	0	CrL	D	gull?	400	420	-	I	
841201	UK/Scotland	Na	SeaHarri.	FA	1	1	1	0	CrL		unkn.	500	450	-	F	
851129*	UK/England	Na	Hunter	FA	1	1	0	0	CrL		unkn.	250	480	-	-	I
871015	N.Ireland	Na	SeaHarri.	FA	1	1	1	0	CrL		large	250	[low]	-	F	
860429	UK/England	Ar	Gazelle	H	1	4	na	0		D	Avoiding Birds	125	[low]	-	-	-
911114	N.Ireland	Ar	Lynx	H	2	11	na	1	CrL	D	Avoiding Birds	low		-	-	-

Table 13.3 (*continued*) Serious military aviation bird-strike accidents in Europe and Israel (includes accidents in other locations that involved European aircraft). All listed accidents involved one or more of the following: destruction of the aircraft and fatalities.

Date Y M D	Location	Service	Aircraft Type	Aircraft Category	# Persons Ab.	# Persons Ej.	# Persons Killed	Flight Phase	Time	Type of Bird Struck	Altitude AGL (feet)	Altitude Speed (knots)	Parts Hit Ws	Parts Hit En	Parts Hit Other
United States (Europe only)															
750305	UK/England	AF	F-111	FA 2	2		0?	CrL		gulls	1000	480	?	?	M
751105	UK/England	AF	F-111	FA 2	2	2	0	CrL	D	duck	400	450	S	-	
801113	Spain	AF	F-4	FA 2	2	1+	1	CrH	D	hawk	3500	530	P	-	
840809	UK/Scotland	AF	F-111	FA 2	2	2	0	CrL	D	Gull, Herring	200	hi	-	I	N
861008	Spain	AF	F-16	FA 1	1	1	0	CrL		Vulture, Griffon	low		-	F	I
870520	Spain	AF	F-4	FA 2	2	0	2	CrH		Vulture, Griffon	2000	[low]	P	-	
840908*	W. Germany	Ar	RV-1	O 2	2	2	0	Cl		>1	[low]			F	U
Former USSR (very incomplete)															
?	Asia	AF	MiG-17	FA 1	1	0?	1	CrL?		swan	v.low				
5304__	Ukraine	AF	Il-28	B 2					D	cranes	650		P		N
60summer	Ukraine	AF	Il-28	B 2			1+		D	bustard		380	P	-	
6604__	Estonia	AF	MiG-17	FA 1	1	0?	1		T	Crane, Eur.	2600	380	P	-	
6804__	USSR?	AF	MiG-21	FA 1	1	1	0?		D	stork	985	215	-	F	
701007	E. Germany	AF	?	FA	1	1	0	Ap	N	Lapwings	1000	162		F	
8003__	Ukraine	AF	MiG-21	FA 1					D	Rooks	330	200		F	
820710	Russia	AF	MiG-21	FA 1	1	1	0	Ap	D	Swift	395	97	-	F	
890608	France	AF	MiG-29	FA 2	1	1	0	Dem		unkn.	525	215	-	F	
911119	E. Germany	AF	MiG-23	FA 1	2	2	0	Ap		goose	500		-	F	

*Unofficial report of uncertain accuracy.

Aircraft Categories: B = Bomber; FA = Fighter/Attack; H = Helicopter; K = Tanker; O = Other; P = Patrol; pT = piston-engined Trainer; T =Trainer. Following digit shows number of engines.

 # Persons: Ab. = Number of aircrew aboard; Ej. = Number who ejected; Killed = Number of aircrew killed or (in one Belgian AF case) number killed on ground.

Flight Phase: TO = Takeoff; Cl = Climb; CrL = Cruise at low-level (up to 1000 ft AGL); CrH = Cruise at high altitude (above 1000 ft AGL); Ap = Approach; La = Land; T&G = Touch and go landing; OvSh = Overshoot; Dem = Demonstration flight; cir. = In circuit; Hov = Hover.

Time: D = Day; N = Night; T = Twilight.

Parts Hit: Ws = Windscreen: - = Not struck; S = Struck, not reported as penetrated; P = Penetrated.
En = Engine(s): - = No ingestion; I = Ingestion, damage limited or uncertain; F = Engine failure after ingestion.

Other parts reported struck: A = Probe; F = Fuselage; I = Intake; L = Landing gear; M = Multiple parts; N = Nose or radome; T = Tail; U = Unknown other parts; W = Wing(s).

Table 13.3 (*continued*) Serious military aviation bird-strike accidents in Europe and Israel (includes accidents in other locations that involved European aircraft). All listed accidents involved one or more of the following: destruction of the aircraft and fatalities.

Types of aircraft

The data up to and including 1995 indicate that most military aircraft involved in serious bird-related accidents have been single-engine fighters or attack aircraft (121 of 167) flown by one pilot. Single-engine trainers accounted for 12 of the losses. Twin-engine fighters and attack aircraft accounted for 21 accidents. Other twin-engine fixed-wing aircraft—mainly Canberra and Il-28 light bombers—accounted for eight losses. Other losses include three helicopters, two four-engine aircraft and one CIS fighter of unknown type.

The European data show that more than 92 percent of bird-related accidents involved fighter and attack aircraft and related trainers—aircraft that, for the most part, have no counterpart in civilian aviation.

Helicopter and four-engine aircraft losses are of interest because these aircraft are similar to civilian models. An East German Mi-8 helicopter was lost in 1975 after its turboshaft engine ingested a bird. Two British Army helicopters were reportedly lost after striking wires and crashing while avoiding birds. An RAF Victor four-engine tanker was lost in 1976 after multiple gull strikes led to an aborted takeoff above decision speed. It was later concluded that the bird strike caused little damage and the aircraft could have taken off.

A Nimrod four-engine patrol aircraft was lost in 1980 when three engines failed because of multiple gull strikes immediately after takeoff. One four-engine aircraft was reported lost in the U.K. before 1950. In 1944, an RCAF Halifax bomber was destroyed in a crash landing after a bird penetrated the windscreen and disabled the only fully qualified pilot. The relative rarity of serious bird-related accidents involving helicopters and four-engine aircraft is noteworthy and mirrors the civilian experience. However, when major damage does occur, the risk is high. Ejection seats are the exception—and non-existent in helicopters—and there are often a large number of personnel on board. Recent incidents involving large four-engine military aircraft are discussed later in this chapter.

Phases of flight

Of the 148 accidents for which phase of flight is known, 90 (61 percent) occurred away from the airport environment during cruise and weapons-range flight. Most of these serious en-route bird strikes (78 of 90) were in low-level flight at less than 1,000 ft AGL. Overall, bird-strike accidents to aircraft during low-level flight comprised 53 percent of the total recorded. Just over half of the accidents occurred during types of flight that are exclusive to military aircraft.

Of these same 148 bird-related accidents, 58 (39 percent) took place at or near airfields during takeoff, climb, approach, touch-and-go landings, overshoots and flight demonstrations—most occurred during takeoff and climb-out. The two known accidents involving European four-engine aircraft between 1950 and 1995 happened during or immediately following takeoff. Two subsequent European four-engine accidents involved a NATO E-3 AWACS on takeoff and a Belgian Air Force C-130 Hercules on short final approach.

Altitudes and speeds

Regarding bird-related accidents at known altitudes, 103 (72 percent) of 143 were encounters at 500 ft AGL or less; 27 more (19 percent) occurred between 501 and 1,000 ft. Of these 130 low-altitude strikes, 50 were near aerodromes and 72 were during low-altitude cruise or weapons-range flights. The highest altitudes at which strikes resulted in aircraft loss were 2,500 to 3,500 ft, where eight strikes occurred. Reported speeds during bird encounters that caused aircraft loss ranged from 0 kts for a hovering Mi-8 to 595 kts. Seven of these strikes were at 500 to 595 kts. Almost all high-speed accidents—above 400 knots—transpired during cruise or weapons-range flights and mainly at low altitude.

Parts of aircraft struck

Engines were reported as the aircraft part most commonly struck. Of the 144 serious accidents in which the part struck was reported, 102 involved the engines, and 24 were to windscreens and canopies; a further 11 involved engines and windscreens. There were only seven serious accidents in which the reported parts struck did not include either engines or windscreens.

Types of birds

Figure 13.1 summarizes the types of birds that have caused serious accidents in military aircraft in Europe between 1950 and 1995. The species of bird involved was unknown in 66 cases. In four additional cases, the accidents resulted from efforts to avoid birds rather than actually striking them. The birds responsible in the 98 identified strikes were:

- gulls (35),
- buzzards and hawks (11),
- ducks (8),
- pigeons (8), and
- corvids (6).

Other groups accounting for at least three to four accidents each were:

- seabirds (Gannet and two others),
- pelicans,
- herons, egrets and storks,
- cranes,
- geese,
- waders (lapwings or plovers in each case) ,and
- vultures.

All values should be considered minimums because of the many accidents for which bird type is unknown.

Gulls posed the greatest problem both near aerodromes and during low-level cruise, but caused only one known accident during cruise above 1,000 ft AGL. Similarly, pigeons caused accidents both near aerodromes and during low-level cruise. In

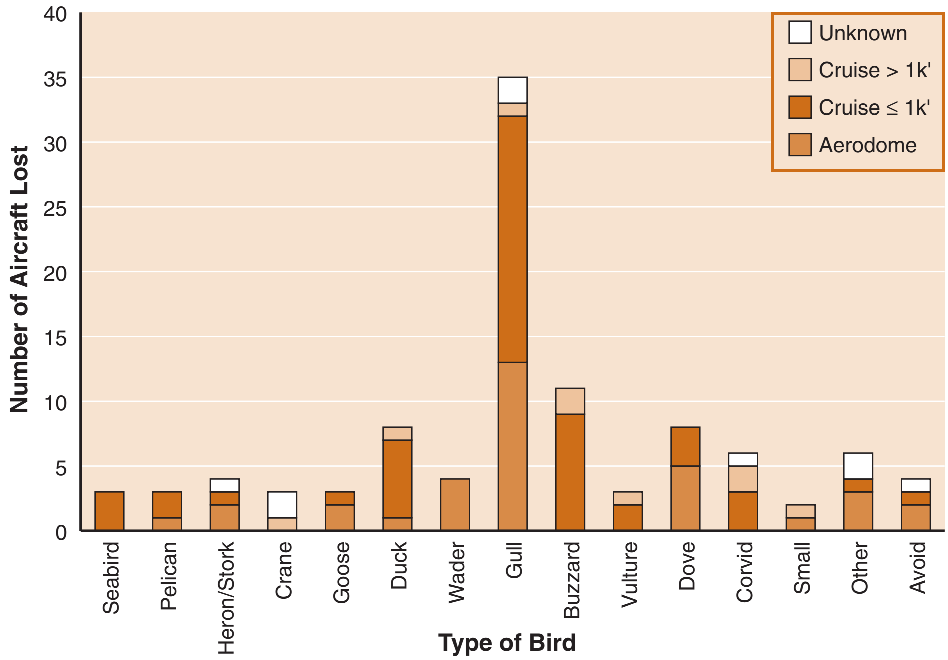


Figure 13.1 Types of birds causing serious accidents to military aircraft in Europe (1950-1995)

contrast, there were no known losses to buzzards or corvids near aerodromes; however, these birds were struck during both low- and high-altitude cruise. Losses to ducks were mainly during low-level cruise, as were all losses to seabirds and pelicans.

Canadian and U.S. experience

Table 13.4—adapted from preliminary work by West and Richardson (2000)—lists the serious military accidents that have involved birds in Canada and the United States. The table excludes accidents involving Canadian and U.S. aircraft in Europe.

There have been ten Canadian Forces aircraft lost to bird strikes in domestic airspace. They include five CF-104 Starfighters and five CT-114 Tutor trainers. There were two fatalities, both occurring when the crew of a Tutor was unable to safely eject after steering its aircraft away from the city of Regina.

Table 13.4 presents 55 serious accidents involving U.S. military aircraft in American airspace. These accidents involved 42 fatalities—24 in the crash of the E-3 AWACS at Anchorage, Alaska in 1995.

Overall, there were 62 Canadian and American accidents in which the phases of flight were known—24 (39 percent) were caused by birds during low-level flights.

This Canadian/American figure is somewhat lower than Europe's, where 72 percent (103 of 143) of accidents occurred during low-level flights.

There were major differences between the types of birds struck in North America and Europe. In Europe, gulls caused the most accidents—36 percent. In Canada and the U.S., gulls comprised only 11 percent (5 of 44) of the accidents caused by identified species. The most important group were vultures—Turkey Vulture and Black Vulture—which comprised 30 percent (13 of 44) of the accidents. Vultures were also responsible for 9 (38 percent) of the crashes that occurred during low-level flight. The remaining groups are:

- hawks and eagles, six accidents—14 percent—including five low-level flight accidents (21 percent);
- ducks (three accidents);
- White Pelican (two accidents);
- Snow Goose (two);
- Canada Goose (two);
- Sandhill Crane (two); and
- European Starling (two).

Case Studies

There have been several recent major bird-strike accidents involving military aircraft. Although fighter and attack aircraft are most frequently involved, fatalities are relatively few due to small flight crews and the availability of ejection seats. There has, however, been greater loss of life in the smaller number of large-aircraft accidents—aircraft similar to those found in the civilian jet transport fleet. Examples of accidents involving both types of aircraft are reviewed in some detail below.

Fighter and attack aircraft

As discussed earlier in this chapter, high-speed flights at low levels—the altitude zone that is occupied by most birds—are at the highest exposure to bird strikes. Fighter and attack aircraft and associated trainers fly the majority of missions at this altitude—89 percent of all serious accidents in Canada and the U.S. comprised these aircraft. Fighter and attack aircraft move so fast that birds—and pilots—have virtually no time to react. Large birds such as vultures, hawks, gulls, pelicans and cranes are often struck while soaring in the path of quickly moving aircraft. In these high-speed collisions, even small birds can cause serious damage.

For example, a swift penetrated the canopy of an F-111 strike aircraft during low-level flight over Zion National Park in Utah. Both crew members ejected safely before the aircraft crashed. In another incident, one engine of a twin-engine T-38A trainer ingested swallows on takeoff from Dallas Naval Air Station—the aircraft flew for one minute before crashing. Both members of the crew ejected safely. In yet another example, a T-38A ingested a Horned Lark on takeoff from Reese AFB in Texas. The pilot rejected the takeoff, overran the runway and the crew ejected. One crew member was paralyzed as a result of the accident.

Date Yr Mo Day	Aircraft Type	Bird Species	Crew**	Circumstance
Canada				
66 10 12	CF-104	Snow Goose	1E	Engine ingested bird and parts of intake, then failed. Ocurred at 2000 ft near CFB Cold Lake, Alberta.
67 03 30	CF-104		1E	Engine ingested bird on climbout from CFB Cold Lake, Alberta.
68 11 15	CF-104	ducks	1E	Engine ingested birds; 1 bird penetrated windscreen during low-level flight near Unity, Saskatchewan.
69 08 19	CF-104	hawk?	1E	Bird struck fuselage, engine failed during low-level flight near Cold Lake, Alberta.
74 05 27	CF-104	large	1E	Engine ingested bird during low-level flight near Cold Lake, Alberta.
76 05 11	Tutor		1E	Engine ingested bird and flamed out during touch and go at CFB Moose Jaw, Saskatchewan.
76 05 31	Tutor	Mallard	2E(K)	Engine ingested bird and failed during climbout from Regina, Sask.; crew turned away from city and ejected late.
80 06 24	CF-104		2E	Engine ingested bird and failed during low-level flight at Cold Lake, AB.
91 02 26	Tutor		2E	Engine ingested bird just after takeoff from CFB Moose Jaw, Sask.
97 09 25	Tutor		2E	Engine ingested bird and suffered compressor stall while in cruise over Assiniboia.
United States of America Air Force				
62 10 10	F-102	starlings		Engine ingested multiple birds along runway at Westover AFB, MA.
64 10 31	T-38A	Snow Goose	1E(K)	Bird penetrated windscreen on approach to Ellington AFB, TX; parts of windscreen ingested, both engines failed, pilot ejected too low.
66 --- ---	T-38		Unk	Engine ingested bird on takeoff; aircraft destroyed; location unknown.
66 --- ---	F-100	gulls		Birds struck landing gear on takeoff; gear collapsed on landing.
66 --- ---	T-38	gulls	2E	Birds penetrated windscreen and ingested in both engines on climb.

Table 13.4 Serious military accidents involving birds in Canada and United States.*
All listed accidents involved one or more of the following: destruction of the aircraft, pilot ejections or fatalities.

* Excludes accidents involving Canadian and U.S. military aircraft in Europe.

** E=ejected safely; K=killed; E(K)=ejected but killed; inj=injured (very incomplete).

Date Yr Mo Day	Aircraft Type	Bird Species	Crew**	Circumstance
Air Force *continued*				
66 10 --	T-37	Sandhill Crane	[1K]	Bird penetrated windscreen at 1200 ft and 240 kt; pilot killed; 2nd pilot landed aircraft at Reese AFB, Texas.
67 --- ---	T-38		Unk	Bird penetrated windscreen on approach; pilot incapacitated, aircraft dived into ground. Location unknown.
67 09 --	F-100	hawk	1K	Crashed after striking bird. No further details available.
68 --- ---	F-100		1K	Bird penetrated windscreen during low-level flight; aircraft dived into ground. Location unknown.
68 --- ---	F-100	Golden Eagle	2E	Bird penetrated windscreen during low-level flight. Location unknown.
69 --- ---	T-37B	vulture	1K	Bird penetrated windscreen during climb, aircraft dived into ground. Location unknown.
70 --- ---	T-37B	vulture	[1K]	Bird penetrated windscreen on climb at 2000 ft and 195 kt; pilot killed; 2nd pilot landed aircraft safely. Location unknown.
70 --- ---	T-38A	small birds	2E	Nose and windscreen struck small birds while climbing; radome disintegrated and ingested into engines. Location unknown.
71 --- ---	RF-4C	vulture	[1E]	Bird penetrated windscreen on low-level flight. One crew member ejected, other landed plane safely. Location unknown.
71 --- ---	F-101B	small bird	2K	Engine ingested bird on takeoff; aborted takeoff and overran the runway; aircraft burned. Location unknown.
71 --- ---	F-111	vulture	2E	Bird penetrated windscreen on low-level flight; pilot lost control. Location unknown.
72 --- ---	T-38A	Sandhill Crane	[1E]	Bird penetrated windscreen at 9000 ft; one pilot ejected but second pilot landed aircraft safely. Location unknown.
73 --- ---	F-111A	swift	2E	Bird penetrated windscreen during low-level flight at Zion NP, Utah.

Table 13.4 Serious military accidents involving birds in Canada and United States.*
All listed accidents involved one or more of the following: destruction of the aircraft, pilot ejections or fatalities.

* Excludes accidents involving Canadian and U.S. military aircraft in Europe.

** E=ejected safely; K=killed; E(K)=ejected but killed; inj=injured (very incomplete).

Date Yr Mo Day	Aircraft Type	Bird Species	Crew**	Circumstance
Air Force *continued*				
74 01 14	T-38A		2E(1K)	Bird penetrated windscreen during climb from Randolph AFB, Texas; debris ingested causing power fluctuations.
74 05 06	T-38A		2E	Engines ingested birds just after takeoff at Randolph AFB, Texas; dual flameout.
79 07 27	A-10A		1E	Bird severed hydraulic lines in wing leading edge at 1100 ft; aircraft caught fire and crashed at Bonita, Arizona.
81 09 08	T-38A	gulls	2E(1K)	Both engines ingested gulls just after takeoff from Cleveland Lakefront Airport, Ohio.
82 05 11	F-16A	White Pelican	1E	Bird hit radome causing severe damage; debris ingested in engine at 2000 ft over Great Salt Lake, Utah.
85 04 02	T-38A	Br.hd. Cowbird	2E	Engine ingested birds at 500 ft in climb from Sheppard AFB, Texas.
85 10 30	A-10A		1E	Tail and wing hit wires as pilot attempted to avoid birds during low-level flight at Emerickville, Pennsylvania; aircraft became uncontrollable.
86 10 20	F-4E	vulture	2E(1K)	Bird penetrated fuselage, ruptured fuel lines and caused fire during low-level flight over Georgia.
87 09 28	B-1B	White Pelican	3E(3K)	Bird penetrated wing/nacelle junction rupturing hydraulic lines during low-level flight over La Junta, Colorado; inflight fire resulted.
89 01 04	F-16A	vulture	1E	Bird penetrated windscreen during low-level flight over Avon Park Range, Florida.
89 01 05	F-16C	starlings	1 inj	Engine ingested birds on takeoff from Shaw AFB, South Carolina; takeoff aborted, aircraft burnt out.
90 04 10	OA-37B	vulture?	1E	Lost control and crashed when avoiding birds on approach to Howard AFB, Panama.
91 04 18	F-16A	vulture	1E	Engine ingested bird at low level near Fort Smith, Arkansas.
92 09 03	T-38A	vulture	[1K]	Pilot killed when bird penetrated windscreen during low-level flight near Abilene, Texas; rear pilot landed aircraft safely.

Table 13.4 Serious military accidents involving birds in Canada and United States.*
All listed accidents involved one or more of the following: destruction of the aircraft, pilot ejections or fatalities.

* Excludes accidents involving Canadian and U.S. military aircraft in Europe.

** E=ejected safely; K=killed; E(K)=ejected but killed; inj=injured (very incomplete).

Date Yr Mo Day	Aircraft Type	Bird Species	Crew**	Circumstance
Air Force *continued*				
92 09 18	F-16A	plovers	1E	Engine ingested birds on rotation at Duluth, MN; crashed after 2 minutes.
92 12 17	F-16A	hawk	1E	Engine ingested bird and seized during low-level flight over the Dixie Range, Texas.
93 06 20	T-38A	swallows	2E	One engine ingested birds on takeoff from Dallas NAS, Texas; flew for 1 minute before crashing.
93 07 06	T-38A	Horned Lark	2E	Engine ingested bird on takeoff from Reese AFB, Texas, aborted takeoff, overran, ejected; 1 crew member paralyzed.
94 05 06	T-38A			Extensively damaged after birdstrike; details unknown.
94 07 01	F-16B	vulture	2E	Engine ingested bird during low-level flight near Eagle Pass, Texas.
95 09 25	E-3B	Canada Geese	24K	Struck many geese on takeoff from Elmendorf AFB, Alaska; 2 engines failed; crashed in trees.
97 10 22	AT-38B		2K	Struck by F-16B that was avoiding birds during a photographic run at Edwards AFB, California.
United States of America Navy and Marine Corps.				
7? --- ---	A-7B	vulture	1E	Bird struck radome and was ingested during climb somewhere in southeast U.S. (Year?); aircraft lost power.
7? --- ---	A-4B	gull	1E	Engine ingested bird on takeoff, pilot aborted too late, overran into river. Location and time are unknown.
73 03 21	AV-8A		1E	Struck bird at Beaufort, South Carolina. (Year?)
80 05 ---	TA-4J		2E	Apparently crashed after striking birds. No further details.
80 09 29	T-34C		[1E]	Bird penetrated windscreen at 2800 ft; instructor ejected, student landed aircraft safely at Brewton, Alabama.

Table 13.4 Serious military accidents involving birds in Canada and United States.*
All listed accidents involved one or more of the following: destruction of the aircraft, pilot ejections or fatalities.

* Excludes accidents involving Canadian and U.S. military aircraft in Europe.

** E=ejected safely; K=killed; E(K)=ejected but killed; inj=injured (very incomplete).

Date Yr Mo Day	Aircraft Type	Bird Species	Crew**	Circumstance
Navy and Marine Corps *continued*				
80 10 31	A-4M		1E	Bird hit wing slat during low-level flight over Dare County Range, North Carolina; aircraft became uncontrollable and hit trees.
84 05 05	A-4E		1E	Bird penetrated windscreen on approach to Cecil NAS, Florida.
86 01 17	AV-8B	Red-tail Hawk	1E	Bird penetrated windscreen on low-level flight near Yuma, Arizona.
90 04 21	TAV-8B	vulture	2E	Engine ingested bird and failed during low-level flight, Beaufort, SC.
92 05 28	F-18A	vulture	1E(K)	Bird penetrated windscreen on low-level flight near Gainesville, Florida; pilot ejected but killed.
93 10 15	AV-8B	hawk	1E	Engine ingested bird and failed during low-level flight, Raleigh, NC.
94 03 08	EA-6B	Canada Goose	4E	Engine ingested bird while doing touch and go at Bogue Field, North Carolina; one engine failed, inflight fire.
95 01 14	TAV-8B	Herring Gull	2E	Bird penetrated rear cockpit through canopy and blast shield during low-level flight near Rocky Mount, North Carolina.
95 10 05	FA-18D		2E	Left engine ingested large bird on low-level flight over SW Arizona.
96 11 01	T-45A	duck	2E	Engine ingested bird on night approach to Kingsville NAS, Texas.

Table 13.4 Serious military accidents involving birds in Canada and United States.*
All listed accidents involved one or more of the following: destruction of the aircraft, pilot ejections or fatalities.

* Excludes accidents involving Canadian and U.S. military aircraft in Europe.

** E=ejected safely; K=killed; E(K)=ejected but killed; inj=injured (very incomplete).

USAF B-1B bomber

The Strategic Air command of the USAF maintains a low-level bombing range in eastern Colorado. On September 28, 1987, a four-engine Rockwell B-1B bomber was training on the range at an altitude of 600 ft AGL at an indicated air speed of 560 kts when a 15-pound White Pelican struck the aircraft just above the right engine nacelle. The bird strike started a fire that ignited and deteriorated the hydraulic systems until the aircraft entered a slow and uncorrectable roll to the right. Three of the six crew were unable to eject and died in the crash.

The accident investigation revealed that there had been approximately 50 bird strikes along the same instrument route (177) during the previous eight years—a route dangerously close to two reservoirs that harboured large numbers of White Pelicans and Sandhill Cranes. A further contributing factor was that the B-1B was not designed to take a major bird strike; the B-1 fleet was subsequently modified to reduce its vulnerability.

USAF/NATO E-3 AWACS

The E-3 AWACS aircraft is the military version of the four-engine Boeing 707 passenger jet, flying similarly long missions at high altitudes. The E-3 is equipped with sophisticated radar and communications systems, including a large circular top-mounted radome. Until 1995, these aircraft operated without a crash since first entering service in 1977.

On the morning of September 22, 1995, a fully loaded USAF E-3B AWACS began its takeoff roll at Elmendorf Air Force Base in Anchorage, Alaska. The mission was to be a routine 6.5-hour training flight. The tower air-traffic controller had seen a flock of geese near the runway but failed to notify the flight crew. As it lifted off the runway, the aircraft struck a flock of Canada Geese. At least 31 birds were involved, some ingested by the two left engines—one of which had to be shut down while the other lost power. The aircraft could not gain altitude or be controlled. It rolled left and crashed into a treed hillside. All 24 crew members were killed.

Subsequent investigations determined that the air-traffic controller should have warned the flight crew about the presence of geese. At the same time, the crew should have been concerned since geese were often in the area, and the bird-watch condition for the airport was moderate—indicating a probable bird hazard. The investigators also criticized the personnel in charge of flying operations at Elmendorf AFB for not having instituted an aggressive bird-management program. Following an inspection of the base in July 1995, the USAF BASH team had warned of the dangers posed by the resident Canada Goose population.

The case of the E-3 is a wake-up-call for the civil-aviation system. Many airports have insufficient bird-control programs to deal with problem geese. The E-3's similarity to many commercial airliners means an identical accident could occur with a civilian jet transport aircraft—an aircraft loaded with passengers.

Remarkably, another E-3 AWACS crashed after a bird strike on 14 July 1996. The NATO aircraft was taking off from Aktion airbase in Greece when multiple bird strikes caused the crew to reject the takeoff at high speed. The E-3 ran off the runway, travelled along a stone pier and veered into the sea. The impact broke the fuselage between the wings and the cockpit. Fortunately, there was no fire and all 14 members of the crew survived without serious injury.

Belgian Air Force C-130H

On July 15, 1996, a Belgian Air Force four-engine C-130H Hercules transport with 41 persons on board crashed while on short final to the Dutch Air Force Base at

Wreckage of the E-3B AWACS on September 22, 1995. On July 14, 1996 the only other loss of an E-3 AWACS occurred when a NATO version was lost to a bird strike at Aktion airbase, Greece.

Eindhoven, Holland. A massive bird strike has been confirmed as the primary cause of the crash. A flock of as many as 600 lapwings (a large shorebird) and starlings—out of view of the control tower—flew into the path of the Hercules just prior to landing. Many of the birds hit the cockpit and port wing—dozens ended up in the engines, three of which lost power. The left wing dropped until the aircraft hit the ground beside the runway, damaging the fuel tanks. All 41 persons on board survived the crash, but as the aircraft came to rest at 18:02 a fuel fire immediately enveloped the forward fuselage.

The crew tried to rescue the passengers by extinguishing the fires and opening the rear fuselage doors; however, impact damage prevented opening the doors from the inside. The air-traffic controller on duty knew that there was a significant number of passengers on board but did not relay that information to the fire brigade, which began fighting the fire five minutes after the crash and completed the task two minutes later. Unaware that there were passengers on board, and assuming the four-person crew had perished on impact, the fire brigade proceeded to extinguish the engine fires. Only at 18:38—some 36 minutes after the crash and 29 minutes after they extinguished the main fire—did the firemen force open the rear door of the aircraft to discover there were passengers present. By this time, 31 had died from toxic fumes. Three others died later, for a death toll of 34.

The ability of a large flock of relatively small birds to cause the crash of a large military transport aircraft—one also used in many civilian roles—underlines the risks associated with bird strikes.

Conclusion

While the sharing of knowledge between civilian- and military-aviation sectors remains critical, military aviation appears to have little to teach its civilian counterpart. The differences in aircraft types and flight profiles preclude many direct comparisons, especially considering the more stringent bird-strike certification standards facing civilian aircraft. Wildlife-management programs at military and civilian aerodromes also employ the same techniques and equipment. Furthermore, military aviation's greater flexibility in flight scheduling and route selection make it possible to avoid known areas of bird activity at all times of the year—a luxury not afforded the tightly scheduled world of civilian aviation.

Chapter 14

Solutions on the Horizon

Introduction

In striving to resolve the wildlife-strike problem, the aviation industry must continue to rely on the system safety approach to reduce exposure to, and probability and severity of, wildlife strikes. Although increasing numbers of some hazardous species and a growing aviation industry pose significant challenges to reducing exposure, a reduction in risk should be achievable. New technologies will contribute to the management of wildlife-associated risk, providing wildlife-detection and deterrence capabilities, and improving the ability of aircraft to avoid wildlife encounters.

Most wildlife-management methods now employed at airports have been in use for several decades. While some new products such as chemical feeding repellents have proven relatively successful, technological advances have, for the most part, been in the refinement of existing products and techniques. Studies have shown that habitat modifications and active wildlife-management techniques remain the most successful long-term solutions when implemented by skilled operators.

Research on new methods to reduce bird-strike probability is currently being pursued on two fronts:

- deterring and dispersing wildlife using technologies that play to recently discovered sensory abilities of birds and mammals; and
- detecting birds and mammals and predicting their movements.

Wildlife deterrent and dispersal technology

Although yet to be developed, there is great appeal in the concept of an airframe-mounted device that disperses birds by stimulating specific bird senses to induce avoidance behaviour. Through such a device, airspace immediately ahead of an aircraft would be automatically cleared of birds. This technology could also be implemented on the ground to disperse birds from runways.

Bird Avoidance Models (BAM) and Avian Hazard Advisory Systems (AHAS) may prove to be the best risk management tools for addressing bird hazards that are beyond the reach of traditional airport wildlife management programs.

Developing this technology will be difficult; its effectiveness would almost certainly vary among bird species and in different environmental conditions. Obtaining industry acceptance would also be a challenge. Nevertheless, research continues on several high-tech fronts. Readers should note that technologies discussed in this chapter are, for the most part, unproven, hypothetical research topics at this time.

Audible radar

There is evidence that some wildlife can 'hear' microwaves; for example, anecdotal reports suggest that birds avoid specific radar frequencies used in military applications. This phenomenon was first noted in humans who described being able to hear high-frequency clicks, buzzes, and hisses. If it is possible to deliver a warning to hazardous wildlife through microwave propagation, perhaps an effective wildlife-dispersal system could be developed using this technology.

There is no clear understanding of how microwaves may affect birds, but two theories have emerged: microwaves may affect bird behaviour by producing a sense of nausea, or may provide an auditory cue of impending danger. Preliminary experimental results based on limited studies do indicate that birds can audibly detect microwaves, and that this cue can lead to avoidance behaviour. Research continues to determine how best to deliver the microwave signal; specific frequency and modulation patterns may work more effectively on different bird species. While experiments in this field are in their infancy, there has been even less research on mammal behaviour and microwaves. The testing of a prototype system is undoubtedly several years away.

In one application of this technology, microwave-emitting radar systems would be mounted on and projected ahead of aircraft to act as early-warning devices. The microwaves would be projected approximately one mile forward of an aircraft, making the system most effective at low speeds, and therefore during flight phases when aircraft are at the highest risk of being struck: takeoff and initial climb-out, and final approach and landing. Birds would detect the auditory cue, direct their attention to the oncoming aircraft, and then initiate avoidance manœuvers.

Still, microwave-emitting radar technology faces numerous hurdles relating to product effectiveness, interference with other onboard equipment, additional airframe weight, potential effects on humans, not to mention the costs associated with research, development and implementation. This technology would not likely be applicable to military aircraft flying low-level missions, since these aircraft fly at speeds at which neither pilots nor birds would have time to react. Furthermore, airframe manufacturers and airlines will have to be convinced there's a payoff, since additional weight greatly affects the revenue-generating capacity of commercial aircraft.

Infrasound

Low-frequency sound—or infrasound—occurs naturally in the atmosphere, created by events such as earthquakes, volcanoes, severe weather systems and jet streams. Some animals use low frequency sound to communicate, and at least some species of birds can detect infrasound. This raises the possibility of using infrasound to intentionally communicate threat warnings that will make birds leave and avoid airfields, as well as the paths of oncoming aircraft.

This technology could be used two ways. Installing infrasound generators along runways would deter birds from aircraft operating areas, including approach/departure paths. These generators could also be attached to aircraft, although various economic, technological and certification challenges might render this approach unfeasible.

Preliminary studies are underway to investigate infrasound's potential as a wildlife-management tool. To be successful, birds would have to detect the infrasound, associate it with a threat and move away. As with any wildlife-management initiatives, habituation to infrasound could limit its effectiveness.

Strobe and pulsed landing lights

A number of laboratory and field studies have investigated the use of strobe lights as warning devices. While there is evidence that birds respond to strobe lights, the data does not clearly indicate that birds are inclined to avoid them.

The Transportation Development Centre—the research division of Transport Canada—commissioned a comprehensive study to examine the responses of Laughing Gulls and American Kestrels to strobe lights of varying wavelengths and frequencies. The tests

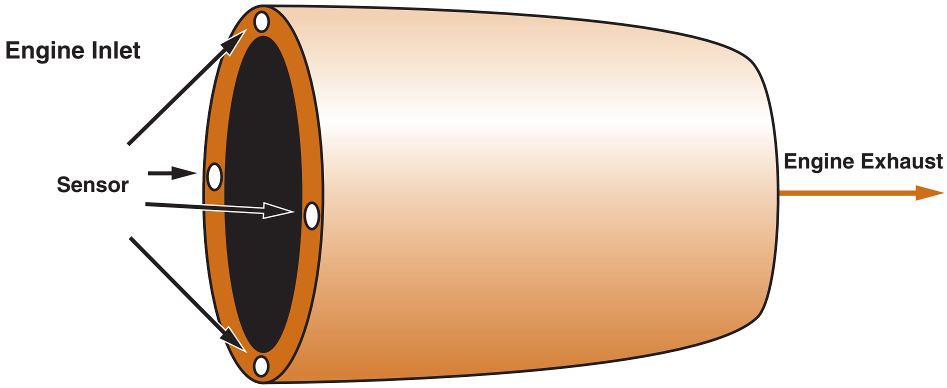


Figure 14.1 Foreign Object Ingestion Detection System (FOIDS)

clearly demonstrated that the test birds were aware of the strobe-light stimuli and responded physiologically with increased heart rates. Overt avoidance reactions were not observed, leading the authors to conclude that while strobe lights may attract the attention of birds, these tools do not result in obvious fright-and-flight responses *when there are no other threatening stimuli*. If birds could associate strobe lights' visual cues with a threat—such as an approaching aircraft—they might initiate evasive responses. If no real threat exists, habituation would likely develop.

Strobe lights are mounted on many aircraft as anti-collision devices, and while birds may detect an approaching aircraft by its flashing strobes sooner than an aircraft without lights, there is no data at this time to support the concept.

Another area that may hold some promise is the use of pulsed landing lights. Current research indicates that birds become aware of an approaching vehicle equipped with pulsed lights sooner than one without. Floatplane pilots on the Pacific coast of Canada insist that pulsed landing lights reduce their bird-strike incident rate.

Lasers

In recent decades, public demand has grown for non-lethal, non-injurious and environmentally benign airport wildlife-management interventions. The use of relatively low-power, hand-held Class-II and III laser devices—which are silent, highly directional, and accurate over distances— may help address this demand. Current laser technology poses little risk of eye damage to birds, and offers some promise as a bird-dispersal solution (the authors are unaware of any work undertaken to examine the effectiveness of lasers in dispersing mammals).

Some of the most recent and illuminating work has been conducted at the United States Department of Agriculture's National Wildlife Research Centre (NWRSC) in Sandusky, Ohio (www.aphis.usda.gov/ws/nwrc). In 2002, NWRSC conducted a series

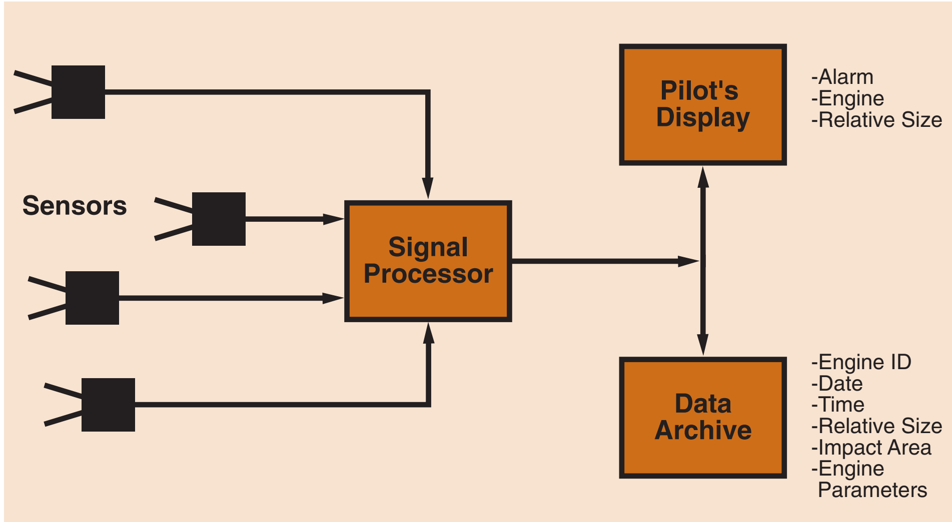


Figure 14.2 Outputs from the FOIDS Signal Processor

of experiments to examine laser-avoidance behaviours of brown-headed cowbirds, European Stalrings and Canada geese, among other birds. Results demonstrated that wildlife-control methods are often species- and context-specific. For example, neither cowbirds nor starlings were repelled by lasers used in the experiments, while geese exhibited marked avoidance behaviour.

The researchers contend that lasers will prove to be valuable components of comprehensive bird-management programs; however, these experts stress that further controlled studies are needed to examine the technique in greater detail.

Available laser devices include models designed specifically for bird dispersal, and at least one brand that is used by military and law-enforcement agencies for threat deterrent; prices range from approximately USD$5,600 to USD$7,500. One manufacturer has indicated it intends to combine its laser with Dopler radar to enable site-specific, on-demand targeting of problem birds.

Wildlife-detection technology

The detection of wildlife activity is a key component of any wildlife-strike reduction program. Early detection allows time to plan and implement strategic and tactical measures to either manage birds or—if possible—adjust flight profiles.

Warning of foreign-object ingestion

Existing detection technologies could be applied to inform flight crews when an engine has ingested birds—information vital in assisting pilot decision-making following an actual or suspected bird strike.

Ongoing research and development work in the U.S. using existing radar technology may someday provide real-time warnings of bird activity that will benefit airport wildlife management teams, pilots and ATS providers.

A project is underway to develop a foreign-object ingestion-detection system (FOIDS), employing four Doppler radars mounted on the engine nacelle (see Figure 14.1). Foreign objects, including birds and bird remains, are detected and tracked as they enter an engine. The relative size of an object, its velocity, track and likely point of impact within the engine are all computed.

FOIDS could provide pilots with time-critical information on the magnitude of engine damage following an actual bird strike. Furthermore, if flight crews were in doubt as to whether or not a bird strike had occurred, FOIDS would be able to confirm, or deny, it. The value of such information is clear considering often unnecessary and costly precautionary flight returns to airports—and the even more costly repairs that result when maintenance and repairs are delayed.

The FOIDS signal processor (see Figure 14.2) is also an excellent tool for maintenance personnel. It would allow engine inspectors to confirm a FOD event and adjust engine-inspection procedures and schedules based on the severity of the event. This could both enhance safety by preventing delayed FOD-related engine failure, and reduce costs associated with unnecessary engine teardowns.

Bird avoidance models (BAM) and Avian Hazard Advisory Systems (AHAS)

Radar and other detection and telemetry techniques—including satellite telemetry—have long been used in the study of bird migration routes, nocturnal migrations, flight altitudes, bird numbers and daily movement patterns. A significant database exists—a compilation of historical information on movement patterns from many areas of the world.

In the early 1980s, a bird-avoidance model (BAM) was conceived by the U.S. Air Force to warn flight crews of bird activity, and to take advantage of existing bird-movement detection capabilities and data. By compiling historical data on hazardous bird populations and their movements, BAM gives pilots and mission planners the information needed to consider evasive action.

Through BAM, bird density is overlaid on a standard map. Each square km of the 48 contiguous U.S. states is assigned a unique bird-strike risk value (BAM development is currently underway for Alaska and Western Europe). BAM provides data on 60 species of birds most hazardous to aircraft flying at low levels. (These species include Turkey Vultures and Red-tailed Hawks—birds that account for 27 percent of identified strikes and 53 percent of the risk (probability of damage) to low-level missions.) To simplify the system, these 60 species are grouped into 16 composite types according to behaviour. BAM is accessed through a menu-driven, Web-based PC program, allowing users to obtain bird-hazard information according to geographic locations, time of year, time of day, and selected routes. By comparing the relative risk of different flight plans, users are able to select the safest times and locations in which to fly.

BAM has proven to be an extremely useful tool in forecasting bird positions based on past knowledge of their locations. Flight planners and pilots in all aviation sectors can use this information for planning in advance of 24 hours.

Together, BAM and the Avian Hazard Advisory System (AHAS) support long and short-term flight planning by focusing on bird movements and behaviours. In fact, AHAS was developed to extend the capacity of BAM and provide more immediate, near real-time information on bird concentrations and behaviours. AHAS is designed to link:

- BAM's historical data on bird activity;
- weather conditions in relation to bird activity; and
- strike rates for specific bird species.

To meet the need for information on real-time bird concentrations and behaviours, the Avian Hazard Advisory System (AHAS) was developed, extending the capacity of BAM. AHAS is designed to link:

In addition, AHAS now incorporates data on bird activity gathered by next-generation weather radar (NEXRAD), making it possible to provide bird-strike risk-level information that's updated every 20 to 35 minutes. AHAS now operates over the contiguous 48 states of the U.S.

Applying bird-avoidance modeling techniques: two examples

Example 1

Integrating bird migratory data in the planning of flight routes and schedules has led to a dramatic reduction in the number of fatal and costly bird strikes experienced by the Israeli Air Force.

Israel is at the migratory crossroads of Europe, Asia, and Africa; large numbers of birds pass through the region twice a year to avoid the Mediterranean Sea. Particularly significant are the hundreds of thousands of hawks, eagles, storks, pelicans, and cranes that move through the area—large to extremely large birds that pose serious threats to aircraft.

Intensive studies have been carried out using radar, radio telemetry, gliders, and the coordinated observations of large numbers of ground personnel, all examining the movements of these birds through Israel. Observations have shown that movements occur:

- during well-defined weather conditions,
- at predictable times of the year, and
- along routes that are similar from year to year.

The effects of daily variations such as local crosswinds are monitored in real-time with radar, supplementing the predictive models and providing very accurate and current information.

Example 2

Studies of soaring pelicans have recently been conducted at Naval Air Station (NAS) Fallon, near Reno, Nevada. Satellite telemetry transmitters were attached to ten American White Pelicans. The transmitters enabled monitoring of the geographic location and altitude of each bird as it flew between a nesting colony and a distant feeding area. Additional climatological data was also gathered. This information is being analyzed to determine whether there are predictive relationships between flight paths and altitudes used by the pelicans and local climatological conditions—especially boundary layers within the airspace used by pelicans.

A work in progress, this technique shows promise in accurately predicting daily flight behaviour of White Pelicans in the area. The timing and routing of pilot-training flights can be scheduled to reduce the risk of strikes involving these birds.

The future of bird-warning systems

There is potential to enhance the BAM concept in the future, perhaps leading to a national or even global database of bird movements and bird strikes.

Bird-warning systems in Europe and the U.S. have worked well in military aviation, where the ability to forecast bird migrations provides a fit with the flight planning flexibility available in most peacetime military missions. For the same reason, however, the value of bird movement data in commercial aviation may be limited.

Commercial aviation is relatively inflexible—bound to schedules, flight routes and altitudes that are dictated by factors other than bird movements. And yet there is value to any new risk-management tool, including those that predict bird movements. If airline operators and pilots can enhance their knowledge of the presence of birds—and associated risk—they can make informed decisions to accept or reject the risk; when risk is too high, flights can be delayed and rerouted.

Conclusion: research directions

While technological advances have the potential to reduce the level of damage to aircraft from wildlife strikes, economic and operational realities may render impractical the goal of protecting aircraft and engines from all bird and mammal destruction.

Meanwhile, wildlife-management tools and methods may be derived from ongoing research that focuses on two aspects of wildlife behaviour—wildlife response to stimuli and wildlife-prediction modeling.

Still more research is required to develop new and effective wildlife-management methods. As discussed in this book, the annual economic losses from wildlife strikes are significant. The possibility of a catastrophic accident is clearly evident in strike data and risk analysis. There must be renewed urgency on the part of national authorities, airport operators and the aviation industry to continue efforts to reduce the probability and severity of wildlife strikes to aircraft.

Chapter 15

Conclusion

Introduction

Throughout this book, we have referred to the system safety approach as a fundamental component of all safety-management programs. System safety is founded in teamwork, and few industries demand—and promote—teamwork as aggressively as aviation. The industry's high-consequence environment demands a culture in which decisions and actions ensure safety is the highest priority. And nowhere in aviation is this demand higher than in managing the hazards associated with wildlife.

Striving for consistency in wildlife-hazard management

Throughout the world, wildlife-management programs vary in scope, quality and sophistication. Programs in developing countries and at smaller airports can range from ineffective to non-existent. At private-sector airports where corporate liability is a concern—and at airports owned and managed by governments—wildlife-management programs are often progressive and science-based.

The influence and control that national regulatory bodies exert over wildlife-management programs varies among jurisdictions. Some agencies are enlightened and highly structured in their regimes; others are not, deferring to the will of stakeholders. Prescriptive regulations such as those found in various national regulatory programs—and the recommended practices of the International Civil Aviation Organization (ICAO)—are of limited effectiveness because of difficulties in monitoring and enforcement. This is due to both the highly adaptive and mobile characteristics of wildlife, and the constantly changing environments in which wildlife-management programs are conducted. Changes in climate, the human landscape and environmental regulations—as well as capricious societal expectations—are among the many factors that make wildlife management an extremely dynamic and challenging task. The nature of the wildlife problem demands not only the system safety approach but also regulatory frameworks that are, above all else, performance-based.

Communication

The bird-strike vulnerability of commercially operated jet transport aircraft became apparent in the early 1960s, soon after their use began to grow. As the size of these aircraft grew and their complexity increased, so did the size and structure of the aviation system. At every step along the way, the successful management of risks associated with wildlife has depended on effective cooperation and communication amongst all stakeholders. If liability propels wildlife-associated risk management, then communication improves it.

National and international initiatives

In Canada, the establishment of the Associate Committee on Bird Hazards to Aircraft in the early 1960s marked the world's first formal gathering of experts in the field of wildlife-management and aviation. The first meeting of Bird Strike Committee Europe was convened in Frankfurt, Germany, in 1966. Since then, numerous national bird-strike committees have been established, and participation at the two largest committees—Bird Strike Committee USA/Canada and the International Bird Strike Committee—grows each year.

The value these committees add to the system safety approach cannot be overstated. They are a critical forum for the exchange of information among wildlife-management practitioners and other key stakeholders. Each meeting provides an opportunity to compare notes on techniques and equipment used in different parts of the world. Commercial exhibitors have the opportunity to showcase and demonstrate products. Scientific studies are presented and discussed, helping to improve overall understanding. Perhaps most importantly, committee meetings deliver motivation and new ideas, enabling participants to return to their operations with tools to improve the effectiveness of programs they manage.

Where do we go from here?

At the airport

Experts in the field of wildlife management argue that much of the risk associated with collisions between aircraft and wildlife can be eliminated, but only if airport operators and other responsible agencies follow the prescription offered in manuals and books such as *Sharing the Skies*.

This prescription combines 80-percent habitat management and 20-percent science-based active control initiatives, and alters the schedules and techniques of these measures to counter habituation. Other essential components include:

- a reliable reporting system,
- formal data collection and analysis,
- ongoing research into improved wildlife-management techniques and equipment, and
- a dependable communication network.

These are the tools of dedicated and motivated wildlife-management staff, without whom successful wildlife management would remain unattainable.

Certain recent developments emphasize the critical need for the methodical use of these wildlife-management tools. Data clearly describes a growing problem involving serious bird-strike incidents at altitudes beyond airport operators' range of influence. Meanwhile, populations of many hazardous bird species are rapidly increasing for a variety of reasons, including inappropriate land-use activities adjacent to airports.

Research and development

To advance the cause of successful wildlife management, ongoing research must be supported—and encouraged—through adequate funding. This research will provide the aviation community with a better understanding in areas such as:

- techniques and equipment for managing wildlife;
- animal behaviour with respect to airports and aircraft, including research to determine if wildlife can be conditioned to avoid areas such as runways and taxiways;
- vegetation management and its contribution to wildlife-hazard reduction;
- on-board aircraft systems—such as pulsed landing lights, strobe lights, color schemes, infrasound and microwave generators—that may better warn wildlife of approaching aircraft;
- improved management techniques for land-use activities such as landfills;
- reporting protocols for wildlife incidents and accidents;
- technologies that can detect and disperse wildlife without labor-intensive involvement; and
- technologies that can detect birds and provide warnings of pending or immediate bird threats to air-traffic service providers and pilots.

Education and awareness

Through education and awareness, stakeholders are motivated to address wildlife problems. Several countries have improved the quality of wildlife-management programs by simply initiating aggressive public-relations campaigns. The results of these initiatives can be quantified through both improved bird-strike reporting and greater cooperation among industry stakeholders.

Regulatory initiatives

The aviation industry is likely one of the most heavily regulated in the developed world. Yet numerous bird-strike committee meetings and several ongoing initiatives have failed to establish more than a few comprehensively regulated wildlife-hazard programs throughout the world. Transport Canada has spent years developing regulations and standards pertaining to airport wildlife management; the department anticipates having regulations in place within the near future.

Prescriptive vs. performance-based regulations

One of the problems associated with prescriptive regulations is the danger of such rules establishing a fixed standard—a plateau at which airport operators lose the incentive to continue improving programs. Prescriptive regulations would also have to be policed. Enforcement officers would have to be recruited and receive extensive training in the natural sciences; the costs of such initiatives would be prohibitive, and ensuring standards for such enforcement would add yet another layer of bureaucracy. However, performance-based regulations and standards should provide regulatory bodies with the ability to monitor results through data analysis, thereby minimizing the need for specialized enforcement personnel.

The problems associated with prescriptive regulations are clear in the rules currently established within some developed countries. In some cases, these regulations are, for whatever reason, poorly enforced. For example, prescriptive regulations commonly prohibit operation of food-waste disposal sites within a particular range of airport reference points. Yet many landfills continue to operate within regulated separation zones due to a variety of conflicting concerns, such as zoning costs, jurisdictional boundaries and legacy exemptions. Furthermore, even if they do operate outside separation zones, these sites are often poorly managed, attracting large numbers of birds that routinely occupy aircraft flight paths. From a risk-management perspective, the aviation industry may be better served by performance-based regulations that encourage all stakeholders to collaborate, and landfill operators to manage airport-vicinity sites according to clearly identified and communicated risks.

International Civil Aviation Organization (ICAO)

ICAO recently updated wildlife-management standards contained in Annex 14 of the organization’s *Airport Services Manual*. A true step toward international harmonization, the standards are, in certain cases, highly stringent, and pose challenges for even the most progressive regulators.

ICAO member states, of which there are currently 188, are required to file 'differences' if unable to comply with any of the new standards.

Data collection

Most wildlife-management experts agree that current wildlife-risk management programs lack reliable data. While enforcing mandatory wildlife-incident reporting system would prove difficult, the rewards offered by comprehensive and effective data would justify the effort.

Existing jet-engine certification rules were informed by data that was much less reliable and informative than it is today. Only recently have rule makers had access to complete and accurate data that shows:

- the full extent of damaging events involving strikes on turbofan engines by large flocking birds, and
- the extent of the population growth and physical size of some waterfowl species.

The next step: emerging technologies

Experts in the field are excited by the potential for emerging technologies that can provide advance warning of bird activity, thereby allowing air-traffic service providers and pilots to make flight-management decisions that can reduce the risk associated with bird strikes.

Many military systems originally designed to detect, track, and intercept missiles and other ordnance are well adapted to perform the same functions in monitoring bird activity. Combining these technologies with the existing next-generation weather radar system (NEXRAD)—which tracks airborne precipitation and also indicates airborne birds—will provide real-time and advance warnings of bird activity.

New airport-specific detection technologies will provide real-time warnings of wildlife activity at and adjacent to airports. Thermal-imagery devices, two-dimensional radar, and three-dimensional phased-array radar—all derived from military applications—offer effective targeting of wildlife activity. Over the past decade, the United States Air Force has developed and refined two-dimensional radar for the detection of birds on bombing ranges, but the speed and resolution of three-dimensional phased-array radar are considered superior by many experts.

Consultants in the U.S. are currently developing three-dimensional phased-array radar for civil applications. These systems will accurately locate birds on airport lands and in the surrounding airspace to approximately 3,000 ft AGL. Developers expect the software to be able to differentiate between low- and high-risk bird targets.

Currently, there is debate concerning the use of information provided by these real-time detection technologies. At the very least, a networked system that combines the predictive capability of AHAS/BAM (see Chapter 14) with the real-time warning capability of three-dimensional phased-array radar could provide airport operators with a powerful wildlife-management tool. Knowing where wildlife are located day and night, wildlife-management teams would be able to allocate resources—tactical and strategic—more effectively.

Accurate and reliable data on bird numbers, movements and threats will undoubtedly prove valuable for civil flight crews and air-traffic services staff. Both the Israeli and United States Air Forces have significantly reduced the number of damaging bird-strike events through the use of the AHAS/BAM system.

In light of recent developments in technologies and practices, a number of arguments have emerged that suggest the industry may have reached the limit of its efforts to counter wildlife-strike risks:

- Air-traffic service providers cannot accept additional workloads.
- Pilots cannot accept additional cockpit duties—especially during takeoff and landing flight phases.

- Airframe manufacturers and airlines would be reluctant to reduce the revenue-generating capabilities of aircraft by increasing weight through additional on-board systems.

Pilots generally agree, however, that real-time bird-activity information would be of significant value. While air-traffic management and noise-abatement procedures restrict the ability to manoeuvre their aircraft, flight crews would nonetheless prefer to be aware of threats. Bird-threat information could be made available through a data up-link, and managed in much the same way as weather, microburst and collision-avoidance information. In glass-cockpit aircraft, bird-threat information could be monitored on cockpit displays, and made available to flight crews only when ground-based algorithms have determined that significant threats are imminent.

Once informed of bird activity, flight crews would have a number of options:

- Request that ATS providers permit a minor change in heading, altitude, or speed.
- Decide to alter departure or descent profiles and fly at lower speeds.
- Delay takeoff or initiate go-arounds.

At the very least, flight crews may be motivated to pay closer attention to what is happening on the other side of the windshield.

These real-time detection technologies remain the aviation industry's greatest hope. Nature isn't likely to step in and limit the population growths of some waterfowl species. Sport hunting is in decline, and animal-rights groups will not accept population control initiatives. Although they must be refined—and proven—before the industry seriously considers their implementation, bird-detection and warning systems promise to provide the most significant gains in managing wildlife-strike risks.

Summary

As stated at the beginning of this book, *Sharing the Skies* is not intended as an operational guide to airport wildlife management—a number of excellent manuals fulfill this role, including Transport Canada's *Wildlife Control Procedures Manual*, and the *Prevention and Control of Wildlife Damage* series published jointly by the University of Nebraska, Great Plains Agricultural Council and the United States Department of Agriculture. These manuals offer the best tactical support for wildlife-management teams; *Sharing the Skies* is meant to provide strategic direction.

The aviation industry's safety record is highly respected by all who were involved in the production of this book. Despite this, we believe that the rapid growth of both hazardous bird-species populations and the aviation industry is leading to a point where the risks of catastrophic, fatal hull-loss jet transport accidents are unacceptably high. We sincerely hope that *Sharing the Skies* will do its part in building awareness, promoting cooperation and—ultimately—reducing the risks associated with collisions between aircraft and wildlife.

Appendix A

Bird Strike Committee Information

Bird Strike Committee Canada (BSCC)

Goal:

Bird Strike Committee Canada (BSCC) provides a forum for the discussion of matters relating to bird-hazard awareness and wildlife management at Canadian airports.

Membership:

BSCC permanent members include various government departments and agencies:

- Transport Canada,
- Department of National Defence,
- Health Canada,
- Canadian Museum of Nature, and
- the Canadian Wildlife Service.

Associate members include:

- major Canadian airlines,
- aviation industry associations, and
- other interested parties.

Contact Point:

BSCC Chair
Mr. Bruce MacKinnon
Transport Canada
Aerodromes and Air Navigation Branch
330 Sparks Street
Place de Ville, Tower C
Ottawa, ON
K1A 0N8

Tel: (613) 990-0515
Fax: (613) 990-0508
E-mail: mackinb@tc.gc.ca
Internet home page:
http://www.birdstrikecanada.com/

Bird Strike Committee U.S.A. (BSCUSA)

Goals:

Bird Strike Committee U.S.A. was formed in 1991 to:

- facilitate exchange of information,
- promote collection and analysis of accurate wildlife-strike data,
- promote development of new technologies to reduce wildlife hazards,
- promote professionalism in airport wildlife-management programs through training and advocacy, and
- act as a liaison to similar organizations in other countries.

Membership:

Bird Strike Committee U.S.A. is directed by an eight-person steering committee comprised of two members each from the:

- Federal Aviation Administration,
- U.S. Department of Agriculture,
- Department of Defense, and
- the aviation-industry Wildlife Hazards Working Group.

Associate members include representatives of the following groups:

- Aircraft Owners and Pilots Association,
- aircraft and aircraft-engine manufacturers,
- Airline Pilots Association,
- American Association of Airport Executives,
- airport managers,
- Air Transport Association,
- engineering and environmental-consulting firms,
- FAA regional airport certification personnel,
- International Bird Strike Committee,
- Bird Strike Committee Canada,
- International Civil Aviation Organization,
- state wildlife agencies,
- university and private research facilities,
- USDA wildlife services state directors,
- U.S. Fish and Wildlife Service regional directors, and
- U.S. military aviation groups.

Contact Point:

BSCUSA Chair
Dr. Richard Dolbeer
6100 Columbus Avenue
Sandusky, OH 44870

Tel: (419) 625-0242
Fax: (419)-625-8465
E-mail: richard.a.dolbeer@usda.gov
Internet home page: www.birdstrike.org/

International Bird Strike Committee

Goals:
IBSC is a worldwide network focused on:

- collection, analysis and dissemination of data regarding operational, regulatory and legal aspects of bird-strike risk to aviation;
- description and evaluation of methods to reduce the severity, frequency and costs of bird strikes;
- improving the ability of aircraft to tolerate bird strikes;
- helping air crews anticipate and react to bird strikes;
- cooperating and collaborating with other international stakeholders to minimize duplication of effort.

Membership:
The International Bird Strike Committee is an association of civil, commercial, military and private aviation flight-safety organizations committed to reducing the frequency and risk of bird strikes.

Contact Point:
IBSC Chair
Dr. Luit S. Buurma
Royal Netherlands Air Force
P.O. Box 20703
2500 ES Den Haag
The Netherlands

Tel: +31 70 339 6346
Fax: +31 70 339 6347

Appendix B

Conversion Factors

To Convert	Into	Multiply by
Distance		
Centimeters	Inches	0.394
Metres	Feet	3.281
Kilometres	Nautical miles	0.540
Kilometres	Statute miles	0.621
Inches	Centimeters	2.540
Feet	Metres	0.305
Nautical miles	Kilometres	1.852
Nautical miles	Statute miles	1.152
Statute miles	Kilometres	1.609
Statute miles	Nautical miles	0.868
Weight		
Kilograms	Pounds	2.205
Pounds	Kilograms	0.454
Capacity Measure		
Litres	Imperial gallons	0.220
Litres	U.S. gallons	0.264
Imperial gallons	U.S. gallons	1.201
Imperial gallons	Litres	4.546
U.S. gallons	Imperial gallons	0.833
U.S. gallons	Litres	3.785
Force		
Newtons	Pounds	0.2248
Pounds	Newtons	4.448

Appendix C

Bird- and Mammal-strike Reporting Procedures

Introduction

The geographic location of bird and mammal strikes determines how and where reports are filed. As this book concerns primarily North American jurisdictions, this Appendix concentrates on Canadian and American bird- and mammal-strike reporting procedures.

Recognizing that aviation is a worldwide activity, we have suggested a general process to report international bird and mammal strikes. In the event of a strike, however, aircraft operators and pilots should contact the governing aviation regulatory body to determine proper reporting procedures.

Figure C.1 illustrates the process for reporting bird and mammal strikes in Canada, the U.S. and abroad.

Who should report a bird or wildlife strike?

Since effective wildlife-strike measures result from the analysis of available strike reports, it is imperative that all bird- and mammal-strike events are reported by:

- airport managers,
- wildlife-management personnel,
- airfield workers,
- airport wildlife-management committees,
- air-traffic service providers,
- pilots,
- aircraft-maintenance personnel,
- aircraft operators,
- flight-safety personnel, and
- any other person who finds evidence of a bird or wildlife strike.

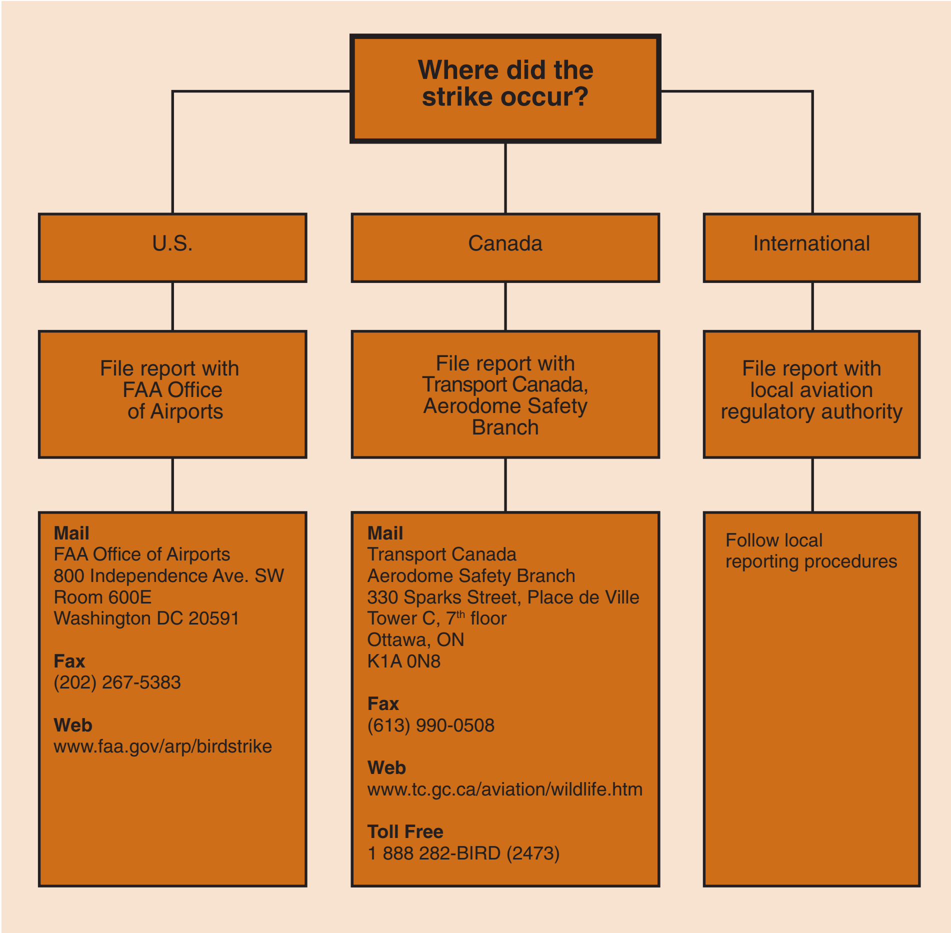


Figure C.1 Wildlife Strike Reporting Process

Reporting authorities

Wildlife-strike reporting forms are available from and should be forwarded to the following organizations:

Canada

Wildlife Control Specialist
Transport Canada,
Aerodromes and Air Navigation Branch
330 Sparks Street
Place de Ville, Tower C, 7th floor
Ottawa, Ontario
K1A 0N8

Tel: (613) 990-3739
Fax: (613) 990-0508

Toll-free Bird/Wildlife Strike Reporting line: 1-888-282-BIRD (In Canada only)
E-mail: russelk@tc.gc.ca
Internet home page: www.tc.gc.ca/birds/birds_e.htm

United States

FAA Office of Airports
800 Independence Avenue SW
Room 600E
Washington, DC 20591

Tel: (202) 267-3389
Fax: (202) 267-5383

Email: ed.cleary@faa.gov
Internet home page: www.faa.gov/arp/birdstrike/

Transport Canada Safety and Security | Transports Canada Sécurité et sûreté | Canada

Bird/Wildlife Strike Report — Rapport d'impact d'oiseau/de mammifère

TYPE	☐ Bird Strike/Impact d'oiseau ☐ Bird Near Miss/Quasi-impact d'oiseau	☐ Mammal Strike/Impact de mammifère ☐ Mammal Near Miss/Quasi-impact de mammifère	DATE	LOCAL TIME HEURE LOCALE

REPORTING SOURCE SOURCE DU RAPPORT	☐ Pilot/Pilote ☐ Site ☐ Other/Autre	☐ Airline/Compagnie aérienne ☐ Museum/Musée	OPERATOR EXPLOITANT	HEIGHT (AGL feet) ALTITUDE (AGL pieds)	SPEED (IAS knots) VITESSE (vi-noeuds)

Aircraft Information – Information sur l'aéronef

Model/Modèle	Registration/Immatriculation	Engine Type/Type de moteur
Make/Marque	Flight No./N^o de vol	Engine Make/Marque du moteur

AIRPORT AÉROPORT	Name/Nom	Code	Province	Region/Région	Runway/Piste

PHASE OF OPERATION PHASE DE L'OPÉRATION	☐ Takeoff Run/Roulement au décollage ☐ Climb/Montée	☐ Approach/Approche ☐ Descent/Descente	☐ Landing Roll/Roulement à l'atterrissage ☐ Taxi/Circulation au sol
	☐ En route/Croisière (Distance from Airport/Distance de l'aéroport ________)		☐ Parked/Stationnement

PART(S) STRUCK/DAMAGED PARTIE(S) TOUCHÉE(S)/ENDOMMAGÉE(S)	Struck Touchée	Damaged Endommagée
Radome/Radôme		
Windshield/Pare-brise		
Nose/Partie avant de l'appareil		
Engine/Moteur 1		
Engine/Moteur 2		
Engine/Moteur 3		
Engine/Moteur 4		
Propeller/Hélice		
Wings/Ailes		
Rotor/Rotor		
Fuselage		
Landing Gear/Train d'atterrissage		
Tail/Queue		
Lights/Feux		
Pitot Static/Antenne Pitot		
Tail Rotor/Rotor anticouple		
Other/Autre ________		

EFFECT(S) ON AIRCRAFT/FLIGHT EFFET(S) SUR L'AÉRONEF/LE VOL	
None Aucun	
Aborted Takeoff Décollagé interrompu	
Precautionary Landing Atterrissage de précaution	
Engine(s) Shut Down Arrêt de(s) moteur(s)	
Forced Landing Atterrissage forcé	
Fire Feu	
Penetration of Airframe Pénétration de la cellule	
Vision Obscured Visibilité réduite	
Engine Ingestion Ingestion dans le moteur	
Engine Uncontained Failure Panne de moteur avec perforation	
Other Autre ________	

LIGHT CONDITION CONDITION D'ÉCLAIRAGE	
Dawn Aube	
Day Jour	
Dusk Crépuscule	
Night Nuit	

SKY CONDITION ÉTAT DU CIEL	
No Cloud Pas de nuage	
Some Cloud Quelques nuages	
Overcast Couvert	

PRECIPITATION PRÉCIPITATION	
Rain Pluie	
Fog Brouillard	
Snow Neige	
Other Autre ________	

Bird / Mammal Information
Information concernant l'oiseau /le mammifère

SPECIES – COMMON NAME ESPÈCE – NOM COMMUN	SIZE OF BIRD TAILLE DE L'OISEAU	NUMBER OF BIRDS NOMBRE D'OISEAUX	Seen Aperçus	Struck Touchés
	☐ Small/Petit	0		
SCIENTIFIC NAME NOM SCIENTIFIQUE	☐ Medium/Moyen	1		
		2-10		
	☐ Large/Grand	11-100		
		More/Plus		

BIRD REMAINS SUBMITTED FOR IDENTIFICATION? LES RESTES DE L'OISEAU ONT-ILS ÉTÉ EXPÉDIÉS POUR IDENTIFICATION?	☐ Yes/Oui ☐ No/Non	PILOT WARNED OF BIRDS? PILOTE AVERTI DE LA PRÉSENCE DES OISEAUX?	☐ Yes/Oui ☐ No/Non

51-0272 (06-97)

Transport Canada Bird/Wildlife Strike Report Form.

Bird/Wildlife Strike Report — Rapport d'impact d'oiseau/de mammifère

INFORMATION ON ENGINE DAMAGE STRIKES
INFORMATION CONCERNANT LE MOTEUR ENDOMMAGÉ PAR L'IMPACT D'OISEAUX

Reason for Failure/Shutdown Raison de la panne/de l'arrêt du moteur	Engine Motor No. – Nº du moteur 1	2	3	4	Comments – Commentaires
Engine Uncontained Failure Panne de moteur avec perforation des parois					
Fire Feu					
Shutdown - Vibration Arrêt-moteur - Vibrations					
Shutdown - Temperature Arrêt-moteur - Température					
Shutdown - Fire Warning Arrêt-moteur - Alarme incendie					
Shutdown - Arrêt-moteur Other (specify)/Autre (précisez)					
Shutdown Unknown Arrêt-moteur inconnu					
Estimated % of Thrust Lost Estimation en % de la perte de puissance					
Estimated Number of Birds Ingested Estimation du nombre d'oiseaux impliqués					

ADDITIONAL INFORMATION
INFORMATION SUPPLÉMENTAIRE

COST INFORMATION INFORMATION SUR LES COÛTS		DAMAGE CATEGORY (DND) CATÉGORIE ENDOMMAGÉE (MDN)
Aircraft Time Out of Service/ Durée de la mise hors service de l'aéronef __________ Hours / Heures	Estimated Cost of Repairs or Replacement/ Estimation des coûts de réparation ou de remplacement $CDN__________ (In Thousands/En milliers)	Estimated Other Costs (e.g., Loss of Revenue, Hotels) Estimation des autres coûts(ex. perte de revenus, hôtels) $CDN__________ (In Thousands/En milliers)

REMARKS – REMARQUES

REPORT BY / DÉPOSÉ PAR: ____________________ DATE: ________________

ORGANIZATION / ORGANISATION: ____________________ TELEPHONE #/Nº DE TÉLÉPHONE #: (____) __________

51-0272 (06-97)

Form Approved OMB NO. 2120-0045

U.S. Department of Transportation
Federal Aviation Administration

BIRD / OTHER WILDLIFE STRIKE REPORT

1. Name of Operator	2. Aircraft Make/Model	3. Engine Make/Model
4. Aircraft Registration	5. Date of Incident ____/____/____ Month Day Year	6. Local Time of Incident ☐ Dawn ☐ Dusk — HR — MIN ☐ Day ☐ Night ☐ AM ☐ PM
7. Airport Name	8. Runway Used	9. Location if En Route *(Nearest Town/Reference & State)*
10. Height *(AGL)* feet	11. Speed *(IAS)* knots	

12. Phase of Flight

- ☐ A. Parked
- ☐ B. Taxi
- ☐ C. Take-off Run
- ☐ D. Climb
- ☐ E. En Route
- ☐ F. Descent
- ☐ G. Approach
- ☐ H. Landing Roll

13. Part(s) of Aircraft Struck or Damaged

	Struck	Damaged		Struck	Damaged
A. Radome	☐	☐	H. Propeller	☐	☐
B. Windshield	☐	☐	I. Wing/Rotor	☐	☐
C. Nose	☐	☐	J. Fuselage	☐	☐
D. Engine No. 1	☐	☐	K. Landing Gear	☐	☐
E. Engine No. 2	☐	☐	L. Tail	☐	☐
F. Engine No. 3	☐	☐	M. Lights	☐	☐
G. Engine No. 4	☐	☐	N. Other: *(Specify)*	☐	☐

14. Effect on Flight

- ☐ None
- ☐ Aborted Take-Off
- ☐ Precautionary Landing
- ☐ Engines Shut Down
- ☐ Other: *(Specify)*

15. Sky Condition

- ☐ No Cloud
- ☐ Some Cloud
- ☐ Overcast

16. Precipitation

- ☐ Fog
- ☐ Rain
- ☐ Snow
- ☐ None

17. Bird/Other Wildlife Species

18. Number of birds seen and/or struck

Number of Birds	Seen	Struck
1	☐	☐
2-10	☐	☐
11-100	☐	☐
more than 100	☐	☐

19. Size of Bird(s)

- ☐ Small
- ☐ Medium
- ☐ Large

20. Pilot Warned of Birds ☐ Yes ☐ No

21. Remarks *(Describe damage, injuries and other pertinent information)*

DAMAGE / COST INFORMATION

22. Aircraft time out of service:	23. Estimated cost of repairs or replacement *(U.S. $)*:	24. Estimated other cost *(U.S. $) (e.g. loss of revenue, fuel, hotels)*:
______ hours	$	$

Reported by *(Optional)*	Title	Date

Paperwork Reduction Act Statement: The information collected on this form is necessary to allow the Federal Aviation Administration to assess the magnitude and severity of the wildlife-aircraft strike problem in the U.S. The information is used in determining the best management practices for reducing the hazard to aviation safety caused by wildlife-aircraft strikes. We estimate that it will take approximately **5 minutes** to complete the form. The information collected is voluntary. Please note that an agency may not conduct or sponsor, and a person is not required to respond to, a collection of information unless it displays a currently valid OMB control number. The OMB control number associated with this collection is 2120-0045.

FAA Form 5200-7 (11-97) Supersedes Previous Edition NSN: 0052-00-651-9005

U.S. Department of Transportation Bird/Wildlife Strike Report Form.

Directions for FAA Form 5200-7
Bird/Other Wildlife Strike Report

1. Name of Operator - This can be an airline (abbreviations okay - UAL, AAL, etc.), business (Coca Cola), government agency (Police Dept., FAA) or if a private pilot, his or her name.
2. Aircraft Make/Model - Abbreviations are okay, but try to include the model (e.g., B737-200).
3. Engine Make/Model - Abbreviations are allowed (e.g., PW 4060, GECT7, LYC 580).
4. Aircraft Registration - This means the N# (for USA registered aircraft).
5. Date of Incident - Give the local date, not the ZULU or GMT date.
6. Local Time of Incident - Check the appropriate light conditions and fill in the hour and minute local time and check AM or PM or use the 24 clock and skip AM/PM.
7. Airport Name - Use the airport name or 3 letter code if a US airport. If a foreign airport, use the full name or 3 letter code and location (city/country).
8. Runway used - Self explanatory.
9. Location if En Route - Put the name of the nearest city and state.
10. Height AGL - Put the feet above ground level at the time of the strike (if you don't know, use MSL and indicate this). For take-off run and landing roll, it must be 0.
11. Speed (IAS) - Speed at which the aircraft was traveling when the strike occurred.
12. Phase of Flight - Phase of flight during which the strike occurred. Take-off run and landing roll should both be 0 AGL.
13. Part(s) of Aircraft Struck or Damaged - Check which parts were struck and damaged. If a part was damaged but not struck, indicate this with a check on the damaged column only and indicate in comments (#21) why this happened (e.g., the landing gear might be damaged by deer strike, causing the aircraft to flip over and damage parts not struck by deer).
14. Effect on Flight - You can check more than one and if you check "Other", please explain in Comments (#21).
15. Sky Condition - Check the one that applies.
16. Precipitation - You may check more than one.
17. Bird/Other Wildlife Species - Try to be accurate. If you don't know, put unknown and some description. Collect feathers or remains for identification for damaging strikes.
18. Number of birds seen and/or struck - Check the box in the Seen column with the correct number if you saw the birds/other wildlife before the strike and check the box in the Struck column to show how many were hit. The exact number, can be written next to the box.
19. Size of Bird(s)- Check what you think is the correct size (e.g. sparrow = small, gulls = medium and geese = large).
20. Pilot Warned of Birds - Check the correct box (even if it was an ATIS warning or NOTAM).
21. Remarks - Be as specific as you can. Include information about the extent of the damage, injuries, anything you think would be helpful to know. (e.g., number of birds ingested).
22. Aircraft time out of service - Record how many hours the aircraft was out of service.
23. Estimated cost of repairs or replacement - This may not be known immediately, but the data can be sent at a later date or put down a contact name and number for this data.
24. Estimated other cost - Include loss of revenue, fuel, hotels, etc. (see directions for #23).
25. Reported by - Although this is optional, it is helpful if questions arise about the information on the form (a phone number could also be included).
26. Title - This can be Pilot, Tower, Airport Operations, Airline Operations, Flight Safety, etc.
27. Date - Date the form was filled out.

Appendix D

Legislative and Regulatory References

Introduction

This appendix will assist the aviation community in referencing legislation and permits that apply to aviation-related wildlife-hazard management. The references include applicable Canadian and U.S. aviation, wildlife-management and environmental legislation, regulations and permits. When available, Internet references have also been provided. These references have been updated for the second edition of this book (2004); however, please note that website addresses are subject to change.

Canadian legislation and regulations

Wildlife-management programs

At the present time, Canadian law has no specific requirement for airports to establish wildlife-management programs. However, the Minister of Transport has the authority to call for such a requirement, as noted under Minister's responsibilities respecting aeronautics in Section 4.2 of the Aeronautics Act:

The Minister is responsible for the development and regulation of aeronautics and the supervision of all matters connected with aeronautics, and in the discharge of those responsibilities the Minister may:

(a) promote aeronautics by such means as the Minister considers appropriate;
(b) construct, maintain and operate aerodromes and establish and provide other facilities and services relating to aeronautics;
(e) control and manage all aircraft and equipment necessary for the conduct of any services of Her Majesty in right of Canada;
(j) cooperate or enter into administrative arrangements with aeronautics authorities of other governments or foreign states with respect to any matter relating to aeronautics;
(l) provide financial and other assistance to persons, governments and organizations in relation to matters pertaining to aeronautics;

(n) investigate matters concerning aviation safety; and
(o) undertake such other activities in relation to aeronautics as the Minister considers appropriate or as the Governor in Council may direct.

Internet home page: www.tc.gc.ca/aviation/regserv/carac/cars/aa/tocaae.htm

Airport zoning

Intended to prevent land-use activities that may lead to wildlife hazards, the following section of the Aeronautics Act concerns zoning of land in the vicinity of airports:

Aeronautics Act—Section 5.4 (2)
The Governor in Council may make regulations for the purposes of:
(a) preventing lands adjacent to or in the vicinity of a federal airport or an airport site from being used or developed in a manner that is, in the opinion of the Minister, incompatible with the operation of an airport;
(b) preventing lands adjacent to or in the vicinity of an airport or airport site from being used or developed in a manner that is, in the opinion of the Minister, incompatible with the safe operation of an airport or aircraft; and
(c) preventing lands adjacent to or in the vicinity of facilities used to provide services relating to aeronautics from being used or developed in a manner that would, in the opinion of the Minister, cause interference with signals or communications to and from aircraft or to and from those facilities.

Internet home page: www.tc.gc.ca/aviation/regserv/carac/cars/aa/tocaae.htm

Land Use in the Vicinity of Airports (TP1247)

This Transport Canada publication describes the operational characteristics of airports and how they are influenced by land-use activities outside airport boundaries. TP1247 also recommends guidelines for land use in the vicinity of airports. The principle recommendation relating to bird hazards states:

> *…provisions must be made for prohibiting the location of garbage dumps, food waste landfill sites, coastal commercial fish processing plants, and/or the planting of crops, that may either attract birds or adversely affect flight visibility, within 8 kilometers of an Aerodrome reference point.*

Internet home page: www.tc.gc.ca/aviation/aerodrme/noise/index_e.htm

Issuance of Airport Certificate: Canadian Air Regulation (CAR) 302.03

This regulation states:

(1) Subject to subsection 6.71(1) of the Act, the Minister shall issue an airport certificate to an applicant authorizing the applicant to operate an aerodrome as an airport if the

proposed airport operations manual, submitted pursuant to, is approved by the Minister pursuant to subsection (2) and;
(a) the standards set out in the aerodrome standards and recommended practices publications are met; or
(b) on the basis of an aeronautical study, the Minister determines that:
(i) the level of safety at the aerodrome is equivalent to that provided for by the standards set out in the aerodrome standards and recommended practices publications, and
(ii) the issuance of the airport certificate is in the public interest and not detrimental to aviation safety.

(2) The Minister shall approve a proposed airport operations manual if it:
(a) accurately describes the physical specifications of the aerodrome; and
(b) conforms to the requirements set out in the aerodrome standards and recommended practices publications that apply in respect of an airport operations manual.

(3) Where an aerodrome does not meet a standard set out in the aerodrome standards and recommended practices publications, the Minister may specify in the airport certificate such conditions relating to the subject-matter of the standard as are necessary to ensure a level of safety equivalent to that established by the standard and as are necessary in the public interest and to ensure aviation safety.

Internet home page:
http://www.tc.gc.ca/CivilAviation/RegServ/affairs/cars/menu.htm

Aerodrome certification

Aerodrome Standards & Recommended Practices (TP312) defines applicable safety standards for certified aerodromes. These regulations are currently under revision and cannot be accessed electronically. Paper copies of this document are available from:

Transport Canada, Aerodromes and Air Navigation Branch
330 Sparks Street
Place de Ville, Tower C, 7th floor
Ottawa, Ontario
K1A 0N8

Internet home page: www.tc.gc.ca

Wildlife Control Procedures Manual (TP11500)

Supporting Transport Canada's policy on wildlife management at airports, this manual provides guidance on the development, implementation and maintenance of airport wildlife-management plans.

Internet home page:
http://www.tc.gc.ca/CivilAviation/Aerodrome/WildlifeControl/menu.htm

Airspeed Limitations: Canadian Aviation Regulation (CAR) 602.32

In light of research that shows a direct correlation between airspeed and bird-strike severity, Transport Canada amended the CARs in 2003 to reduce departure airspeeds to 250 knots for aircraft operations below 10,000 feet MSL (mean sea level).

Part VI - General Operating and Flight Rules
Subpart 2 - Operating and Flight Rules

Airspeed Limitations

602.32 **(1)** Subject to subsection (2), no person shall operate an aircraft below 10,000 feet ASL at an indicated airspeed of more than 250 knots.

(2) No person shall operate an aircraft below 3,000 feet AGL within 10 nautical miles of a controlled airport at an indicated airspeed of more than 200 knots unless authorized to do so in an air traffic control clearance.

(3) Notwithstanding subsections (1) and (2), a person may operate an aircraft at an indicated airspeed greater than the airspeeds referred to in subsections (1) and (2) where the aircraft is being operated on departure or in accordance with a special flight operations certificate - special aviation event issued pursuant to section 603.02.

(4) Where the minimum safe speed for the flight configuration of an aircraft is greater than the speed referred to in subsection (1) or (2), the aircraft shall be operated at the minimum safe speed..

Internet home page:
http://www.tc.gc.ca/aviation/REGSERV/CARAC/CARS/cars/602e.htm#602_32

Canadian environmental legislation and regulations

Migratory Birds Convention Act

The Migratory Birds Convention Act addresses harassment, trapping and extermnination of young and adult birds, as well as the destruction of nests. Airport wildlife-management initiatives involving birds protected under the *Migratory Birds Convention Act* require federal permits from the Canadian Wildlife Service.

No federal permits are required for the killing of pigeons, House Sparrows, crows, blackbirds or starlings; however, some species may be protected by provincial regulations.

The Airport Permits section of the *Migratory Birds Convention Act* states:

Section 28

(1) The Minister may issue a permit:
   (a) to the manager of a civilian airport or the nominee of such manager, or

(b) to the commanding officer of a military airport, or the nominee of such commanding officer, to kill on the airport migratory birds that are considered by such a manager, commanding officer or nominee to be a danger to aircraft operation at such airport.

(2) A permit issued pursuant to subsection (1) is valid from the date of issue to the expiry date specified in the permit or, if it is canceled by the Minister, to the date of cancellation.

Section 4(d) of the *Migratory Birds Convention Act* provides regulations for the granting of permits to kill or take migratory birds, their nests and eggs.

http://www.ec.gc.ca/EnviroRegs/Eng/SearchResults.cfm?intSubCategory=13

Species at Risk Act (National Accord for the Protection of Species at Risk):

Federal, provincial and territorial ministers responsible for wildlife have committed to a national agreement on the protection of species at risk. If the bill becomes law, some aspects of airport wildlife management may be affected. Intended to prevent species in Canada from becoming extinct as a consequence of human activity, the Act will recognize the following:

(1) species do not recognize jurisdictional boundaries; inter-governmental cooperation is crucial to the conservation and protection of species at risk;
(2) the conservation of species at risk is a key component of broader conservation efforts in the Canadian Biodiversity Strategy;
(3) governments have a leadership role in providing both information on and appropriate measures for the conservation and protection of species at risk—the effective involvement of all Canadians is essential;
(4) species-conservation initiatives will be met through complementary federal and provincial/territorial legislation, regulations, policies and programs; and
(5) lack of complete scientific certainty must not be used to delay measures that avoid or minimize threats to species at risk.

Internet home page:
http://www.ec.gc.ca/EnviroRegs/Eng/SearchDetail.cfm?intAct=1049

Endangered-species list

The following list of endangered Canadian bird species was last updated in April 2003:

Northern Bobwhite	Piping Plover
Whooping Crane	King Rail
Spotted Owl	Western Screech-Owl
Eskimo Curlew	Loggerhead Shrike
Horned Lark	Henslow's Sparrow
Acadian Flycatcher	Roseate Tern
Sage Grouse	Sage Thrasher
Barn Owl	Kirtland's Warbler

Burrowing Owl	Prothonotary Warbler
Mountain Plover	White-headed Woodpecker

Internet home page: www.speciesatrisk.gc.ca/Species/English/SearchRequest.cfm

Federal Wetlands Policy

Adopted by Cabinet, the Federal Policy on Wetland Conservation applies to all federal departments, agencies, Crown corporations and programs. The policy must be considered in light of all departmental and other policies and expenditures related to projects subject to federal environmental assessment. The Provincial Wetland Policies of Alberta, Saskatchewan, Manitoba and Ontario have also been adopted at Cabinet level.

In support of the wetland policy's objectives, the federal Government, in cooperation with the provinces and territories and the Canadian public, will strive to achieve the following goals:

- maintenance of the functions and values derived from wetlands throughout Canada
- no net loss of wetland functions on all federal lands and waters
- enhancement and rehabilitation of wetlands in areas where the continuing loss or degradation of wetlands or their functions have reached critical levels
- recognition of wetland functions in resource planning, management and economic decision-making with regard to all federal programs, policies and activities
- securement of wetlands of significance to Canadians
- recognition of sound, sustainable management practices in sectors such as forestry and agriculture that make a positive contribution to wetlands conservation while also achieving wise use of wetland resources
- utilization of wetlands in a manner that enhances prospects for their sustained and productive use by future generations

This policy may affect wildlife-management programs if airports contain or are surrounded by wetlands.

Internet home page: www.ramsar.org/wurc_policy_canada.htm

Federal Fisheries Act

This Act applies to wildlife-management programs whenever fish and their habitat are affected. The applicable sections of the Act are:

Section 37

37. (1) Where a person carries on or proposes to carry on any work or undertaking that results or is likely to result in the alteration, disruption or destruction of fish habitat, or in the deposit of a deleterious substance in water frequented by fish or in any place under any conditions where that deleterious substance or any other deleterious

substance that results from the deposit of that deleterious substance may enter any such waters, the person shall, on the request of the Minister or without request in the manner and circumstances prescribed by regulations made under paragraph (3)(a), provide the Minister with such plans, specifications, studies, procedures, schedules, analyses, samples or other information relating to the work or undertaking and with such analyses, samples, evaluations, studies or other information relating to the water, place or fish habitat that is or is likely to be affected by the work or undertaking as will enable the Minister to determine

(*a*) whether the work or undertaking results or is likely to result in any alteration, disruption or destruction of fish habitat that constitutes or would constitute an offence under subsection 40(1) and what measures, if any, would prevent that result or mitigate the effects thereof; or
(*b*) whether there is or is likely to be a deposit of a deleterious substance by reason of the work or undertaking that constitutes or would constitute an offence under subsection 40(2) and what measures, if any, would prevent that deposit or mitigate the effects thereof.

Section 35
35. (1) No person shall carry on any work or undertaking that results in the harmful alteration, disruption or destruction of fish habitat.
(2) No person contravenes subsection (1) by causing the alteration, disruption or destruction of fish habitat by any means or under any conditions authorized by the Minister or under regulations made by the Governor in Council under this Act.

Internet home page:
http://www.ec.gc.ca/EnviroRegs/Eng/SearchDetail.cfm?intCategory=11&intAct=1017

The *Canadian Environmental Assessment Act* (CEAA)

The CEAA was implemented in the fall of 1994 and is currently under review. It requires that wildlife-management programs meeting specific criteria must—like all federal policies and activities—be assessed to ensure adverse environmental effects are minimized.

Section 4 states that the purposes of the Act are:
(1) to ensure that all environmental effects of projects receive careful consideration before responsible authorities take actions in connection with them;
(2) to encourage responsible authorities to take actions that will promote and maintain a healthy environment and a healthy economy; and
(3) to ensure that serious adverse environmental effects of projects to be carried out in Canada or on federal lands do not occur outside the jurisdiction in which the projects are carried out.

Internet home page:
http://www.ec.gc.ca/EnviroRegs/Eng/SearchDetail.cfm?intAct=1000#regulations

Permits for wildlife management

Provincial, federal and municipal permits may be required for wildlife-management activities that involve harassing, removing or killing wildlife.

Mammals fall under provincial jurisdiction. Permits required for hunting or trapping these animals must be obtained from respective provincial wildlife departments.

To determine applicable provincial and municipal permits, please refer to local regulatory authorities.

Firearms Acts and laws

In Canada, anyone wishing to use or own a firearm must obtain a Possession and Acquisition Licence (PAL). Application forms are available from local police. Applications can be returned to appropriate police agencies once completed.

As of January 1, 2001, the Possession and Acquisition Licence (PAL) is the only licence available to firearm holders in Canada. To obtain a PAL, applicants must first pass the Firearms Safety Course test, as administered by an instructor who is designated by a chief firearms officer. Anyone wishing to acquire handguns or other restricted or prohibited firearms must also pass the Canadian Restricted Firearms Safety Course test.

The Possession and Acquisition Licence (PAL) must be renewed every five years.

Additional information can be obtained from the Canadian Firearms Centre at:
1-800-731-4000 or canadian.firearms@justice.gc.ca

Internet homepage: www.canadianfirearms.com

Canadian provincial environmental regulations:

Under the *Constitution Act of Canada*, the federal government has exclusive jurisdiction over several areas, including federal property and its use in aeronautics. While the Crown is not bound by provincial law, prudent wildlife managers should do their utmost to respect provincial laws, acts and policies that may affect proposed programs. If in doubt, consult a legal officer of the Department of Justice to determine the best course of action.

Canadian pesticide regulations:

Through the *Pest Control Products Act* (PCRA), the *Canadian* federal government regulates products used to control pests and the organic functions of plants and animals. However, use of these products also falls under provincial and territorial jurisdiction. Consult individual provincial and territorial websites for further information.

Health Canada (federal government) Internet home page:
http://www.hc-sc.gc.ca/pmra-arla/english/legis/legis-e.html

U.S. legislation and regulations

Title 14, Code of Federal Regulations, Part 139
Wildlife Hazard Assessment FAR 139.337

FAR 139.337 is currently being revised; the updated regulation will be available on the FAA website once completed.

This regulation requires that a Wildlife Hazard Assessment (ecological study) acceptable to the Federal Aviation Administration (FAA) be conducted when any of the following events occur at or near airports:

- air-carrier aircraft experience multiple bird strikes or engine ingestions;
- air-carrier aircraft experience damaging collisions with wildlife other then birds; and
- wildlife of a size or in numbers capable of causing an event described in the above two situations is observed to have access to any airport-flight pattern or movement area.

Internet home page: http://www1.faa.gov/arp/ace/part139_wildlife.htm

Waste Disposal Sites on or Near Airports (AC 5200.33A)

This advisory circular provides guidance for the establishment, elimination and monitoring of landfills, open dumps, waste-disposal sites and similarly titled facilities at or in the vicinity of airports.

Revisions to this document state that no person shall construct or establish a municipal solid-waste landfill within six miles of public airports that have:

- received grants under Chapter 471, and
- are primarily served by general-aviation aircraft and regularly scheduled flights of aircraft designed for 60 passengers or less.

This revision results from findings that revealed:

- smaller aircraft flying from minor airports are as—if not more—susceptible to damaging bird strikes than larger aircraft at major centres; and
- landfills are largely responsible for attracting birds to smaller airports.

Internet home page: www.faa.gov/arp/pdf/5200-33.pdf

Aircraft Engine Certification (FAR 33)

This regulation prescribes airworthiness standards for airplane and rotorcraft engines.

Internet home page: www.faa.gov/avr/AFS/FARS/far-33.txt

Waste Disposal Site Notification Requirement: Title 40, Code of Federal Regulations, Part 258.10

The United States Environmental Protection Agency (USEPA) requires owners and operators of the following facilities to demonstrate successfully that their installations do not pose hazardous conditions to aircraft:

- municipal solid-waste landfill sites (MSWLF),
- units or lateral expansions of existing MSWLF units located within 10,000 feet of any airport runway used by turbojet aircraft, and
- units or lateral expansions of existing MSWLF units located within 5,000 feet of any airport runway that serves only piston-type aircraft.

The USEPA also requires any operators proposing new or expanded waste-disposal operations within five miles of a runway end to make the proposal known to the appropriate FAA Regional Airports Division Office and the airport operator.

Internet home page: www.epa.gov/epaoswer/hotline/training/mswd.txt

U.S. Environmental Regulations

Depredation Orders and Migratory Bird Permits (50CFR 21.43)

The Federal Migratory Bird Treaty Act protects all birds which:

- belong to a species listed in Section 10.13 of 50 CFR, or
- are mutations or hybrids of the listed species.

Local ordinances must be respected when considering harassment or lethal methods to control problem birds. Consult with local law-enforcement authorities or Regional DEC offices if there are questions concerning specific situations..

Title 50 Code of Federal Regulation Part 21.43

Section 21.43, Title 50 CFR, states that:

> *A Federal Permit shall not be required to control Red-winged, Rusty, and Brewer's Blackbirds, cowbirds, all grackles, crows, and magpies when found committing or about to commit depredations upon ornamental or shade trees, agricultural crops, livestock, or wildlife, or when concentrated in such numbers and manner as to constitute a health hazard or other nuisance.*

Internet home page: www.access.gpo.gov/nara/cfr/waisidx/50cfr21.html

Animal Damage Control Act (7 USC 426-426b) The Act of March 2, 1931 (46 Stat. 1468)

This Act authorizes and directs the Secretary of Agriculture to manage wildlife that are injurious to agriculture interests, other wildlife, and human health and safety—including wildlife that create aviation hazards. The Secretary is authorized to conduct investigations, experiments and tests to determine the best methods of eradication, suppression and control of wildlife.

Internet home page: www.fws.gov

Federal Insecticide, Fungicide and Rodenticide Act, as Amended (7 U.S. Code 36; Public Law 104.317)

Administered by the USEPA, this Act governs the registration, labeling, classification and use of pesticides. Any substance used as a pesticide must be registered with the USEPA and with the respective state pesticide regulatory agency. Anyone who wishes to use restricted pesticides and apply them under any circumstances must be a certified applicator—or work under the direct supervision of a certified applicator—and may use only pesticides covered by the certified applicator's licence.

Internet home page: http://www4.law.cornell.edu/uscode/

State environmental regulations and permits

State, federal and municipal permits may be required for such wildlife-management activities as harassing, removing or killing wildlife. For example, crows in Ohio may not be killed outside of the state crow-hunting season unless a state depredation permit has been issued; black birds may not be killed on Sundays. Non-native birds such as pigeons, House Sparrows and starlings—and gallinaceous game birds such as turkeys, grouse and pheasants—are not protected by the Federal Migratory Bird Treaty Act (MBTA), but may be protected under state laws.

To determine applicable state and municipal permits, please refer to local regulatory authorities.

Appendix E

Bibliography

Introduction

Howard, Fred. Wilbur and Orville: A Biography of the Wright Brothers. Alfred A. Knopf, Inc., 1987.

Harris, Sherwood. The First to Fly: Aviation's Pioneer Days. New York: Simon & Schuster Inc., 1970.

Blokpoel, H. Bird Hazards to Aircraft. Toronto: Irwin Clark, 1976.

Canada. Transport Canada. Wildlife Control Procedures Manual TP11500. Ottawa: Transport Canada, 1994.

Chapter 1

Canada. Transport Canada. Airport Wildlife Management Bulletin Number 22. Ottawa: Transport Canada, 1998.

Canada. Transport Canada. Transportation Development Centre. Initial Estimates of the Costs of Bird-Aircraft Strikes to Canadian Civil Aviation. Montreal: Transport Canada, 1997.

Cleary, E.C., S.E. Wright and R.A. Dolbeer. Wildlife Strikes to Civil Aircraft in the United States, 1992-1999. United States. Department of Transportation. Federal Aviation Administration. Office of Airport Safety and Standards (Wildlife Aircraft Strike Database, Serial Report Number 5). Washington, D.C.: Federal Aviation Administration, 2000.

Hayes, P. Legal Liability—Bird Hazards at Airports. Canada, Report to Transport Canada Safety and Security. Ottawa: Transport Canada, 1997.

Robinson, M. The Potential for Significant Financial Loss Resulting from Bird Strikes in or Around an Airport. Proceedings and Papers. International Bird Strike Committee (IBSC) meeting no. 23, May 1996. London, U.K.: IBSC, 1996. 353-367.

Chapter 2

Canada. Transport Canada. System Safety Directorate. Report of a Post-occurrence Safety Review of a Birdstrike Occurrence to B-737, CDN Flight 661, at Calgary International Airport, June 17, 1993. Ottawa: Transport Canada, 1993.

Canada. Transportation Safety Board of Canada. Aviation Occurrence Report: Bird Strike to Canadian Airlines International Boeing 737-275, C-GIPW, Calgary International Airport, Alberta, 17 June 1993, Report Number A93W0082. Ottawa: Transportation Safety Board of Canada. 1994.

Perrow, Charles. Normal Accidents: Living with High-Risk Technologies. New York: Harper Collins, 1984.

Perry, Bob. "An Early Morning Wake-up Call." Air Line Pilot November/December 1995: 36-39.

Reason, James. Human Error. Cambridge: Cambridge University Press, 1990.

Reason, James. Managing the Risks of Organizational Accidents. Aldershot: Ashgate Publishing Limited, 1997.

Roland, Harold and Brian Moriarty. System Safety Engineering and Management. New York: John Wiley & Sons, 1990.

Sowden, Richard and Kelly, Terry. Risk Analysis of High Speed Aircraft Departures Below 10,000 Feet. Ottawa: Transport Canada. 2002.

United States. National Transportation Safety Board. Recommendations A-96-38 through –42. Washington, D.C.: National Transportation Safety Board, 1996.

Waring, Alan and A. Ian Glendon. Managing Risk: Critical Issues for Survival and Success in the 21st Century. London: International Thomson Business Press, 1998.

Chapter 3

Brooke, M and T. Birkhead. The Cambridge Encyclopaedia of Ornithology. Cambridge: Cambridge University Press, 1991.

Cadma, M.D., P.F.J. Eagles and F.M. Helleiner. Atlas of the Breeding Birds of Ontario. Waterloo, Ontario: University of Waterloo Press, 1987.

Diamond, A.W., and F.L. Filion. The Value of Birds. International Council for Bird Preservation (ICBP) Technical Publication No. 6 (conference proceedings). Kingston, Ontario: ICBP, 1987.

Erskine, A.J. Atlas of the Breeding Birds of the Maritime Provinces. Halifax, Nova Scotia: Nimbus Publishing Ltd. and Nova Scotia Museum, 1992.

Friend, M., ed. Field Guide to Wildlife Diseases: Volume 1. General Field Procedures and Diseases of Migratory Birds. United States Department of the Interior, Fish and Wildlife Service Resource Publication 167. Washington, D.C.: Department of the Interior, 1987.

Gauthier, J., and Y. Aubry, eds. The Breeding Birds Of Quebec: Atlas of the Breeding Birds of Southern Quebec. Canada. Environment Canada. Canadian Wildlife Service. Association Quebecoise des Groupes D'ornithologues (Province of Quebec Society for the Protection of Birds). Montreal: Environment Canada, 1996.

Godfrey, W.E. The Birds of Canada, Revised Edition. Canada. National Museum of Natural Sciences. Ottawa: Government of Canada, 1986.

Joseph, R. J., Jr. and N.K. Johnson. A Century of Avifaunal Change In Western North America. Studies in Avian Biology No. 15. Cooper Ornithological Society. Proceedings of an International Symposium at the Centennial Meeting of the Cooper Ornithological Society. Sacramento, California: Cooper Ornithological Society, 1994.

Welty, J.C. and L. Baptista. The Life Of Birds, Fourth Edition. Toronto, Ontario: Saunders College Publishing, 1988.

Chapter 4

Banfield, A.W.F. The Mammals of Canada. Toronto: University of Toronto Press, 1974.

Burt, W. H., and R. P. Grossenheider. A Field Guide to the Mammals of North America, Second Edition. Boston: Houghton-Mifflin Company, 1964.

Dobbyn, J. S. Atlas of the Mammals of Ontario. Don Mills: Federation of Ontario Naturalists, 1994.

Murie, O. A Field Guide to Animal Tracks. Boston: Houghton-Mifflin Company, 1954.

Chapter 5

Aviation Week & Space Technology Aerospace Source Book. New York: The McGraw Hill Companies, 2000.

Banilower, Howard. Bird Ingestion Into Large Turbofan Engines, Final Report. United States. Department of Transportation. Federal Aviation Administration Report CT-93-14. Washington, D.C.: Federal Aviation Administration, 1995.

Business Aviation Fact Book. National Business Aviation Association (NBAA). Washington, D.C.: NBAA, 1999.

Canada. Transport Canada. Aviation Forecasts 2000 – 2013. Ottawa: Transport Canada, June 2000.

Current Market Outlook. Seattle: The Boeing Company, 1999.

GAMA Statistics. Washington, D.C.: General Aviation Manufacturers Association (GAMA), 9 February 2000.

General Aviation Statistics. United Kingdom: General Aviation Manufacturers and Traders Association (GAMTA), September 1999.

Global Market Forecast 1999 – 2018. Blagnac, France: Airbus Industrie, 1999.

World Jet Inventory, Year End 1999. Woodinville, WA: Jet Information Services, Inc., 2000.

Regional Aircraft Market Outlook. Montreal: Bombardier Aerospace, March 7, 2000.

Sportel, Terah Sunshine. Aircraft Types and How They are Affected by Birds; Fleet Distribution—World-Wide. Waterloo, Ontario: University of Waterloo Faculty of Environmental Studies, 1997.

Chapter 6

Ashford, Norman, Clifton A. Moore, and H.P. Martin Stanton. Airport Operations. New York: McGraw-Hill Inc., 1997.

Canada. Transport Canada. Aerodrome Standards & Recommended Practices TP 312. Ottawa: Transport Canada, 1993.

Canada. Transport Canada. Aviation Forecasts 2000 – 2013. Ottawa: Transport Canada, June 2000.

Canada. Transport Canada. "Land Use Adjacent to Airports." Airport Wildlife Management. Bulletin No. 14. Ottawa: Transport Canada, 1994.

Canada. Transport Canada. Land Use in the Vicinity of Airports TP 1247. Ottawa: Transport Canada, 1989.

Canada. Transport Canada. Wildlife Control Procedures Manual TP 11500. Ottawa: Transport Canada, 1994.

Hodges, K. "Growth Across the Board." Airports International. July/August 1997.

Piers, M. The Development and Application of a Method For the Assessment of Third Party Risk Due to Aircraft Accidents in the Vicinity of Airports. Netherlands. National Aerospace Laboratory, NLR. Amsterdam: Government of the Netherlands.

Rao, Arun and Alistair Pinos. "Bird Strike Threat is Best Countered by Effective Wildlife Control Augmented by Land-use Management." ICAO Journal. October 1998.

Robinson, M. The Potential for Significant Financial Loss Resulting from Bird Strikes in or Around an Airport. Proceedings and Papers. International Bird Strike Committee (IBSC) meeting no. 23, May 1996. London, U.K.: IBSC, 1996. 353-367

Rowe, Richard. "The Catastrophe Business." Airports International. June 1996.

Chapter 7

Banilower, H. and C. Goodall. Bird Ingestion Into Large Turbofan Engines. United States. Department of Transportation. Federal Aviation Administration Report CT-93/14. Technical Center, Atlantic City International Airport, New Jersey. Washington, D.C.: Federal Aviation Administration, 1995.

Canada. Transport Canada. Annual. Bird Strikes to Canadian Aircraft: 1999 (and previous years) Summary Report. Transport Canada, Aerodrome Safety Branch. Ottawa: Transport Canada, 1999.

Cleary, E.C., S.E. Wright and R.A. Dolbeer. Wildlife Strikes to Civil Aircraft in the United States, 1991-1999. United States. Department of Transportation. Federal Aviation Administration, Office of Airport Safety and Standards, Wildlife Aircraft Strike Database, Serial Report Number 5. Washington, D.C.: Federal Aviation Administration, 2000.

Robinson, M. The Potential for Significant Financial Loss Resulting from Aircraft Bird Strikes in and Around an Airport. Minutes of the 25th Meeting of Bird Strike Committee Canada. Ottawa: Bird Strike Committee Canada, 1996.

Thorpe, J. Fatalities and Destroyed Civil Aircraft Due to Bird Strikes, 1912-1995. International Bird Strike Committee (IBSC) meeting no. 23, Paper IBSC/WP1. London, U.K.: IBSC, 1996. 17-31.

Chapter 8

Canada. Transport Canada. Airport Wildlife Management Bulletin TP8240 No. 1-22. Ottawa: Transport Canada, 1987-1998.

Canada. Transport Canada. Wildlife Control Procedures Manual TP11500. Ottawa: Transport Canada, 1994.

Cleary, E. and R. Dolbeer. Wildlife Hazard Management at Airports. United States. Department of Transportation. Federal Aviation Administration. U.S. Department of Agriculture, Wildlife Services. Washington, D.C.: Federal Aviation Administration/U.S. Department of Agriculture, 1999.

Donalds, T. "ORM for Airfield Wildlife Hazard." The Combat Edge. 20-22 December, 1997.

Deacon, N. Airfield Bird Control—Applying the Principles. Proceedings and Papers, International Bird Strike Committee (IBSC) meeting no. 23, May 1996. London, U.K.: IBSC, 1996. 319-325

Hygnstrom, S.E., R.M. Timm and G.E. Larson, eds. Prevention and Control of Wildlife Damage. United States. Department of Agriculture. Animal and Plant Health Inspection Service. Animal Damage Control. Great Plains Agricultural Council Wildlife Committee. University of Nebraska Cooperative Extension. 2 volumes. Lincoln, Nebraska: University of Nebraska, 1994.

International Organization for Standardization. ISO 14001 Environmental Management Systems-Specification with Guidance for Use. Switzerland: International Organization for Standardization, 1996.

Jacques Whitford Environment Limited. Victoria International Airport Wildlife Management Plan. Canada. Transport Canada. Ottawa: Transport Canada, 1996.

MacKinnon, B. The Role and Value of Awareness Programs in Reducing Bird Hazards to Aircraft. Proceedings and Papers. International Bird Strike Committee (IBSC) meeting no. 23, May 1996. London, U.K.: IBSC, 1996. 237-246.

Robinson, M. The Potential for Significant Financial Loss Resulting from Bird Strikes in or Around an Airport. Proceedings and Papers. International Bird Strike Committee (IBSC) meeting no. 23, May 1996. London, U.K.: IBSC, 1996. 353-367.

Seubert, J. L. Assessing the Implementation of Wildlife Hazard Management Programs at Civil Airports. Proceedings of Bird Strike Committee Europe (BSCE) meeting no. 22. Vienna: BSCE, 1994. 275-284.

Steele, W. K. Bird Hazards and their Management at Melbourne International Airport. Birds Australia. Report for Melbourne Airport. 1997.

Rochard, B. Airfield Bird Control—Setting the Standards. Proceedings and Papers, International Bird Strike Committee (IBSC) meeting no. 23, May 1996. London, U.K.: IBSC, 1996. 311-318.

Chapter 9

Canada. Transportation Safety Board of Canada. Aviation Occurrence Report: Bird Strike to Canadian Airlines International Boeing 737-275, C-GIPW, Calgary International Airport, Alberta, 17 June 1993, Report Number A93W0082. Ottawa: Transportation Safety Board of Canada, 1994.

Canada. Transport Canada. Bird Hazard Management: Turning Awareness into Prevention TP 13200. Transport Canada Safety & Security. Ottawa: Transport Canada, 1995.

Canada. Transport Canada. System Safety Directorate. Report of a Post-occurrence Safety Review of a Birdstrike Occurrence to B-737, CDN Flight 661, at Calgary International Airport, June 17, 1993. Ottawa: Transport Canada, 1993.

Manual of Operations (MANOPS). NAV CANADA, current amendment.

Perry, Bob. "An Early Morning Wake-up Call." Air Line Pilot November/December 1995: 36-39.

Chapter 10

Bird Strike Committee Europe. Proceedings. May 13-16, 1996. London, U.K.: International Bird Strike Committee, 1996.

Canada. Transport Canada. Aeronautics Act, current amendment. Ottawa: Transport Canada.

Canada. Transport Canada. A.I.P. Canada (TP2300E). Ottawa: Transport Canada.

Canada. Transport Canada. To current amendment. Canadian Aviation Regulations, Part VI—General Operating and Flight Rules (TP12604E), current amendment. Ottawa: Transport Canada.

Canada. Transport Canada. Bird Avoidance (TP12422). Ottawa: Transport Canada.

Curtis, Todd. Assessment of Bird Strike Accident Risk Using Event Sequence Analysis. Bird Strike Committee Europe meeting no. 23. London, U.K.: International Bird Strike Committee (IBSC), 1996.

Eschenfelder, Captain P. Wildlife Hazards to Aviation. Shannon, Ireland: International Society of Air Safety Investigators, October 2000.

Riddington, R. The Large Flocking Bird Hazard. Civil Aviation Authority of the U.K (CAA). United Kingdom: Flight Safety Foundation, 2000.

Chapter 11

Air Canada. "Potential For Bird Strikes is Growing, An Agenda for Action." Flightline, Air Canada's Flight Operations Safety Review (November 1998). Reprinted from Air Safety Week.

Canada. Transport Canada. Summary of Canadian Bird Strike Statistics for 1997. Ottawa: Transport Canada, 1998.

Carlson, Janice E. "Moves to Reduce Bird-Aircraft Accidents." US Air Force News. United States. United States Air Force. AMC (Air Mobility Command), Scott Air Force Base, Illinois. February 1996.

Curtis, Todd. North American Bird Hazard Reduction Efforts Since the 707 AWACS Accident at Elmendorf AFB. Proceedings, The International Society of Air Safety Investigators. Seattle: Boeing Commercial Airplane Group, 1997.

United States. National Transportation Safety Board. Aviation Accident/Incident Database 1993 -1997. Available online. Washington, D.C.: National Transportation Safety Board.

Chapter 12

Alge, Thomas L., GE Aircraft Engines. Canada. Transport Canada. Commercial Transport Engine Bird-Ingestion Design Considerations. Minutes of the Twenty-Fourth Meeting of Bird Strike Committee Canada, April 1996. Richmond, B.C. Canada: Transport Canada, 1996.

Alge, Thomas L. and John T. Moehring. The Worldwide Bird Problem—Effects on Aircraft, Status of the Problem and Control of the Hazard. Paper. Joint Meeting of the Flight Safety Foundation 49th Annual International Seminar, the International Federation of Airworthiness 26th International Conference and the International Air Transport Association. Dubai, United Arab Emirates, 14 November 1996.

---. The Engine Birdstrike Hazard as Influenced by the Global Environment of Current Regional Airlines and Corporate Jet Operations. Paper. 9th Annual European Aviation Safety Seminar (EASS) of the Flight Safety Foundation, Amsterdam, The Netherlands: 4 March 1997.

Banilower, Howard. Bird Ingestion Into Large Turbofan Engines, Final Report. United States. Department of Transportation. Federal Aviation Administration Report CT-93-14. Washington, D.C.: Federal Aviation Administration, 1995.

Bird Strike Committee USA. Understanding and Reducing Hazards to Aircraft. A presentation to Bird Strike Committee U.S.A. 1998.

Curtis, Todd. North American Bird Hazard Reduction Efforts Since the 707 AWACS Accident at Elmendorf AFB. Proceedings, The International Society of Air Safety Investigators. Seattle: Boeing Commercial Airplane Group, 1997.

General Electric. "Engine Successful in Bird Strike Test." News Release. Evendale, Ohio: General Electric, 10 July 1995.

Martindale, Ian. Rolls-Royce plc. Bird Ingestion and Rolls-Royce Aero Engines. Paper. The International Bird Strike Committee Meeting, no. 23, London U.K. May 1996: IBSC, 1996.

Parker, Richard. Pratt and Whitney. Harmonizing Engine Design Rules United States – Europe. Paper. Bird Strike Committee Europe meeting no. 22. Vienna: BSCE, 1994.

Phillips, Edward H. "Bird Strike Threat Draws New Warning." Aviation Week and Space Technology. 5 February 1996.

Rolls-Royce plc. "Rolls-Royce Trent Passes Major Bird Strike Test." Journal of Aircraft Engineering and Aerospace Technology. 1 November 1993.

Speelman, Ralph J., Malcolm E. Kelley, Robert E. McCarty and Jeffrey J. Short. Aircraft Birdstrikes: Preventing and Tolerating. Paper. The International Bird Strike Committee (IBSC) meeting no. 24, Stara Lesna, Slovakia. September 1998: IBSC, 1998.

United States. Department of Transportation. Federal Aviation Administration. Final Rule 14 CFR Parts 27 and 29 Rotorcraft Regulatory Changes based on European Joint Aviation Requirements, Federal Register: (Volume 61, Number 92). Washington, D.C.: Federal Aviation Administration, 1996.

United States. Department of Transportation. Federal Aviation Administration. Notice Of Proposed Rulemaking, 14 CFR Parts 23, 25 and 33, Airworthiness Standards; Bird Ingestion, Federal Register: December 11, 1998 (Volume 63, Number 238). Washington, D.C.: Federal Aviation Administration, 1998.

United States. Department of Transportation. Federal Aviation Administration. Revised Standard, CFR Part 33, Airworthiness Standards; Bird Ingestion, Federal Register: September 14, 2000. Washington, D.C.: Federal Aviation Administration, 2000.

Chapter 13

Richardson, W.J. Serious Bird Strike-Related Accidents to Military Aircraft of Europe and Israel: List and Analysis of Circumstances. Proceedings and Papers. International Bird Strike Committee (IBSC) meeting no. 23, May 1996. London, U.K.: IBSC, 1996. 33-56.

Richardson, W. J. (Canada) and Tim West (U.K.). Serious Birdstrike Accidents to Military Aircraft: Updated List and Summary. WP-SA1 Proceedings and Papers International Bird Strike Committee (IBSC) meeting no. 25, Amsterdam, The Netherlands, April, 2000. IBSC, 2000. 67-97.

Chapter 14

Green, J., J. Bahr, R. Erwin, J. Buckingham and H. Peel. Reduction of Bird Hazards to Aircraft: Research and Development of Strobe Light Technology as a Bird Deterrent. Canada. Transport Canada. Transportation Development Centre. Report prepared by The Delta Environmental Management Group Ltd. (Vancouver) and The Southwest Research Institute (San Antonio, Texas). Montreal: Transport Canada, 1993.

Greneker, G. Radar to Detect Foreign Object Ingestion by a Jet Engine. Proceedings of the International Society for Optical Engineering, 13th Annual International Symposium on Aerosense, Session 1: Radar Sensor technology IV. Proceedings Volume 3704. Orlando, Florida, 1999.

Blackwell. B. F., G.E. Bernhardt, and R. A. Dolbeer. 2002. Lasers as nonlethal avian repellents. Journal of Wildlife Management 66(1): 250-258.

Leshem, Y., J. Shamoun-Baranes, M. Yanai, R. Tamir and Y. Yom-Tov. The Development of a Global Database on Bird Movements and Bird Strikes in Military and Civilian Flight. Paper. The International Bird Strike Committee (IBSC) meeting no. 24, Stara Lesna, Slovakia. September 1998: IBSC, 1998.

Lovell, C.D. and R.A. Dolbeer. Validation of the United States Air Force Bird Avoidance Model. Wildlife Society Bulletin 27(1)1999: 167-171.

Nordwall, Bruce D. 1997. "Radar Warns Birds of Impending Aircraft." Aviation Week & Space Technology. 10 March 1997: 65-66.

Seegar, W.S., M.R. Fuller, P.W. Howey and Y. Leshem. Satellite Telemetry, a Tool for Tracking and Monitoring Bird Movements from a Local to Global Scale. Proceedings and Papers, International Bird Strike Committee meeting no. 24, Stara Lesna, Slovakia. September 1998: IBSC, 1998. 443-462.

Shannon, H.D., W.S. Seegar, G.S. Young, C.J. Pennycuick, M.R. Fuller, M.A. Yates, B.J. Dayton, M.B. Henke, M.A. Bramer, T. Maechtle and L. Schueck. Bird Flight Forecast and Information System. Proceedings and Papers, International Bird Strike Committee (IBSC) meeting no. 24, Stara Lesna, Slovakia. September 1998: IBSC, 1998. 297-301.

Short, J.J., M.E. Kelley and J. McKeeman. Recent Research into Reducing Birdstrike Hazards. Proceedings and Papers, International Bird Strike Committee (IBSC) meeting no. 23. London, U.K: IBSC, 1996. 443-462.

Appendix 3.1

Common Bird Zoonoses

Type	Arboviral encephalitis	Histoplasmosis	Psittacosis
Description	Inflammation of the brain caused by Arboviral infection.	Infection by the pathogenic fungus *Histoplasma capsulatum*.	Infection by the bacterium *Chlamydia psittaci*.
Birds Involved	Many species such as waterfowl and wild birds.	No birds directly involved as the fungus, *H. capsulatum*, does not infect birds.	Found in both wild and domesticated birds but is more commonly found in the latter.
Source or mode of infection	Transferred to birds from blood-sucking insects (such as mosquitoes and ticks). Humans acquire it from infected mosquitoes.	Acquired through inhalation of spores from fungus in soils contaminated by bird droppings.	Transmitted to host through inhalation of aerosolised particles or by ingesting contaminated food; also acquired through direct contact with infected bird tissues, feces and secreta.
Clinical signs of infection in people	*First symptoms*: fever, chills and headache. *More serious symptoms*: drowsiness, nausea, coma, confusion, rigidity and convulsions; may cause death.	*Different indications of symptoms depending on severity*: ranging from asymptomatic to permanent pulmonary calcification and permanent lesions.	Mostly asymptomatic or mild. *Mild symptoms*: similar to flu. *Severe symptoms*: fever, chills, malaise, myalgia, loss of appetite, headache, cough and chest pain.
Precautions and preventions	Prevent mosquito bites by wearing protective clothing; use repellents, scare tactics and mosquito netting and screening; modify habitats.	Clean up bird droppings regularly; moisten droppings to prevent spores from becoming airborne; wear face masks, disposable coveralls, gloves, boots, surgical caps and goggles during clean-up.	Wear gloves to prevent bird bites and direct contact with feces; wear facemasks, protective clothing and surgical caps; moisten and spray a 1% solution of household disinfectant on the dropping to prevent the bacteria from becoming airborne.

Appendix 5.1

FAA Airworthiness Requirements for Airframes

1. Transport Category Aircraft—FAR 25

1.1. Part 25.571 Damage—Tolerance and Fatigue Evaluation of Structure

(a) General. An evaluation of strength, detailed design, and fabrication must show that catastrophic failure due to fatigue, corrosion, or accidental damage, will be avoided throughout the operational life of the airplane. This evaluation must be conducted in accordance with the provisions of paragraphs (b) and (e) of this section, except as specified in paragraph (c) of this section, for each part of the structure which could contribute to a catastrophic failure (such as wing, empennage, control surfaces and their systems, the fuselage, engine mounting, landing gear, and their related primary attachments).

(e) Damage – tolerance (discrete source) evaluation. The airplane must be capable of successfully completing a flight during which likely structural damage occurs as a result of:

(1) Impact with a 4-pound bird when the velocity of the airplane relative to the bird along the airplane's flight path is equal to Vc at sea level or 0.85Vc at 8,000 feet, whichever is more critical;
(2) Uncontained fan blade impact;
(3) Uncontained engine failure; or
(4) Uncontained high energy rotating machinery failure.

1.2 Part 25.631 Bird Strike Damage—Empennage

The empennage structure must be designed to assure capability of continued safe flight and landing of the airplane after impact with an 8-pound bird when the velocity of the airplane (relative to the bird along the airplane's flight path) is equal to V_c at sea level, selected under Part 25.335(a). Compliance with this section by provision of redundant structure and protected location of control system elements or protective devices such as splitter plates or energy absorbing material is acceptable. Where analysis, tests, or both show compliance, use of data on airplanes having similar structural design is acceptable.

1.3. Part 25.775 Windshields and Windows

(a) Internal panes must be made of non-splintering material.

(b) Windshield panes directly in front of the pilots in the normal conduct of their duties, and the supporting structures for these panes, must withstand, without penetration, the impact of a 4-pound bird when the velocity of the airplane (relative to the bird along the airplane's flight path) is equal to the value of V_C, at sea level, selected under Part 225.335(a).

1.4. Part 25.1323 Airspeed Indicating System

(f) Where duplicate airspeed indicators are required, their respective pitot tubes must be far enough apart to avoid damage to both tubes in a collision with a bird.

2. Normal, Utility, Acrobatic and Commuter Aircraft—FAR 23

2.1 Part 23.775 Windshield and Windows

(h) In addition, for commuter category airplanes, the following applies:

(1) Windshield panes directly in front of the pilots in the normal conduct of their duties, and the supporting structures for these panes, must withstand, without penetration, the impact of a 2-pound bird when the velocity of the airplane (relative to the bird along the airplane's flight path) is equal to the airplane's maximum approach flap speed.

(2) The windshield panels in front of the pilots must be arranged so that, assuming the loss of vision through any one panel, one or more panels remain available for use by a pilot seated at a pilot station to permit continued safe flight and landing.

2.2. Part 23.1323 Airspeed Indicating System

(f) For commuter category airplanes, where duplicate airspeed indicators are required, their respective pitot tubes must be far enough apart to avoid damage to both tubes in a collision with a bird.

3. Normal Category Rotorcraft—FAR 27

There are no specific requirements for bird proofing within these standards.

4. Transport Category Rotorcraft—FAR 29

Part 29.631 Bird Strike

The rotorcraft must be designed to ensure capability of continued safe flight and landing (for Category A) or safe landing (for Category B) after impact with a 2.2-lb. bird when the velocity of the rotorcraft (relative to the bird along the flight path of the rotorcraft) is equal to VNE or VH (whichever is less) at altitudes up to 8,000 feet. Compliance must be shown by tests or by analysis based on tests carried out on sufficiently representative structures of a similar design.

Appendix 5.2

Airworthiness Standards Aircraft Engines—FAR 33

Airworthiness Standards Aircraft Engines—FAR 33

Part 33.77 Foreign Object Ingestion

(a) Ingestion of a 4-pound bird, under the conditions prescribed in paragraph (e) of this section, may not cause the engine to:
   (1) Catch fire;
   (2) Burst (release hazardous fragments through the engine case);
   (3) Generate loads greater than those ultimate loads specified in Sec. 33.23(a); or
   (4) Lose the capability of being shut down.

(b) Ingestion of a 3-pound bird or 1.5-pound bird, under the conditions prescribed in paragraph (e) of this section, may not:
   (1) Cause more than a sustained 25 percent power or thrust loss;
   (2) Require the engine to be shut down within 5 minutes from the time of the ingestion; or
   (3) Result in a potentially hazardous condition.

(c) (relates to ice ingestion)
(d) (relates to protective devices)
(e) Compliance with paragraphs (a), (b), and (c) of this section must be shown by engine tests under the following conditions:

Foreign Object (BIRDS)	Test Quantity	Speed of Foreign Object	Engine Operation	Ingestion
3-ounce size	One for each 50 square inches of inlet area or fraction thereof, up to a maximum of 16 birds. 3-ounce bird ingestion not required if a 1.5-pound bird will pass the inlet guide vanes into the rotor blades.	Liftoff speed of typical aircraft.	Takeoff	In rapid sequence to simulate a flock encounter, and aimed at selected critical areas.
1.5-pound size	One for the first 300 square inches of inlet area, if it can enter the inlet, plus one for each additional 600 square inches of inlet area, or fraction thereof, up to a maximum of eight birds.	Initial climb speed of typical aircraft.	Takeoff	In rapid sequence to simulate a flock encounter, and at selected critical areas.
4-pound size	One, if it can enter the inlet.	Maximum climb speed of typical aircraft if the engine has inlet guide vanes. Liftoff speed of typical aircraft, if the engine does not have inlet guide vanes.	Takeoff	Aimed at critical area.

Part 23.903 Normal, Utility, Acrobatic, and Commuter Category Airplanes; and Part 25.903 Transport Category Airplanes

Both sections have identical wording as follows:

(2) Each turbine must either:
- (i) Comply with Secs. 33.77 and 33.78 of this chapter in effect on April 30, 1998; or as subsequently amended;
- (ii) Comply with Sec. 33.77 of this chapter in effect on October 31, 1974, or as subsequently amended prior to April 30, 1998, and must have a foreign object ingestion service history that has not resulted in any unsafe condition; or
- (iii) Be shown to have a foreign object ingestion service history in similar installation locations, which has not resulted in any unsafe condition.

Appendix 12.1

Bird-impact Forces — The Physics

Introduction

This book features a series of tables that assist readers in understanding the impact forces that are generated by birds of various weights at a variety of speeds:

- Table 12.1—Bird Impact Forces vs. Speed
- Table 12.2—FAR 33 Engine Certification Standard Bird Weights
- Table 5.5—FAR 23, 25 & 29 Airframe Certification Standard Bird Impact Forces
- Table 5.6—FAR 33 Engine Certification Standards (Old) Bird Impact Forces

Knowledge of impact force and the potential for aircraft damage are critical in the design and certification of aircraft components. This section summarizes the methodology applied in the calculation of bird-impact forces.

Impact-force calculation assumptions

There are a number of factors that affect the impact of a bird strike. These include:

- impact speed,
- bird weight,
- bird density,
- bird rigidity,
- angle of impact,
- impact-surface shape, and
- impact-surface rigidity.

To simplify the calculation, the following assumptions were made:

- impact speed is equal to the speed of the aircraft;
- impact angle is 90 degrees;
- bird shape is spherical;
- bird is deformed by one half of its size on impact;
- aircraft impact surface does not deform; and
- aircraft impact surface is flat.

Bird-impact force mathematical equation

The bird-strike impact-force equation was developed with the assistance of Mr. A. C. Tribble of the Advanced Technology Center at Rockwell Collins. The equation was derived as follows:

1. The energy transfer—or pressure—that results from a bird strike to an aircraft hull can be estimated through relatively simple calculations. Taking the simplest approximation—where the bird is at rest and 'sticks' to the aircraft after the collision—the change in a bird's kinetic energy is

$$\Delta KE = W = Fd = \frac{1}{2}mv^2$$

   where W is the work, F is the force, d is the distance over which the force is delivered, m is the mass of the bird and v is the velocity of the aircraft.

2. The force that the bird felt—the same force that the airplane felt—is given by

$$F = \frac{\Delta KE}{d} = \frac{mv^2}{2d}$$

   We can estimate the bird's mass, m, and the aircraft speed, v, with ease. The key parameter then is the distance d over which the impact is delivered.

3. As a first approximation, let's assume it is half the distance traveled by the aircraft in moving through the bird-impact event. If we further assume that the bird can be represented as a sphere, we end up with

$$F = \frac{mv^2}{2r}$$

4. If we assume the bird is spherical, then the bird's size depends on its mass according to the relation

$$m = V\rho = \frac{4}{3}\pi r^3 \rho$$

   where ρ is the bird's density.

5. Combining the two previous expressions gives

$$F = \frac{2\pi r^2 \rho v^2}{3}$$

Glossary

Active management • A type of wildlife management in which short-term solutions, such as pyrotechnics and distress calls, are employed to disperse wildlife from airport property.

Aerodrome • Any area of land, water (including ice surfaces) or other supporting surface used, designed, prepared, equipped or designated for the arrival and departure, movement or servicing of aircraft. Includes all associated buildings, installations and equipment.

Aeronautics • The science, art and practice of aerial navigation.

Aeronautics Act • A legal document that stipulates regulations and safety standards pertaining to aircraft and aerodromes.

AGL • Altitude above ground level.

Airport • In Canada, an aerodrome for which an airport certificate has been issued by the Transport Minister under Part III of the Air Regulations.

Air Traffic Control Unit • An area control centre (ACC); a terminal control unit (TCU); an airport tower control unit.

Airport tower control unit • A control unit established to provide air-traffic control service to airport traffic.

Airport wildlife activity • The presence of any birds and mammals within airport ground perimeters and the airspace up to 200 feet above ground level on approach, and up to 500 feet above ground level on takeoff.

Airport wildlife incident • Any airport wildlife activity that presents flight safety hazards or causes pilots to take evasive action.

Airport wildlife occurrence • Any wildlife incident, bird strike, or mammal strike that takes place within airport ground perimeters and the airspace up to 200 feet above ground level on approach, and up to 500 feet above ground level on takeoff.

Airport zoning regulations • In Canada, a regulation made by the Governor in Council respecting a given airport pursuant to section 5.4 of the Aeronautics Act.

Air traffic • All aircraft in flight or operating on the manoeuvring area of an aerodrome.

ATS Providers • Air-traffic service providers; a collective term for air-traffic controllers, terminal controllers, arrival controllers, departure controllers, ground controllers and flight-service specialists.

Altitude • Height above sea level (ASL) or ground (AGL).

Area Control Centre (ACC) • A control unit established to provide air-traffic control service to IFR flights and controlled VFR flights.

Arrival control(ler) • An ATS provider who expedites the flow of inbound IFR flights within a terminal control area, and who may also service VFR flights.

ASL • Altitude above sea level.

Audibility • The range of sound-wave frequencies that can be heard by humans: 30 to 20,000 Hz.

Bird strike • As determined by Bird Strike Committee Canada, a bird strike has occurred when:

- a pilot reports a bird strike;
- aircraft-maintenance personnel identify aircraft damage caused by a bird strike;
- personnel on the ground report seeing an aircraft strike one or more birds; and
- bird remains, whether in whole or in part, are found on an airside pavement area or within 200 feet of a runway—unless another reason for the bird's death is identified.

Carnivore • An animal that feeds on animal tissue.

Competitor • Two or more animals competing for the same food source.

Conservation • Preservation of the natural environment.

Controller • A person authorized to provide air-traffic control services.

Crepuscular • Appearing or active in twilight.

Departure control(ler) • An ATS provider who expedites the flow of outbound IFR flights within a terminal control area and who may also service VFR flights.

Deterrence • Active or passive wildlife management for the purpose of minimizing animal activity on airport property.

Dispersal • Active wildlife-management measures that drive animals from airport property.

Diurnal • Animals active during daylight hours.

Endangered Species • Species that have become threatened or rare, and that are protected under federal or provincial legislation.

Feral • An organism (animal) that is wild or untamed.

Flight Service Specialist • A person who works at a flight-service station, such as Nav Canada, and manages such items as flight planning and weather indicators.

Frost heave • The cyclic cooling and warming of ground layers which causes expansion and cracking of the ground, including runway surfaces.

Fungicide • A pesticide intended specifically for use against undesirable fungus. (See pesticide.)

Generalist • An organism, such as a gull, that consumes a range of different foods and is able to live in many different climates; opposite of specialist.

Glider • An un-powered heavier-than-air aircraft that derives its lift from aerodynamic reactions on surfaces that remain fixed during flight.

Gregarious • Living in flocks or communities.

Ground-movement controller • An ATS provider who is responsible for safe and orderly flow of aircraft movements on the ground.

Habitat management • The manipulation and management of wildlife-attracting land features at and around airports for the purpose of making these features less attractive to wildlife. Also refers to habitat modification. (See passive management.)

Habituation • The tendency for wildlife to become accustomed to sounds and objects.

Hazard • The conditions and circumstances that could lead to the damage or destruction of an aircraft, or to loss of life as the result of aircraft operations.

Hazardous Wildlife • Species of wildlife—including feral and domestic animals—that are associated with bird and mammal strikes, and are capable of causing structural damage to aircraft and airport facilities. Hazardous wildlife species also include those that attract other wildlife to airport environments.

Herbicide • A pesticide intended specifically for use against undesirable plants. (See pesticide.)

Herbivore • Animal that feeds on plant tissue.

Incursion • The act of an animal entering airport property.

Infrasound • Having or relating to a frequency below the audible range of the human ear.

Insecticide • A pesticide intended specifically for use against undesirable insects. (See pesticide.)

Insectivore • An animal that feeds on insect tissue.

Loaf • he act, by an animal, of resting or stopping at a particular spot (e.g., *Gulls loaf on the runway*).

Mammal strike • As determined by Bird Strike Committee Canada, a mammal strike has occurred when:

- a pilot reports a mammal strike;
- aircraft maintenance personnel identify aircraft damage caused by a mammal strike;
- personnel on the ground report seeing an aircraft strike one or more mammals; and
- mammal remains, whether in whole or in part, are found on an airside pavement area or within 200 feet of a runway—unless another reason for the mammal's death is identified.

Microwaves • A comparatively short electromagnetic wave, between approximately one millimeter and one meter in wavelength.

Minister • In Canada and other Commonwealth nations, the head of a government department.

Military airport • An aerodrome used solely for the purpose of military aircraft.

Movement area • The part of an aerodrome used for the takeoff, landing and taxiing of aircraft, comprising manoeuvring areas and aprons.

Nocturnal • Active during the night.

Normal category (rotorcraft) • Official aircraft specification that permits maximum gross weight operations, but prohibits certain manoeuvres such as spins and steep turns.

Obstacle limitation surfaces • According to regulations, a defined area that limits the extent to which objects may project into airport airspaces. Includes takeoff, approach, transitional and outer airport areas.

Off-airport wildlife activity • Any wildlife activity outside airport perimeters and the airspace higher than 200 feet above ground level on approach, and higher than 500 feet above ground level on takeoff.

Off-airport wildlife incident • Any off-airport wildlife activity that presents flight safety hazards and causes pilots to take evasive action.

Off-airport wildlife occurrence • Any wildlife incident, bird and mammal strike that takes place outside airport perimeters and the airspace higher than 200 feet above ground level on approach, and higher than 500 feet above ground level on takeoff.

Omnivore • An animal that feeds on both plant and animal tissue.

Passive management • Wildlife-management activities in which long-term solutions—such as habitat management and pesticide use—are employed to deter wildlife from airport properties.

Pesticide • **1** Any substance and mixture intended for preventing, destroying, repelling, and mitigating pests. **2** Any substance or mixture of substances intended for use as a plant regulator, defoliant, or desiccant. **3** Any nitrogen stabilizer.

Predator • An organism that preys, destroys, or devours.

Pyrotechnics • Various combustible projectiles launched from a shotgun, pistol or other device to frighten wildlife by producing noise, light or smoke.

Resident species • Organisms that can be found at and around airports throughout the year, such as non-migrating birds and rodents.

Risk • In aviation, the consequence of a hazard, measured in terms of likelihood and severity.

Rodenticide • A pesticide intended specifically for use against undesirable rodents. (See pesticide.)

Roosting • The act of settling for sleep. Roosting sites are safe areas in which organisms congregate and sleep in large numbers.

Soaring • To fly aloft; to sail or hover in the air often at a great height; to fly without engine power and without loss of altitude. Sometimes referred to as *towering*. Vultures ride thermals to soar and tower. (See thermals.)

Specialized (specialist) • An organism that consumes a limited variety of food types. Opposite of generalist.

Stakeholder • A person or organization interested in, associated with or responsible for an issue or event.

Tactile • Associated with the sense of touch.

Taxonomy • The study of the general principles of scientific classification; the orderly classification of plants and animals according to presumed natural relationships.

Telemetry • The science or process of transmitting data and the recorded readings of instruments by radio.

Terminal Control Area (TCA) • An airspace extending upwards from a base altitude within which a terminal control unit provides ATC services to IFR flights.

Terminal Control Unit • A control unit established to provide air-traffic control service to IFR flights and controlled VFR flights operating within a terminal control area.

Thermals • Rising parcels of warm air that allow soaring and towering by birds such as vultures. (See soaring.)

Tower controller • A tower-based air-traffic controller who conducts all traffic within the control zone surrounding an airport to ensure efficient and safe movements.

Towering • See soaring.

Transport-category aircraft • An aircraft certified pursuant to Chapter 525 of the *Airworthiness Manual* or an equivalent foreign airworthiness standard; a helicopter certified pursuant to Chapter 529 of the *Airworthiness Manual* or an equivalent foreign airworthiness standard.

V_1 • Critical engine-failure recognition speed. The point at which the pilot has to decide to continue or reject takeoff.

Wildlife attractants • Any land-use practice and geographic feature or structure that can attract or sustain hazardous wildlife within the landing and departure airspace, aircraft movement area, loading ramps, and aircraft parking areas of an airport. These attractants include architectural features, landscaping, waste-disposal sites, wastewater-treatment facilities, agricultural or aquacultural activities, surface mining and wetlands.

Wildlife Hazard • See hazard.

Zoonosis • A disease communicable from animals to humans under natural conditions.

Acronyms

ACC — Area control centre

AGL — Above ground level

AHAS — Avian-hazard advisory system

AIP — Aeronautical Information Publication

AME — Aircraft maintenance engineer

ATIS — Automatic terminal-information service

AWMP — Airport wildlife-management plan

BAM — Bird-avoidance model

BASH — Bird/aircraft strike-hazard team

BSCC — Bird Strike Committee Canada

CADORS — Canadian Aviation Damage Occurrence Reporting System

CARs — Canadian Aviation Regulations

CFS — Canada Flight Supplement

DND — Department of National Defence (Canada)

FAA — Federal Aviation Administration (U.S.)

FARs — Federal Aviation Regulations (U.S.)

IBIS — ICAO Bird Strike Information System

ICAO — International Civil Aviation Organization

IFR — Instrument flight rules

JAA — Joint Aviation Authority (Europe)

MTOW — Maximum takeoff weight

NAP — National Airports Policy

NTSB — National Transportation Safety Board (U.S.)

RAC — Rules of the Air and Air Traffic Services Section of the AIP

SOP — Standard operating procedures

TCU — Terminal control unit

USAF — United States Air Force

USDA — United States Department of Agriculture

VFR — Visual flight rules

VNAP — Vertical noise-abatement profile

The Production Team

Six years in the making, the first edition of *Sharing the Skies* compiled information collected by Transport Canada. Under the direction of Bruce MacKinnon, cooperative education students from the University of Waterloo and the University of Manitoba gathered, researched and analyzed much of the content. Additional material was created through private consulting-firm contracts paid for and managed by Transport Canada. Jacques Whitford Environment Limited of Ottawa, Canada, managed and administered the contract to produce *Sharing the Skies*.

Editors

Bruce MacKinnon

Mr. MacKinnon is a graduate of the University of Calgary, where he specialized in large mammal behaviour. He spent 22 years working throughout Canada in the National Park Warden Service, and was involved in wildlife-management, mountain-rescue and avalanche-control programs. He is currently the Wildlife Control Specialist for Transport Canada, Civil Aviation, and has chaired Bird Strike Committee Canada since 1993. He is also chair of awareness for the International Bird Strike Committee. Mr. MacKinnon has written and edited numerous publications on wildlife-hazard issues, and has been involved as an advisor and expert witness in the management of bird-strike issues and land-use conflicts around the world. He is a general-aviation pilot, and builds experimental aircraft.

Captain Richard Sowden

Captain Sowden is a 21-year veteran of Air Canada, and is currently an A320 Line Indoctrination Training Captain. A 1977 graduate of the Aviation and Flight Technology program at Seneca College, Richard has maintained a keen interest in flight-safety issues throughout his career. He was instrumental in the development of the Air Canada Pilot

Association's (ACPA) Technical and Safety Division, serving for five years as its first Chairman. He is also active as ACPA's representative on the NAV CANADA Advisory Committee, where he chairs the safety sub-committee. Captain Sowden is a member of the Bird Strike Committee Canada, and has been a pilot representative on wildlife-hazard safety-review teams since 1991. In 1993 Richard founded Avian Aviation Consultants to evaluate bird- and wildlife-strike hazards, develop reduction strategies and provide related aviation-industry training. A 13,000-hour pilot intimately familiar with today's highly sophisticated flying environment, Richard finds his escape in a simpler pursuit. As a member of the Ontario Aviation Historical Society, he builds, flies and demonstrates replicas of the open-cockpit, fabric-covered aircraft of World War I.

Kristi Russell

A graduate of Ontario's University of Waterloo (Honours Bachelor of Environmental Studies in Geography), Kristi has been an important part of Transport Canada's wildlife-management team since 1999. She began with the Department as a co-op student, during which time she participated actively in preparing the first edition of *Sharing the Skies*. Since joining the Aerodrome Safety Branch as Assistant Wildlife Control Specialist in 2002, Kristi has made a number of important contributions to the field. She played a key role in researching, writing and revising the third edition of the Department's *Wildlife Control Procedures Manual*, and currently manages Transport Canada's National Birdstrike Database. Most recently, Kristi supervised revisions for the second edition of *Sharing the Skies*.

Stewart Dudley

As a senior writer with the firm of Stiff Sentences Inc., Stewart Dudley is a seasoned communicator with 20 years experience as a writer, editor, video director and producer. Honours for his creative accomplishments range from Gemini Awards nominations to New York Film Festival commendations. Meticulous, determined and creative, Stewart brought his considerable knowledge of the fine points of grammar, syntax and diction to bear on the final drafts of this work.

Contributors

Rolph A. Davis, Ph.D.

Dr. Davis received his doctoral degree in Avian Ecology from the University of Western Ontario in 1972. He joined LGL Limited—an environmental research consulting company—that same year and became president in 1979. A specialist in aircraft-related bird-hazard issues, Dr. Davis has appeared as an expert witness before numerous regulatory bodies and tribunals. Dr. Davis authored and co-authored more than 100 reports and papers on aircraft bird hazards, as well as bird health and nuisance issues related to landfills and airports.

Terry Kelly

Mr. Kelly's career in safety spans more than 20 years. He was educated at the University of Waterloo and obtained a graduate degree from the University of Alberta. Starting his career as a military pilot, Mr. Kelly has acquired more than 5,000 flying hours. Since his move to the private sector, he has dedicated his professional energies to safety. Mr. Kelly led proactive safety-risk assessments of such multi-million dollar projects as the runway expansion at Toronto's Lester B. Pearson airport and the development of the Sea Island Conservation Area at Vancouver International Airport. He is the author of numerous articles and technical papers, and is president of Safety Management Systems, based in Ottawa, Canada.

Ron Huizer, B.Sc.

A Senior Biologist with Jacques Whitford Environment Limited, Mr. Huizer is a graduate of the University of Western Ontario where he earned an Honours B.Sc. in zoology. He is a specialist in biological and ecological surveys and environmental assessment. Over the past decade, Mr. Huizer has developed wildlife-control management plans for airports, conducted assessments of potential bird hazards associated with various land uses near airports, and participated in the establishment of bird-hazard zones for Canadian airports. Through the 1990s he was a primary instructor for the Transport Canada Wildlife Control Training course provided to airport staff across Canada.

W. John Richardson

Dr. Richardson received his B.Sc. in biology from McMaster University in 1968, and his Ph.D. in animal behavior from Cornell University in 1976. He is Executive Vice President of LGL Limited, where he has worked since 1973. From 1965 to 1971, Dr. Richardson conducted radar studies of bird movements in many parts of Canada and the Caribbean on behalf of the National Research Council Associate Committee on Bird Hazards to Aircraft. He helped to establish the bird-forecast system at Canadian Forces Base Cold Lake, and to initiate radar studies of roost and migratory movements in Ontario. After joining LGL, Dr. Richardson performed radar and bird studies near Toronto as part of the planning for a new Toronto airport at Pickering during 1973-74; he also conducted migration studies using DEW radars in Yukon and Alaska between 1975 and 1977. As an ongoing project, he is compiling a worldwide database of serious bird-strike accidents, emphasizing military experiences. Since 1980, Dr. Richardson has devoted much of his time to studies of marine mammals, especially their reactions to noise and disturbance.

Paul A. Hayes, M.B.A.

Mr. Hayes was one of the founding partners of AeroCan Aviation Specialists Inc. in 1983, and is now president of the firm. He has more than 30 years of experience providing management-consulting and aviation-planning services to clients in both the public and private sectors. Prior to establishing AeroCan Aviation, Mr. Hayes spent 13 years as a senior consultant and manager with KMPG in the firm's general-management consulting practice. He is a commercial pilot, licensed on fixed- and rotary-wing aircraft, and brings a strong practical viewpoint to all his aviation-consulting assignments.

Howard M. Malone, P.Eng., MCIP, RPP

One of the founding partners of AeroCan Aviation Specialists Inc. in 1983, Mr. Malone is now a vice-president of the firm. He has more than 25 years consulting experience with specific emphasis on aviation planning. Mr. Malone also has more than 30 years of flying experience and holds a current Airline Transport Rating pilot's licence endorsed for the DC9, DC8, B727, B767 and B747. Mr. Malone's experience in aviation planning includes assignments on airport and airside-master and system planning, airport crash, fire and rescue capabilities, general aviation operations, aviation policy and regulation, airport zoning and obstacle-clearance protection and bird-hazard assessment and management.

Ross E. Harris, M.Sc.

A wildlife biologist with specialized knowledge and experience in ornithological studies, Mr. Harris has observed and closely studied birds for more than 30 years. He works with LGL Limited, and has conducted over 20 bird-hazard projects in Canada and the United States. These include many studies of gull populations and movements associated with landfill sites near airports, an extensive literature review of the efficacy of bird-control products and techniques for use at airports, and a review of the wildlife-control program at Lester B. Pearson International Airport.

Printed in Canada