Bird Strike Damage
&
Windshield Bird Strike

Final Report

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Executive Summary

Background to the Study

This report presents the findings of a study carried out by Atkins and the UK Food & Environment Research Agency (FERA). The study was commissioned in 2009 by the European Aviation Safety Agency (EASA), under contract number EASA.2008.C49 [1.]. Its aim was to investigate the adequacy of the current aircraft certification requirement in relation to current and future bird strike risks on aircraft structures and windshields.

Bird strikes are random events. The intersection of bird and aircraft flight paths, the mass of the bird and the part of the aircraft struck are all random elements that will determine the outcome. In managing risk all that can be controlled are the design and testing of the aircraft driven by certification specifications, the aircraft's flight profile and, to a limited extent, the populations of birds near airports.

The bird strike data presented in this report covers US, Canada and UK reported bird strikes from 1990 to 2007. Unfortunately, it was not possible to obtain data from other countries via ICAO, but the data obtained did provide an adequate basis for analysis – approximately 11,000 incidents for which complete data on aircraft type, speed and bird species were available. The study also reviewed worldwide accident and serious incident data.

Conclusions

1. Airframe bird strikes are a relatively rare cause of accidents, representing only 0.3% of the total aircraft Fatal Accident Frequency Rate from all causes. However there are significantly more airframe strikes than engine strikes (by a ratio of 4.6 to 1). 51 accidents worldwide have been identified since 1962, of which only 14 (7 of them fatal), fell within the scope of this study. All of these accidents were to CS-23 and CS-27 aircraft. Where accidents have occurred, they have usually been associated with high energy impacts – heavy birds (greater than 2 lb/0.9 kg) encountered at relatively high speed, resulting in Kinetic Energies of impact that are often several times the certification values.
2. The main conclusion from this report is that, given the reported level of accidents, the bird strike requirements in CS-25, and 29 are currently providing an adequate level of safety. However there are indications that the accident rate is increasing (although still very low), and that those species that cause the highest kinetic energy impacts are increasing in population (although the number of strikes recorded as involving the Canada Goose is reducing, this may be due to bird control measures near airports). .
3. In CS-23 (excluding commuter) and CS-27 aircraft categories there are currently no specific bird strike requirements and this is reflected in a higher rate of bird strike accidents (particularly windshield penetrations). Based on the accident record to date, a pre-existing requirement that such aircraft withstand collision with a 2lb/1kg bird at

V_{mo}/V_h may have significantly reduced the number of accidents to these categories of aircraft by 26% and 66% respectively.

4. It may, however, be difficult to engineer an effective solution to increasing the bird strike resistance of these aircraft at acceptable cost. Additionally, due to the relatively low turn over rate, a change in the regulations may take some time to be effective. The use of helmets and visors might therefore represent a more practical and timely option

5. Other conclusions are listed below.

    - 96% of strikes occur during take off, climb, approach and landing. Strikes en-route are much less frequent but 34% of these result in damage when they do occur. Over 800 ft altitude, strikes and damage are dominated by heavier birds such as Canada Geese and Turkey Vultures and the likelihood of damage is much higher.
    - The certification requirements for CS-23 Commuter Aircraft (2 lb, windshield only) and CS-29 Transport Helicopters (1 kg) result in an undesirably large proportion of bird strikes (5 to 11%) above the certification value. The equivalent value for CS-25 aircraft is around 0.3%.
    - Although data is very limited, it is noted that for fixed wing aircraft with certification requirements, the few accidents that have occurred are in the range 2.7 to 6.6 times the certification value.
    - All those accidents which have occurred have involved bird masses above 0.78kg. Most have involved very high values of Kinetic Energy, well above current certification values, and 90% of accidents involved impact KE above 1500 J.
    - CS-25 aircraft had the highest rate of reported bird strikes (186 per million flying hours) and the lowest proportion of damaging strikes (9%), probably due to better reporting of all strikes. CS-27 (small helicopters) had the highest proportion of strikes resulting in damage at 49% - predominately windshields.
    - 28% of strikes reported involved multiple birds, and for these the likelihood of damage resulting was approximately twice that for an equivalent single strike. Neither the FAA nor EASA non-engine regulations currently contain any requirements relating to multiple bird strikes of the type that may arise from bird flocking behaviour. Such multiple strikes may result in some “pre-loading” of aircraft structures and windshields and may mean that the current certification analysis and test regimes are inadequate to model this scenario.
    - The aircraft parts most likely to be damaged are the nose/radome/fuselage and the wing.
    - KE is a better indicator of damage likelihood than bird mass. The proportion of strikes with KE above the certification value appears to be a useful safety indicator. The current value for CS-25 aircraft is around 0.3%. The certification requirements for CS-23 Commuter Aircraft and CS-29 Large/Transport Helicopters result in a larger proportion of bird strikes (5-11%) above the current certification KE value, which is undesirable and posses a safety risk.
    - Windshield penetration was a feature of 50% of all accidents. A detailed analysis of windshield strikes showed a strong correlation between impact KE,

certification requirements and probability of damage. Increasing the certification requirement is very effective in reducing the incidence of damage.

- Detailed analysis of tail strike data shows no reduction in the probability of damage resulting from the higher FAR Part 25 requirements for empennage for strikes between 1.8 and 3.6 kg. However, 100% of the 13 reported tail strikes above 3.6 kg resulted in moderate or severe damage, compared to only 47% of the strikes to wings. There have been no accidents or serious incidents identified as due to bird impact damage to the tail surfaces since the original Vickers Viscount accident in 1962 that gave rise to this requirement. Only 2.7% of reported bird strikes are to this part of the aircraft.
- Apart from a single incident affecting an Airbus 320 in 1989, there have been no accidents or serious incidents causing failure of integrated avionics through shock.
- The discussion on the effect of bird strikes on aircraft systems concluded that such effect involved mainly external sensors. However 180 US and 32 UK reports of bird strike damage to landing gear and associated electrical and hydraulic components were noted – approximately $7x10^{-7}$ per flying hour based on CS-25/FAR part 25 aircraft flying hours alone (although this is likely to be a low estimate due to under reporting). Such a strike also resulted in one of the few hull loss accidents to a large transport aircraft.
- VLJs have high-speed performance similar to large transport and business jets, but currently have no bird strike requirements. Given the relatively light airframe, single pilot operation and the likelihood that such aircraft will be operated from smaller regional airports and private airstrips, they may be more likely to encounter birds and less likely to be able to withstand the high KE impacts resulting.
- The proportion of strikes above the certification value of KE is very similar for the CS-25 Jet and Propeller aircraft (0.27% and 0.31%). Both exhibit very low rate of accidents, so effectively there is no measurable difference in the level of safety provided by CS-25 bird strike requirements between these two categories of aircraft. This confirms that the regulations adequately address the difference in V_C between the two types of aircraft.
- Some aircraft have a relatively low quoted V_C below 8000 ft with a rapid increase in V_C above this altitude. This results in a lower value of certification KE, increasing the ratio of impact KE to certification KE for any given impact – especially at the higher speeds above 8000 ft. The effect of KE ratio as a determinant of the likelihood of damage and accidents means that such aircraft will be at increased risk.
- The ICAO Rules of the Air restrict operational indicated airspeed to 250 kts below 10.000 ft above mean sea level, in certain classes of airspace depending on applicable flight rules. For an aircraft such as the Boeing 737 whose V_C is 340 kts, an encounter with a 3.4 kg bird at 250 kts would still be within the certification KE value. Even a strike by a Canada Goose would be only marginally above the certification KE value, and well below the range of KE ratios at which accidents have been observed to occur.

Recommendations

1. Improve the capture rate and completeness of bird strike reporting.

2. Monitor the growth in bird strike risk for each category of aircraft by monitoring the proportion of bird strikes above the certification equivalent value of KE.

3. Given the apparent success in controlling Canada Goose populations, the current efforts on bird control at airports should continue and perhaps be expanded in line with the recommendations of FAA AC 150/5200-33B, *Hazardous Wildlife Attractants On or Near Airports*. Other options should continue to be pursued.

4. Investigate the trends in population of other birds listed in Table 5-1 as causing high KE impacts, to determine if the above control measures should be extended to these species.

5. Investigate the high proportion of helicopter windshield bird strike penetrations, especially those with KE below the CS-29 requirements, and whether changes in requirements could effectively reduce the occurrence rate. It is recognised that much of the current fleet pre-dates the CS-29 requirements.

6. Ideally, the introduction of a requirement that both CS-23 and CS-27 category aircraft be capable of surviving a windshield impact with a 2lb/1kg bird would be the preferred option. However, due to the relatively high windshield areas (cost and performance penalty) and the long timescales involved, this may be impracticable for these aircraft types. Therefore, consider requiring helicopter pilots to wear helmets and visors to mitigate the effects of windshield bird strike penetrations.

7. For future aircraft certification, consider revising the regulations for CS-23 Commuter class twin turboprop aircraft above 5670 kg to increase bird strike requirements to match those of other aircraft above 5670 kg (i.e. CS-25 requirements)..

8. Consider the development of a risk-based model utilising the information presented in this report to provide projections of future risk levels in support of regulatory decision making.

9. The effects of preloading resulting from multiple bird strikes (possibly involving flocking birds) and the potential impact on the regulatory regime, should be examined in more detail.

10. For large aeroplanes, the relevant part of the regulations (i.e. clause 25.631) be extended to explicitly include landing gear as part of the aircraft structure.

11. Consider introducing requirements for the protection of bird strikes offered to VLJ aircraft currently certified under the CS-23 (Normal) aircraft requirements.

Abbreviations

Abbreviation	Definition
a/c	Aircraft
agl	Above Ground Level
AMC	Acceptable Means of Compliance
Amdt	Amendment
amsl	Above Mean Sea Level
AOA	Angle of Attack
APC	Approach Category Code
ASI	Air Speed Indicator
ATC	Air Traffic Control
BTO	British Trust for Ornithology
CAA	Civil Aviation Authority
Can	Canada
Cat	Category
CFI	Chief Flying Instructor
CFR	Code of Federal Regulations
CRT	Cathode Ray Tube
CS	Certification Specifications
Delam	Delamination
DNA	Deoxyribonucleic Acid
EASA	European Aviation Safety Agency
EU	European Union
FAA	Federal Aviation Administration
FAAR	Federal Aviation Authority of Russia
FAFR	Fatal Accident Frequency Rate
FAR	Federal Airworthiness Regulation
FERA	Food and Environment Research Agency
FH	Flying Hours
FL	Flight Level
ft	Feet
g	grams
GA	General Aviation
GPS	Global Positioning System
HMI	Human-Machine Interface
IAC AR	Aviation Register of the Interstate Aviation Committee (of Russia)
IAS	Indicated Air Speed
ICAO	International Civil Aviation Organization
J	Joules
JAA	Joint Aviation Authorities
JAR	Joint Aviation Requirements
KE	Kinetic Energy

kg	Kilograms
KIAS	Knots Indicated Air Speed
kJ	Kilo Joules
kts	Knots (nautical miles per hour)
KIAS	Knots Indicated Air Speed
Lb	pounds
LG	Landing Gear
L/H	Left Hand
m	Mass
m	meters
MOR	Mandatory Occurrence Report
mph	Miles per hour
MSL	Mean Sea Level
MTOW	Maximum (Certified) Take-Off Weight
n	Number
N/K	Not Known
NTSB	National Transportation Safety Board
OAT	Outside Air Temperature
oz	ounces
Ref	Reference
R/H	Right Hand
RW	Runway
S/Board	Starboard
TAS	True Air Speed
TAT	True Air Temperature
TCDS	Type Certification Data Sheet
UK	United Kingdom
USA	United States of America
USDA	US Department of Agriculture
v	velocity
V_2	Take off Safety Speed
V_C	Design cruising speed, also known as the optimum cruise speed
V_{FE}	Maximum flap extended speed
VFR	Visual Flight Rules
V_H	Maximum speed in level flight at maximum continuous power
V_{NE}	Never exceed speed
V_{TH}	Speed at runway threshold (on landing)
V_{mcs}	Velocity (minimum control speed)
V_{MO}	Maximum Operating Speed
VHF	Very High Frequency
VLA	Very Light Aircraft
VLR	Very Light Rotorcraft

Table of Contents

Executive Summary **3**
Background to the Study 3
Conclusions 3
Recommendations 6

Abbreviations **7**

Section 1 Introduction **12**
1.1 Objective 12
1.2 Background 12
1.3 Scope 13
1.4 Study Structure 14

Section 2 Regulatory Review **15**
2.1 Aim 15
2.2 Data Sources 15
2.3 Regulatory Categories 15
2.4 Summary of Bird Strike Certification Requirements 16
2.5 Multiple Bird Strike Requirements 18
2.6 Acceptable Means of Compliance 18
2.7 Kinetic Energy Equivalence of Bird Strike Requirements 18

Section 3 Literature Search & Review **20**
3.1 Bird Strike Data 20
3.2 Population Trend Data 21

Section 4 Analysis of Bird Strike Data **24**
4.1 Methodology 24
4.2 Damage by Single and Multiple Bird Strikes and by Aircraft Category 24
4.3 Bird Strikes to Different Parts of Aircraft 27
4.4 Bird Strikes to Windshield 28
4.5 Empennage 30
4.6 Level of Damage Caused (US Data Only) 32
4.7 Phase of Flight 35
4.8 Altitude 36
4.9 Conclusions 38

Section 5 Analysis of Trends **39**
5.1 Trends in Bird Mass 39
5.2 Selection of Key Species 41
5.3 Trend Analysis 42
5.4 Conclusions 45

Section 6 Analysis of Accident Data		**46**
6.1	Accident Data	46
6.2	Basic Quantification	46
6.3	Parts Struck	47
6.4	Overall Time Trend	48
6.5	Transport Category Accidents	49
6.6	Bird Mass	50
6.7	Kinetic Energy	51
6.8	Conclusions	53
Section 7 Comparison of Bird Strike and Accident Data		**54**
7.1	Introduction	54
7.2	CS-23 Normal/Utility/Aerobatic Aircraft (Categories 1 and 2)	55
7.3	CS-23 Commuter Aircraft (Categories 3 and 4)	57
7.4	CS-25 Transport Aircraft (Propeller) (Category 5)	58
7.5	CS-25 Transport Aircraft (Jet) (Category 6)	59
7.6	CS-27 Small/Normal Helicopters (Category 7)	60
7.7	CS-29 Large/Transport) Helicopters (Category 8)	61
7.8	Conclusions	62
Section 8 System Vulnerability		**63**
8.1	General	63
8.2	Identification of Relevant Records	63
8.3	Relevant Records from Bird Strike Data	63
8.4	UK CAA Mandatory Occurrence Reports	65
8.5	Relevant Records from Previous Bird Strike Reports	66
8.6	Discussion	68
8.7	Conclusions	70
Section 9 Risk Assessment		**72**
9.1	Target	72
9.2	Current Risk	73
9.3	Trends in Bird Population	75
9.4	Recent Accidents	75
Section 10 Regulatory Options and Impact Assessment		**77**
10.1	Risk, Bird Mass and Certification Specifications	77
10.2	CS-23 Normal/Utility/Aerobatic and CS-27 Small Helicopters	77
10.3	CS-23 Commuter Aircraft	77
10.4	CS-25 Large Aircraft	78
10.5	CS-29 Transport Helicopters	78
10.6	All aircraft –Operational Measures	78
Section 11 Conclusions and Recommendations		**80**
11.1	Conclusions	80
11.2	Recommendations	82
References		**84**

Appendix A: USA and European Bird Strike Regulations 86

Appendix B: Aircraft Performance Data and Certification Kinetic Energy Values 91

Appendix C: Population Trends from External Studies 104

Appendix D: Detailed Bird Strike Data 116

Appendix E: Flying Hours Data 121

Appendix F: Accident Data 122

Appendix G: Serious Incident Data 142

Appendix H: Damage Rates to Aircraft Parts 150

Appendix I: Detailed Bird Strike Trends Data 168

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Section 1 Introduction

1.1 Objective

1.1.1 This report presents the findings of a study carried out by Atkins and the UK Food & Environment Research Agency (fera) (previously known as CSL) . The study was commissioned in 2009 by the European Aviation Safety Agency (EASA), under contract number EASA.2008.C49 [2.]. Its aim was to investigate the adequacy of the current aircraft certification requirement in relation to current and future bird strike risks on aircraft structures and windshields. The study does not consider the bird strike risks to aircraft engines.

1.1.2 This study assesses both the scope of the requirements and the levels of protection afforded in meeting current and foreseeable risks from increased bird size, increased populations and flocking behaviour.

1.2 Background

1.2.1 Bird strike represents a continuing global danger to the safety of air travel. Recent events such as the bird strike to Ryanair Flight FR4102 at Rome, Ciampino and the loss of a Cessna Citation 500 at Oklahoma City's Wiley Post airport have dramatically highlighted the effect that bird strikes can have on commercial aviation.

1.2.2 The first of these incidents involved bird ingestion into the aircraft engines. Current certification bird strike requirements for engines are contained in EASA Airworthiness Code CS-E 800 'Bird Strike and Ingestion' [3.] (corresponding FAA requirements are given in CFR Part 33) [4.]. These have been progressively updated to take account of both evidence of an increase in the size of birds impacting aircraft and issues raised by the recent development of very large inlet engines[1].

1.2.3 However, as the second of the two events described above demonstrates, bird strike is also an issue for aircraft structures. Bird strike data contain reports of birds penetrating windshields, radomes and bulkheads, causing crew injuries (including fatalities) and damaging flight controls and instrumentation. In contrast to engine certification requirements, airframe and windshield certification requirements have remained largely unchanged since the early 1970s.

[1] The flocking bird requirements were introduced in CS-E 800 as follows:
JAR-E Amdt 11 (01/11/2001) – Up to 1.15kg bird, depending on throat area (JAA NPA E-20)
CS-E Initial issue (24/10/2003) – Large flocking bird up to 2.5kg, depending on throat area @200kts (JAA NPA E-45)

1.2.4 During the period since the current airframe and windshield certification requirements were drafted, there have been significant changes in the materials and technology used in structural components and in control and instrumentation systems. Aircraft structures now make increasing use of composites in their construction.

1.2.5 Aircraft systems can also be vulnerable to bird strike. External system components such as air data sensors, lights, antennae, de-icing equipment and undercarriage components are vulnerable to direct bird strike. Some protection is provided by redundancy and segregation (e.g. pitot systems). There are also systems components within the airframe that can be damaged following penetration of the aircraft skin by bird strike, and designers do consider the placement of these systems where possible (e.g. behind other structure or away from skin likely to be deformed by bird strike). Finally, there is increasing reliance on integrated electronic systems and displays both to provide crew situational awareness and to implement and monitor aircraft control commands. Although these systems are heavily redundant, the concentration of system components (displays, signal paths) in the cockpit area leaves them potentially vulnerable to zonal common-cause failure such as shock or penetration by a bird.

1.2.6 The bird strike threat is not limited to large aircraft. Smaller general aviation (GA) category aircraft (both fixed and rotary wing) also experience bird strike damage. Indeed, as the majority of bird strikes are experienced near to the ground, the threat may be higher for such aircraft. Commuter, air taxi and other GA aircraft also tend to operate from smaller aerodromes where bird control measures are less sophisticated or perhaps non-existent. The consequences of bird strike on GA aircraft may also be more severe, due to factors such as single pilot operation, single engine aircraft, more fragile (lighter) airframe structure and less cockpit and control systems redundancy. Finally there are no specific bird strike certification requirements for GA category aircraft (apart from windshields on commuter aircraft).

1.2.7 Finally, the volume of air traffic (number of flights) has been increasing year-on-year over the last few decades of the 20th Century and the early years of the 21st Century, as have the numbers and physical size of various species of bird involved in aircraft bird strikes. These factors have led to the perception, by EASA, that the risk of a significant bird strike to an aircraft airframe or windshield may be increasing.

1.3 Scope

1.3.1 Ideally this study would consider global bird species and populations. However, the level of reporting of bird strike incidents is not uniform across all continents, and bird strike reporting has become effective only in recent years in some areas. Also, this study has been dependent on the goodwill of data collection and collation agencies for access to bird strike data across the globe. Therefore the study is based on bird strike report data from the UK and North America only, for the period 1990 to 2007. In addition all civil aircraft fatal and hull loss accidents that were identifiable as due to non-engine bird strikes were reviewed and included in the analysis (worldwide, 1962 to 2009).

1.3.2 The study scope includes the risks to aircraft structure (including windshields) and systems, but excludes engines and propellers. Aircraft categories considered in this study are:

- Normal, Utility, Acrobatic and Commuter Category Aeroplanes ("CS-23") [6.]
- Large turbine powered aircraft ("CS-25") [7.]
- Small Rotorcraft ("CS-27") [8.]
- Large Rotorcraft ("CS-29") [9.]

Note: The CS numbers refer to EASA Certification Specifications. Aircraft may be certificated to comparable standards from other Aviation Authorities (e.g. FARs).

1.4 Study Structure

1.4.1 The study divided into discrete, interrelated tasks, organised into three phases as follows (Section numbers refer to sections of this report):

Phase I

- Regulatory Review (Section 2)
- Literature Search & Review (Section 3)

Phase II

- Bird Strike Data Analysis (Section 4)
- Analysis of Trends (Section 5)

Phase III

- Accident and Incident Data Analysis (Section 6)
- Comparison of Accident And Bird Strike Data (Section 7)
- System Vulnerability (Section 8)
- Risk Assessment (Section 9)
- Regulatory Options and Impact (Section 10)

1.4.2 Each of these tasks is reported as a separate section of this report, with supporting Appendices where necessary containing detailed data and analysis. Conclusions and recommendations are summarised in Section 11.

Section 2
Regulatory Review

2.1 Aim

2.1.1 The aim of this task was to identify the current certification requirements within US and European aircraft airworthiness codes and to highlight where no requirements currently exist. The review considered FAA and EASA bird strike certification requirements and standards as defined in the current Federal Airworthiness Regulations (FARs) & Certification Specifications (CS) documentation. Generally it is the aim of the FAA and EASA to harmonise requirements as far as possible.

2.1.2 Other National Authorities tend to use one or other of these codes with special requirements to adapt for regional use. For example, in Russia, the Aviation Register of the Interstate Aviation Committee (IAC AR) is responsible for the certification and continued airworthiness of aircraft. Such certification is based on the FAR and the FAAR Special Requirements AC 21-2J. The JAA regulations (applicable in non-EU European countries) have been harmonised with the EASA regulations, while other major aircraft manufacturing countries (China, Brazil) use the FAA regulations, modified where required to take account of differences in units of measurement, etc.

2.2 Data Sources

2.2.1 The EASA website (easa.europa.eu) gives access to the current CSs, and also gives their complete change histories (including details of changes and their justification).

2.2.2 Access to the FARs was obtained via the electronic Code of Federal Regulations (e-CFR) internet website. This website gives immediate access to the current CFR Title 14, Aeronautics and Space regulations, Chapter 1, commonly known as the FARs. The FARs are also available, together with detailed change history, via the FAA Regulation and Guidance Library[2].

2.3 Regulatory Categories

2.3.1 Aircraft are divided into differing categories for the purposes of defining appropriate airworthiness requirements. The regulatory categories for used by the FAA and EASA are given in Table 2-1 below. Although the category names vary in some cases, the category definitions are effectively identical. It is also noted that there are

[2] http://www.airweb.faa.gov/Regulatory_and_Guidance_Library/rgFAR.nsf/Frameset?OpenPage

no equivalents in the FARs to the EASA categories Very Light Aeroplanes and Very Light Rotorcraft.

Table 2-1 - Aircraft Regulatory Categories

EASA			FAA		
CS-23	Normal, Utility, Acrobatic and Commuter Category Aeroplanes [6]	MTOW: 5,670 kg (12,500 lb) or less Seats: 9 or less (excluding pilots) Commuter Category: Propeller-driven twin-engined aeroplanes MTOW: 8,618 kg (19,000 lb) or less 19 or fewer seats (excluding pilots)	Pt 23	Normal, Utility, Acrobatic and Commuter Category Airplanes [13]	MTOW: 12,500 lb or less Seats: 9 or less (excluding pilots) Commuter Category: Propeller-driven, multiengine airplanes MTOW: 19,000 lb or less. 19 or fewer seats (excluding pilots)
CS-25	Large (turbine powered) Aeroplanes [7]	MTOW: >5,670 kg (12,500 lb)	Pt 25	Transport Category Airplanes [14]	MTOW >12,500 lb
CS-27	Small Rotorcraft [8]	3,175 kg (7,000 lbs) or less and nine or less passenger seats	Pt 27	Normal Category Rotorcraft [15]	MTOW: 7,000 lbs or less Seats: 9 or less passenger seats
CS-29	Large Rotorcraft [9]	Cat A – weight greater than 9,072 kg (20,000 pounds) and 10 or more passenger seats Cat B - other	Pt 29	Transport Category Rotorcraft [16]	Cat A greater than 20,000 lbs and 10 or more passenger seats Cat B - other

2.4 Summary of Bird Strike Certification Requirements

2.4.1 The applicable sections of the FAA and EASA airworthiness requirements for each category are tabulated side-by-side in Table A-1 (Appendix A). The Table contains the full text of each requirement related to bird strike and all non-relevant sections have been deleted for clarity. The main requirements for each category of aircraft are summarised below.

2.4.2 CS-23/FAR Part 23 - Normal, Utility, Acrobatic and Commuter Category Aeroplanes

2.4.2.1 In general there are no requirements relating to bird strike for Normal, Utility and Aerobatic aircraft. The only requirements relate to Commuter Category aircraft, and address only the windshield and pitot tubes:

- The windshield must withstand (without penetration) a single impact from a 0.91 kg (2 lb) bird at the aircraft's maximum approach flap speed. Also the wind shield panels must be arranged such that if one panel is obscured (e.g. through bird strike) other panels must be available to a seated pilot.
- Duplicate pitot tubes (where fitted) must be far enough apart to avoid damage to both tubes in a collision with a single bird.

2.4.2.2 The requirements for commuter aircraft are far less stringent than those for CS-25 category aircraft – even the windshield requirement is less demanding (a 2 lb bird at maximum approach flap speed, V_{FE} rather than a 4 lb bird at cruise speed, V_C). There are no requirements for the rest of the aircraft. This appears somewhat anomalous as commuter aircraft may be expected to fly more regularly in uncontrolled airspace (i.e. without speed control) and to cruise at lower altitudes where bird strikes are more likely.

2.4.2.3 Therefore, the personal risk to aircraft occupants would seem to be higher for aircraft in this category. This difference in the acceptable level of personal risk also seems somewhat anomalous given that the distinction in classification between CS-23 commuter aircraft and CS-25 transport aircraft may not always be evident to the passenger.

2.4.2.4 The advent of "high performance" aircraft in this category with high cruise speeds (e.g. Very Light Jets) may also increase risk. These aircraft will be operating at considerably higher speed than most GA aircraft and the likelihood of severe damage resulting from a bird strike will therefore be higher.

2.4.3 CS-25/FAR Part 25 - Large Turbine Powered/Transport Aeroplanes

2.4.3.1 The FAA and EASA requirements for this category of aircraft, which includes commercial passenger aircraft, are worded somewhat differently but the principal requirements are effectively the same:

- Continued safe flight and landing after impact with a 4 lb bird at cruise speed (V_C) at sea level or 0.85 V_C at 8000 ft (2438 m), whichever is the most critical.
- Windshields and supporting structure are to withstand the above impact without penetration or critical fragmentation.

2.4.3.2 The FAA and EASA requirements differ as follows.

- CS-25 requires that an openable window be provided unless it can be shown that an area of the wind shield remains sufficiently clear following a bird strike with a 1.8kg bird at V_C. There is no such requirement in the FAR.
- The FAR has an additional requirement that the empennage structure should withstand the impact of an 8lb bird at cruise speed (V_C). CS-25 has no separate requirement for the empennage, which is therefore covered by the general structural requirement of 4 lb at V_C.

2.4.3.3 This is the most significant difference between European and US requirements. This particular requirement was the result of a single aircraft accident in 1962 where a Vickers Viscount struck a Whistling Swan (average weight 6Kg) resulting in structural damage to the tail causing the aircraft to crash with the loss of all 17 persons on board. As noted in Attachment A of the GSHWG report [18.] of June 2003, this requirement was not adopted for either JAR or CS 26.631. The European regulations therefore continue to address the complete aircraft using a lower (4lb) bird weight.

2.4.4 CS-27/FAR Part 27 - Small Rotorcraft

2.4.4.1 Neither the FAA nor the EASA codes for this category of aircraft contain any requirement for protection against bird strike.

2.4.5 CS-29/FAR Part 29 - Large Rotorcraft

2.4.5.1 The FAA and EASA requirements for this type of aircraft are identical. Both require that:

- The aircraft is able to continue safe flight and landing (Cat A) or safe landing (Cat B) following impact with a single 1kg bird at the greater of the maximum safe airspeed (V_{NE}) or maximum level-flight airspeed at rated power (V_H) (at up to 8,000 ft).

2.5 Multiple Bird Strike Requirements

2.5.1 Neither the FAA nor EASA non-engine regulations currently contain any requirements relating to multiple bird strikes of the type that may arise from bird flocking behaviour. Such multiple strikes may result in some "pre-loading" of aircraft structures and wind shields and may mean that the current certification analysis and test regimes are inadequate to model this scenario

2.6 Acceptable Means of Compliance

2.6.1 The FAA and EASA regulations give guidance on acceptable means of compliance (AMC) by which manufacturers may demonstrate compliance with the regulations – generally test or analysis supported by previous test. Review of the AMC for the bird strike related regulations has shown that the FAA and EASA AMC are equivalent.

2.7 Kinetic Energy Equivalence of Bird Strike Requirements

2.7.1 Most of the specific Bird Strike certification requirements involve a bird mass and an impact velocity related to particular aircraft performance parameters (e.g. V_C or V_{FE}). The energy of the collision between the bird and the aircraft can be used as an indicator of the potential for structural damage to the aircraft. This section investigates what the regulatory definitions mean in terms of the energy of the collision between the aircraft structure and the bird, at the certification criteria limits. Assuming, for simplicity, that the bird does not deflect from the airframe, the kinetic energy (KE) of the collision is given by the expression

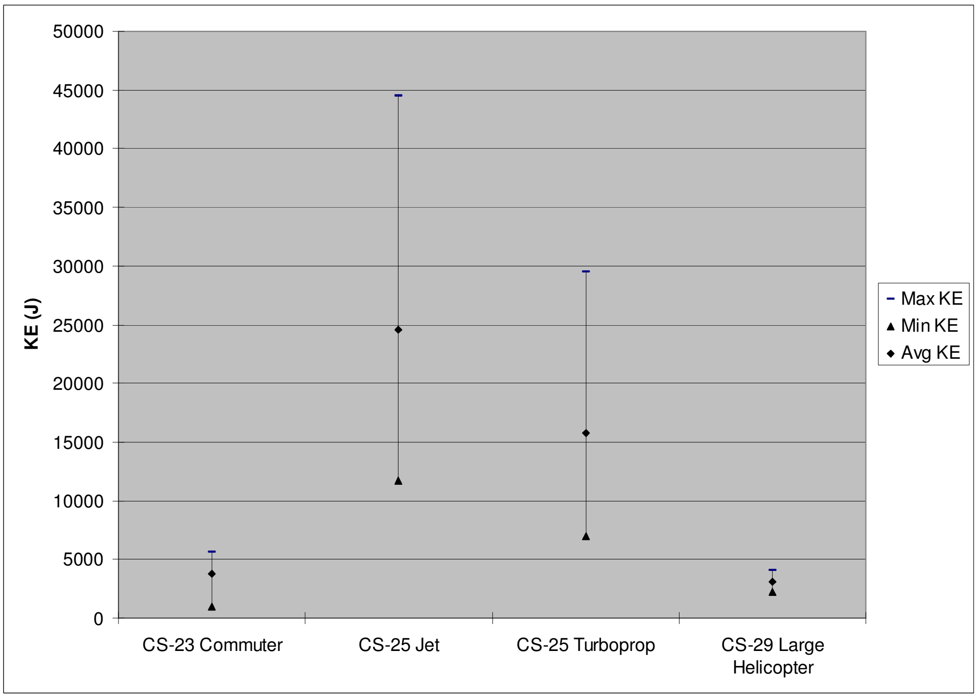
$$KE = \frac{1}{2}mv^2$$

where *m* is the bird mass and *v* is the relative velocity (simplified to the velocity of the aircraft).

2.7.2 Appendix B, Table B-1 presents indicative performance data for a variety of common in-service aircraft across all certification categories. The aim is to give a representative sample of current in-service aircraft. The main source of this data is the EUROCONTROL Aircraft Performance Database [5.], augmented where necessary by data from the FAA or EASA Type Certification Data Sheet (TCDS) [28.] for the particular aircraft type. This data has been used in other parts of the analysis to estimate impact speeds where bird strike reports do not state a value. In this section, it has been used to estimate the KE equivalent of the certification requirement for each aircraft.

2.7.3 The results of this analysis are presented below. For each category of aircraft with bird-strike certification requirements the graphs present the range of different KE values across the various types (note that these are not weighted by the fleet size for each type).

Figure 2-1 Range of Aircraft Certification Requirements Expressed as Kinetic Energy



2.7.4 Naturally only those categories for which certification requirements exist are shown. The effect of the different aircraft performance values and the different bird masses are apparent. The large ranges within each category indicate the effects of the square of certification speed between different aircraft types, even within a sub-category such as CS-25 turboprops

Section 3
Literature Search & Review

3.1 Bird Strike Data

3.1.1 The bird strike literature search and review (part of Phase I of this study) was designed to identify sources of bird strike data that are suitable for analysis, to examine these data in order to identify bird species that should be subjected to a review of their population trends and to obtain the necessary literature to enable those trends to be analysed.

3.1.2 It had been intended to use the International Civil Aviation Organization (ICAO) database of bird strike statistics as a prime source of bird strike information, giving details of worldwide bird strike incidents and accidents. However, despite the best endeavours of fera, Atkins and EASA, it was not possible to gain access to this source of information. Therefore the literature search does not include data from regions such as Asia and Australia. Reporting levels from these regions are low and it is likely that even with access to ICAO data, there would be limited useful information available beyond that already available from UK and USA/Canada sources. It is estimated, based on previous fera Bird Management Unit experience, that the UK and USA/Canadian data obtained represents approximately 50% of all worldwide bird strike reports. Also regions such as Russia, China and South America do not routinely contribute data to the ICAO database.

3.1.3 The time period covered by the data was 1990 to 2007. This was considered to give enough data points to analyse and a period long enough to identify trends whilst limiting the exposure to poorer bird strike reporting practices in previous decades.

3.1.4 The study was therefore limited to information available from UK, US and Canadian sources. Bird strike data has been obtained from UK (Civil Aviation Authority), USA (US Department of Agriculture and others) and Canadian sources between 1990 and 2007. The literature search and review identified a large number of bird strike records from these sources – some 94,000 separate reports. At least a proportion of these records contain full information on aircraft type, bird species, altitude, speed and damage caused to allow assessment of risks and trends. Table 3-1 below shows how the overall data set reduced as more information was requested for each record:

Table 3-1 Bird Strike Records Completeness

Data includes	No. of Records
Total data set	94,743
With Species and Aircraft Type defined	16,845
Above excluding Engine Only strikes	11,569
Above with details of either speed or altitude (or sufficient information to estimate)	10,919

3.1.5 Thus the non-availability of ICAO data on bird strikes from other regions of the world did not prevent development of the study. However the assessment of bird population trends and their effect on bird strike rates was necessarily limited in its scope to those countries / regions from where data was available. In addition, while the lack of these worldwide data did not affect the analysis of aircraft accidents, it did limit the number of serious bird strike incident records that were available for analysis during Phase III of the study.

3.1.6 In collating any bird strike data, one must recognise that there is a tendency towards under reporting - that is, not all bird strikes are reported. This under reporting is believed to be particularly applicable to strikes where no damage was caused and to strikes involving GA aircraft. Such under reporting could lead to a bias in the records. From Jan 2004, pilots are required to report all bird strikes in UK airspace to the CAA. Before this date it was mandatory to report only those strikes that caused damage, significant damage or which might affect flight safety.

3.2 Population Trend Data

3.2.1 Population trends can be estimated directly from the incidence of bird strikes reported for each species year-by-year, and this is addressed later in this report. However there is also a wealth of information from other ornithological and environmental studies of bird populations and trends. These could be useful to support the results of analysis of trends in the strike data, and also to indicate the background trends in the population of key species.

3.2.2 A search of relevant zoological and environmental literature databases was carried out during Phase I. A database of bird species references has been collated, and contains 7885 references for input to the initial literature search. In order to reduce this to a manageable number as input to the study, the bird strike data described above was used to identify the top five species, rated by bird strike frequency, for each of six weight categories (see Table 3-2).

3.2.3 UK and North American data were kept separate and only records where species were identified were included in the analysis. To limit the extent of the literature search, species were grouped into weight categories, with only the top five most frequently struck species per weight category being selected for further population analysis (although in some instances fewer than five species were recorded). Other species were also added where they are recognised to be causing particular problems to aviation safety.

Table 3-2 - Weight categories used to group bird species

Category	Weight	
1	< 4 oz	< 100 g
2	4oz to 1lb	101 – 450 g
3	1 to 2 lb	451 – 900 g
4	2 to 4 lb	901 – 1800 g
5	4 – 8 lb	1801 – 3600 g
6	> 8 lb	>3600 g

3.2.4 Searches were conducted across the following national and international literature databases.

Table 3-3 – Literature Archives Searched

Data Source
Zoological Records Online
CAB Abstracts
Biosis Previews
CSA Life Sciences Abstracts
Elsevier Biobase
Environmental Sciences
Pascal
Geobase
ScieSearch

3.2.5 The results of the literature search are presented in Appendix C: For each species, the Appendix identifies the species, the number of strikes within the dataset, the trend reported in the scientific literature, the particular reference used and the "quality" of that study in terms of its scope and size

3.2.6 Table C-1 shows the results for UK birds, and includes population estimates for Europe as well where these are available. .

- In the UK, 10 of the 26 most commonly stuck species are showing an increasing trend in population, six are decreasing, two have stable populations and eight have no information on population trends available.
- The top five species by weight have increasing populations, whereas four of the bottom seven by weight have decreasing populations. Two have no information available and the other is increasing.
- In terms of strike frequency three of the top five most commonly struck species are decreasing. Black-headed Gull, the most commonly struck species, is increasing and one is stable. Five of the six least frequently struck species are

increasing (these are also the five heaviest species struck), only White-fronted Goose of this group is decreasing.

3.2.7 Table C-2 shows similar results for North American Species.

- Of the 30 most commonly struck or heaviest species in USA, 13 are showing an increasing population trend, 14 a decreasing trend and three are remaining stable.
- Of the 10 heaviest species, seven are increasing, two are decreasing and one is remaining stable. Of the lightest species, eight are decreasing and two are remaining stable.
- Of the ten most commonly struck species, six are decreasing, three are increasing and one is remaining stable. Of those decreasing, all are below 2kg.

3.2.8 These population trends indicated by external, published scientific research will be compared to the trends indicated by analysis of the bird strike data in later sections of the report.

Section 4
Analysis of Bird Strike Data

4.1 Methodology

4.1.1 As reported in the previous section, bird strike data from 1990 to 2007 has been obtained from the UK (Civil Aviation Authority); Canada (Transport Canada) and the USA (US Department of Agriculture). In total 94,743 bird strike reports were obtained, although these varied greatly in terms of the quality and amount of data recorded for each strike. The dataset has been edited to include only those records where information is available on species hit, and aircraft type. Furthermore, strikes involving engines and propellers have been excluded from the final dataset.

4.1.2 Note that data from the USA is incomplete for 2005. Strikes between June 2005 and December 2005 are missing (the data was provided in two tranches, from 1990 to June 2005, and January 2006 to December 2007). To allow the analysis of year on year trends, all data from 2005 has been excluded from analysis of this nature.

4.1.3 The data includes, to varying level of completeness, records of the damage caused (if any), the part struck, the phase of flight, altitude and speed. This data has been analysed to determine how these factor affect the likelihood of damage resulting from a bird strike.

4.2 Damage by Single and Multiple Bird Strikes and by Aircraft Category

4.2.1 There were a total of 10,919 strike reports involving airframes where there was information on both aircraft type and bird species hit. This data set was used for the majority of the Phase II analysis. Of the 10,919 strikes, 1,517 (13.9%) were reported as resulting in some level of damage to the aircraft.

4.2.2 Bird strike reports can involve single or multiple strikes. Three classifications are used in bird strike reporting: Single bird, between 2 and 10 birds and more than 10 birds:

Table 4-1 Single and Multiple Strikes

No Birds Struck	No of Strikes	% Damage
1	7,704	11.9%
2 - 10	2,726	18.9%
> 10	320	23.8%
Total	10,750	

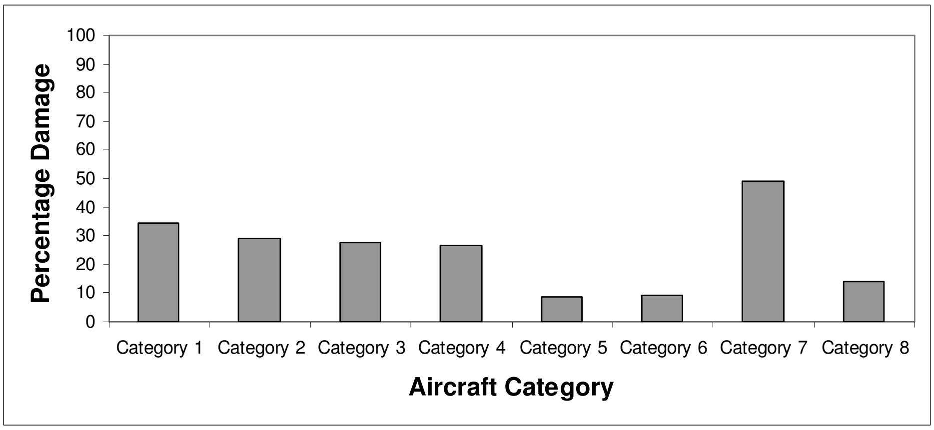
4.2.3 As expected, it is more likely that an aircraft will receive damage from a strike if more than one bird is hit – approximately twice the rate based on this data. However, the majority (72%) of incidents reported are as a result of a collision with a single bird. (Note that this table shows the number of birds struck and hence excludes data where this parameter was not available, hence the discrepancy with the figure of 10,919 reported in Section 4.2.1 above.)

4.2.4 To explore the relative vulnerability of different classes of aircraft, aircraft were categorised into 8 groups in line with classifications provided by EASA (see Appendix C).

Table 4-2 Aircraft Classification

Aircraft Cat.	CS Category	Aircraft Classification	No. of Strikes	% Damage
1	CS-23	Normal/Utility/Aerobatic (Propeller)	1369	34.6%
2	CS-23	Normal/Utility/Aerobatic (Jet)	72	29.2%
3	CS-23	Commuter	418	27.5%
4	CS-23	Business Jets	226	26.6%
5	CS-25	Large Aeroplanes (Propeller)	1375	8.7%
6	CS-25	Large Aeroplanes (Jet)	7266	9.3%
7	CS-27	Small Helicopters	65	49.2%
8	CS-29	Large Helicopters	128	14.1%

Figure 4-1 Aircraft category against the percentage of strikes causing damage.



4.2.5 It can be seen that there is a direct relationship between the type of aircraft and the proportion of reported strikes resulting in damage. Those aircraft which are the subject of comprehensive bird strike certification requirements (categories 5, 6 and 8) are much less likely to sustain damage. However, it is likely that reporting biases exaggerate this finding (i.e. transport aircraft pilots may be more likely to report bird strikes that do not result in damage).

4.2.6 It is also indicated that the aircraft most likely to suffer damage given that a bird strike occurs are small helicopters (Category 7). This is based on the smallest number of reports (65) for any category, but may indicate a particular risk for this category of aircraft.

4.2.7 For information, the detailed breakdown of damaging bird strikes by aircraft category and by number of birds struck is shown in Appendix D, Section D1.

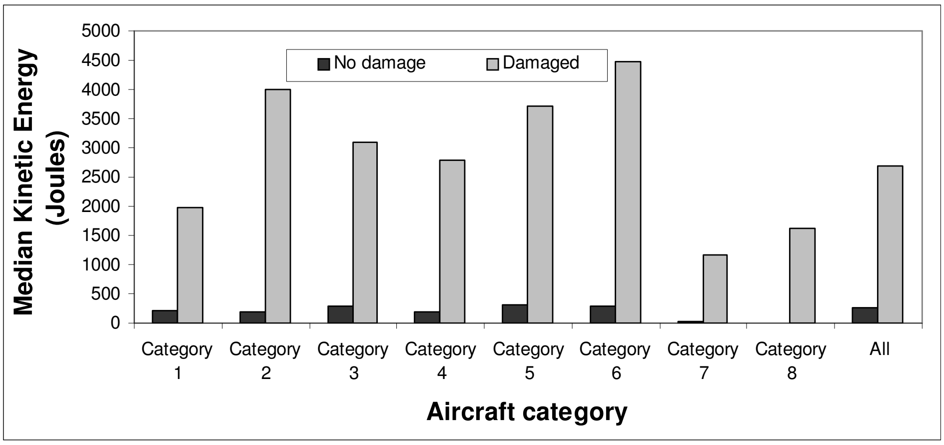
4.2.8 KE has been calculated only for those records for which a speed is stated, and where a species is stated. Bird Strike records generally state speed as Indicated Air Speed (IAS). True Air Speed (TAS) has been calculated from IAS using the simple formula: TAS = IAS + (0.02 x IAS x altitude in 1000ft). This simple formula is often used by pilots and, although not entirely accurate, has been used here as it does not require any information (e.g. temperature, local air pressure) that is not present in the bird strike reports.

Table 4-3 Kinetic Energy (Joules) of bird strikes where no damage or damage was caused.

	No Damage	Damage
Number	5914 Events	1115 Events
Median	268.9 Joules	2698.9 Joules
25 Percentile	111.7 Joules	864.1 Joules
75 Percentile	863.8 Joules	6927.6 Joules

Using this data, it is apparent (and not unexpected) that the median energy of damaging strikes is far greater than those of non-damaging strikes – i.e. KE is a strong indicator of the likelihood of damage. One surprising indication is that the median KE of damaging strikes for Category 8 (CS-29 Large Helicopters) is low, and at 1500 Joules, somewhat below the lower end of the range of Certification KE values for this category of aircraft (Figure 4-2). Note however that there is a difference between reportable damage and loss of ability to continue safe flight and/or landing. Also Bird strike requirements for rotorcraft were not introduced in the US and parts of Europe until FAR Amendment 29-40 (1996) and JAR-29 first issue (1993) although UK requirements existed prior to this under BCAR-G (believed to be prior to 1986). As these FAR and JAR requirements are relatively recent, much of the helicopter fleet may have been designed without consideration of bird strike, and only adapted where required for import into countries where a standard existed.

Figure 4-2 Median Kinetic Energy by Aircraft Categories for Damage and No Damage Strikes.



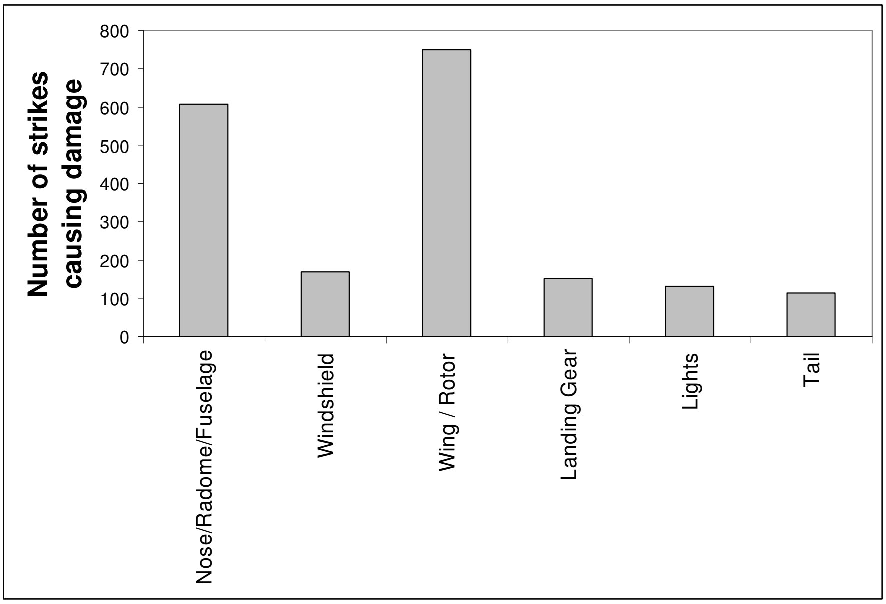
4.3 Bird Strikes to Different Parts of Aircraft

4.3.1 Bird strike reports should include identification of the part struck: Windshield, Nose, Radome, Fuselage, Wing (aeroplanes) or Rotor (helicopters), Tail, Landing Gear, Lights. In practice, given that most bird strikes are to the frontal aspects of the aircraft, there is ambiguity in reporting between Nose, Radome and Fuselage. Therefore these categories have been combined in the data below, by agreement with EASA.

Table 4-4 Percentage of Strikes causing damage by aircraft part

Part Struck	No of Strikes	% of strikes causing Damage
Nose/Radome/Fuselage	6393	9.5%
Windshield	2546	6.6%
Wing / Rotor	3006	25%
Landing Gear	1595	9.5%
Lights	183	71%
Tail	381	30%

Figure 4-3 Number of Strikes causing damage by aircraft part



4.3.2 It is clear that the most frequent damaging strikes are those to the Wing/Rotor and the Nose/Radome/Fuselage. Although these parts should be amongst the strongest, they also present a large frontal area and experience the highest number of strikes. The windshield also reports a high number of strikes, but strikes to the windshield are far more likely to be reported.

4.3.3 The table indicates that the lights are most likely to be damaged if struck (as might be expected).

4.3.4 Further information on the split of this data by aircraft category is presented in Appendix H.

4.4 Bird Strikes to Windshield

4.4.1 One objective of this study is to examine the bird strike risk to windshields. The Tables and Figures below show the bird strike data for windshield in more detail.

4.4.2 The first part of the analysis shows the data for strikes to windshields broken down by **bird mass** for each aircraft category: The table shows for each combination of Bird Mass and Aircraft Category the percentage of strikes resulting in damage and (in brackets) the total number of strikes recorded.

Table 4-5 Windshield Strikes and Proportion causing damage, by Mass

Aircraft Cat.	Mass Range (kg)					
	< 0.1	*< 0.45*	*< 0.9*	*< 1.8*	*< 3.6*	*> 3.6*
1	11.1% (36)	5.1% (78)	23.1% (26)	34.5% (29)	64.3% (42)	54.5% (11)
2	0% (3)	0% (5)	- (-)	0% (1)	66.7% (3)	- (-)
3	0% (20)	0% (19)	0% (6)	60.0% (10)	33.3% (12)	50.0% (2)
4	4.8% (21)	5.3% (19)	0% (1)	22.2% (9)	66.7% (6)	100.0% (1)
5	1.7% (121)	4.1% (121)	13.6% (22)	8.7% (23)	75.0% (8)	33.3% (6)
6	1.0% (797)	2.1% (664)	9.2% (130)	13.2% (136)	45.6% (90)	37.5% (16)
7	0% (1)	100.0% (2)	0% (1)	100.0% (2)	0.0% (1)	- (-)
8	0% (3)	0% (4)	50.0% (2)	100.0% (2)	- (-)	- (-)

4.4.3 Not surprisingly, the higher mass impacts are much more likely to result in damage for all classes of aircraft. Aircraft Category 1 (CS-23 Normal/Utility/Aerobatic) has no certification requirements for windshields and shows appreciable rates of damage in all weight categories.

4.4.4 The fixed wing categories with certification requirements (category 3, CS-23 Commuter; and categories 4 to 6, CS-25 Large Transport Aircraft) generally show lower rates of damage.

4.4.5 The Helicopter categories have insufficient data to draw conclusions (this data contains only those records for which complete bird species and impact speed information exists).

4.4.6 The second part of the analysis shows the same data but broken down by impact **kinetic energy** for each aircraft category:

Table 4-6 Windshield Strikes and Proportion causing damage, by KE

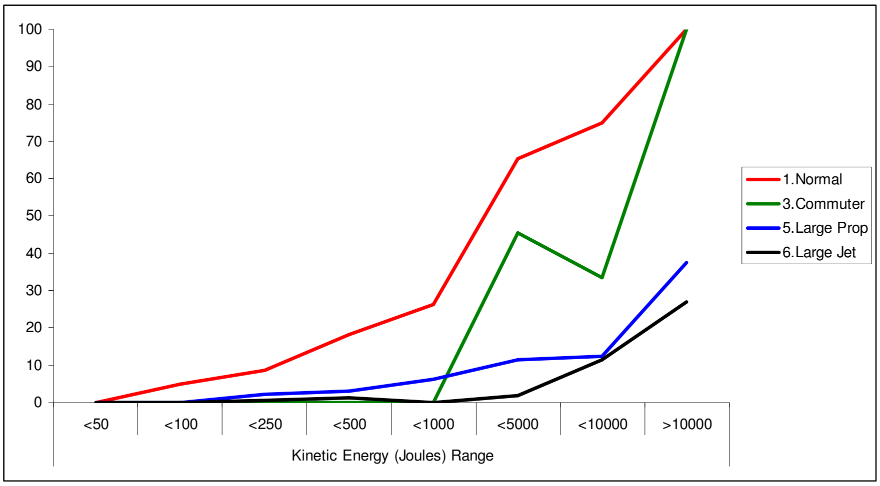
Aircraft Cat.	Kinetic Energy (Joules) Range							
	<50	*<100*	*<250*	*<500*	*<1000*	*<5000*	*<10000*	*>10000*
1	0% (35)	4.8% (21)	8.6% (58)	18.2% (33)	26.3% (19)	65.4% (52)	75% (20)	100% (2)
2	- (-)	- (-)	0% (3)	0% (1)	100% (1)	0% (1)	0% (1)	0% (1)
3	0% (5)	0% (4)	0% (23)	0% (6)	0% (8)	45.5% (11)	33.3% (6)	100% (2)
4	0% (2)	0% (2)	0% (13)	0% (3)	0% (3)	50% (4)	50% (2)	0% (1)
5	0% (36)	0% (28)	2.2% (45)	3.1% (32)	6.3% (32)	11.5% (26)	12.5% (8)	37.5% (8)
6	0% (138)	0% (121)	0.6% (330)	1.1% (188)	0% (140)	1.9% (160)	11.4% (35)	27.0% (37)
7	0% (5)	0% (1)	50% (6)	100% (2)	100% (5)	92.3% (13)	100% (2)	- (-)
8	0% (11)	- (-)	0% (3)	0% (1)	0% (3)	50% (4)	100% (2)	- (-)

4.4.7 In this case the distinction between low and high KE, and aircraft with and without certifications requirements, is much clearer.

4.4.8 Although there is only limited data for category 7 (CS-27 Small Helicopters) and hence should be treated with caution from a statistical analysis perspective, the high proportions of damage above 250 joules is striking. A similar picture is evident with the more numerous data in category 1 (CS-23 Normal/Utility/Aerobatic) with a steady rise in damage rates with increasing kinetic energy.

4.4.9 Categories 5 (CS-25 Propeller) and 6 (CS-25 Jet) show lower rates of damage throughout. The effects of the different certification ranges are shown below for the main categories of fixed wing aircraft.

Figure 4-4 Proportion of Windshield Strikes causing damage, by KE



4.4.10 Two conclusions may be drawn:

- Kinetic Energy is a more revealing parameter than bird mass alone.
- The certification requirements are effective in reducing damage probability for a given energy of impact.

Further information on the detailed breakdown of bird strike data by aircraft category, part struck, bird mass and energy is provided in Appendix H.

4.5 Empennage

4.5.1 The significant point of difference between US and European Certification Requirements is the 8lb requirement for empennage (Tail and horizontal stabilizer) as shown in Appendix A and discussed in Section 2. This requirement was introduced following a single accident in 1962 involving a Vickers Viscount hit a swan with the loss of 17 lives:

"Loss of control after separation of left horizontal stabilizer due to collision with two whistling swans. Aircraft was in the cruise at 6,000ft."

As far as is known at the time of writing, no similar accidents affecting civil aircraft have occurred since. To investigate the need for this separate requirement, the bird strike data relating to tail bird strikes was examined further.

4.5.2 As before, the first part of the analysis shows the data for strikes to tails broken down by **bird mass** for each aircraft category: Data for category 5 and 6 aircraft only is shown as the requirement is relevant to these aircraft only. As before the table shows for each combination of Bird Mass and Aircraft Category the percentage of strikes resulting in damage and (in brackets) the total number of strikes recorded. The relevant weight categories relevant to this requirement are highlighted.

Table 4-7 Tail Strikes and Proportion causing damage, by Mass

Aircraft Cat.	Mass Range (kg)					
	< 0.1	*< 0.45*	*< 0.9*	*< 1.8*	*< 3.6*	*> 3.6*
5	0% (5)	10.0% (20)	33.3% (3)	22.2% (9)	71.4% (7)	50.0% (2)
6	4.8% (42)	14.3% (42)	37.5% (16)	39.3% (28)	55.9% (34)	75.0% (4)

4.5.3 47 reported strikes were above the 4 lb/1.81 kg certification value applied to the rest of the airframe. Of these, 6 (13%) were above 3.6 kg. 59% of all reported strikes over 1.81 kg resulted in damage.

4.5.4 Wing structure is generally similar to tail structure, although the loads are generally lower in level flight. As a comparator to the above, the following table shows the reported strikes that were reported for wings.

Table 4-8 Wing Strikes and Proportion causing damage, by Mass

Aircraft Cat.	Mass Range (kg)					
	< 0.1	*< 0.45*	*< 0.9*	*< 1.8*	*< 3.6*	*> 3.6*
5	3.28% (61)	4.1% (146)	3.2% (31)	17.2% (58)	53.8% (39)	33.3% (6)
6	2.6% (426)	6.7% (505)	23.0% (152)	28.0% (211)	59.6% (203)	46.2% (26)

4.5.5 274 reported strikes were over 1.81 kg (wings experience more strikes than tails due simply to presented area). Of these 32 (12%) were above 3.6 kg. 58% of all reported strikes over 1.81 kg resulted in damage.

4.5.6 Assuming that the majority of aircraft within the data set are subject to the 8 lb requirement for empennage (as most of the data is from the US and most of the aircraft in the data for this category were designed to meet this requirement) the additional requirement appears to make little difference in practice to the probability of damage.

4.5.7 To explore this further, US data for moderate and substantial damage to large transport aircraft has been reviewed. It can be seen that the rates of damage in the range 1.82 kg to 3.6 kg, where the additional empennage requirement would be expected to be most effective, are almost exactly the same. The damage rates are different above 3.6 kg (higher moderate but lower substantial damage rates for the tail), but the number of tail strikes (13) is now very limited and hence should be treated with caution from a statistical significance perspective.

Table 4-9 Comparison of Damage Severity for Wings and Tails (US Data only)

		Wing	Tail
Bird Mass between1.81 kg and 3.6 kg	Number of strike reports where severity identified	252	42
	Moderate Damage	35%	33%
	Substantial Damage	24%	26%
Bird Mass above 3.6 kg	Number of strike reports where severity identified	34	13
	Moderate Damage	38%	85%
	Substantial Damage	9%	15%

4.5.8 The conclusion from this analysis is that the increased empennage requirement in the USA is not apparently reducing the rate of moderate or substantial damage for reported strikes between 1.81 kg and 3.6 kg. However, based on the very limited data available, there is much more likelihood of damage to the tail than the wing for strikes above 3.6 kg.

4.6 Level of Damage Caused (US Data Only)

4.6.1 US bird strike reports contain information on the level of damage caused, graded as either no damage, damage, moderate or substantial.

Table 4-10 Level of Damage (US Only)

Level of Damage	Number of Incidents
No damage	5250
Damage	8
Moderate	1075
Substantial	424

(Note: Reports relating to engine damage only have been removed, but those with damage to engines and other parts have been retained. Therefore it is likely that some of those incidents where substantial damage is recorded may have been due to uncontained engine damage.)

4.6.2 The majority of reports (77%) record no damage, 16% are recorded as Moderate and 6% are recorded as substantial. It would be expected that the majority of Moderate or Substantial reports relate to collisions with heavier birds. To explore this, the top five species in the Moderate and Substantial categories have been identified and are listed below.

Table 4-11 Top 5 Species Causing Moderate/Substantial Damage (US Only)

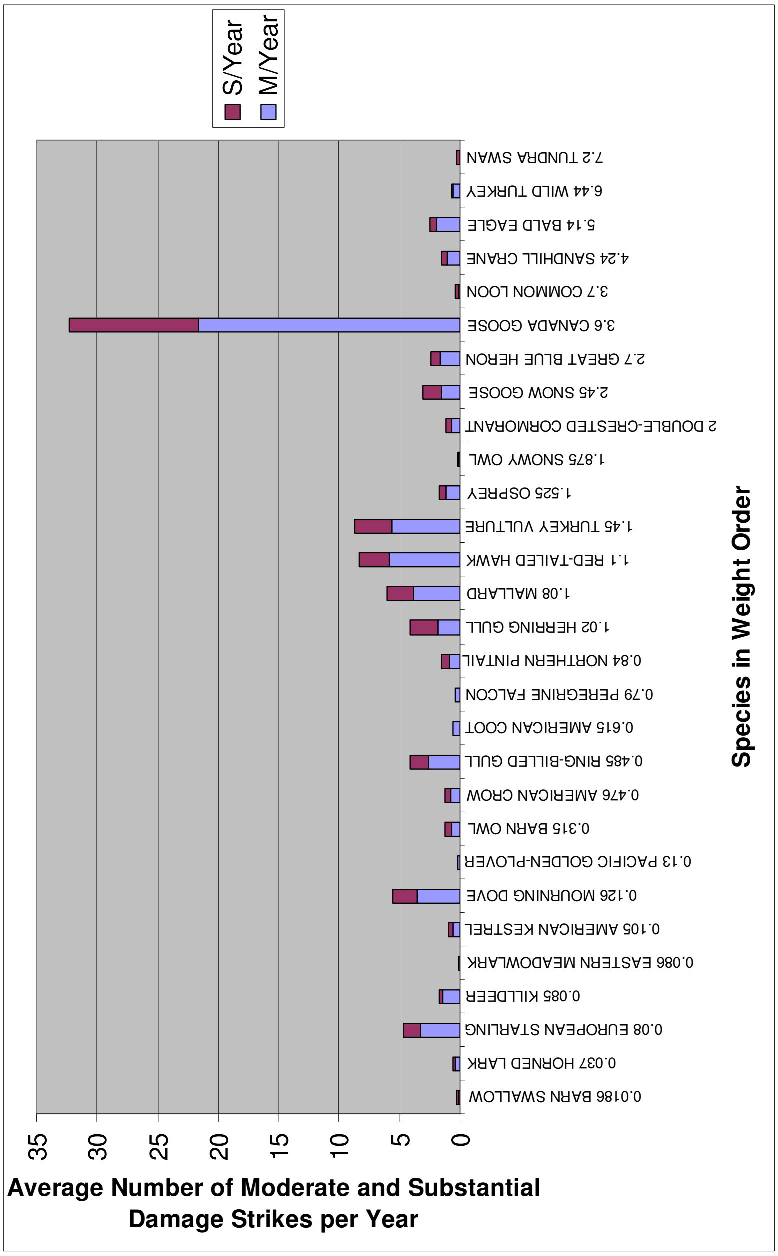
Damage Level	Species	% Strikes	n
Moderate	Canada Goose	29.1	313
	Rock Pigeon	7.5	81
	Turkey Vulture	7.3	78
	Red-Tailed Hawk	6.3	68
	Mallard	4.7	51
Substantial	Canada Goose	31.8	135
	Turkey Vulture	9.2	39
	Rock Pigeon	7.1	30
	Mallard	5.2	22
	Snow Goose	4.2	18

4.6.3 These lists are dominated by birds over one kg – Canada Goose (3.6 kg), Turkey Vulture (1.45 kg), Red Tailed Hawk (1.1 kg), Mallard (1.08 kg), Snow Goose (2.45 kg).

4.6.4 It is important to understand which species are causing the most damaging strikes as the growth or decline in the populations of these birds will partly determine the future risk from bird strike. To explore this further, the data was reassessed to identify all the major species contributing to moderate and substantial damage strikes – See Figure 4-5 below.

4.6.5 The Canada Goose stands out as the highest risk species in this respect, followed by the Turkey Vulture, Red Tailed Hawk and Mallard.

Figure 4-5 Species Causing Moderate or Substantial Damage (US Only)



4.7 Phase of Flight

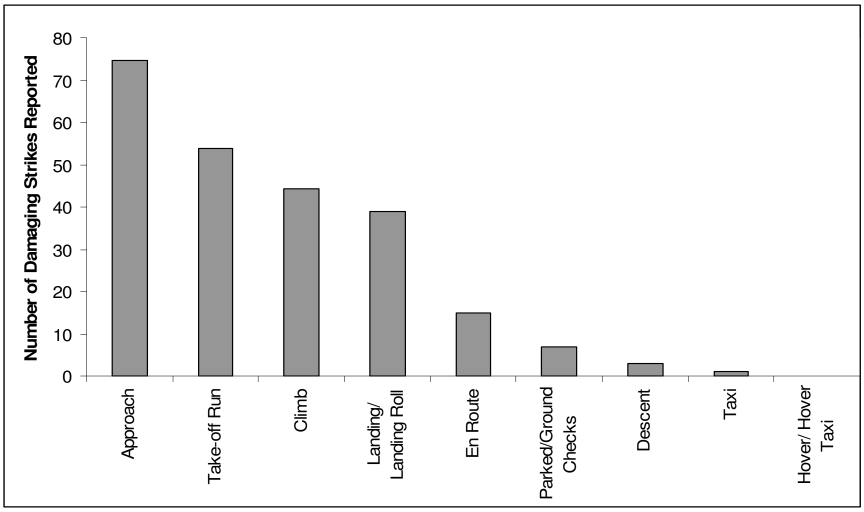
4.7.1 UK and Canadian Bird Strike data contains information on Flight Phase. This has been analysed to identify where strikes occur and how the percentage of strikes resulting in damage varies between flight phases.

Table 4-12 Strikes to Aircraft by Flight Phase (UK/Canada Data only).

Phase	Number of Strikes	% Damage
Landing/Landing Roll	1351	3%
Approach	1130	7%
Take-off	996	5%
Climb	433	10%
Parked/Ground Checks	53	13%
En Route	44	34%
Taxi	30	3%
Descent	30	10%
Hover/ Hover Taxi/ On deck	11	0%

4.7.2 From the data available (i.e. records for which the flight phase was stated) the total number of strikes are dominated by Approach and Landing, Take-off and Climb – i.e. the majority of phases with significant velocity close to the ground. Together these account for 96% of the strikes. The proportion of these strikes resulting in damage is 5% overall, compared to 34% in the en route phase – 7 times higher. However, given the relatively small total number of strikes en route, the total number of damaging strikes is still low compared to the low altitude phases –see Figure 4-6 below.

Figure 4-6 Damaging Strikes to Aircraft by Flight Phase (UK/Can Data only)



4.7.3 Appendix D, Section D-4 identifies the top five species hit for each phase of flight and the ratio of damaging strikes for each. Broadly this is in line with expectations in terms of bird mass and speed. The data is sparse for the en route phase (it is difficult to identify species unless remains are recovered from the aircraft), but the Herring Gull is the highest with 5 occurrences.

4.8 Altitude

4.8.1 There is a strong relationship between strike altitude and percentage of strikes causing damage (Table 4-13). It is likely that this is caused by the underlying speed/altitude relationship, i.e. aircraft are generally at greater speeds at higher altitudes and it is this greater speed that results in a greater proportion of damaging strikes.

Table 4-13 Strikes to Aircraft by Height

Height ft	Number of Strikes	% Damage
0	3589	6%
< 100	2277	9%
< 200	735	12%
< 400	655	12%
< 600	316	20%
< 800	118	21%
< 1000	110	27%
< 2000	368	36%
> 2000	339	52%
>=8000	27	67%

Figure 4-7 Number of Damaging Strikes at Different Height Bands.

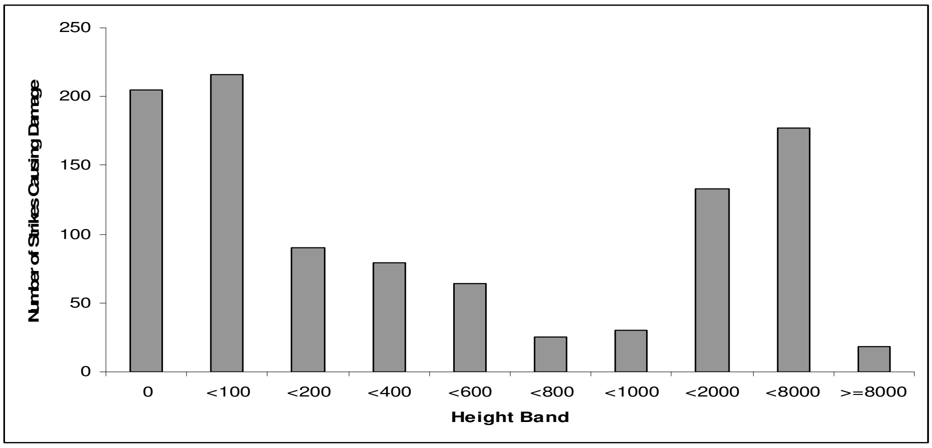


Table 4-14 Top 5 species hit at each height category

Height (ft)	Species	Number of Strikes	% Damage
0	Mourning Dove	416	2.2
	European Starling	385	2.9
	Feral Pigeon	332	9.6
	Barn Swallow	257	0.8
	Canada Goose	199	47.2
< 100	European Starling	335	4.5
	Feral Pigeon	209	17.7
	Mourning Dove	196	4.6
	Lapwing	196	10.7
	Canada Goose	176	59.7
< 200	European Starling	65	6.2
	Canada Goose	54	48.1
	Feral Pigeon	35	20.0
	Barn Swallow	31	0.0
	Lapwing	25	4.0
< 400	European Starling	61	4.9
	Feral Pigeon	39	20.5
	Pigeons	29	13.8
	Canada Goose	29	51.7
	Barn Swallow	22	0.0
< 600	European Starling	33	3.0
	Canada Goose	25	64.0
	Feral Pigeon	21	14.3
	Barn Swallow	18	0.0
	Pigeons	11	0.0
< 800	Turkey Vulture	22	63.6
	Canada Goose	17	82.4
	European Starling	13	0.0
	Swift	7	0.0
	Feral Pigeon	5	0.0
	Pigeons	5	40.0
< 1000	Turkey Vulture	16	75.0
	Canada Goose	14	50.0
	Swift	13	7.7
	European Starling	9	0.0

Height (ft)	Species	Number of Strikes	% Damage
	Mourning Dove	8	25.0
	Herring Gull	8	37.5
< 2000	Canada Goose	58	74.1
	Turkey Vulture	45	86.7
	European Starling	21	9.5
	Mallard	13	69.2
	Barn Swallow	12	0.0
> 2000	Canada Goose	103	78.6
	Snow Goose	26	92.3
	Mallard	17	70.6
	Turkey Vulture	14	78.6
	European Starling	12	0.0

4.8.1.1 The predominance of the Canada Goose and Turkey Vulture above 800 ft is notable, as are the generally higher damage ratios at these altitudes.

4.9 Conclusions

4.9.1 The bird strike reports have been analysed to identify which parts of the aircraft, phases of flight, altitudes and categories of aircraft suffer the greatest numbers of strikes and the highest proportions of damaging strikes.

4.9.2 Overall, 13.9% of strikes reported result in damage. 28% of strikes reported involved multiple birds, and for these the likelihood of damage was higher.

4.9.3 CS-25 aircraft had the lowest proportion of damaging strikes, but this may have been due to better reporting of non-damaging strikes in these cases. CS-27 (small helicopters) had the highest proportion of strikes resulting in damage at 49%. The aircraft parts most likely to be damaged are the nose/radome/fuselage and the wing/rotor, probably due to their projected area.

4.9.4 A detailed analysis of windshield strikes showed a strong correlation between impact KE, certification requirements and probability of damage. There is one exception with CS29 (Large Helicopters) where damage is apparently being reported at a KE lower than the certification requirements. In general KE is a good indicator of damage likelihood.

4.9.5 96% of strikes occur during take off, climb, approach and landing. Strikes during the en-route phase of flight are much less frequent but 34% of these result in damage when they do occur reflecting the higher aircraft velocity and hence higher KE when a strike does occur. Over 800 ft altitude, strikes and damage are dominated by Canada Goose and Turkey Vulture which are high mass birds and hence contribute further to the higher KE of strikes at altitude.

Section 5
Analysis of Trends

5.1 Trends in Bird Mass

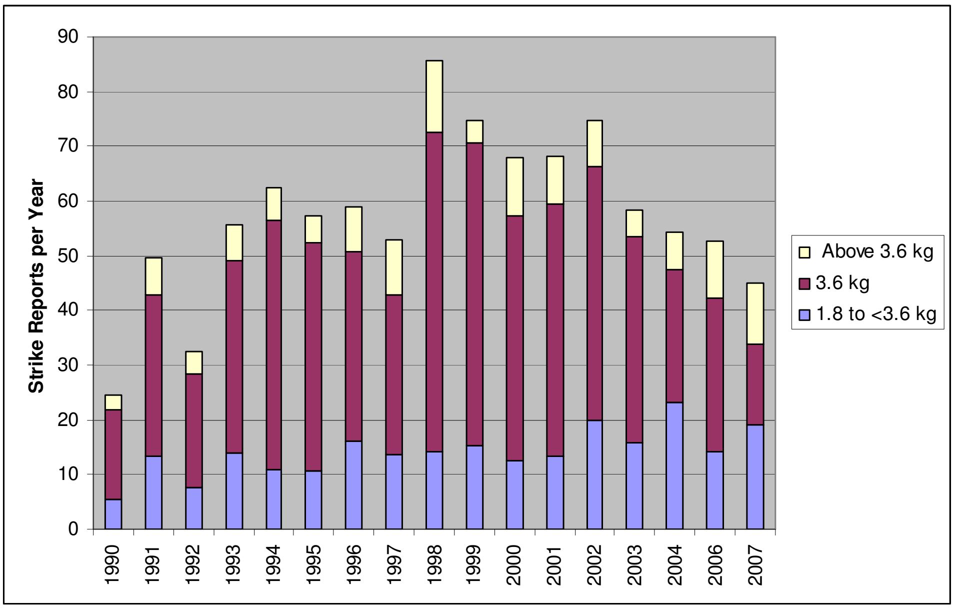
5.1.1 One of the primary aims of this study is to examine whether there is an increasing threat from higher mass birds due to population growth. Therefore the trend in bird strike mass has been examined, and in particularly those above the current 1.81 kg requirement for CS-25 aircraft.

5.1.2 All strike reports involving CS-25 category aircraft and birds above 1.81 kg have been collated and sorted into three bands:

- From 1.81 to below 3.6 kg
- 3.6 kg. This value is primarily the Canada Goose.
- Above 3.6 kg.

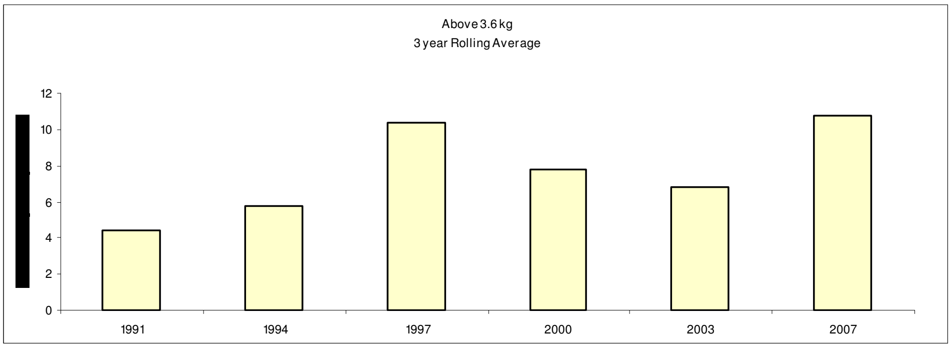
Note that 2005 data has been removed as it is incomplete, and figures have been normalised to remove the effects of the growth in air traffic over the period (see Appendix E).

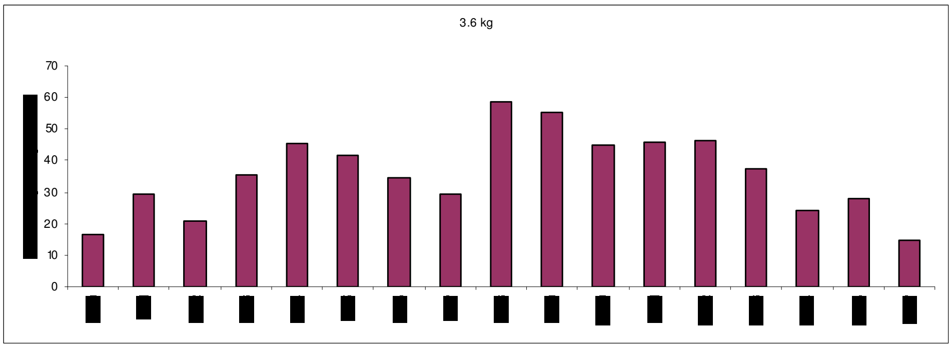
Figure 5-1 : Strike reports above 1.81 kg

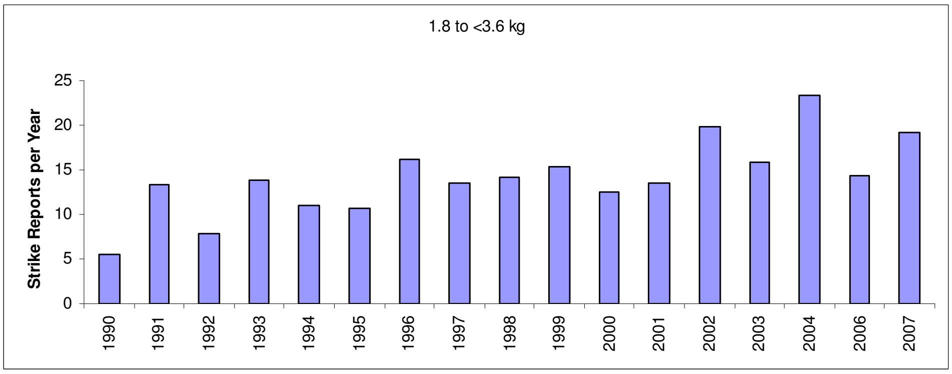


5.1.3 The three categories are shown separately below. The 3.6kg/Canada Goose category contributes 61% of all the strikes over 1.81 kg, and its profile reflects the success in specific control measures targeting this species in high risk areas near airports (although the overall population may not be falling to the same extent). The other two categories show gentle growth throughout the period. The number of strikes over 3.6 kg is small (hence the data is presented and as a 3 year rolling average, again normalised to remove the effects of the growth in air traffic over the period (see Appendix E)) but their growth is of concern.

Figure 5-2 : Strike reports above 1.81 kg Separated







5.2 Selection of Key Species

5.2.1 To explore the trends in more detail, the species contributing most to high KE impacts have been identified. These species are the major contributors to high mass/high energy impact across the whole data set (UK/US/Canada combined). Again the Canada Goose is the most important species, but other species that may fly at high altitude and therefore may be encountered at high speed are included.

Table 5-1 Species Contributing to High Mass/High KE Impacts

Place	Average bird mass Kg	Number of strikes	Bird species
1	3.6	594	Canada Goose
2	1.02	303	Herring Gull
3	1.1	173	Red Tailed Hawk
4	1.45	143	Turkey Vulture
5	1.08	125	Mallard
6	2.7	56	Great Blue Heron
7	5.14	51	Bald Eagle
8	2.45	43	Snow Goose
9	4.24	42	Sandhill Crane
10	1.525	33	Osprey
11	0.465	32	Wood Pigeon
12	1.69	28	Great Black-Backed Gull
13	3.5	26	Brown Pelican
14	1.71	24	Black Vulture
15	0.429	19	Pigeon
=15	0.82	19	Lesser Black-Backed Gull
No. of Included Strikes		1711	
Percentage		81.1%	

5.2.2 It is shown later in Section 6 that 90% of the accidents identified in this report involve impact kinetic energies above 1500 J and bird masses above 0.9 kg. Together these 16 species represent 81% of the strikes whose impact is in excess of 1500 J, and 85% of the strikes where the mass is above 0.9 kg.

5.2.3 A single list has been used rather than separate UK/North American lists because the objective is a single harmonised set of requirements across both regulatory domains.

5.3 Trend Analysis

5.3.1 The following table shows the year by year strikes for each of these species, based on the complete set of strike records for which species was known and whose impact is in excess of 1500 J (29,600 records for all bird species).

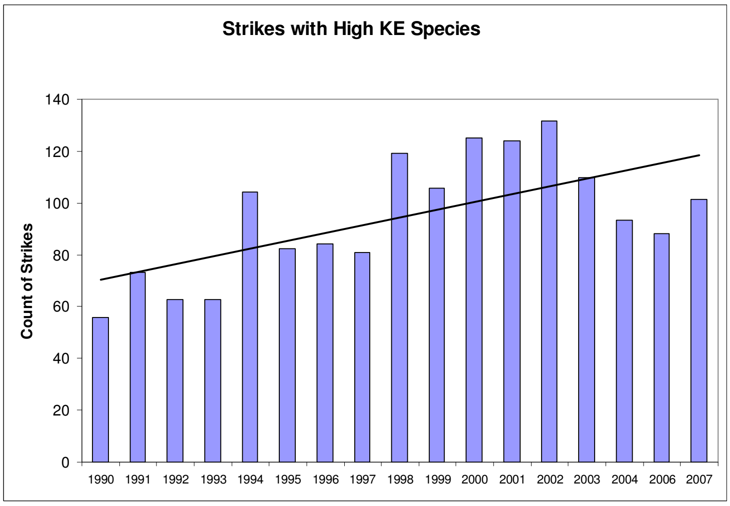
5.3.2 The table also shows the trends identified by ornithological population studies (see Section 3.2 and Appendix C), which generally indicate either growth or stability in these particular populations.

Table 5-2 Strikes Recorded By Species

	Strikes per Year, normalised against flying hours																		Population Studies	
Birds	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**UK**	**US**
Canada Goose	26	28	28	26	46	36	31	24	41	46	44	43	46	42	28	8	26	23	Increase	Increase
Herring Gull	8	17	10	7	7	14	23	19	31	23	19	28	30	7	12	4	7	6	Stable	Decrease
Red Tailed Hawk	1	4	6	2	8	5	5	8	3	5	14	10	15	19	14	10	13	22		Increase
Turkey Vulture	3	6	3	5	8	5	3	7	10	3	12	12	6	12	15	4	8	16		Increase
Mallard	4	1	4	5	15	3	5	6	6	10	5	8	11	11	6	6	7	5		Decrease
Great Blue Heron	0	3	0	3	5	2	3	2	4	2	2	1	5	6	4	3	4	6		Increase
Bald Eagle	0	1	1	1	6	2	1	1	5	1	4	5	1	3	4	0	7	6		Increase
Snow Goose	2	2	1	5	2	0	2	0	3	5	5	2	4	2	3	0	2	3		Increase
Sandhill Crane	1	1	2	5	1	2	2	2	3	4	5	2	2	1	1	3	4	6		Increase
Osprey	1	1	0	0	0	0	1	3	1	4	4	2	1	2	4	2	2	3		Increase
Wood Pigeon	1	2	1	0	0	0	3	1	1	0	7	4	5	0	0	0	2	0		
Great Black-Backed Gull	2	1	0	2	2	0	2	4	3	3	1	1	1	1	2	0	0	1	Stable	
Brown Pelican	0	3	2	0	2	4	1	1	1	1	2	1	2	0	0	0	4	2		
Black Vulture	1	0	0	1	0	0	0	0	2	0	3	3	2	5	0	2	3	2		
Pigeon	4	2	4	1	1	8	0	0	0	0	0	0	0	0	0	0	0	0		
Lesser Black-Backed Gull	0	0	0	0	0	0	0	2	4	0	1	3	2	0	0	0	0	0	Increase	
Total	56	73	63	63	104	83	84	81	119	106	125	124	132	110	93	42	88	101		

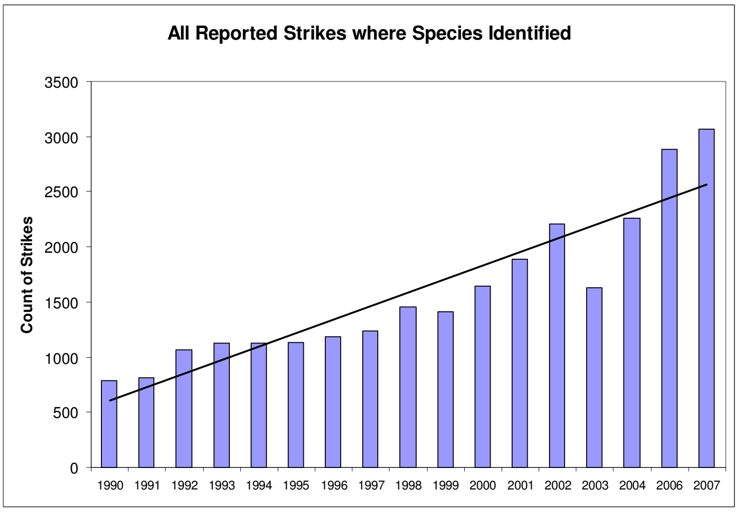
5.3.3 The overall trend for this set of species is shown below. The trend line suggests a growth in these strikes (approximately 3% per year), although there is an apparent reduction since 2002. This may reflect the increased effectiveness of airport bird control measures, particularly for Canada Goose.

Figure 5-3 Strike Trend for High Mass/High KE Species



5.3.4 A significantly greater trend can be seen for all species, indicating that the above may simply be part of the general trend in bird strike reporting driven by the increased attention to reporting <u>all</u> strikes (mandatory in the UK since 2004). This is likely to affect mainly the low mass, non-damaging strikes that would previously have gone unreported.

Figure 5-4 Strike Trends for All Species



5.4 Conclusions

5.4.1 The analysis for all strikes above 1.81 kg shows no strong overall trend as it is dominated by the Canada Goose strikes which have reduced recently. However the population trend for the other birds over 1.81 kg is upwards.

5.4.2 A more detailed examination based on those birds contributing most to high KE impacts (including the Canada Goose) has also been carried out. The trend in number of strikes reported for these birds is upwards, supported by ornithological studies reporting growing populations for many of them. However, this may be part of the upward trend in the reporting of all bird strikes.

5.4.3 The situation for particular species is well understood. Lapwings for example, are now of conservation concern because of the decline in population, and the strike rate for this species is showing a similar downward trend. The upward trend in Canada Goose strikes mirrored the increase in feral birds around many of the major UK and USA population centres up until 1998. From 1998, airport bird control teams started to take concerted action and the strike rate has since fallen. A detailed investigation of other species on this list may provide explanations for their trends, however such an investigation is outside the scope of this report.

5.4.4 Given this level of uncertainty, it is considered that the upward trend of approximately 3% per annum shown in Figure 5-3 should be assumed to be valid until more information becomes available, noting that the dip since 2002 for high mass / high KE birds is not yet conclusive compared to the trend shown in Figure 5-4 and is further compounded by the change in reporting requirements in the UK since 2004.

Section 6
Analysis of Accident Data

6.1 Accident Data

6.1.1 This section presents an analysis of the historical accident data relating to airframe bird strikes. The purpose of this analysis is to identify the current rate of accident occurrence relating to airframe bird strikes, and if possible, to assess any trend in the rate of occurrence due to changes in bird populations.

6.1.2 Accidents are included in the analysis if they satisfy both of the following criteria:

- The primary accident cause was bird strike(s) to any part of the aircraft other than the engines or propellers. This excludes accidents as a result of striking other types of wildlife, manoeuvring to avoid birds, or bird strikes to engines (including secondary damage to the airframe as a result of engine failure).
- The consequences include one or more fatal injuries or destruction of the aircraft. This excludes accidents resulting only in non-fatal injuries and/or repairable damage to the aircraft, where it could be argued that "continued safe flight and landing" (the criteria for certification) was still achieved.
- For the avoidance of doubt, a fatal accident is one where a person is fatally injured as a result of being in the aircraft, or in direct contact with any part of the aircraft, including parts which have become detached from the aircraft, or as a result on jet blast . An injury resulting in death within thirty days of the date of the accident is classified as a fatal injury by ICAO..[c]

6.2 Basic Quantification

6.2.1 A total of 51 such accidents have been identified between 1962 and November 2009. It is very likely that others have occurred, and either have not been reported in the sources used (primarily papers submitted to the International Bird Strike Committee) or were never recognised as bird strike accidents.

Table 6-1 Non-Engine Bird Strike Accident Statistics

Aircraft EASA Certification Category	CS-23	CS-25	CS-27	CS-29
Identified Accidents due to Airframe Bird Strikes, 1962-2009	35	6	9	1
Accidents in US/Canada/UK, 1990-2007 for which Airframe Bird Strike is primary cause.	10	0	4	0
Fatal Accidents in US/Canada/UK, 1990-2007 for which Airframe Bird Strike is primary cause.	5	0	2	0

[c] ICAO Working Paper 10th Session of the Statistics Division STA/10-WP/23 13/10/09.

COMMERCIAL-IN-CONFIDENCE

Aircraft EASA Certification Category	CS-23	CS-25	CS-27	CS-29
Million Flying Hours for US/Canada/UK, 1990-2007 (from Appendix E)	441.03	308.41	35.75	9.59
Accident Rate per Million Flying Hours	0.023		0.11	
Fatal Accident Frequency Rate per Million Flying Hours	0.014		0.056	

6.2.2 Thus only 14 accidents and 7 fatal accidents were identified within the period and regions covered by this study. None of these involved the transport category aircraft (CS-25 and CS-29). Based on the limited data available, and recognising that these are likely to understate the true risk, Accident Frequency Rates have been calculated for the other two categories.

- The calculated rate for small fixed wing aircraft (CS-23) is 0.023 per million flying hours for accidents, and 0.014 per million flying hours for fatal accidents, compared to an overall Fatal Accident Frequency Rate per million flying hours of 4.8 in the UK (Ref. CAP780 Annual Safety Review 2008) and 12.5 for all General Aviation in the US (Ref NTSB Aviation Accident Statistics 2008 Preliminary Statistics). Using the lower UK rate, the calculated Fatal Accident Frequency Rate for non-engine bird strike is just 0.2% of the total rate from all causes.
- The rate for small helicopters (CS-27) is 0.11 per million flying hours for accidents, and 0.056 per million flying hours for fatal accidents. However the fatal accident figure is based upon only two events. This compares to an overall Fatal Accident frequency rate of 14.4 in the UK. (Ref. CAP780 Annual Safety Review 2008), such that the calculated Fatal Accident Frequency Rate for non-engine bird strike is just 0.3% of the total rate from all causes.

6.2.3 All that can be concluded from this quantification is that airframe bird strikes appear to be a relatively rare cause of accidents, particularly for those aircraft for which formal certification requirements exist (CS-25 and CS-29). It suggests that the current regulatory requirements have been effective in preventing loss of Transport Aircraft due to airframe bird strikes, at least measured over the period 1990 to 2007.

6.2.4 It is clear that with such limited data it is not possible to quantify risk, and particularly trends in risk, with any confidence. However, the accident data can be used to understand the relationship between bird strikes and accidents, and the remainder of this section attempts to explore this.

6.3 Parts Struck

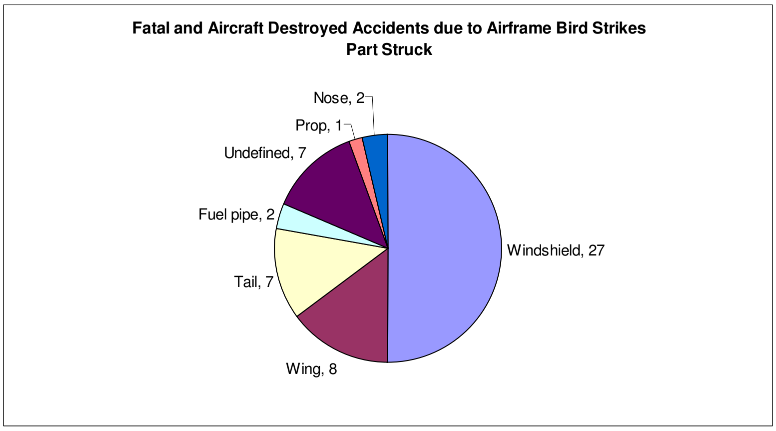
6.3.1 The bird strike database contains 94,943 records. Of these, 52,713 are airframe only strikes, 8,319 engine only strikes and 3972 are engine and airframe strikes. Therefore there are (12,291) engine strikes and 56,685 airframe strikes. The ration of airframe to engine strikes is therefore 4.6 to 1.

6.3.2 Appendix F: shows the detailed data available for each of the accidents during the period 1962 to 2009. The table in Appendix F: shows the date, aircraft type, speed and bird type, etc. Where possible the part of the aircraft struck has been identified.

6.3.3 This shows the predominance of windshield impacts resulting in loss of the aircraft or fatality. These are particularly evident for small fixed wing and rotary wing aircraft (CS-23 and CS-27). This is a recognised issue, and reflects both the absence of regulatory requirement on windshield resistance to impact and the fact that in many cases there is no second pilot. Most military operators require pilots of helicopters and light fixed wing aircraft to wear helmets with visors.

6.3.4 None of the accidents appeared to be due to damage to modern avionic systems or composite materials.

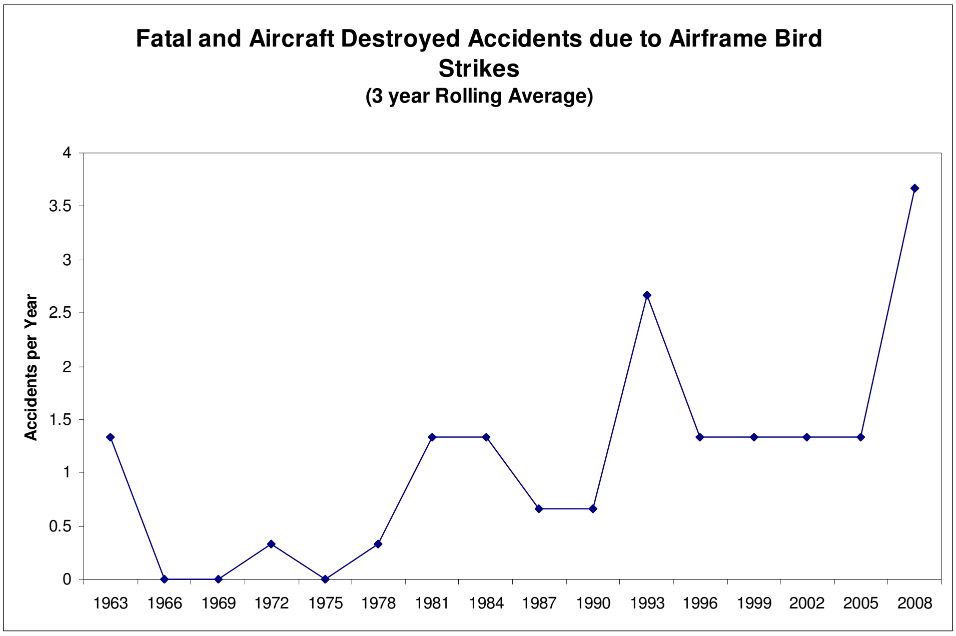
Figure 6-1 Parts Struck during Non-Engine Bird Strike Accidents



6.4 Overall Time Trend

6.4.1 The distribution of these accidents over time is presented below, as 3 year rolling average values for the period 1963 to 2008.

Figure 6-2 Trend in Non-Engine Bird Strike Accidents



6.4.2 The apparent trend is at least partly due to incomplete data reporting, particularly pre-1980. Nevertheless, the steady increase in airframe bird strike accidents, even after 1980, is of concern.

6.5 Transport Category Accidents

6.5.1 The existing certification requirements for bird strike resistance are focussed on transport category aircraft – CS-25 and CS-29. There have been relatively few accidents involving these aircraft, and it is worth considering them individually: It is notable that none of these accidents fell within the geographical areas and time period covered by the main part of the study.

Table 6-2 Transport Aircraft Accidents

Date	Location	Aircraft	Synopsis
15-Aug-62	Lahore, Pakistan	DC3	Indian Airlines flight was in the cruise between Kabul and Amritsar when the crew spotted a vulture (up to 10 Kg) above and to one side. The co-pilot was killed when it "attacked" the aircraft and penetrated the windshield.
23-Nov-62	Maryland, USA	Vickers Viscount	Loss of control after separation of left horizontal stabilizer due to collision with two whistling swans. Aircraft was in the cruise at 6,000ft.
26-Jul-78	St Elena, Guatemala	DC3	Aircraft was taking off when it hit a flock of birds. Forced landing attempted but aircraft overran the runway, ending in a swamp.

Date	Location	Aircraft	Synopsis
13-Oct-92	Kiev, Russia	Antonov 124	At about 19,700 ft in a high-speed descent (estimated at 330 kts), a bird (about 1.8Kg) was struck, holing the nose. Ram air pressure caused further structural damage resulting in fatal crash and loss of this prototype aircraft.
28-Nov-04	Schiphol, Netherlands	B 737-400	Bird strike occurred on take off. On landing at Barcelona the pilots were unable to keep the aircraft on the runway. Bird remains (Buzzard, 0.8Kg) were found in the nose gear jamming the steering cables to one side.
04-Mar-08	Oklahoma City, USA	Cessna Citation 500	Airplane wing-structure damage sustained during impact with one or more large birds (American white pelicans), which resulted in a loss of control of the airplane.
04-Jan-09	Lousiana, USA	S76++	The helicopter was cruising at 138 knots at about 700 feet. The cockpit voice recorder indicates a loud noise followed by a substantial increase in the background noise level and the torque of both engines dropped to near zero. Microscopic remains of a hawk variety DNA were present. The windshield exhibited concentric ring fractures.

6.5.2 The first three accidents involved aircraft that predated modern bird strike requirements. The Viscount accident is notable as it led to the US-specific requirement for 8lb (3.6kg) resistance in the empennage.

6.5.3 Little information is available on the 1992 Antonov accident. On the basis of the available information,, this appears to be a relatively high energy impact at an unusually high altitude leading to structural failure. It is curious that the bird mass was estimated but the species was not reported. The aircraft was operating outside its normal flight envelope (high speed) on a test flight.

6.5.4 The 2004 Boeing 737 accident was due to jamming of the nose steering gear rather than a penetration of either airframe or windshield, resulting in running off the runway on landing. As a result, a comparatively low-energy impact led to damage beyond economic repair.

6.5.5 The 2008 loss of a Cessna 500 was the first structural failure of a western transport aircraft since the Viscount accident in 1962. The NTSB report contains recommendations for a revision of certification requirements so that all parts of Part 25 aircraft have a consistent level of protection.

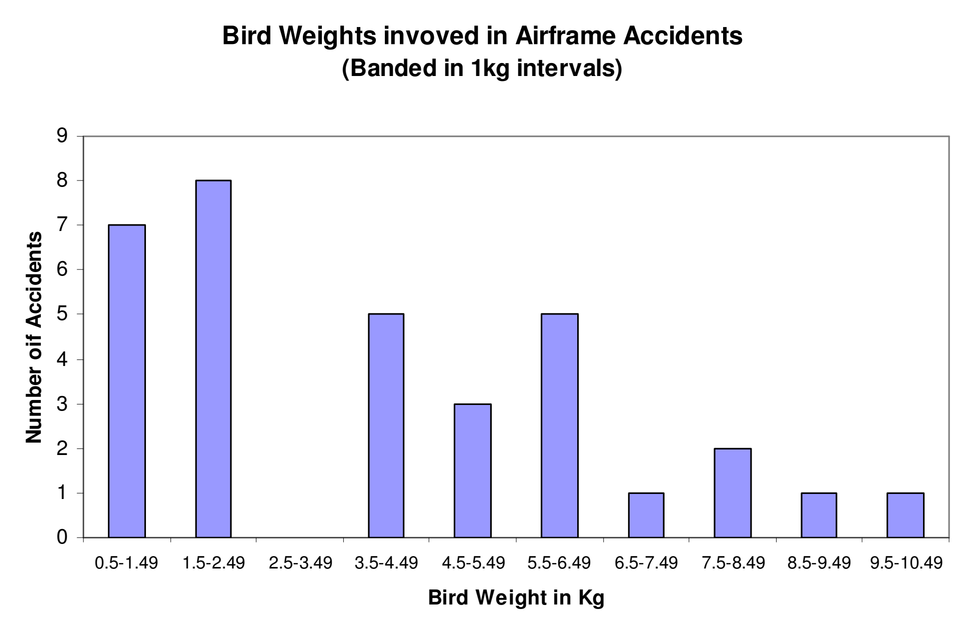
6.5.6 The 2009 loss of an S76++ is the sole recorded loss of a transport category helicopter due to non-engine bird strike in this data set. The report is not yet released, but it appears likely that this involved windshield penetration and possibly incapacitation of both pilots.

6.5.7 It is notable that these two transport aircraft accidents where existing certification requirements have not prevented loss of life have occurred within the last two years.

6.6 Bird Mass

6.6.1 The distribution of the bird masses involved in Accidents is presented below. Of the 33 accidents for which an estimate of bird mass could be made, 31 were over 1 kg and the lowest value recorded was 0.78kg. The average of all accident bird masses was 3.8kg. Naturally it is to be expected that accidents are associated with high mass bird strikes, but the absence of any bird mass less than 0.78kg in this accident data is significant.

Figure 6-3 Accident Bird Mass Distribution



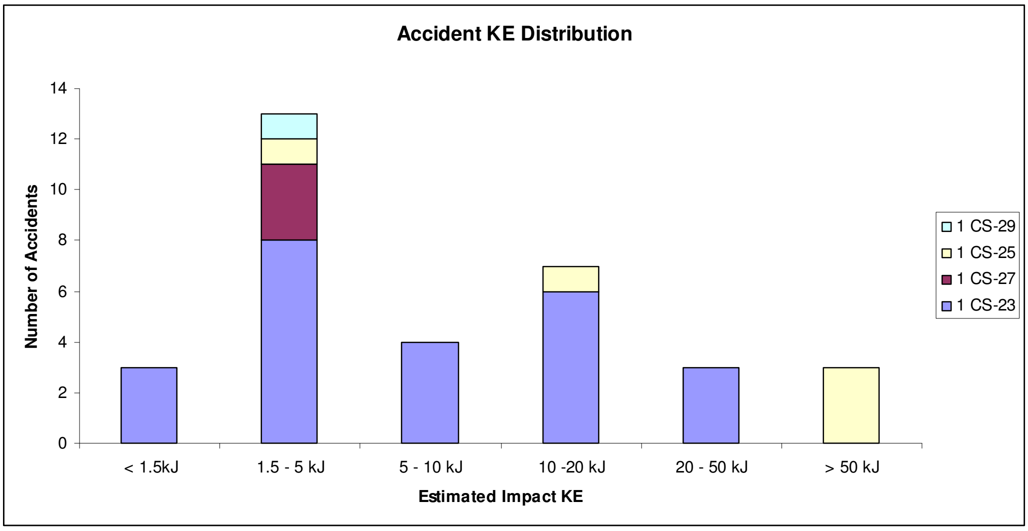
6.7 Kinetic Energy

6.7.1 It is the combination of mass and velocity that determines the level of damage and hence the probability of an accident resulting from a bird strike. This may be expressed as Kinetic Energy (0.5 x mass x velocity$^{\wedge 2}$) which is used in a number of fields of engineering as an indicator of the likelihood of damage resulting from impact. A number of other expressions involving mass and velocity have been used to represent the force or shock effect of an impact, but there has not been a wide acceptance of these so far.

6.7.2 Wherever possible an attempt has been made to estimate the Kinetic Energy (KE) value of the impact in each accident. This requires the bird mass and the true air speed at the time of collision. True airspeed has been estimated either from the reported height and indicated airspeed, or using the phase of flight and the performance of the aircraft type where speed had not been reported. It is accepted that this is a very approximate estimation in some cases, but it was considered important to make the best use of the limited accident data available.

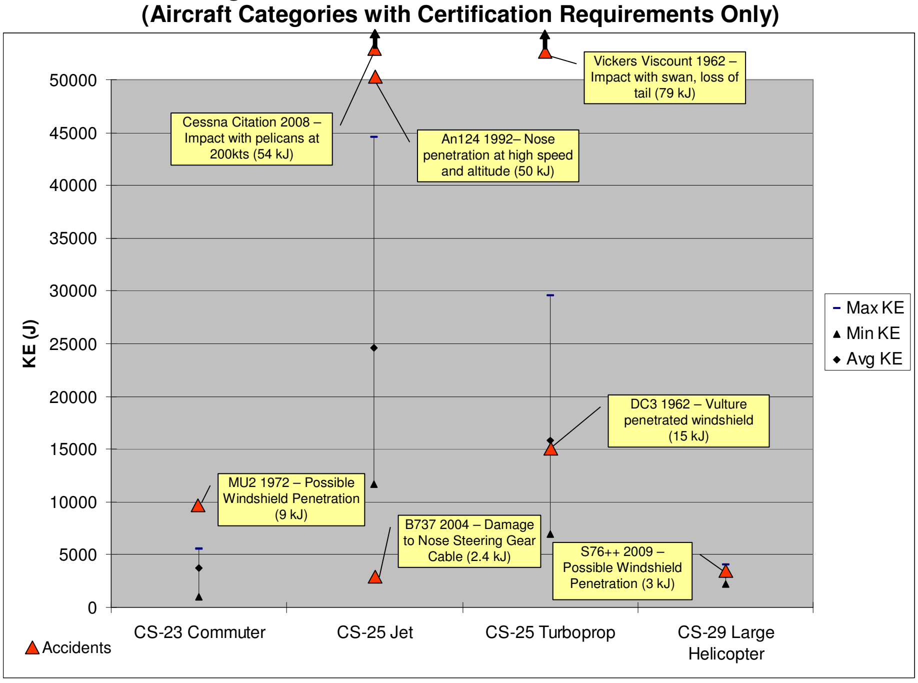
6.7.3 Figure 6-4 shows the distribution of estimated KE values for the 33 accidents for which bird mass could be established, with individual CS category identified. 90% of accidents involve impact energies above 1500 J. The lower and mid areas of the distribution are dominated by CS-23 and CS-27 accidents, whereas the few accidents above 50 kJ are all CS-25 aircraft.

Figure 6-4 Accident KE Distribution



6.7.4 Figure 6-5 below compares the certification KE ranges identified in Section 2 to the estimated KE of accidents affecting aircraft in these categories.

Figure 6-5 Accident KE vs Certification KE
(Aircraft Categories with Certification Requirements Only)



6.7.5 There are only seven accidents involving transport or commuter category aircraft for which KE can be estimated.

- In four cases the accident KE is well above the range of certification values for that category of aircraft.
- The only one below the category certification range is the 2004 Boeing 737 nose steering gear jamming accident.
- The S76++ accident is still under investigation at the time of writing but the estimated KE is just above the certification value for this aircraft type.

6.8 Conclusions

6.8.1 From the review of accident data, it is concluded:

- Non-engine bird strike is a relatively minor cause of hull loss/fatal accidents, particularly for transport category aircraft. Only seven such accidents have been identified. Two of these occurred since March 2008.
- There is evidence of an upward trend in accidents, and in particular in the last two years. However, the numbers are still very low and hence not of sufficient statistical significance to enable a firm conclusion to be drawn.
- Aircraft without certification requirements appear to suffer more accidents, particularly at low and mid impact KE values
- Aircraft with certification requirements appear to suffer few accidents, and the majority of these are associated with very high KE values.
- Windshield penetrations were a feature of 50% of all accidents.
- All those accidents which have occurred have involved heavier birds (above 0.78 kg). Several have involved very high values of Kinetic Energy well above current certification values, and 90% of accidents involved impact KE above 1500 J.

Section 7
Comparison of Bird Strike and Accident Data

7.1 Introduction

7.1.1 In an attempt to understand better the relationship between the very infrequent accident events and the reasonably frequent bird strike events, accidents and bird strike data have been combined together for the following parameters:

1. For Category 1,2 and 7 aircraft without certification requirements (CS-23 excluding Commuter and CS-27): The Kinetic Energy of the strike.

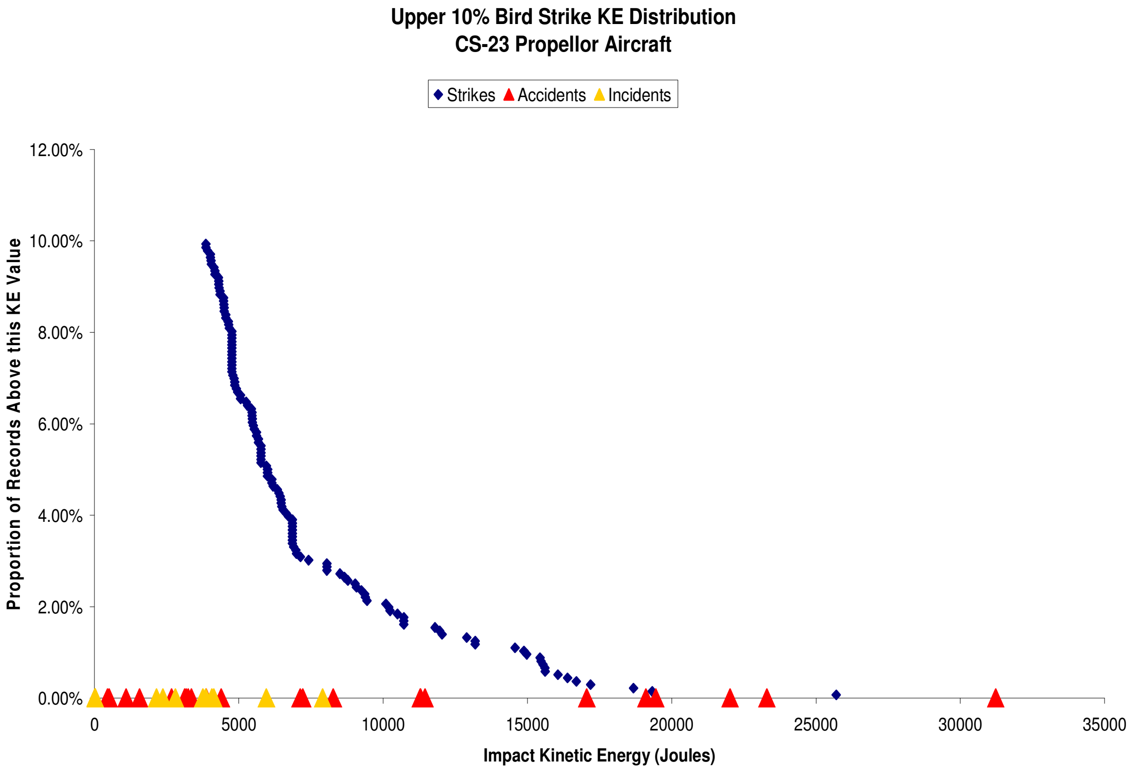
2. For Category 3, 5, 6 and 8 aircraft with certification requirements (CS-23 Commuter, CS-25 and CS-29): The Ratio between impact KE and certification KE (where relevant)

7.1.2 In each case the Bird Strike data is shown as the proportion of records greater than each value of the parameter (KE or ratio). This shows the upper tail of the distribution, against which the accident values are shown as separate data points. The purpose of this is to see how the accident events are positioned relative to the upper tail of the distribution.

7.1.3 In view of the limited number of accidents for transport category, serious incidents have also been included in the plot. These are incidents identified from UK Mandatory Occurrence Reports [26.] and US Significant Bird Strikes [27.] reports where there has been damage that could have resulted in an accident – i.e. the structure or windshield has failed under bird strike, but safe continued flight and landing was still possible. A complete list of these events and the source of the data is provided in Appendix G.

7.1.4 The data is presented in a series of graphs, for each of the categories of aircraft identified in Table 4-2. However, data in Categories 2 (CS-23 Jets below 5670 kg) and 4 (Jet Commuter Aircraft) was insufficient to produce a plot and hence these were combined with Categories 1 and 3 respectively.

7.2 CS-23 Normal/Utility/Aerobatic Aircraft (Categories 1 and 2)



7.2.1 This graph shows the upper tail of the KE distribution. As there is a wide range of aircraft performance within this category, the impact KE values are widely distributed, such that 2% of strikes are over 10 kJ (equivalent to a 8 lb/3.6 kg bird at 97 kts).

7.2.2 Accidents and serious incidents occur across this full range of KE values, including some at relatively low values of KE unlike other categories of aircraft. It is possible that this is a consequence of the absence of any bird strike certification requirements for CS-23 normal/utility/aerobatic aircraft.

7.2.3 The above graph shows a relatively high number of incidents and accident at relatively low values of KE. However, if we were to apply an imaginary retrospective requirement based on 2lb bird at V_{mo}, then a total of 6 accidents (26%) would be removed from the accident record. The resulting graph is shown below. Note however that some of the records removed are for aircraft such as the Boeing Stearman (biplane) which pre-date the existing regulations.

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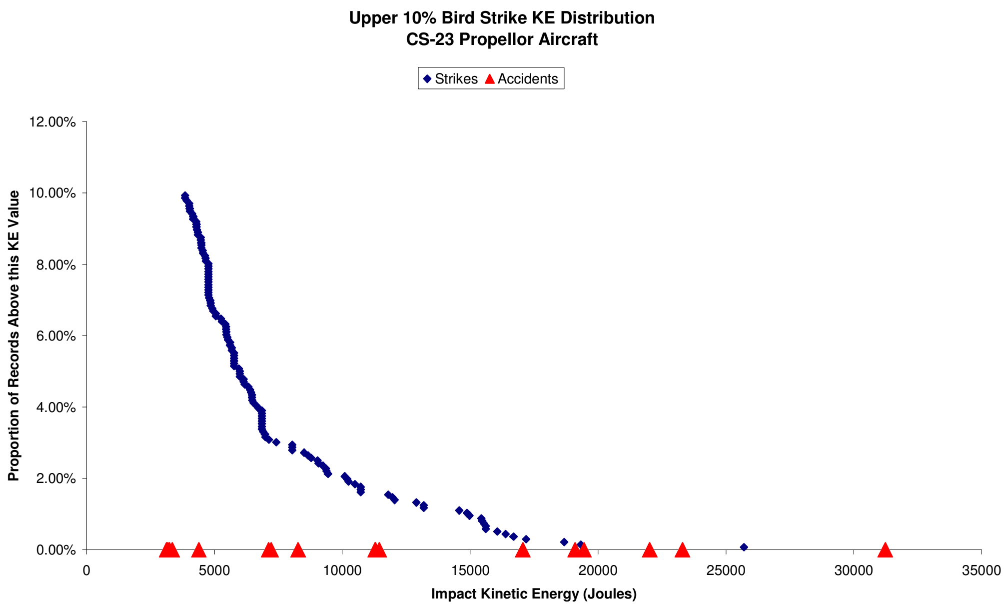
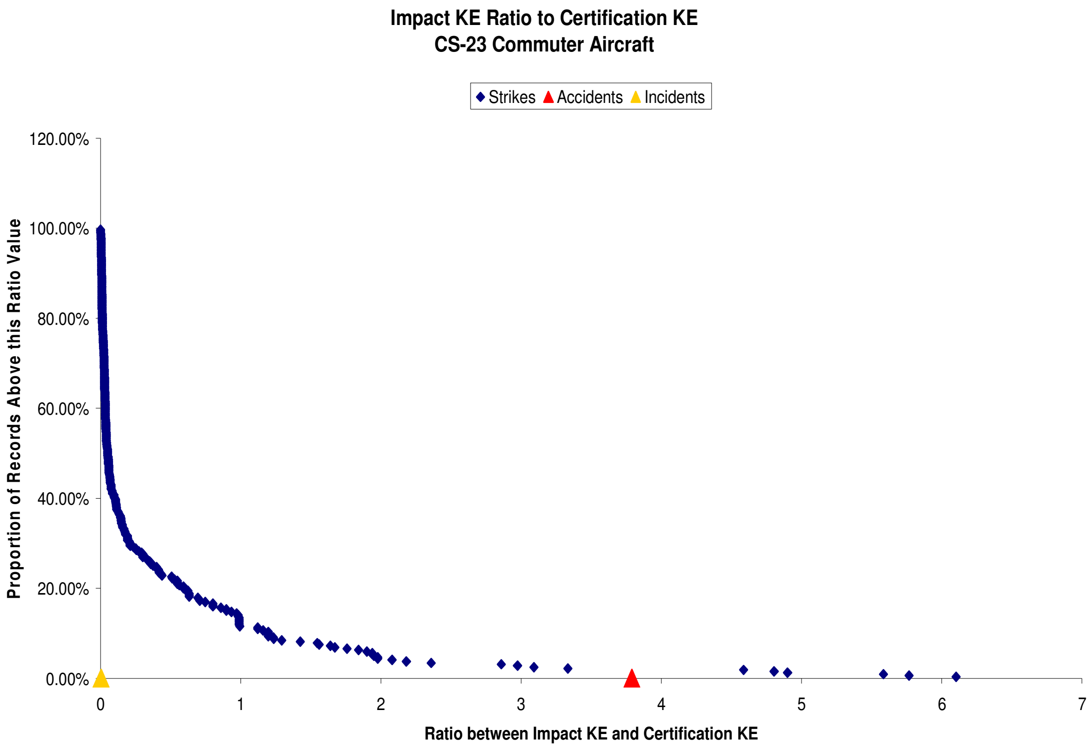

Upper 10% Bird Strike KE Distribution
CS-23 Propellor Aircraft
Strikes
Accidents
Proportion of Records Above this KE Value
12.00%
10.00%
8.00%
6.00%
4.00%
2.00%
0.00%
0
5000
10000
15000
20000
25000
30000
35000
Impact Kinetic Energy (Joules)

7.3 CS-23 Commuter Aircraft (Categories 3 and 4)



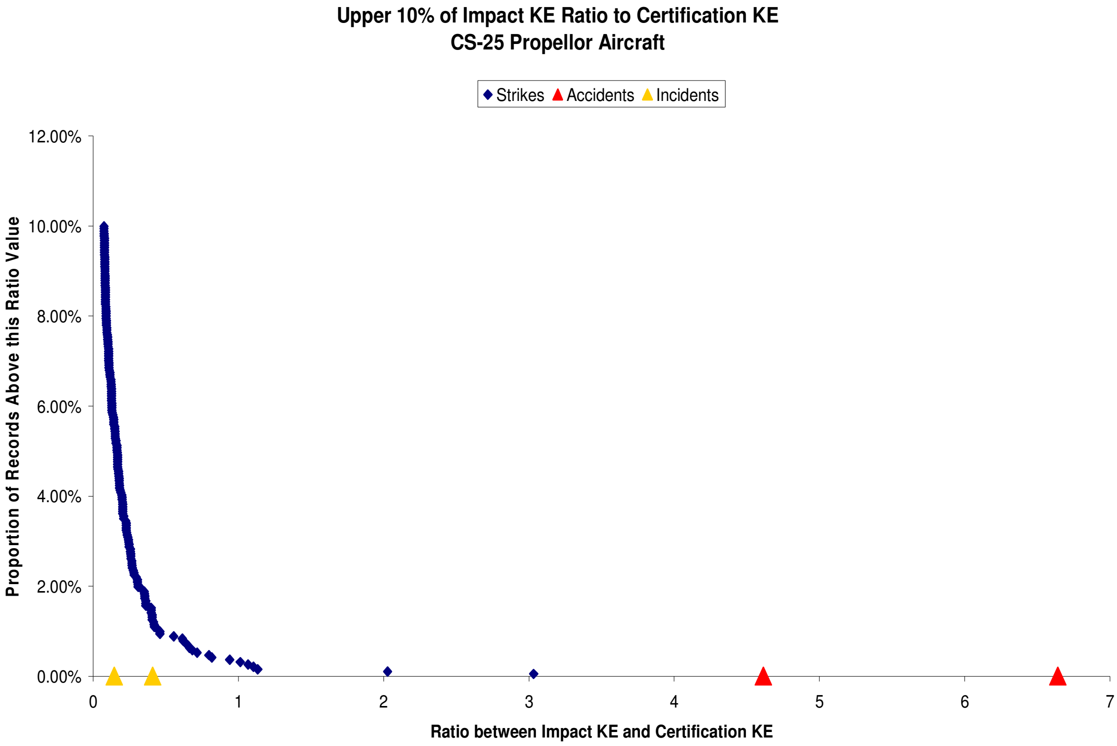
Note: Unlike other graphs in this section, this shows the whole distribution (due to the relatively small data set)

7.3.1 This graph shows the values of KE for each bird strike, accident and incident expressed as its ratio to the certification value for the particular aircraft type involved (in this case, a 0.91 kg mass at V_C for that aircraft). The certification value is applicable to the windshield only.

7.3.2 As this is a small group of aircraft there is relatively little data and only a single accident. However, 11% of the recorded bird strikes are actually above the certification value, with some recorded as much as six times the requirement. This may be a consequence of the low bird mass in this particular CS requirement. Given that there are such a high proportion of strikes above the requirement (although the absolute number recorded so far is quite small due to the relatively small size of the fleet) this suggests that the requirement should be increased.

7.3.3 The single accident recorded is close to four times the certification value. This is a Mitsubishi 2 accident from 1972 where there is evidence that geese hit the windshield, possibly incapacitating one or both pilots.

7.4 CS-25 Transport Aircraft (Propeller) (Category 5)



7.4.1 In this case only 0.31% of the reported strikes have a KE above the certification equivalent value. This is significant in that there are fewer "non-accident" bird strikes that are above the certification KE compared to the graph for CS-23 Commuter category aircraft shown above. The higher mass required in the CS-25 specification may be a factor, but the significance is that only a very small proportion of bird strikes are above the certification value.

7.4.2 The two accidents represented here are the Vickers Viscount and DC3 accidents of 1962 and described in Table 6-2. The certification values for these aircraft have been estimated based on the current rules (1.81 kg at V_C). The ratio values for these accidents are such that the accidents would probably still had occurred had present rules being applied to these Aircraft at the time.

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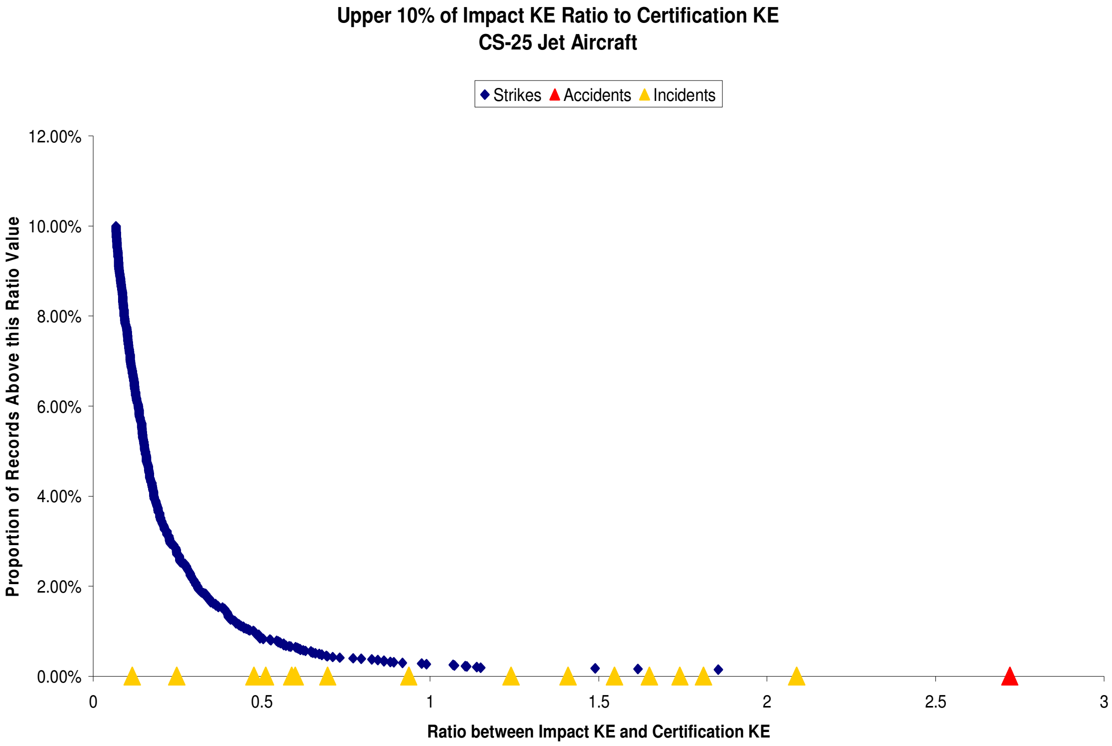
7.5 CS-25 Transport Aircraft (Jet) (Category 6)



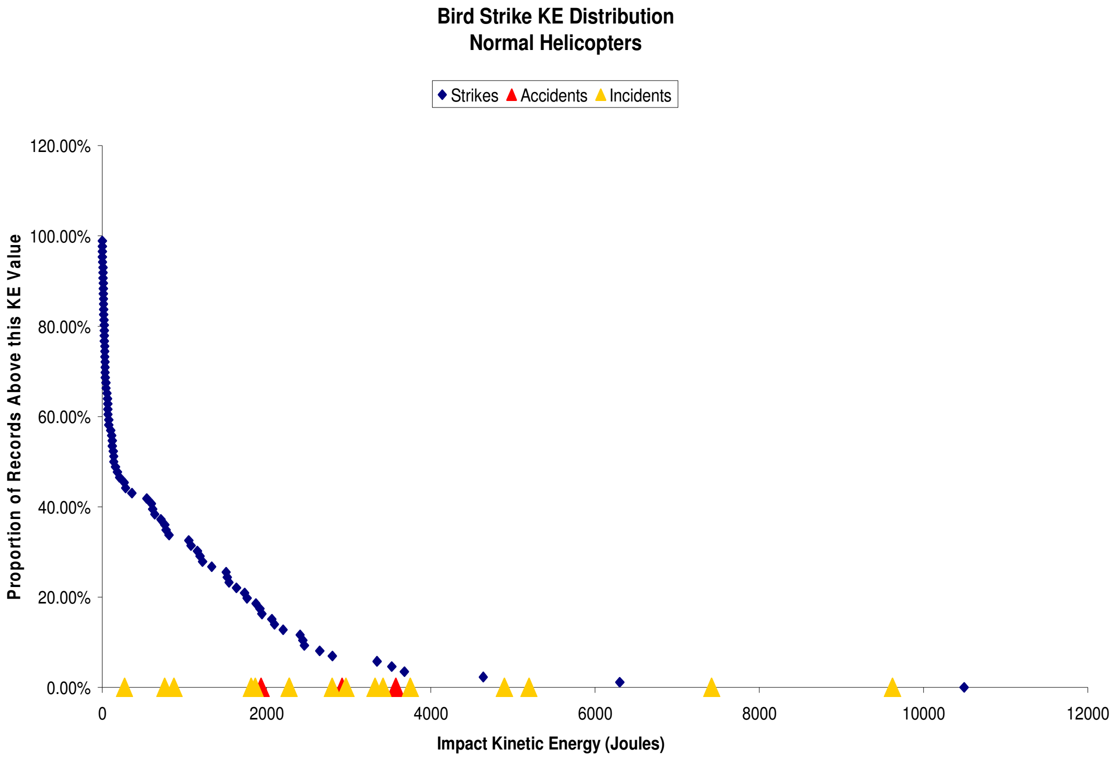
7.5.1 As in the previous case, only 0.27% of the reported strikes have a KE above the certification equivalent value and not all such strikes resulted in an incident or an accident..

7.5.2 The single accident represented here is the Cessna 500 accident of 2008, where the aircraft hit very heavy birds (Pelicans, approximately 5 times heavier than the certification standard of 1.81 kg) at a speed below the certification value (200 kts vs 287 kts). A second accident (Boeing 737 at Schipol, 2004) is not shown in this case as the accident mechanism (jamming of the nose steering) is not related to the KE of the impact.

7.5.3 In this case there are a number of incidents with KE ratio values between 0.1 and 2.1. Although there is no strong pattern evident, the very sharp reduction in the bird strike distribution over this range suggests a strong relationship between the KE ratio and the likelihood of a serious incident.

7.5.4 Across all 3 categories of fixed wing aircraft with certification requirements, the 4 accidents reported have ratio values of 2.7, 3.8, 4.6 and 6.6.

7.6 CS-27 Small/Normal Helicopters (Category 7)



Note: Unlike other graphs in this section, this shows the whole distribution (due to the relatively small data set)

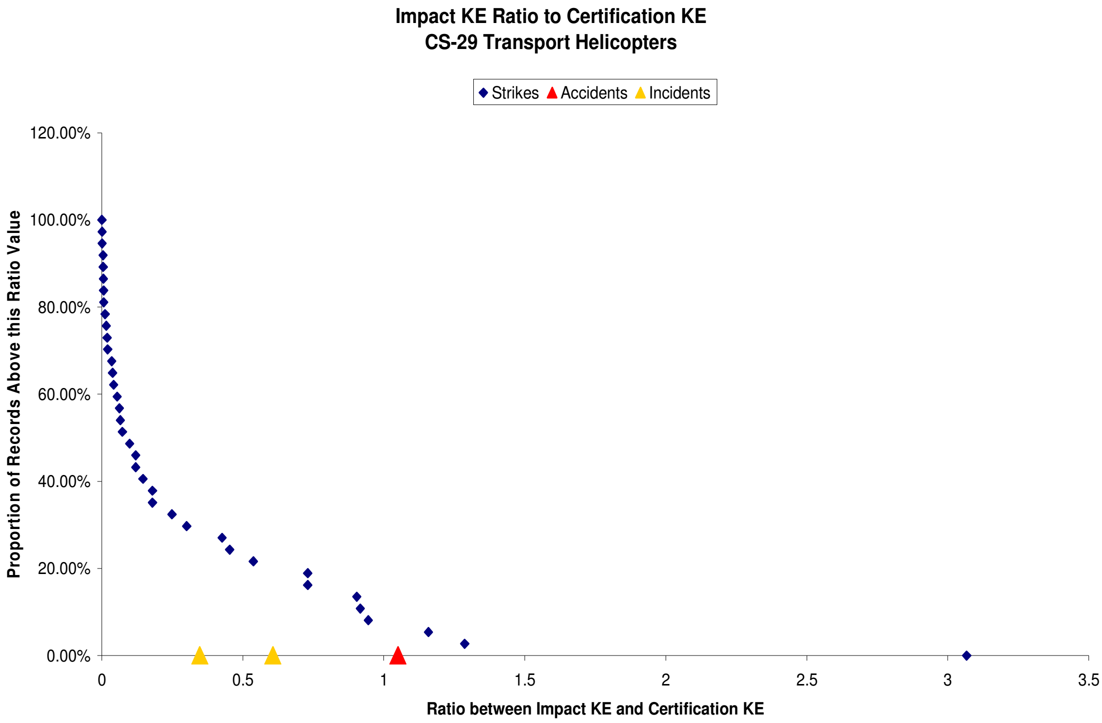
7.6.1 There is no certification requirement for this category and therefore this is a distribution of absolute KE rather than a ratio. The distribution shows relatively low values of KE, well below the equivalent values for the CS-23 fixed wing normal aircraft – reflecting the lower speed range of helicopters.

7.6.2 Three accidents are shown, at KE values between 2 and 4 kJ – quite low values compared even to the majority of CS-23 accidents. All 3 are windshield penetrations, involving birds between 1.2 kg and 2 kg. Further details are shown in Appendix F.

7.6.3 If we were to apply an imaginary retrospective requirement based on 1 kg bird at V_h, then the two lowest energy accidents (66%) would be removed from the accident record.

7.6.4 Again there are a number of serious incidents, all involving windshield penetration. The four incidents between 4 and 10 kJ all involved birds between 2.5 and 4.2 kg (golden eagle, canada goose, vulture, snow goose).

7.7 CS-29 Large/Transport) Helicopters (Category 8)



Note: Unlike other graphs in this section, this shows the whole distribution (due to the relatively small data set)

7.7.1 In this case the data is presented as a ratio against the CS-29 requirement of 1kg at V_H / V_{NE}.

7.7.2 Once again the data is sparse. The distribution indicates that between 5 and 8% of bird strikes are above the certification value, a comparatively high value but of limited statistical significance given the small number of events.

7.7.3 The single accident shown is the S76++ accident which is still under investigation. It may be a windshield penetration by a hawk (estimated mass 1.1 kg). Note that, in the absence of specific data from the ongoing accident investigation, the aircraft speed shown in the graph above has been taken as from the performance tables given at Appendix B.

7.7.4 The two incidents recorded also involve windshield penetration, at low KE ratios. One of the birds involved was heavy (gannet, 2.9 kg) but the other was within the certification requirement in both bird mass and speed. Niether of the aircraft involved (MBB-BK 117 and Bell 212) were originally certificated against CS-29/FAR Part 29. as the type certification dates precede the introduction of the relevant regulation.

7.8 Conclusions

7.8.1 From the comparison of bird strike and accident data, it is concluded:

- There is a marked increase in the vulnerability to low KE impacts of aircraft without bird strike certification requirements (CS-23 Normal/Utility/Aerobatic and CS-27 Normal Helicopter category aircraft).
- CS23 aircraft have no bird strike certification requirements. The pre-existence of a 2lb / V_{mo} requirement for such aircraft may have avoided 26% of the CS-23 accidents reported.
- CS-27 aircraft also have no bird strike certification requirements. The pre-existence of a 1kg requirement for such aircraft may have avoided 66% of the reported accidents.
- The certification requirements for CS-23 Commuter Aircraft and CS-29 Large rotorcraft result in an undesirably large proportion of bird strikes (5 to 11%) above the certification value. The equivalent value for CS-25 aircraft is around 0.3%.
- Although data is very limited, it is noted that for fixed wing aircraft with certification requirements, the few accidents that have occurred are in the range 2.7 to 6.6 times the certification value. Increasing the certification bird weight would not preclude these bird strikes from exceeding the "certification KE" but may be of benefit in reducing the margin thus increasing the probability of survival for such incidents.
- The proportion of strikes above the certification value of KE is very similar for the CS-25 Jet and Propeller aircraft (0.27% and 0.31%). Both exhibit very low rate of accidents, so effectively there is no measurable difference in the level of safety provided by CS-25 bird strike requirements between these two categories of aircraft. This confirms that the regulations adequately address the difference in V_C between the two types of aircraft.
- Some aircraft have a relatively low quoted V_C below 8000 ft with a rapid increase in V_C above this altitude. This results in a lower value of certification KE, increasing the ratio of impact KE to certification KE for any given impact – especially at the higher speeds above 8000 ft. The effect of KE ratio as a determinant of the likelihood of damage and accidents means that such aircraft will be at increased risk.
- FAR 91.117(a) restricts operational indicated airspeed to 250 kts below 10.000 ft above mean sea level. This is not applicable in all countries, and not universally enforced where it is applied. For an aircraft such as the Boeing 737 whose V_C is 340 kts, an encounter with a 3.4 kg bird at 250 kts would still be within the certification KE value. Even a strike by a Canada Goose would be only marginally above the certification KE value, and well below the range of KE ratios at which accidents have been observed to occur.

Section 8
System Vulnerability

8.1 General

8.1.1 In modern aircraft, there is increasing reliance on aircraft electronic systems (avionics) to inform crew situational awareness and to implement and monitor aircraft control commands. This trend, which has already been implemented in all modern transport (CS-25/CS-29) aircraft, can now increasingly be seen in commuter and normal (CS-23/CS-27) category aircraft.

8.1.2 Given this trend for increasingly integrated and complex avionics, there is some concern over their vulnerability, both to direct damage from bird penetration of sensitive areas and from the effects of shock generated as a result of bird strike.

8.1.3 Although flight critical instruments are duplicated for each pilot, the concentration of such systems' Human-Machine Interfaces (HMIs) and associated signal paths, etc, in the cockpit area may make them vulnerable to a "zonal" type of common-cause failure.

8.2 Identification of Relevant Records

8.2.1 The possible occurrence of such events was investigated by reviewing the following data sources:

- All 94,743 bird strike records collated during this study.
- The UK CAA's Mandatory Occurrence Reports (MORs) for bird strike occurrences involving damage to aircraft.
- Existing bird strike reports (see references) for references to damage to aircraft systems other than engine.

8.3 Relevant Records from Bird Strike Data

8.3.1 The 94,743 records from Phase II contained a significant number of records (2,774 UK records plus 800 US records) identifying a non-blank "narrative" field (UK data) or "other damage" (US data) relating to aircraft systems damage caused by bird strike.

8.3.2 As shown in Table 8-1, only 32 "system" related bird-strike incidents were identified from the UK data set. The majority of these records related to externally mounted system elements (antennae, de-icing components, etc). All others relate to damage to landing gear, lights, etc. None relate to damage to, or effect on, internal systems or avionics.

Table 8-1 Possible System Effects noted in UK Bird Strike Reports

POSSIBLE SYSTEM EFFECTS		Aerial	Ice Sensor	OAT Probe	Pitot	Hyd	Slats/ Flaps	De-icing	Other
2 VHF AERIALS HIT		1							
AERIAL SPRAYING DEMO - COMPLETED RUN AND LANDED NORMALLY. ALSO STRUCK AERIAL.		1							
ALSO STRUCK ICE DETECTOR. APPROX. 15 GULLS. AIRCRAFT RETURNED, MINOR DAMAGE.			1						
BIRD STRUCK PROPELLOR, REMAINS DEFLECTED ON TO PITOT HEAD WHICH WAS BENT.					1				
BUZZARD. BROKE HYDRAULIC HOSE IN LEFT MAIN LEG.						1			
CANADA GOOSE. TWO FLOCKS SEEN, ONE BIRD FROM FIRST FLOCK STRUCK. NO.3 SLAT DAMAGED.							1		
CRACKING & DELAM OF COMPOSITE UNDERSURFACE OF FLAP, FLAP SECTION CHANGED.							1		
DAMAGE APPROX 6-8 DIA. ON SB SIDE OF COWLING. WING LEAD EDGE SLIGHT DENT. LIGHT BULB BLOWN									1
DAMAGE AT FUEL TANK/WING SEAM.									1
DENT ON LEADING EDGE PORT WINGTIP, FUSELAGE AIR VENT GRILL DAMAGED, S/BOARD ENG INTAKE BLOCKED. ENG 1 & 2.									1
DENTS - L/H TANKS PANEL & LEADING EDGE, R/H WING FILLET & VOR AERIAL COVER.		1							
FLEX TO TAXI LIGHT RIPPED AND GLASS SMASHED. 11 OYSTER CATCHERS + 1 DUNLIN.									1
FLOCK STRUCK 5 KTS BEFORE ROTATE SPEED. RH INBOARD WING LEADING EDGE FRACTURED, OAT GAUGE (WINDSHD MOUNTED) DISPLACED. ATC STATE BIRD NOT VISIBLE.				1					
LESSER BLACK-BACKED GULL. IMPALED ON PITOT TUBE, WHICH WAS BENT BACK INTO THE WING.					1				
MINOR DAMAGE TO NOSEWHEEL SENDOR SYSTEM.									1
MINOR DAMAGE TO OAT PROBE SHIELD AND NOSE TAXI LIGHT.				1					
MINOR DAMAGE TO PORT WING DE-ICE BOOT.									1
OAT PROBE AND PROTECTIVE SHIELD HIT AND DAMAGED.				1					
OAT PROBE DAMAGED.				1					
OAT SHEARED OFF.				1					
PITOT BLOCKED, MAY NEED REPLACING.					1				
PITOT BLOCKED.					1				
PROP DEICE BOOT SLIGHTLY DAMAGED.								1	
prop de-ice mat shorted out - due damage. Body recovered afs.								1	
QUARTER INCH HOLE IN WING DE-ICING BOOT								1	
ROOK. TKS DISTRIBUTION STRIP DENTED.								1	
SLIGHT PUNCTURES OF DE-ICE BOOT. 28 DEAD LAPWINGS ON RW.								1	
STALL WARNING VANE AEROFOIL SECTION BROKEN OFF. STALL WARNING (STICK SHAKER OPERATED DURING CLIMB WHEN SPEED WAS BELOW 150 KTS.									1
STRUCK OAT PROBE, RIPPING HOLE 2 3/4 INCHES X 1 1/2 INCHES IN ROOF PERSPEX PANEL.				1					
STRUCK TAT PROBE - CAUSING ERRONEOUS SAT INDICATIONS.				1					
SWIFT (REPORTED AS SWALLOW, BUT PROBABLY TOO HIGH). KNOCKED OFF OAT GAUGE AND CRACKED WINDSHIELD.				1					
WHIMBREL? CURLEW MORE LIKELY, BUT REPORTER CERTAIN. BIRD DAMAGED OAT GAUGE, BENDING IT BACKWARD. THIS PRISED THE WINDSCREEN OUTWARD, CAUSING IT TO BREAK.				1					
Totals	**32**	3	1	9	4	1	2	5	7
Based on review of 2774 CAA Bird Strike reports text									
No damage to/effects on internal systems									
Mainly externally mounted system elemnts (probes, aerials, de-icing systems)		22							
Hyd/Slat/Flaps		3							
Others -		7							

8.3.3 Similarly, the US data contains approximately 180 records of bird strike damage to external system elements such as antennae, pitot sensors, angle of attack vanes, etc. In addition, it also contains five records of damage to internal aircraft/avionics system elements. These five records are presented at Table 8-2. From the limited description available, it was not possible to determine whether these incidents were as a result of aircraft hull penetration or impact shock effect.

Table 8-2 Possible System Effects noted in US Bird Strike Reports

Date	Aircraft	Category	Altitude (ft)	KIAS	Bird	Damage
02/05/2002	737-800	6	N/K	N/K	N/K	Flight Contol System
08/01/2003	DHC8	5	1000	200	Lesser Scaup	DC Power System & Instrumentation
16/05/2003	Sabreliner 60	6	700	200	Vultures	Weather Radar & Avionics
19/03/2005	Cessna 310	1	6000	165	N/K	Magnetic Compass
04/12/2007	767-200	6	3000	210	Snow Goose	Weather Radar

8.3.4 Two of the five accidents listed (items 2 and 5) do appear in previously published literature concerning significant strikes (Significant Bird and other Wildlife Strikes, Bird Strike Committee-USA, [25.] and Some Significant Wildlife Strikes To Civil Aircraft In The United States [27.]). Searches of previously published reports on significant bird strikes have failed to yield any further information on the other three incidents. The status of these remaining three incidents therefore remains indeterminate, although it is noted that they are not identified as significant in the way that the Airbus 320 incident (see below) was.

8.4 UK CAA Mandatory Occurrence Reports

8.4.1 Data was requested from the UK CAA covering all MORs involving bird strike for the period 1980 to 2007 (ref 26). A total of 31 aircraft systems related records were identified (see Table 8-3). Again, the majority of these relate to damage to external system elements, including a significant number (10 out of 31) relating to system elements that are exposed on take-off, initial climb, approach and landing (landing gear sensors, cables and hydraulic components).

8.4.2 Only one MOR is identified as relating to a shock induced effect (see occurrence no. 198903530 at the foot of Table 8-3). In this incident the shock wave from the bird strike is identified as causing loss of EFIS displays and an engine due to induced spurious relay operation.

8.4.3 The details of this incident are as follows:
10 August 1989 *Aircraft: A320*
Airport: Near Delhi, India
Phase of Flight: En-route (2,500' AGL)
Effect on Flight: N/K
Damage: EFIS displays and engine controls
Wildlife Species: Bengal Vulture
Source: UK MOR data
Information on 4 of the 6 EFIS screens was lost. Bird was identified as a 5.5kg Bengal vulture. Collision occurred at 2500ft and 250 kts. Investigation showed that the engine shutdown push-button switches could be moved to a stable (but unlocked) intermediate position during maintenance for example where relatively

slight knocks could result in closure of the low pressure fuel valves. Airbus Industrie investigation report brings about 3 action items: (1) operators to be provided with procedure to ensure correct 'locked-in' positionn of engine/apu buttons. (2) modification to prevent engine/apu push buttons being set in intermediate position. (3) development of modified push button switches to withstand shock loads >75g. Source: 8.5.1 e) below.

8.5 Relevant Records from Previous Bird Strike Reports

8.5.1 In an effort to supplement the above sources of data, the following previous bird strike reports were reviewed.

a) Assessment of Wildlife Strike Risk to Airframes, ARCE, University of Illinois, December 2002.

b) An Assessment Of The World-wide Risk To Aircraft From Large flocking Birds, Bird Strike Committee-USA/Canada, 1999

c) WILDLIFE STRIKES TO CIVIL AIRCRAFT IN THE UNITED STATES 1990–2007, FEDERAL AVIATION ADMINISTRATION, NATIONAL WILDLIFE STRIKE DATABASE, SERIAL REPORT NUMBER 14

d) Crash of Cessna 500, N113SH, Following an In-Flight Collision with Large Birds, NATIONAL TRANSPORTATION SAFETY BOARD, July 2009

e) HIGH SPEED FLIGHT AT LOW ALTITUDE: HAZARD TO COMMERCIAL AVIATION?, Bird Strike Committee-USA/Canada, Paul F. Eschenfelder, August 2005

f) Understanding and Reducing Bird Hazards to Aircraft, Significant Bird Strikes, Bird Strike Committee-USA, 2002

g) Significant Bird and other Wildlife Strikes, Bird Strike Committee-USA, 2008

Table 8-3 Possible System Effects noted in UK MORs

Occurrence Number	Date Of Occurrence	Aircraft Type	Location Of Occurrence	Phase Of Flight	Pretitle
199904348	04.07.1999	B737	MADRID	Initial Climb	Bird Strike With Damage : "A" hyd system failed following birdstrike after take-off. "Pan" declared, a/c returned. RH MLG uplock actuator hose damaged.
200001428	05.03.2000	A321	Faro	Initial Climb	Bird strike on RH side of aircraft during initial climb (500ft) at Faro. P2 airspeed indication lost, engine vibration. ATC advised, aircraft returned.
200008207	05.11.2000	B737	Amsterdam	Approach	Multiple birdstrike on either side of a/c nose (and P2 pitot tube) at approx 800ft during approach caused erroneous indications on P2 ASI and EADI.
198601075	07.04.1986	B747		Descent	Occurrence : RADOME SCANNER AND FRONT PRESSURE BULKHEAD DAMAGED BY CUCKOO
200710202	07.10.2007	A319	Milan Malpensa	Descent	Birdstrike during descent at 7400ft. Nose cone punctured. Bird penetrated radome and radar.
200203128	09.05.2002	Piper PA34	Oxford	Take Off	Birdstrike during take off. Take off rejected. OAT gauge dislodged and windscreen broken.
199801056	10.03.1998	BAE146	AMSTERDAM	Take Off	Bird Strike With Damage : Lapwing struck nose of a/c during take-off, causing damage to LH ice detection probe.
200008406	13.11.2000	Piper PA28	South Downs	Cruise	UK Reportable Accident : Bird strike with damage - LH wing struck bird. Pitot tube ripped off and wing dented.
200201172	14.02.2002	Hawk	Valley	Circuit	PAN declared due birdstrike. Extensive damage to aircraft nose/nosewheel bay area. Nosewheel failed to extend. Nosewheel up landing with emergency services in attendance.
199204235	14.10.1992	Jetstream 31	WOODFORD	Initial Climb	Other Occurrence : A/C RAN INTO FLOCK OF LAPWINGS AT 30FT AFTER T/O FROM R/W25. A/C RETURNED. OAT PROBE DAMAGED.
199802592	15.05.1998	Fokker 100	AMSTERDAM	Landing	Bird Strike With Damage : One of a number of pigeons impacted radome when a/c at approx 40ft(R). Radome cracked, nr2 ILS aerial damaged.
198002117	15.06.1980	B707	RIMINI	Approach	Occurrence : BIRDSTRIKE DAMAGED WING AND ANTI ICING PIPE
200304719	15.07.2003	Cessna 152	Shoreham	Take Off	Birdstrike : During the take off run the aircraft struck a seagull, which became impaled upon the pitot head, bending it down through approx 30deg and pushing it up into the wing.
198403852	15.11.1984	B737	BRINDISI	Initial Climb	Occurrence : BIRDSTRIKES ON T/O DIFFICULTY IN LOWERING GEAR BEFORE LANDING
198504409	16.12.1985	B737	MALTA	Approach	Occurrence : AIR/GROUND SENSOR CABLE DAMAGED BY BIRDSTRIKE
200000982	17.02.2000	A321	Belfast (BEL)	Landing	Multiple bird strike to windshield & wing during landing roll. Probe damaged.
200106789	20.09.2001	A300	Kefallinia	Initial Climb	Collided with bird at 800ft after take off. Captain's ASI subsequently unreliable. Pitot tube blocked/damaged.
200000342	22.01.2000	B757	London-Gatwick	Descent	"Pan" declared due suspected NLG extension problem. Go-around & flypast inspection. Birdstrike initially suspected. Retraction/downlock actuators damaged.
200711528	22.11.2007	A319	Amsterdam	Approach	Birdstrike: Canada goose struck LH MLG between wheels during final approach. Aircraft landed normally. Brake hose damaged resulting in small hydraulic fluid leak. Aircraft AOG.
200204447	26.06.2002	Beagle 121 Pup	Shipdham	Circuit	Birdstrike: Large bird crashed through the windscreen and into the cockpit. No injuries. Handheld GPS unit damaged.
199001755	28.04.1990	BAC 111	GERONA	Take Off	Occurrence : BIRD STRIKE ON T/O LG RETRACTION PROBLEM A/C DIVERTED
198601085	29.03.1986	Piper PA23	FAIROAKS	Initial Climb	Occurrence : FLOCK OF PIGEONS DAMAGED WING LEADING EDGE AND BRAKE HOSE ON RH GEAR
198601387	29.04.1986	Concorde	Washington Dulles	Approach	Occurrence : INCIDENCE VANE FOUND ON ARRIVAL DAMAGED BY BIRDSTRIKE
199602017	29.05.1996	BAE146	EDINBURGH (EDI)	Parked	Bird Strike With Damage : Pre-flight check revealed hydraulic fluid leak from damaged hydraulic line on bottom of LH undercarriage.
198502598	29.07.1985	HS125	WARTON	Take Off	Occurrence : BIRDSTRIKE BROKE HF AERIAL AND DENTED FUSELAGE SKIN TAKE OFF ABORTED
198400250	30.01.1984	Concorde		Initial Climb	Bird Strike With Damage : TO LG BAY CAUSING LOSS OF GREEN HYD SYS. A/C RETURNED. AFTER LANDING YELLOW HYD CONTENT INDCN FELL TO LOW.
200606935	30.07.2006	B737	Bologna	Initial Climb	Just after rotation, a bird struck LH side of nose hitting pitot probe and AOA vane. Captain's main ASI under reading by approx 50kts and stick shaker activated. PAN declared and a/c returned.
200008868	30.11.2000	B767	Manchester (MCT)	Approach	Bird strike at 250ft. Suspected pitot head damage.
199801552	31.03.1998	A320	BIRMINGHAM	Landing	Bird Strike With Damage : During flare, numerous strikes experienced to P2 pitot, RH engine & RH flaps. P2 ASI & nr1 flight augmentation computer (FAC) failed.
200206251	01.09.2002	Saab F340	HARDY	Cruise	Front RH windscreen cracked. Immediate descent requested but as two way communications became intermittent a relay aircraft was used and PAN declared. Aircraft diverted with a suspected birdstrike.
198903530	10.08.1989	A320	DELHI	Descent	Other Occurrence : ENGINE LOSS DUE SHOCK EFFECT ON RELAY BY BIRD STRIKE AT TOP OF P1 WINDSCREEN.

N.B.: The term "accident" used in record no. 200008406 above is not an accident as defined in this report. i.e. it did not result in a fatality or in aircraft hull loss.

8.5.2 Review of the documents listed at Section 8.5.1 highlighted the following additional bird strike reports that resulted in damage to aircraft systems.

8.5.3 14 June 2004
A Boeing 737 struck a great horned owl during a night time landing roll at Greater Pittsburgh International Airport (PA). The bird severed a cable in front main gear. The steering failed, the aircraft ran off the runway and became stuck in mud. Passengers were bussed to the terminal. They replaced 2 nose wheels, 2 main wheels and brakes. Aircraft out of service was 24 hours. Cost estimated at $20,000.
Source: 8.5.1 g) above

8.5.4 Date: 29 October 2007
Aircraft: BK-117
Airport: Near Hamburg, PA
Phase of Flight: Enroute (1,400' AGL)
Effect on Flight: Emergency landing in parking lot
Damage: Windshield, and rear door window
Wildlife Species: Wood duck
Source: 8.5.1 c) above
Comments from Report: Helicopter was enroute to an accident scene when it hit a flock of ducks. Two penetrated the aircraft. One broke through the front windscreen and the second through the rear door window. The impact forced both throttles into the "idle" position which caused the aircraft to lose power. The pilot placed the aircraft into autorotation for an emergency landing and sent a "mayday" notice to the local airport. When he realized what caused the power failure he returned both throttles into the "fly" position and landed in a nearby parking lot, a mile from their intended pickup location. One injury. Crew wearing helmets with visors. Time out of service was 8 days. Cost of repairs estimated at $8,000

8.5.5 Date: 4 December 2007
Aircraft: B-767
Airport: John F. Kennedy Intl. (NY)
Phase of Flight: Approach (3,000' AGL)
Effect on Flight: Emergency landing
Damage: Windshield, radome, radar & vertical stabilizer
Wildlife Species: Snow goose
Source: 8.5.1 c) above
Comments from Report: Geese penetrated the radome, damaged the radar and then penetrated the fuselage into the aircraft. The vertical stabilizer was dented. ID by Smithsonian, Division of Birds

8.6 Discussion

8.6.1 From Sections 8.2 to 8.5 above, it is clear that bird strikes to aircraft structures often have secondary effects on aircraft systems.

8.6.2 Where there has been only external damage, components such as anti-ice/de-ice boots on wing/tail leading edges, antennae, outside air temperature probes and pitot sensors are prone to bird strike damage. Of these, only the pitot sensors are considered to be directly safety related, primarily flight data to the pilot/co-pilot primary flight displays and air data information to automatic flight control systems. To help mitigate the effects of bird strike on pitot systems, the regulations require that, for commuter and transport category aircraft, "*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*" (23.1323f and 25.1323j). Given that no hull loss or fatal accidents have been attributed to pitot sensor strikes, it is concluded that the regulations seem to be adequate at present.

8.6.3 A significant number of strikes are reported as causing damage to the landing gear and its associated sensors and hydraulics. These incidents occur when the landing gear is deployed (landing/take off role, climb out or approach) and thus are not technically fuselage penetrations.

8.6.4 Bird strikes that result in the penetration or serious deformation of an aircraft fuselage or wing may result in damage to internal systems such as fuel tanks, weather radar, flying controls and instrumentation. Review of the data above shows that, while the damage can sometimes be extensive, no aircraft hull losses or fatalities have been attributed to these types of bird strike. The reports do however include instances of significant damage to instrument systems and injury to flight crew following cockpit penetration by a bird.

8.6.5 The concentration of such instrumentation and display systems Human-Machine Interfaces (HMIs) makes modern aircraft potentially vulnerable to zonal types of common-cause failure such as cockpit penetration by a bird. Although flight critical instruments are duplicated for each pilot, such damage causing incidents can have a major effect on crew workload. The records also show that cockpit penetration is also a source of injury to aircrew

8.6.6 The above discussion has been limited to commuter and transport category aircraft. However, the recent introduction of fast very light jet (VLJ) aircraft such as the Embraer Phenom 100, Cessna Mustang and the Eclipse 500, and the potential future introduction of other such aircraft (Hondajet, , Phenom 300, etc) complicates the current picture. These aircraft are designed to be small, light (less that 5670kg) and to have only a small number of seats (less than 10). As such they fall within the CS-23 (normal) aircraft category. However, like current transport category aircraft, VLJs have high-speed performance and highly integrated instrumentation and flight control systems. They are thus likely to be as vulnerable to systems damage from bird strike. Indeed, given the relatively light airframe and the likelihood that such aircraft will be operated from smaller regional airports and private airstrips, they may be more vulnerable. Thus, it may be prudent to consider increasing the protection to bird strike offered to such aircraft.

8.6.7 In one of the incidents described above (see Section 8.4.3), serious damage was caused to the electronic flight instrument displays and to an engine control switch in the cockpit of an A320 due to indirect bird strike consequences. In this instance, the damage was caused be the shock wave from a high speed collision with a vulture at a position just above the wind shield. From the data given at Section 8.4.3, this incident involved a large bird (5.5kg) and a high aircraft speed (263 kts Air Speed). The impact energy (KE) of this strike was therefore high (50kJ) and was far in excess of the certification value for this aircraft (30kJ). Such high energy strikes are extremely rare.

8.6.8 This 1989 incident is the only confirmed such incident in any of the literature or data sets searched. In the certification requirements there is no comment on shock wave effects for any category of aircraft.

8.7 Conclusions

8.7.1 The 94,743 records from Phase II contained 3574 records (2,774 UK records plus 800 US records) identifying a non-blank "narrative" field (UK data) or "other damage" (US data). Each of these records was searched to highlight those potentially pertaining to an aircraft system effect. The available "system effect" records from Phase II record set was supplemented by identifying similar records from the UK MOR database and the previously published literature identified at Section 8.5.1.

8.7.2 From the information available, only one confirmed system effect resulting from bird strike shock has been identified. As well as being originally reported in the UK MOR data, this incident also appears in numerous places in other literature and was identified by EASA as a candidate incident at the beginning of this study. Despite an extensive search of the American and UK bird strike reports, no further incidents of the nature can be confirmed.

8.7.3 Out of the total of 248 incidents identified above where bird strike has had a noticeable effect on aircraft systems, the majority have affected air data sensors located externally. None of these incidents of sensor damage is identified as causing a serious problem of the type that might have prevented the aircraft from carrying out continued safe flight and landing. It would seem reasonable to conclude therefore that the protection afforded to such aircraft by compliance with the CS-23 (commuter) and CS-25 (transport) aircraft regulations regarding pitot sensors is sufficient.

8.7.4 A large proportion of the above identified bird strikes result in damage to landing gear and associated sensors and hydraulics. These incidents occur at relatively low speed (take off, climb out, approach and landing) when the landing gear is exposed outside the aircraft. Effects recorded have included difficulty in lowering the landing gear (or confirming that it is down and locked), hydraulic leaks, loss of steering capability and damage to gear actuators. Such damaging strikes clearly have the potential to preclude "safe flight *and landing*" but are not explicitly covered by the regulations. It is recommended that, for transport category aircraft, the relevant part of the regulations (i.e. clause 25.631) be extended to explicitly include landing gear as part of the aircraft structure.

8.7.5 Bird penetration of the cockpit (for both fixed wing aircraft and helicopters) has, on a number of occasions, resulted in damage to flight instruments and to aircraft or engine primary flight controls. The number of such incidents is small and represents only a tiny fraction of the systems-related strikes identified above (2 out of 248).

8.7.6 Only one incident of a non-penetrating bird strike causing aircraft instrumentation and engine controls has been identified. It is thus concluded that neither penetrating nor non-penetrating bird strikes currently present a challenge to the existing transport category aircraft. However the advent of CS-23 category VLJs, with their transport category-like performance and integrated avionics systems but small field capability may be more vulnerable to such incidents. VLJs represent a relatively recent aircraft innovation and as such do not appear to fit well within the current regulatory structure. It may be prudent to consider increasing the protection to bird strike offered to such aircraft by introducing special conditions relating to bird strike resistance even though their maximum weight and passenger capacity puts them firmly in the CS-23 normal/utility/aerobatic category.

Section 9
Risk Assessment

9.1 Target

9.1.1 The risk assessment must address two questions

- Is the current level of risk acceptable?
- Are there trends or changes that could make it unacceptable in the future?

9.1.2 The first step in the quantitative approach to risk assessment is to set a quantified Target Level of Safety (TLS) - the maximum frequency of occurrence (usually per flying hour or per flight) that is tolerable for the undesired event, in this case the loss of an aircraft due to bird strike. This can be used to determine whether the current risk is tolerable, or whether it will remain tolerable in future forecast changes in the level of exposure/risk.

9.1.3 Historically, the setting of a TLS for aviation has been driven by the need for airworthiness authorities to place quantified targets on the contribution made by aircraft systems to aircraft accidents. In Europe these targets have been embodied in the EASA Certification Standards for Large Aircraft CS-25, paragraph 1309, which states that each failure condition of systems that could result in a catastrophe (loss of the aircraft) should be extremely improbable, defined as less than 1×10^{-9} per flying hour.

9.1.4 This value has been used in a number of risk assessments, both in aircraft systems and in other aspects of aviation (e.g. Air Traffic Management). Before considering its application in bird strike, it is worth reviewing how the figure was derived.

- The target was originally set by the Joint Airworthiness Authorities (JAA) and recorded in the Joint Airworthiness Requirements (JAR 25.1309) that subsequently became CS-25.1309 under EASA.
- Historical Date (in practice 1960's accident data) demonstrated the accident rate attributable to "operational and airframe causes" to be of the order 1 per million flying hours – i.e. 1×10^{-6} per flying hour.
- Of this, approximately 10% could be attributed to failure conditions caused by all aircraft systems. This resulted in a design requirement for new designs that the probability of an accident resulting from any system failure condition should not exceed 1×10^{-7}.
- It was assumed arbitrarily that there were around 100 potential failure conditions that could cause an accident. Assuming an equal apportionment of the overall target, the maximum probability of occurrence for each failure condition would be 1×10^{-9} per flying hour.

9.1.5 It is notable that these targets, despite being established over 30 years ago, are still current in the latest issue of CS-25. The underlying accident rate has improved – EASA's Annual Safety review for 2007 shows a figure of 3 x 10^{-7} per flying hour for accidents resulting in a fatality (for EASA member state registered aircraft over 2,250 kg). However, approximately 25% of accidents were classified as involving system or component failure, so the total value for any system failure condition is similar at 0.75 x 10^{-7} compared to 1 x 10^{-7} above.

9.1.6 It should be noted that the categories of aircraft covered, the definition of an accident and the proportion of accidents reported may differ significantly between the recent EASA data and the historical data on which the original requirements were based. It should also be noted that the 1 x 10^{-6} target is for hull loss. Not all hull loss accidents result in fatalities (e.g. the aircraft may be damaged beyond economic repair.

9.1.7 One of the ways a bird strike can cause an accident is by disrupting aircraft systems. Therefore bird strike can be considered analogous to one of many potential system failure conditions. On this basis, the use of the CS-25.1309 TLS of 1 x 10^{-9} can be used to assess the tolerability of the risk posed by Bird Strike, at least for the large turbine-powered aircraft to which this standard applies.

9.2 Current Risk

9.2.1 The key risk indicators that have been measured over the study period are listed below. All figures relate to non-engine bird strikes and fatal or aircraft destroyed accidents only.

Table 9-1 Risk Indicators By Certification Category

<table>
<tr><th>Aircraft Category CS</th><th>Bird Mass Certification Value</th><th>Strikes per million FH (2004-2007)</th><th>Damaging Strikes per million FH (2004-2007)</th><th>% Strikes above Certification KE</th><th>Accidents per million FH (1990-2007)</th><th>Accidents (1962-2009)</th></tr>
<tr><td>Category 1 & 2
CS-23/FAR Part23</td><td>None</td><td rowspan="2">12.7</td><td rowspan="2">3.7</td><td>Not Applicable</td><td rowspan="2">0.023</td><td>34</td></tr>
<tr><td>Category 3 & 4
CS-23/FAR Part23 Commuter</td><td>0.91kg (Windshield only)</td><td>11%</td><td>1</td></tr>
<tr><td>Category 5 & 6
CS-25/FAR Part 25</td><td>1.81kg (Tail 3.6kg)</td><td>186</td><td>11.6</td><td>0.3%</td><td>0</td><td>6</td></tr>
<tr><td>Category 7
CS-27/FAR Part 27</td><td>None</td><td>6.6</td><td>3.6</td><td>Not Applicable</td><td>0.11</td><td>9</td></tr>
</table>

Category 8 CS-29/FAR Part 29	1 kg	6.0	2.8	5-8%	0	1
All Aircraft					0.018	51

Notes

1. Bird Strike Rates will be significantly underestimated due to low capture rates for non-transport category aircraft and non-damaging bird strikes, particularly in earlier years. To limit this, data from 2004 to 2007 has been used for bird strike data.
2. Accident rates will also be underestimated as some accidents will not have been reported as bird strikes due to lack of evidence.
3. It has not been possible to separate CS-23 Commuter flying hours from other categories.
4. Given the long period covered by the accident data, not all accidents will involve aircraft certificated to the latest standards.

9.2.2 Only six relevant accidents affecting **CS-25/FAR part 25** transport aircraft have been identified. None of these occurred within the geographical and time period covered by the study, representing 306 million flying hours. On this simple basis it is very difficult to demonstrate that the current risk is unacceptable. There has been one relevant accident just after the period (Cessna 500 March 2008), which if included would give a point estimate of 0.003 per million flying hours, or 3 x 10^{-9} per hour. This accident is discussed below in Section 9.4.

9.2.3 Just 0.3% of bird strikes exceed the certification value of KE (i.e. the kinetic energy of the specified bird mass at the specified velocity stated in the CS). The few accidents that have occurred (outside the study period) have involved very high levels of KE, 2.7 to 6.6 times the equivalent certification value. Of the six accidents:

- Three (Vickers Viscount, two DC3) involved obsolete aircraft with lower levels of bird strike resistance;
- One (B737 Schipol) was due to jamming of the nose steering gear rather than structural/windshield failure and;
- One (An-124) was during a test flight outside the normal flight envelope.

9.2.4 The situation for **CS-29/FAR Part 29** large or transport helicopters is similar – no reported accidents within the period covered by the study, estimated to represent 9.6 million flying hours. 5-8% of incidents exceed the certification value of KE, which is of concern as it makes it more likely that there will be encounters of sufficiently high KE ratio to cause an accident. In addition there has been one possibly relevant accident just after the period (S76++ January 2009) which, if included, would give a point estimate of 0.1 per million flying hours. This accident is discussed below.

9.2.5 The accident rates for **CS-23/FAR Part 23** and **CS-27FAR Part 27** aircraft are measurable at 0.023 and 0.11 per million flying hours respectively. Both figures are only a very small proportion of the overall accident rate (0.3% based on fatal accident rates). However it is clear that the risk to these aircraft without certification requirements is much higher than the CS-25 and CS-29 categories.

9.2.6 The majority of these accidents are caused by windscreen penetration (100% in the case of the CS-27 helicopters). Although the overall rate is not high, there may be an argument for taking action to reduce this particular risk if possible.

9.3 Trends in Bird Population

9.3.1 There is some evidence that the risk from airframe bird strike may be increasing:

- Trends in high mass bird strikes. Although the proportion of strikes involving birds over 1.81 kg is not rising, if the Canada Goose is excluded there is a slight upward trend.
- Trends in high energy bird strikes. The group of bird species that together account for 80% of the high energy impacts (including Canada Goose) have a rising trend in bird strike reports of approximately 3% per annum over the period 1990 to 2007.
- External scientific studies on this set of species generally indicate increasing population.
- There appears to be an upward trend in the accident statistics for all categories of aircraft, but the numbers of accidents per year are too low and hence not statistically significant for this to be confirmed with confidence.

If the trend of the order of 3% per year suggested is real and sustained, a approximately 34% increase in high energy incidents may be expected over the next 10 years, with a similar rise in the number of accidents, assuming no changes in regulations or existing mitigating actions.

9.4 Recent Accidents

9.4.1 As noted above there have been two significant accidents since the end of the period covering the study.

9.4.2 The fatal crash of an S76++ helicopter in January 2009 is still under investigation. On 23rd February 2009 the US National Transportation Safety Board (NTSB) issued an Advisory note stating that:

- Traces of hawk DNA had been found in the windshield.
- The original production laminated glass windscreens had been replaced with a lighter weight, cast acrylic windscreen that was approved by the Federal Aviation Administration (FAA) via a Supplemental Type Certificate (STC).

The energy of the impact (based on an assumed mass of 1.1 kg for the bird) was just 1.05 times the certification KE, an unusually low ratio. It is not clear yet whether the replacement windscreen was a factor in the accident, but the investigation continues. It is understood that the S76++ certification and the windscreen STC both predate FAR Part 29 Amendment 29-40 (08/08/96) which introduced the bird strike requirement for transport helicopters.

9.4.3 A Cessna 500 crashed in March 2008 following collision with a flock of pelicans (estimated mass 9 kg) at 200 kts. The NTSB report [22.] concluded that the crash resulted from wing structure damage. If so, this is the first bird strike causing failure of the primary structure of a western CS-25 aircraft since 1962 and is therefore a very significant event in terms of this study. The NTSB report recommendations included the following:

- Revise Part 25 certification requirements to be consistent across all airframe structures, based on an analysis of the most current bird strike data.
- Develop guidance for pilots in devising precautionary operational strategies for bird strike, including maximum airspeeds based on the aircraft's demonstrable bird strike energy (i.e. the kinetic energy equivalent of the certification requirements for aircraft).

It may be significant that the Cessna 500 is one of the lightest CS-25 aircraft, with a MTOW of 12,500 lbs/5670 kg – the dividing line between CS-23 and CS-25. Some NAA's have required in the past a thicker leading edge skin for Cessna 500 aircraft registered in Europe. It has not been included in the EASA type-certification basis."

9.4.4 After a long period with no fatal accidents affecting transport category aircraft, it is significant the two have occurred within a single year. The trends reported above indicate a modest rise in high mass/KE impacts. These two events and the general rise in accident rate suggest that the effect of this needs to be monitored carefully.

Section 10
Regulatory Options and Impact Assessment

10.1 Risk, Bird Mass and Certification Specifications

10.1.1 The risk levels from non-engine bird strikes are currently low, but may be increasing. The evidence may not yet be sufficient to justify a change in regulation on a statistical basis, but the recent growth in accident rate makes a consideration of options worthwhile.

10.2 CS-23 Normal/Utility/Aerobatic and CS-27 Small Helicopters

Option 1 –Introduce a (low mass) requirement applicable to the whole airframe or to the windshield alone.

Pros: Addresses the highest number of accidents (13% of CS-25 accidents) and serious incidents (80% and 37% respectively) due to airframe bird strikes.
Certification requirements appear very effective in reducing damage (Section 4.4).

Comment [h1]: What does this mean?

Cons: Difficult to engineer a solution without reducing payload performance substantially.
Most of these aircraft have large windscreens (especially helicopters) that would be very difficult (and costly) to produce to the required strength.
Fleet turnover is low – if new aircraft are produced to a new, more demanding requirement it would be several decades before they formed a significant proportion of the fleet.

Option 2 – Require or recommend that Pilots wear helmets with visors.

Pros: Likely to be very cost effective.
Relatively rapid to implement.
Already common practice amongst military helicopter pilots.

Cons: Pilot resistance to change.
Limited space in some aircraft.
Will protect only the pilot's head, which is the area of impact most likely to result in impairment of the pilot's ability to continue safe and controlled flight.

10.3 CS-23 Commuter Aircraft

Option 1 –Increase the bird weight and scope (i.e. not just windshields) of current requirement to CS-25 levels

Pros: Removes the existing discrepancy in individual risk from bird strike for this category of aircraft (compared to CS-25 aircraft).
Currently 11% of strikes exceed the certification energy value. The likelihood of an accident is therefore higher.

Cons: Would be an additional cost in a cost-sensitive sector.
Other aspects of the commuter aircraft are not to full CS-25 standards.

10.4 CS-25 Large Aircraft

Option 1 – For CS-25 Adopt the US 3.6 kg requirement for empennage

Pros: Gives an increased level of protection to the tail.
Many aircraft will already be designed/certified to this standard under FAR Part 25.

Cons: Little evidence that tails are less subject to damage than wings, even in the US (Section 4.5).
Introduces an inconsistency in structural requirements across the aircraft (already present in the US).

Option 2 - Increase the overall bird mass requirement from 1.8 kg to (for example) 3.6 kg

Pros: Maintains the current safe level of strikes beyond the certification value in the face of a possible upward trend in heavier birds.
May be possible without excessive increase in structural weight through the use of new materials (e.g. thermoplastic) with good impact resistance.
Boeing are already modifying in-service windshields to improve resistance to fragmentation.

Cons: Evidence does not yet justify a major change in regulation.
Will take several years to implement a significant change across the fleet population.

10.5 CS-29 Transport Helicopters

Option 1 - Increase the overall bird mass requirement from 1 kg to circa 1.8 kg

Pros: Reduce the proportion of strikes beyond the certification value from 5-8% to below 1% as per other transport category.

Cons: Evidence is currently limited May be difficult to engineer a solution on larger windshields.
Loss of commonality with equivalent military models.
Some evidence that windscreens are failing in impact energies below current requirements. Requires investigation before increasing the requirement.

10.6 All aircraft –Operational Measures

Option 1 – Better Bird Control at More Airports

Outside scope of this study.

Option 2 – Introduce/enforce 250kt "Speed Limit" below 10,000ft

Pros: Quick to implement.
Low cost.

Cons: May reduce operational flexibility.
May not be enforceable in uncontrolled airspace without changes to law.
May not reduce risk by a great deal.

Option 3 - Introduce Airspeed/Bird Mass Charts as recommended by NTSB

Pros: Quick to implement.

Low cost.

Cons: Requires knowledge of bird risk species within the area.
Increase in pilot workload.
May reduce stall margin in some instances.

Section 11
Conclusions and Recommendations

11.1 Conclusions

11.1.1 Airframe bird strikes are a relatively rare cause of accidents for those aircraft certificated against formal bird strike requirements. 51 accidents worldwide have been identified since 1962, of which only 7 (all CS-23 and CS-27 aircraft) fell within the scope of this study. Where accidents have occurred, they have usually been associated with high energy impact – heavy birds (greater than 2 lb/0.9 kg) encountered at relatively high speed, resulting in Kinetic Energies of impact that are often several times the certification values.

11.1.2 The main conclusion from this report is that the bird strike requirements in CS-25, and 29 are currently providing an adequate level of safety. However there are indications that the accident rate is increasing (although still very low), and that those species that cause the highest kinetic energy impacts are increasing in population (although the number of strikes recorded as involving the Canada Goose is reducing. This may be due to bird control measures near airports). .

11.1.3 In CS-23 (excluding commuter) and CS-27 aircraft categories there are currently no specific bird strike requirements and this is reflected in a higher rate of bird strike accidents (particularly windshield penetrations). Based on the accident record to date, a pre-existing requirement that such aircraft withstand an airframe (including windshield) collision with a 4lb/1kg bird may significantly reduced the number of serious incidents, by 80% and 37% for CS-23 and CS-27 category aircraft respectively. Additionally it may have avoided 19% of the CS-23 category accidents. It may, however, be difficult to engineer an effective solution to increasing the bird strike resistance of the, typically, large windscreens of these aircraft at acceptable cost. Additionally, due to the relatively low turn over rate, a change in the regulations may take some time to be effective. The use of helmets and visors might therefore represent a more practical and timely option.

11.1.4 Other conclusions are listed below.

- 96% of strikes occur during take off, climb, approach and landing. Strikes en-route are much less frequent but 34% of these result in damage when they do occur. Over 800 ft altitude, strikes and damage are dominated by heavier birds such as Canada Geese and Turkey Vultures and the likelihood of damage is much higher.
- The reduced certification requirements for CS-23 Commuter Aircraft (2 lb, windshield only) and CS-29 Transport Helicopters (1 kg) result in an undesirably large proportion of bird strikes (5 to 11%) above the certification value. The equivalent value for CS-25 aircraft is around 0.3%.

- Although data is very limited, it is noted that for fixed wing aircraft with certification requirements, the few accidents that have occurred are in the range 2.7 to 6.6 times the certification value.
- All those accidents which have occurred have involved bird masses above 0.78kg. Most have involved very high values of Kinetic Energy, well above current certification values, and 90% of accidents involved impact KE above 1500 J. For fixed wing aircraft with certification requirements, the few accidents that have occurred are in the range 2.7 to 6.6 times the certification value.
- CS-25 aircraft had the highest rate of reported bird strikes (186 per million flying hours) and the lowest proportion of damaging strikes (9%), probably due to better reporting of all strikes. CS-27 (small helicopters) had the highest proportion of strikes resulting in damage at 49% - predominately windshields.
- 28% of strikes reported involved multiple birds, and for these the likelihood of damage resulting was approximately twice that for an equivalent single strike. Neither the FAA nor EASA non-engine regulations currently contain any requirements relating to multiple bird strikes of the type that may arise from bird flocking behaviour. Such multiple strikes may result in some "pre-loading" of aircraft structures and windshields and may mean that the current certification analysis and test regimes are inadequate to model this scenario.
- The aircraft parts most likely to be damaged are the nose/radome/fuselage and the wing.
- KE is a better indicator of damage likelihood than bird mass. The proportion of strikes with KE above the certification value appears to be a useful safety indicator. The current value for CS-25 aircraft is around 0.3%. The certification requirements for CS-23 Commuter Aircraft and CS-29 Large/Transport Helicopters result in a larger proportion of bird strikes (11%) above the current certification KE value, which is undesirable and posses a safety risk.
- Windshield penetration was a feature of 50% of all accidents. A detailed analysis of windshield strikes showed a strong correlation between impact KE, certification requirements and probability of damage. Increasing the certification requirement is very effective in reducing the incidence of damage.
- Detailed analysis of tail strike data shows no reduction in the probability of damage resulting from the higher FAR Part 25 requirements for empennage for strikes between 1.8 and 3.6 kg. However, 100% of the 13 reported tail strikes above 3.6 kg resulted in moderate or severe damage, compared to only 47% of the strikes to wings. There have been no accidents or serious incidents identified as due to bird impact damage to the tail surfaces since the original Vickers Viscount accident in 1962 that gave rise to this requirement. Only 2.7% of reported bird strikes are to this part of the aircraft.
- Apart from a single incident affecting an Airbus 320 in 1989, there have been no accidents or serious incidents causing failure of integrated avionics through shock.
- The discussion on the effect of bird strikes on aircraft systems concluded that such effect involved mainly external sensors. However a significant number of reports of bird strike damage to landing gear and associated electrical and hydraulic components were noted. Such a strike also resulted in one of the few hull loss accidents to large transport aircraft.

- VLJs have high-speed performance, similar to large transport and business jets, but currently have no bird strike requirements. Indeed, given the relatively light airframe, single pilot operation and the likelihood that such aircraft will be operated from smaller regional airports and private airstrips, they may be more likely to encounter birds and less likely to be able to withstand the high KE impacts resulting.
- The proportion of strikes above the certification value of KE is very similar for the CS-25 Jet and Propeller aircraft (0.27% and 0.31%). Both exhibit very low rate of accidents, so effectively there is no measurable difference in the level of safety provided by CS-25 bird strike requirements between these two categories of aircraft. This confirms that the regulations adequately address the difference in V_C between the two types of aircraft.
- Some aircraft have a relatively low quoted V_C below 8000 ft with a rapid increase in V_C above this altitude. This results in a lower value of certification KE, increasing the ratio of impact KE to certification KE for any given impact – especially at the higher speeds above 8000 ft. The effect of KE ratio as a determinant of the likelihood of damage and accidents means that such aircraft will be at increased risk.
- FAR 91.117(a) restricts operational indicated airspeed to 250 kts below 10.000 ft above mean sea level. This is not applicable in all countries, and not universally enforced where it is applied. For an aircraft such as the Boeing 737 whose V_C is 340 kts, an encounter with a 3.4 kg bird at 250 kts would still be within the certification KE value. Even a strike by a Canada Goose would be only marginally above the certification KE value, and well below the range of KE ratios at which accidents have been observed to occur.

11.2 Recommendations

1. Improve the capture rate and completeness of birds strike reporting.

2. Monitor the growth in bird strike risk for each category of aircraft by monitoring the proportion of bird strikes above the certification equivalent value of KE.

3. Given the apparent success in controlling Canada Goose populations, the current efforts on bird control at airports should continue and perhaps be expanded in line with the recommendations of FAA AC 150/5200-33B, *Hazardous Wildlife Attractants On or Near Airports*. Other options should continue to be pursued.

4. Investigate the trends in population of other birds listed in Table 5-1 as causing high KE impacts, to determine if the above control measures should be extended to these species.

5. Investigate the high proportion of helicopter windshield bird strike penetrations, especially those with KE below the CS-29 requirements, and whether changes in requirements could effectively reduce the occurrence rate. It is recognised that much of the current fleet pre-dates the CS-29 requirements.

6. Consider increasing the certification KE value of CS-29 large rotorcraft to reduce the proportion of bird strikes occurring above the current certification value. This is

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because a relatively high proportion of bird strikes (5 to 8%) are occurring above the current certification KE value.

7. Consider requiring helicopter pilots to wear helmets and visors to mitigate the effects of windshield bird strike penetrations. If adopted and shown to reduce risk, This recommendation could also be extended to CS-23 aircraft.

8. For future aircraft certification, consider applying special conditions to CS-23 Commuter class twin turboprop aircraft above 5670 kg to increase bird strike requirements to match those of other aircraft above 5670 kg (i.e. CS-25 requirements)..

9. Consider the development of a risk-based model utilising the information presented in this report to provide projections of future risk levels in support of regulatory decision making.

10. The effects of preloading resulting from multiple bird strikes (possibly involving flocking birds) and the potential impact on the regulatory regime, should be examined in more detail.

11. For transport category aircraft, the relevant part of the regulations (i.e. clause 25.631) be extended to explicitly include landing gear as part of the aircraft structure.

12. Consider increasing the protection to bird strike offered to VLJ aircraft currently certified under the CS-23 aircraft requirements.

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[4.] Airworthiness Standards for Aircraft Engines, CFR Title 14, Part 33, current issue at 10 Mar 2009.

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[6.] Certification Specifications for Normal, Utility, Aerobatic, and Commuter Category Aeroplanes, CS-23, Amdt 1, 12 Feb 2009

[7.] Certification Specifications for Large (Turbine Powered) Aeroplanes, CS-25, Amdt 5, 5 September 2008

[8.] Certification Specifications for Small Rotorcraft, CS-27, Amdt 2, 17 November 2008

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[16.] Airworthiness Standards: Transport Category Rotorcraft, CFR Title 14, Chapter 1, Subchapter C, Part 29, current version, 10 March 2009

[17.] Airworthiness Standards: Propellers, CFR Title 14, Chapter 1, Subchapter C, Part 35, current version, 10 March 2009

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[28.] FAA, Type Certification Data Sheets (Make Model), web address - http://rgl.faa.gov/Regulatory_and_Guidance_Library/rgMakeModel.nsf/MainFrame?OpenFrameSet

Note: References for Bird Population Studies are listed in Appendix C.
References for Historical Flying Hour Data Sources are listed in Appendix E
References for Aircraft Accident Data Sources are listed in Appendix F

Appendix A: USA and European Bird Strike Regulations

A1.1 This Appendix presents the current FAA and EASA regulations relating to each of the different categories of aircraft that are the subject of this study. The relevant parts of the regulations are presented paragraph-by-paragraph, side-by-side for ease of comparison.

A.1.1.1 The text of the FAA regulations has been extracted from the electronic Code of Federal Regulations (eCDR) web-site, “http://ecfr.gpoaccess.gov”. The text of the EASA regulations was obtained from the web site “http//www.easa.europa.eu/ws_prod/g/rg_certspecs.php”.

A.1.1.2 The Appendix also presents the Kinetic Energy (KE) equivalent for Certification Requirements for various common aircraft types.

Table A-1 FAA and EASA Airworthiness Requirements

FAA			EASA		
Category	**Clause**	**Requirement**	**Category**	**Clause**	**Requirement**
Part 23 Normal, Utility, Acrobatic and Commuter Category Airplanes	23.775(h) (Amdt. 23-49, 11/03/96)	(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 two-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.	Normal, Utility, Acrobatic and Commuter Category Aeroplanes CS-23, Amdt 1 (Feb 1009)	23.775 h	(h) In addition for commuter category aeroplanes, the following applies: (1) Windshield panes directly in front of the pilot(s) in the normal conduct of their duties, and the supporting structures for these panes must withstand, without penetration, the impact of a 0·91 kg (2 lb) bird when the velocity of the aeroplane relative to the bird along the aeroplane's flight path is equal to the aeroplane'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.
	23.1323(f) (Amdt. 23-49, 11/03/96)	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.		23.1323 f	For commuter category aeroplanes, 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.

FAA			EASA		
Category	**Clause**	**Requirement**	**Category**	**Clause**	**Requirement**
Part 25 - Transport Category Airplanes	25.571(e) (Amdt 25-96, 31/03/98)	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	Large Turbine Powered Aircraft CS-25, Amdt 5 (Sept 2008)	25.571 e1	The aeroplane must be capable of successfully completing a flight during which likely structural damage occurs as a result of bird impact as specified in CS 25.631.
	25.631 (Amdt 25-23, 08/05/70)	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 §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 compliance is shown by analysis, tests, or both, use of data on airplanes having similar structural design is acceptable.		25.631	The aeroplane (all structure, including windshield) must be designed to assure capability of continued safe flight and landing of the aeroplane after impact with a 4 lb bird when the velocity of the aeroplane (relative to the bird along the aeroplane's flight path) is equal to V_C at sea-level or 0·85 V_C at 2438 m (8000 ft), whichever is the more critical. Compliance may be shown by analysis only when based on tests carried out on sufficiently representative structures of similar design. (See AMC 25.631.)
		No equivalent bird strike requirement		25.773b4	The openable window specified in sub-paragraph (b)(3) of this paragraph need not be provided if it is shown that an area of the transparent surface will remain clear sufficient for at least one pilot to land the aeroplane safely in the event of – (ii) An encounter with severe hail, birds, or insects.

FAA			EASA		
Category	**Clause**	**Requirement**	**Category**	**Clause**	**Requirement**
Part 25 - Transport Category Airplanes (contd.)	25.775(b) (Amdt 25-38, 01/02/77)	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 four-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 §25.335(a).	Large Turbine Powered Aircraft CS-25, Amdt 5 (contd.)	25.775b	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 bird impact conditions specified in CS 25.631.
	25.775 (c) Amdt 25-38, 01/02/77)	Unless it can be shown by analysis or tests that the probability of occurrence of a critical windshield fragmentation condition is of a low order, the airplane must have a means to minimize the danger to the pilots from flying windshield fragments due to bird impact.		25.775c	Unless it can be shown by analysis or tests that the probability of occurrence of a critical windshield fragmentation condition is of a low order, the aeroplane must have a means to minimise the danger to the pilots from flying windshield fragments due to bird impact.
	25.1323(j) Amdt 25-38, 01/02/77)	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.		25.1323j	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.

FAA			EASA		
Category	**Clause**	**Requirement**	**Category**	**Clause**	**Requirement**
Part 27 Normal Category Rotorcraft	-	No Bird Strike related requirements	Small Rotorcraft CS-27, Amdt 2 (Nov 2008) <3175kg, <9 seats	-	No Bird Strike related requirements

FAA			EASA		
Category	**Clause**	**Requirement**	**Category**	**Clause**	**Requirement**
Part 29 Transport Category Rotorcraft	29.631 (Amdt. 29-40,. 08/08/96)	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 (1.0 kg) bird when the velocity of the rotorcraft (relative to the bird along the flight path of the rotorcraft) is equal to V_{NE} or V_H (whichever is the lesser) 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 similar design	Large Rotorcraft CS-29, Amdt 2 (Nov 2008) (>3175Kg)	29.631	The rotorcraft must be designed to assure capability of continued safe flight and landing (for Category A) or safe landing (for Category B) after impact with a 1 kg bird, when the velocity of the rotorcraft (relative to the bird along the flight path of the rotorcraft) is equal to V_{NE} or V_H (whichever is the lesser) at altitudes up to 2438 m (8 000 ft). Compliance must be shown by tests, or by analysis based on tests carried out on sufficiently representative structures of similar design.
Part 35 - Propellers	35.36 (Amdt. 35-8, 23/12/08)	The applicant must demonstrate, by tests or analysis based on tests or experience on similar designs, that the propeller can withstand the impact of a 4-pound bird at the critical location(s) and critical flight condition(s) of a typical installation without causing a major or hazardous propeller effect. This section does not apply to fixed-pitch wood propellers of conventional design	Propellers CS-P	360	It must be demonstrated, by tests or analysis based on tests or experience on similar designs, that the Propeller is capable of withstanding the impact of the birds which are specified in the aircraft specifications applicable to the intended installation of the Propeller, except that the mass of the bird must not exceed 1.8 kg, at the most critical location and the flight conditions which will cause the highest blade loads in a typical installation without causing a Major or Hazardous Propeller Effect.

Appendix B: Aircraft Performance Data and Certification Kinetic Energy Values

B1 General

B1.1 This Appendix presents typical aircraft performance data for a variety of aircraft in current operational use. The information covers all categories of aircraft within the scope of this study. Data presented includes general aircraft data such as MTOW, Approach Category Code (APC), take-off and landing speeds as well as data specifically related to bird strike certification (V_C and V_{FE}).

B1.2 The data was obtained from examination of the EUROCONTROL Aircraft Performance Database, version 2.0, supplemented by manufacturers' and Type Certificate Data Sheet (TCDS) data.

B2 Kinetic Energy Calculations

B2.1 For each category of aircraft, the regulations specify the bird weight and aircraft velocity at which the airframe and wind shield are to be certified. Using this data, the kinetic energies of collision for each aircraft type has been calculated at the certification limits. These kinetic energy data are presented in the final columns of the Appendix tables.

B2.2 For transport (CS-25) aircraft the critical parameters is cruise speed (V_C) at sea level and 8000 feet. As this is not quoted in the EUROCONTROL database and is not always available from public sources, the aircraft maximum operating speeds (V_{MO}) has been used instead in some cases. In most cases this has been obtained from the FAA or EASA Type Certification Data Sheet (TCDS) for the particular aircraft.

B2.3 For Commuter Category (CS-23) aircraft the critical parameter is the maximum flap approach speed. Maximum approach speed with flaps extended (V_{FE}) values have also been taken from TCDS.

B2.4 For large rotary wing (CS-29) aircraft the maximum horizontal velocity (V_H or V_{NE}) has in general been taken from the TCDS.

B2.5 The final two (right hand) columns of Table B-1 give (subject to the stated assumptions) the kinetic energies involved in a bird strike at the regulatory limits of bird weight and aircraft velocity, using the appropriate bird mass for that category of aircraft and the specific certification velocity for that type of aircraft.

Table B-1 Performance Data and Kinetic Energy of Collision at Certification Conditions for a Variety of Aircraft

Reqt	Category	A/C Type	MTOW (kg)	V_2 (KIAS)	V_{th} (KIAS)	V_{MO} (KIAS)	Initial Climb (to 5000ft)	Climb (to FL150)	Descent (to FL100)	App-roach	Ceiling	KE (Struc-ture)	KE (Wind shield)
							Speed (KIAS)	Speed (KIAS)	Speed (KIAS)	Speed (KIAS)			(0.91kg, V_{FE})
CS-23	Normal, Utility, Aerobatic <10 seats <5670kg	Commander 112	1480	70	70	121	100	110	140	140	FL160	N/A	N/A
		An-2	5500	45	55	100	75	75	100	100	FL150	N/A	N/A
		Beech 23	1090	60	70	132	90	90	120	110	FL130	N/A	N/A
		Beech 36	1650	75	70	152	95	95	160	120	FL180	N/A	N/A
		Cessna 150	680	55	55	104	85	N/K	90	85	FL140	N/A	N/A
		Cessna 152	760	60	55	111	85	90	100	74	FL147	N/A	N/A
		Cessna 172	1050	60	65	122	90	90	120	87	FL130	N/A	N/A
		Cessna 182	1270	65	65	139	80	85	140	87	FL180	N/A	N/A
		Cessna 206	1630	75	70	148	105	110	140	110	FL200	N/A	N/A
		Cessna 208	3629	85	75	175	115	130	160	175	FL260	N/A	N/A
		Cessna 210	1820	70	75	150	100	140	170	170	FL270	N/A	N/A
		Cessna 340	2710	95	110	200	125	140	170	160	FL265	N/A	N/A
		Cessna 402	2860	95	110	200	125	140	220	156	FL270	N/A	N/A
		Cessna 424	3060	100	110	200	130	150	200	156	FL310	N/A	N/A
		Cessna Mustang	3921	N/K	N/K	250	N/K	N/K	N/K	N/K	FL410	N/A	N/A
		DHC2	2190	N/K	N/K	135	N/K	N/K	N/K	91	N/K	N/A	N/A
		DHC3	3450	N/K	N/K	159	N/K	N/K	N/K	82	N/K	N/A	N/A
		DHC6	5252	80	70	160	110	130	160	102	Fl260	N/A	N/A

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Reqt	Category	A/C Type	MTOW (kg)	V_2 (KIAS)	V_{th} (KIAS)	V_{MO} (KIAS)	Initial Climb (to 5000ft)	Climb (to FL150)	Descent (to FL100)	App-roach	Ceiling	KE (Struc -ture)	KE (Wind shield)
							Speed (KIAS)	Speed (KIAS)	Speed (KIAS)	Speed (KIAS)			(0.91kg, V_{FE})
		Robin Cadet	1100	60	65	140	100	100	140	140	FL150	N/A	N/A
		Grob 115	990	65	60	135	95	100	130	130	FL160	N/A	N/A
		PZL	4700	85	80	100	100	100	100	100	FL210	N/A	N/A
		Mooney 20	1450	75	70	130	105	140	170	170	FL240	N/A	N/A
		PA 28	1100	70	70	120	100	100	140	140	FL120	N/A	N/A
		PA 32	1640	75	75	149	105	130	160	109	FL200	N/A	N/A
		PA34 Seneca	2160	80	80	165	100	140	180	109	FL250	N/A	N/A
		PA38 Tomahawk	760	60	65	108	90	90	100	87	FL110	N/A	N/A
		PA 44 Seminole	1720	75	80	169	110	120	160	111	FL180	N/A	N/A
		P46 Malibu	1950	80	75	173	110	170	200	200	FL250	N/A	N/A
		PC9	3200	90	90	270	120	230	270	250	FL380	N/A	N/A
		Tucano	3200	85	90	220	115	180	180	180	FL300	N/A	N/A
		AC 560	3060	80	70	160	110	130	170	170	FL190	N/A	N/A
		AC680FL	4650	80	75	170	110	130	170	170	FL200	N/A	N/A
		Aerostar 601	2860	95	100	217	125	180	230	160	FL290	N/A	N/A
		Beech 18	3040	N/K	N/K	174	N/K	N/K	N/K	102	N/K	N/A	N/A
		Beech 33	1315	75	70	161	105	110	160	120	FL170	N/A	N/A
		Beech 58 Baron	2500	100	95	161	130	145	180	160	FL200	N/A	N/A
		Beech 60	3050	95	95	207	125	180	220	174	FL300	N/A	N/A
		Beech 76	1770	85	85	154	110	110	140	140	FL200	N/A	N/A

Reqt	Category	A/C Type	MTOW (kg)	V_2 (KIAS)	V_{th} (KIAS)	V_{MO} (KIAS)	Initial Climb (to 5000ft)	Climb (to FL150)	Descent (to FL100)	App-roach	Ceiling	KE (Struc -ture)	KE (Wind shield)
							Speed (KIAS)	Speed (KIAS)	Speed (KIAS)	Speed (KIAS)			(0.91kg, V_{FE})
		Beech 77	760	N/K	N/K	119	N/K	N/K	N/K	90	N/K	N/A	N/A
		Beech 90	4581	100	105	208	130	200	240	130	Fl290	N/A	N/A
		Beech 95	1810	N/K	N/K	139	N/K	N/K	N/K	113	N/K	N/A	N/A
		Cessna T303 Crusader	2340	85	110	175	115	130	160	125	FL250	N/A	N/A
		Cessna 421	3100	100	95	200	130	150	190	190	FL310	N/A	N/A
		P180 Avanti	5250	120	120	260	150	280	320	320	FL410	N/A	N/A
		Piper Navajo	2950	90	90	188	120	140	190	190	FL270	N/A	N/A
		Piper Cheyenne 400	5470	125	120	245	155	260	340	300	FL350	N/A	N/A
		Citation 525A	5613	115	115	260	145	230	230	210	N/K	N/A	N/A
		Learjet 23	5670	N/K	N/K	350	N/K	N/K	N/K	165	N/K	N/A	N/A
		King Air	4580	100	105	226	130	200	240	130	N/K	N/A	N/A
		BN2T Islander	3175	60	65	145	90	120	140	110	N/K	N/A	N/A
CS-23	**Commuter**	Super King Air 350	6800	120	110	263	150	230	280	202	Fl350	N/A	4914
	<20seats	EMB110 Bandeirante	5900	90	100	230	120	220	220	180	FL220	N/A	3902
	<8618kg	Beech 99	7600	115	110	226	145	200	240	132	N/K	N/A	2098
		Beech 200	5670	115	100	270	145	230	250	200	FL350	N/A	4817
		Beech 300	6350	N/K	N/K	259	N/K	N/K	N/K	200	N/K	N/A	4817
		An28	6500	80	105	170	110	140	170	90	N/K	N/A	975

Reqt	Category	A/C Type	MTOW (kg)	V_2 (KIAS)	V_{th} (KIAS)	V_{MO} (KIAS)	Initial Climb (to 5000ft)	Climb (to FL150)	Descent (to FL100)	App-roach	Ceiling	KE (Struc -ture)	KE (Wind shield)
							Speed (KIAS)	Speed (KIAS)	Speed (KIAS)	Speed (KIAS)			(0.91kg, V_{FE})
		MU-2	4560	120	100	250	150	260	300	140	FL290	N/A	2360
		Skyvan	6200	90	90	178	120	120	150	130	N/K	N/A	2035
		Beech 1900	7690	110	120	270	145	210	250	200	FL250	N/A	4817
		Amivest SJ30	13950	N/K	N/K	320	N/K	N/K	N/K	200	FL490	N/A	4817
		Fairchild SA- 227	5700	115	120	265	145	220	260	215	FL270	N/A	5566

Reqt	Category	A/C Type	MTOW (kg)	V_2 (KIAS)	V_{th} (KIAS)	V_{MO} (KIAS)	Initial Climb (to 5000ft)	Climb (to FL150)	Descent (to FL100)	App-roach	Ceiling	KE (struc-ture)	KE (Wind shield)
							Speed (KIAS)	Speed (KIAS)	Speed (KIAS)	Speed (kts IAS)		(1.82kg, Vc)	(1.82kg, V_C)
CS-25	**Large (Turbine Powered) Aircraft** >5670kg	**Short/Medium Haul**											
		An72	34500	110	100	260	140	230	230	170		16280	16280
		A31x	64000	135	130	460	165	290	290	250		50961	50961
		A32x	83000	145	137	450	175	290	290	225		48769	48769
		BAe146	46000	125	125	380	155	250	250	250		34776	34776
		B727	95300	145	150	450	175	290	280	210		48769	48769
		B737	79015	150	150	460	185	290	290	250		50961	50961
		B757	123600	145	140	490	175	270	270	230		57824	57824
		CRJ700	33000	135	135	440	165	290	290	250		46626	46626
		CRJ900	36510	170	150	465	230	260	250	220		52074	52074
		DC9	54930	140	130	440	170	290	290	250		46626	46626
		DC10	259459	150	150	350	180	290	300	250		29502	29502
		EMB135	19990	125	130	250	160	300	250	210		15052	15052
		EMB145	21198	130	210	250	165	300	250	210		15052	15052
		EMB170	35990	N/K	N/K	300	N/K	N/K	N/K	N/K		21675	21675
		EMB190	47790	N/K	N/K	300	N/K	N/K	N/K	N/K		21675	21675
		RJ85	42190	125	125	N/K	155	220	250	250		-	-
		F28	33100	135	125	390	165	250	250	250		36631	36631
		F70	36700	125	120	320	155	250	250	230		24661	24661

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Reqt	Category	A/C Type	MTOW (kg)	V_2 (KIAS)	V_{th} (KIAS)	V_{MO} (KIAS)	Initial Climb (to 5000ft)	Climb (to FL150)	Descent (to FL100)	App-roach	Ceiling	KE (struc-ture)	KE (Wind shield)
							Speed (KIAS)	Speed (KIAS)	Speed (KIAS)	Speed (kts IAS)		(1.82kg, Vc)	(1.82kg, V_C)
		F100	43390	135	130	405	165	250	250	250		39503	39503
		MD8x	67800	140	150	440	170	290	290	250		46626	46626
		RJ100	42190	125	125	300	155	220	250	250		21675	21675
		Tu154	100000	150	130	475	180	290	290	250		54338	54338
		Tu2x4	93500	150	140	460	180	290	290	250		50961	50961
		Yak40	15500	100	120	245	130	200	200	200		14456	14456
		Yak42	63000	130	130	400	160	270	270	250		38533	38533
		BAC-111	45200	140	150	333	150	250	350	250		26706	26706
		Do328J	15660	135	120	270	165	240	240	240		17557	17557
		Learjet 45	9230	140	140	330	170	290	290	250		26227	26227
		Learjet 60	10660	140	140	250	170	290	290	250		15052	15052
CS-25	**Large (Turbine Powered) Aircraft** >5670kg	**Long Haul**											
		An124	405000	140	140	430	160	270	290	250		44530	44530
		A300	165000	160	130	480	190	290	290	240		55488	55488
		A310	150000	160	130	480	190	260	290	240		55488	55488
		A330	230000	145	130	475	175	290	290	220		54338	54338
		A340	368000	145	150	480	175	290	290	250		55488	55488
		A380	560000	150	138	520	190	240	300	250		65122	65122
		B707	150800	130	140	470	160	290	300	250		53200	53200
		B747-400	396890	185	160	510	215	300	300	250		62641	62641

Reqt	Category	A/C Type	MTOW (kg)	V_2 (KIAS)	V_{th} (KIAS)	V_{MO} (KIAS)	Initial Climb (to 5000ft)	Climb (to FL150)	Descent (to FL100)	App-roach	Ceiling	KE (struc-ture)	KE (Wind shield)
							Speed (KIAS)	Speed (KIAS)	Speed (KIAS)	Speed (kts IAS)		(1.82kg, Vc)	(1.82kg, V_C)
		B767-400	204120	160	150	460	190	290	290	230		50961	50961
		B777	299370	170	150	490	200	300	300	240		57824	57824
		BD-700 (Global Xpress)	42410	120	125	460	150	300	300	250		50961	50961
		DC8x	162025	160	150	460	190	290	290	240		50961	50961
		IL62	165000	150	130	460	180	290	290	250		50961	50961
		IL76	170000	120	120	430	150	250	250	250		44530	44530
		IL86	206000	155	150	490	185	290	290	250		57824	57824
		L1011	195040	150	140	485	180	290	290	250		56650	56650
		MD11	286000	160	150	500	190	300	300	250		60209	60209
		VC10	146500	145	150	480	175	300	300	250		55488	55488
CS-25	**Large (Turbine Powered) Aircraft** >5670kg	**TurboProp**											
		748	21090	110	120	220	140	180	220	220		11656	11656
		An12	61000	130	110	310	160	220	300	150		23144	23144
		An22	250000	?	140	350	N/K	N/K	250	200		29502	29502
		An24/6	21000	110	120	240	140	200	240	240		13872	13872
		An28	6500	80	105	170	110	140	170	90		6960	6960
		ATR42	18600	110	110	255	140	220	300	250		15660	15660
		ATR72	21500	110	120	275	140	210	260	200		18213	18213
		ATP	22930	105	105	265	140	185	230	180		16913	16913

Reqt	Category	A/C Type	MTOW (kg)	V_2 (KIAS)	V_{th} (KIAS)	V_{MO} (KIAS)	Initial Climb (to 5000ft)	Climb (to FL150)	Descent (to FL100)	App-roach	Ceiling	KE (struc-ture)	KE (Wind shield)
							Speed (KIAS)	Speed (KIAS)	Speed (KIAS)	Speed (kts IAS)		(1.82kg, Vc)	(1.82kg, V_C)
		Do228	13990	110	110	200	140	220	280	250		9633	9633
		Do328	13640	110	110	270	140	220	280	250		17557	17557
		Dash 7	21320	90	90	220	120	180	220	160		11656	11656
		Dash 8	28990	116	116	242	150	210	270	245		14104	14104
		Brasilia	12000	120	120	250	150	220	290	250		15052	15052
		F27	20400	100	120	224	130	200	240	240		12084	12084
		F50	20820	120	120	340	130	210	220	220		27840	27840
		Gulfstream 1	15600	N/K	N/K	290	N/K	N/K	N/K	N/K		20254	20254
		Viscount	69000	N/K	N/K	267	N/K	N/K	N/K	200		17169	17169
		DC3	26200	N/K	N/K	189	N/K	N/K	N/K	N/K		8603	8603
		DC6	40000	N/K	N/K	261	N/K	N/K	N/K	N/K		16406	16406
		L-188 Electra	51250	120	130	324	150	250	330	250		25282	25282
		C-130	70310	120	120	290	140	180	250	145		20254	20254
		Jetstream 31/41	10886	110	125	220	140	230	280	200		11656	11656
		Saab 2000	21000	110	110	250	140	250	340	250		15052	15052
		SF-340	12900	110	115	250	140	210	280	250		15052	15052
		Short 360	12300	110	100	198	140	170	180	180		9442	9442
CS-25	**Large (Turbine Powered) Aircraft**	**Business Jets**											
		1125 Astra	11180	130	120	470	160	290	290	200		53200	53200
		Beechjet 400	7300	130	120	420	160	290	290	200		42483	42483

Reqt	Category	A/C Type	MTOW (kg)	V_2 (KIAS)	V_{th} (KIAS)	V_{MO} (KIAS)	Initial Climb (to 5000ft)	Climb (to FL150)	Descent (to FL100)	App-roach	Ceiling	KE (struc-ture)	KE (Wind shield)
							Speed (KIAS)	Speed (KIAS)	Speed (KIAS)	Speed (kts IAS)		(1.82kg, Vc)	(1.82kg, V_C)
	>5670kg	Citation 550	6850	115	110	261	145	240	250	220		16406	16406
		Citation 560	8709	115	125	260	145	270	270	200		16280	16280
		Citation 650	14060	125	130	305	155	300	300	250		22404	22404
		Citation 750 (10)	16195	125	130	270	155	320	320	250		17557	17557
		Falcon 20x	13160	125	110	350	150	270	270	250		29502	29502
		Falcon 50	17600	120	130	350	150	290	290	250		29502	29502
		Falcon 10	8318	N/K	N/K	350	N/K	N/K	N/K	N/K		29502	29502
		BD700 (Global Express)	42410	120	125	300	150	300	300	250		21675	21675
		Gulfstream 2	28000	N/K	N/K	367	N/K	N/K	N/K	N/K		32438	32438
		Gulfstream 3	31620	145	135	340	175	300	300	250		27840	27840
		Gulfstream 4/5	40370	145	145	367	175	300	300	250		32438	32438
		BAe125-700 / Hawker 800	14060	125	132	285	155	290	290	250		19562	19562
		Beechjet 400	7300	130	120	290	160	290	290	200		20254	20254
		CL-60x	19000	N/K	N/K	300	N/K	N/K	N/K	N/K		21675	21675
		Learjet 24	5900	N/K	N/K	300	N/K	N/K	N/K	N/K		21675	21675
		Learjet 25	7700	130	125	300	160	290	290	250	FL510	21675	21675
		Learjet 31	7030	130	120	300	160	290	290	250	FL510	21675	21675
		Learjet 35	8300	140	125	300	170	290	290	250	FL410	21675	21675
		Learjet 36	7700	N/K	N/K	300	N/K	N/K	N/K	N/K		21675	21675

Reqt	Category	A/C Type	MTOW (kg)	V_2 (KIAS)	V_{th} (KIAS)	V_{MO} (KIAS)	Initial Climb (to 5000ft)	Climb (to FL150)	Descent (to FL100)	App-roach	Ceiling	KE (struc-ture)	KE (Wind shield)
							Speed (KIAS)	Speed (KIAS)	Speed (KIAS)	Speed (kts IAS)		(1.82kg, Vc)	(1.82kg, V_C)
		Learjet 55	9100	140	140	300	170	290	290	250	FL510	21675	21675

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Reqt	Category	A/C Type	MTOW (kg)			V_H	Initial Climb (to 5000ft)	Climb (to FL150)	Descent (to FL100)	App-roach	Ceiling	KE (struc-ture)	KE (Wind shield)
						KIAS	Speed (Kt)	Speed (Kt)	Speed (Kt)	Speed			
CS-27	**Light Rotorcraft** <10 seats <3175kg	EC130B4	2427		5 seats	130	No Requirements						
		EC135	2910		8 seats	137	No Requirements						
		AS350B3	2250		7 seats	155	No Requirements						
		AS355	2100			150	No Requirements						
		AW119	3150		8 seats	152	No Requirements						
		AW109S	3000		8 seats	168	No Requirements						
		MD520	1519		5 seats	152	No Requirements						
		MD600	1860		8 seats	155	No Requirements						
		MD Explorer	2835		10 seats	140	No Requirements						
		Schwiezer 333	1157		4 seats	95	No Requirements						
		Bell 206B3	1519		5 seats	150	No Requirements						
		Bell 407	2270			140	No Requirements						
		Bell 430	2406		10 seats	150	No Requirements						
		BO 105	2105		5 seats	145	No Requirements						
		R22	623		2 seats	98	No Requirements						

Reqt	Category	A/C Type	MTOW (kg)			V_H	Initial Climb (to 5000ft)	Climb (to FL150)	Descent (to FL100)	App-roach	Ceiling	KE (struc-ture)	KE (Wind shield)
							Speed (Kt)	Speed (Kt)	Speed (Kt)	Speed		(1.82kg, V_H)	(1.82kg, V_H)
CS-29	Large Rotorcraft >3175kg	EC145	3585		11 seats	133						2341	2341
		AS265N3	4300		12 seats	165						3603	3603
		AS365	3400			175						4053	3179
		EC155B1	4920		12 seats	175						4053	2594
		AS332L1	9370		22 seats	167						3690	2594
		EC225	11222		26 seats	140						2594	3603
		AW139	6400		16 seats	165						3603	8945
		BA609	7631		11 seats	260						8945	3179
		S76++	5306		14 seats	155						3179	3017
		S92	12202		21 seats	165						3603	1970
		Bell 212	5080			130						2236	2859
		Bell 214	6260			130						2236	2236
		Bell412	5397		17 seats	140						2594	2594
		Bell429	3175		8 seats	147						2859	2859
		BO 117	3210		8 seats	150						2977	2977
		Bell 222			10 seats	150						2977	2977

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Appendix C: Population Trends from External Studies

C1 General

C1.1 This Appendix identifies the most frequently struck bird species found in the North American and UK bird strike records over 1990 to 2007, and identifies population trends from published ornithological studies.

C1.2 The data is presented in separate tables for America and the UK and is grouped by bird weight according to the following weight categories:

Category	Weight	
1	< 4 oz	< 100 g
2	4oz to 1lb	101 – 450 g
3	1 to 2 lb	451 – 900 g
4	2 to 4 lb	901 – 1800 g
5	4 – 8 lb	1801 – 3600 g
6	> 8 lb	>3600 g

C1.3 The assessed trend (Increase/Stable/Decrease) is shown in the Population Trend column. The particular reference used and the "quality" of this reference (based on the scope and size of the original study) is also shown.

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Table C-1 Top five most frequently struck bird species in the UK, by weight category.

Species	Latin name	Weight category	No of Strikes	Mean Weight (g)	Population Size (UK)*	Population size Europe*	Population trend	Reference	Quality of reference 1 - 3 (1 = only a small city studied, 3 = nationwide pop count)
Swallow	Hirundo rustica	1	721	19	Summer 678 thousand territories 2000	Summer 14 – 29 million pairs	Decrease	(Lowe 2002)	2
							Decrease	(Evans 2003)	3
Skylark	Alauda arvensis	1	651	38.6	Summer 1.7 million pairs 2000	Summer 25 – 45 million pairs	Decrease	(Van Strien 2001)	2
Swift	*Apus apus*	1	623	41	Summer 80 thousand pairs 1988-91	4.4 – 12 million pairs	Fluctuating	(Thomson 1996)	1
Starling	*Sturnus vulgaris*	1	372	80	Summer 80.1 - 10.8 million 1994 - 2000	Summer 21 – 46 million pairs	Decrease	(Robinson 2005)	3
House Martin	*Delichon urbica*	1	151	17	Summer 253 - 505 thousand pairs 2000	Summer 9.1 – 22 million pairs			
Black-headed Gull	Larus ridibundus	2	932	275	Summer 128 thousand pairs 1998-02, Winter 2.1 - 2.2 million 1993	Summer 1.3 – 1.7 million pairs	Increase	(Burton & Musgrove 2003)	3
							Decrease	(Banks *et al.* 2005)	2
							Decrease	(Musgrove *et al.* 2007)	2
							Increase	(Mavor *et al.* 2002; Mavor *et al.* 2003; Mavor *et al.* 2006)	2
Lapwing	Vanellus vanellus	2	897	215	Summer 154 thousand pairs 1985-98, Winter 1.5 to 2 million 1981-92	Summer 1.1 – 1.7 million pairs	Decrease	(Baillie, S.R. et al 2000)	3
							Decrease	(Wilson 2001)	3
							Decrease	(Van Strien 2001)	2
							Decrease	(Shrubb 1991)	3

Species	Latin name	Weight category	No of Strikes	Mean Weight (g)	Population Size (UK)*	Population size Europe*	Population trend	Reference	Quality of reference 1 - 3 (1 = only a small city studied, 3 = nationwide pop count)
							Decrease	(Henderson 2002)	3
							Increase (on wetlands)	(Banks *et al.* 2005)	2
Kestrel	*Falco tinnunculus*	2	450	204	Summer 53 - 58 thousand pairs 2007	Summer 290 – 44 thousand pairs			
Common Gull	Larus canus	2	423	420	Summer 48 thousand pairs 2998 -02, Winter 670 - 721 thousand 1993	Summer 340 – 500 thousand pairs	Increase	(Burton & Musgrove 2003)	3
							Decrease	(Banks *et al.* 2005)	2
							Decrease	(Musgrove *et al.* 2007)	2
							Increase	(Mavor *et al.* 2003)	2
Rook	*Corvus frugilegus*	2	360	430	Summer 1 - 1.3 million pairs 2000	Summer 5 – 8 million pairs	Decrease	BirdLife International	2 (global pop figures)
Lesser Black-backed Gull	Larus fuscus	3	110	820	Summer 110 thousand pairs 1998 - 02, Winter 118 - 131 thousand 1993	Summer 300 - 350 thousand	Increase	(Burton & Musgrove 2003)	3
Buzzard	*Buteo buteo*	3	76	800	Summer 31 - 41 thousand territories 2000	Summer 510 - 700 thousand pairs	Increase	(Clements 2002)	3
Carrion Crow	*Corvus corone corone*	3	115	530	Summer 790 thousand territories 2000	Summer 5.5 - 12 million pairs	Decrease	BirdLife International	2 (global pop figures)
Oystercatcher	*Haematopus astralegus*	3	125	500	Summer 99 - 127 thousand pairs 1985 - 98, Winter 315 thousand 1994 - 99	Summer 293 - 425 thousand pairs			
Woodpigeon	*Columba polumbus*	3	627	465	Summer 2.5 - 3 million territories 2000	Summer 8 - 14 million pairs			
Herring Gull	Larus argentatus	4	671	1020	Summer 131 thousand pairs 1998 - 02, Winter 696 - 763 thousand 1993	Summer 660 - 900 thousand pairs	Increase	(Burton & Musgrove 2003)	3
							Increase	(Banks *et al.* 2005)	2
							Stable	(Musgrove *et al.* 2007)	2

Species	Latin name	Weight category	No of Strikes	Mean Weight (g)	Population Size (UK)*	Population size Europe*	Population trend	Reference	Quality of reference 1 - 3 (1 = only a small city studied, 3 = nationwide pop count)
							Decrease (coastal)	(Mavor *et al.* 2002; Mavor *et al.* 2003; Mavor *et al.* 2006)	2
							Stable	(Banks *et al.* 2005) (Musgrove *et al.* 2007)	2
							Increase	(Mavor *et al.* 2002;. 2003;. 2006)	2
Pheasant	*Phasianus colchicus*	4	63	1100	Summer 1.7 - 1.8 million females 2000	Summer 3.4 - 4.7 million pairs			
Mallard	*Anas platyrhynchos*	4	59	1080	Summer 48 - 114 thousand pairs 1988 - 91, Winter 352 thousand 1994 - 99	Summer 2 - 3.4 million pairs	Decrease	BirdLife International	2 (global pop figures)
Grey Heron	Adrea cinera	4	40	1500	Summer 13 thousand nests 2003	Summer 185 - 230 thousand pairs	Increase	(Marchant 2004)	3
							Stable	(Banks *et al.* 2005)	2
							Stable	(Musgrove *et al.* 2007)	3
Great Black-backed Gull	Larus marinus	4	37	1690	Summer 17 thousand pairs 1998 -02, Winter 71 to 81 thousand 2003 - 05	Summer 110 - 180 thousand pairs	Increase	(Burton & Musgrove 2003)	3
							Decrease	(Banks *et al.* 2005)	2
							Stable	(Musgrove *et al.* 2007)	2
							Stable	(Mavor *et al.* 2002)	2
							Decrease (coastal)	(Mavor *et al.* 2003; Mavor *et al.* 2006)}	2

Species	Latin name	Weight category	No of Strikes	Mean Weight (g)	Population Size (UK)*	Population size Europe*	Population trend	Reference	Quality of reference 1 - 3 (1 = only a small city studied, 3 = nationwide pop count)
Canada Goose	Branta canadensis	5	20	3600	Summer 82 thousand adults 1999, winter 82 thousand 1999	2500 - 10 thousand pairs	Increase	(Austin & Rehfisch 2007)	2
							Increase	(Banks *et al.* 2005)	3
							Increase	(Musgrove *et al.* 2007)	3
Greylag Goose	Anser anser	5	7	3325	Summer 3200 wild pairs 1997, Winter 121 thousand 1994 – 1999	100 – 145 thousand pairs	Increase	(Austin & Rehfisch 2007)	2
							Increase (decrease in Icelandic population)	(Banks *et al.* 2005; Musgrove *et al.* 2007)	3
							Decrease in Icelandic population	(Hearn & Mitchell 2004)	2
Gannet	*Morus bassanus*	5	3	2900	Summer 219 thousand nests 2003 - 2004		Increase	(Wanless, Murray & Harris 2005)	3
Mute Swan	Cygnus olor	6	4	10000	Summer 5299 pairs in 1990, Winter 38 thousand 1994 - 1999		Increase	(Kirby, Delany & Quinn 1994)	3
							Increase	(Ward 2007)	3
							Increase GB, decrease NI	(Banks *et al.* 2005)	3
							Increase GB, decrease NI	(Musgrove *et al.* 2007)	3
White-fronted Goose	Anser albifrons	5	2	2350	Winter 27 thousand pairs 1994 - 1999	1700 2 thousand pairs	Decrease, from 1999	(Fox 2006)	3
							Increasing but local extinctions (up to 1992)	(Fox 1998)	3
							Decrease from 1999	(Banks *et al.* 2005)	3
							Decrease	(Musgrove *et al.* 2007)	3

Species	Latin name	Weight category	No of Strikes	Mean Weight (g)	Population Size (UK)*	Population size Europe*	Population trend	Reference	Quality of reference 1 - 3 (1 = only a small city studied, 3 = nationwide pop count)
							Decrease	(Hearn 2004)	2
Whooper Swan	Cygnus cygnus	6	2	10000	Summer 3 – 7 pairs 1996 - 2000, Winter 5720 in 1994 - 1999		Stable (increase in NI)	(Kirby *et al.* 1992)	3
							Increase	(Banks *et al.* 2005)	3
							Increase	(Musgrove *et al.* 2007)	3

*** Data obtained from the BTO**

Table C-2 Top five most frequently struck bird species in the US, by weight category.

Species	Latin Name	Weight category	No of strikes	Mean Weight (g)	Global Population†	Population trend	Reference	Quality of reference 1 - 3 (1 = only a small city studied, 3 = nationwide pop count)
European Starling	*Sturnus vulgaris*	1	1376	80	310,000,000	Decrease	BirdLife International	2 (global pop figures)
Killdeer	*Charadrius vociferus*	1	576	85	1,000,000	Decrease	(Sanzenbacher 2001)	3
Horned Lark	*Eremophila alpestris*	1	343	37	140,000,000	Decrease	BirdLife International	2 (global pop figures)
Barn Swallow	*Hirundo rustica*	1	302	19	190,000,000	Decrease	BirdLife International	2 (global pop figures)
Eastern Meadowlark	*Sturnella magna*	1	251	86	10,000,000	Decrease	BirdLife International	2 (global pop figures)
Mourning Dove	Zenaida macroura	2	1591	126	130,000,000	Decrease	(Sauer 1994)	3
						Decrease (mainly in west)	(Dolton 2004)	3
						Decrease	(Elmore 2007)	2
						Decrease	Dolton 2004	2
Rock Pigeon	*Columba livia*	2	1119	393	260,000,000	Decrease	BirdLife International	2 (global pop figures)
American Kestrel	*Falco sparverius*	2	990	105	6,000,000	Stable	BirdLife International	2 (global pop figures)
Pacific Golden-Plover	*Pluvialis fulva*	2	277	130	190,000 - 250,000	Decrease	BirdLife International	2 (global pop figures)
Barn Owl	*Tyto alba*	2	268	315	5,000,000	Stable	BirdLife International	2 (global pop figures)
Ring-billed Gull	*Larus delawarensis*	3	535	485	2,600,000	Increase	BirdLife International	2 (global pop figures)
American Crow	*Corvus brachyrhynchos*	3	177	476	31,000,000	Increase	BirdLife International	2 (global pop figures)
Peregrine Falcon	*Falco peregrinus*	3	77	790	1,200,000	Increase	(Enderson 1995)	3
Northern Pintail	*Anas acuta*	3	31	840	5,300,000 - 5,700,000	Decrease	BirdLife International	
American Coot	*Fulica americana*	3	27	615	6,000,000	Decrease (15%, 10yrs)	(Swift 2005)	2 (global pop figures)
Red-tailed Hawk	*Buteo jamaicensis*	4	592	1100	2,000,000	Increase	BirdLife International	2 (global pop figures)
Herring Gull	*Larus argentatus*	4	423	1020	2,700,000 - 5,700,000	Decrease	BirdLife International	2 (global pop figures)

Species	Latin Name	Weight category	No of strikes	Mean Weight (g)	Global Population†	Population trend	Reference	Quality of reference 1 - 3 (1 = only a small city studied, 3 = nationwide pop count)
Mallard	*Anas platyrhynchos*	4	325	1080	19,000,000	Decrease (11%, 10yrs)	(Swift 2005)	2
Osprey	*Pandion haliaetus*	4	100	1525	500,000	Increase	BirdLife International	2 (global pop figures)
Turkey Vulture	*Cathartes aura*	4	219	1450	5,000,000	Increase (esp in eastern US)	(Avery 2004)	3
Canada Goose	Branta canadensis	5	926	3600	5,500,000 - 5,900,000	Increase (30%, 10 yr)	(Swift 2005)	2
						Increase	(Fox, Glahder & Mitchell 1996)	2
Great Blue Heron	*Ardea herodias*	5	141	2700	6,500	Increase	BirdLife International	2 (global pop figures)
Double-crested Cormorant	*Phalacrocorax auritus*	5	35	2000	1,100,000 - 2,200,000	Increase	BirdLife International	2 (global pop figures)
Snowy Owl	*Bubo scandiacus*	5	55	1875	300,000	Decrease	BirdLife International	2 (global pop figures)
Snow Goose	*Chen caerulescens*	5	38	2450	7,600,000	Increase	BirdLife International	2 (global pop figures)
Bald Eagle	*Haliaeetus leucocephalus*	6	65	5140	300,000	Increase	BirdLife International	2 (global pop figures)
Sandhill Crane	*Grus canadensis*	6	52	4240	520,000 - 530,000	Increase	BirdLife International	2 (global pop figures)
Wild Turkey	*Meleagris gallopavo*	6	31	6440	1,300,000	Increase	BirdLife International	2 (global pop figures)
Common Loon	Gavia immer	6	9	3700	610,000 - 640,000	Decrease	BirdLife International	2 (global pop figures)
						Stable	(Groves 1996)	2 (Alaska only)
Tundra Swan	*Cygnus columbianus*	6	5	7200	300,000	Decrease	BirdLife International	2 (global pop figures)

†Data obtained from BirdLife International

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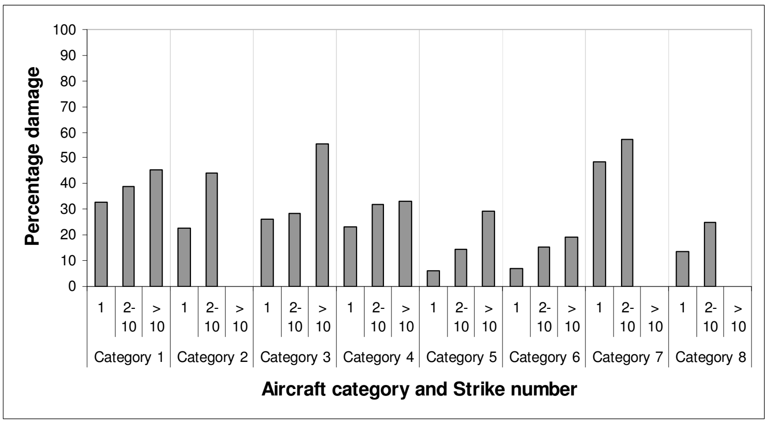
Appendix D: Detailed Bird Strike Data

D1 Multiple Bird Strikes

Table D-1 Percentage of multiple strikes causing damage to each aircraft category

Aircraft Cat.	No. Birds Struck	No. of Strikes	% of Strikes causing Damage
1	1	1011	32.9
	2 - 10	320	38.8
	> 10	22	45.5
2	1	44	22.7
	2 - 10	25	44.0
	> 10	2	-
3	1	278	26.3
	2 - 10	126	28.6
	> 10	9	55.6
4	1	139	23.0
	2 - 10	75	32.0
	> 10	12	33.3
5	1	973	6.2
	2 - 10	327	14.4
	> 10	41	29.3
6	1	5083	7.1
	2 - 10	1842	15.5
	> 10	234	19.2
7	1	58	48.3
	2 - 10	7	57.1
	> 10	0	-
8	1	118	13.6
	2 - 10	4	25.0
	> 10	0	-

Figure D-1 Proportion of Multiple Strikes Resulting in Damage by Aircraft Category



D2 Strike Kinetic Energy By Aircraft Category

Table D-3 Kinetic Energy (Joules) of Bird Strikes where no damage and damage was caused for each Aircraft Category ..

Aircraft Category		No damage	Damaged
1	Median	217.7	1978.1
	25%	104.5	559.5
	75%	512.6	4076.5
	Mean	644.2	3085.9
2	Median	197.2	4010.5
	25%	127.4	558.5
	75%	437.4	6594.8
	Mean	381.8	4687.6
3	Median	277.5	3105.6
	25%	133.8	107.8
	75%	915.6	6743.1
	Mean	1407.3	5300.8
4	Median	198.4	2778.4
	25%	121.9	1080.1
	75%	863.8	6755.3
	Mean	1179.1	5155.9
5	Median	308.3	3725.7
	25%	105.5	614.0

Aircraft Category		No damage	Damaged
	75%	736.0	7940.3
	Mean	806.1	5979.0
6	Median	288.2	4466.4
	25%	123.6	1216.9
	75%	942.7	9904.1
	Mean	1139.3	7792.4
7	Median	35.6	1158.7
	25%	0.4	550.5
	75%	132.7	2409.3
	Mean	342.5	1863.7
8	Median	1.4	1617.9
	25%	0.0	117.4
	75%	67.1	3950.2
	Mean	156.2	2285.7
All	Median	268.9	2698.9
	25%	111.7	864.1
	75%	863.8	6927.6
	Mean	1024.9	5403.3

D3 Species involved in strikes for each phase (UK/Canadian Data only)

Table D-4: Top five species hit for each phase of flight

Phase	Species	n	% Damage
Approach	Lapwing	141	7.8
	Swallow	131	1.5
	Swift	120	1.7
	Pigeon	114	5.3
	Woodpigeon	76	5.3
Climb	Lapwing	58	17.2
	Pigeon	40	12.5
	Woodpigeon	33	9.1
	Black-Headed Gull	33	6.1
	Herring Gull	31	25.8
	Swift	31	0.0
Descent	Swift	5	0.0
	Pigeon	5	0.0
	Swallow	4	0.0
	Woodpigeon	3	33.3
	Herring Gull	2	50.0
Discovered After Flight	Black-Headed Gull	2	0.0
En Route	Herring Gull	8	62.5
	Swift	6	0.0

Phase	Species	n	% Damage
	Swallow	6	0.0
	Black-Headed Gull	2	0.0
	Gannet	2	100.0
	Bald Eagle	2	50.0
	Lapwing	2	50.0
	Redwing	2	0.0
	Starling	2	50.0
	Buzzard	2	50.0
Ground Checks	Rook	2	0.0
	Barn Owl	2	0.0
	Feral Pigeon	2	0.0
	Woodpigeon	1	0.0
	Hooded Merganser	1	100.0
	House Martin	1	0.0
	Lapwing	1	100.0
	Double Striped Thicknee	1	0.0
	Skylark	1	0.0
	Wigeon	1	100.0
Hover	Pigeon	3	0.0
	Sparrow	1	0.0
Hover Taxi	Stock Dove	1	0.0
Landing	Semipalmated Plover	2	0.0
	Canada Goose	2	100.0
	Glaucous-Winged Gull	2	0.0
	Red-Tailed Hawk	2	50.0
	Ring-Billed Gull	2	0.0
Landing Roll	Black-Headed Gull	117	1.7
	Lapwing	112	7.1
	Swallow	102	0.0
	Pigeon	101	1.0
	Skylark	96	1.0
On Deck, Rotors Running	Feral Pigeon	4	0.0
	Arctic Tern	1	0.0
	Curlew	1	0.0
Parked	Pigeon	11	9.1
	Feral Pigeon	7	0.0
	Golden Plover	3	0.0
	Black-Headed Gull	2	0.0
	Curlew	2	50.0
	Dunlin	2	0.0
	Herring Gull	2	0.0
Rotation	Swallow	1	0.0
	Kestrel	1	0.0
	Pigeon	1	0.0
Take Off	Swallow	2	0.0
	Semipalmated Sandpiper	2	0.0
	California Gull	1	0.0
	Killdeer	1	0.0

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Phase	Species	n	% Damage
	Mallard	1	0.0
	Pigeon	1	0.0
	Rough-Legged Hawk	1	100.0
	Horned Lark	1	0.0
	Snow Bunting	1	0.0
	Snowy Owl	1	0.0
	Swainson's Hawk	1	100.0
Take-Off Roll	Skylark	58	1.7
	Black-Headed Gull	54	3.7
	Swallow	52	0.0
	Herring Gull	44	6.8
	Woodpigeon	36	5.6
Take-Off Run	Lapwing	76	9.2
	Black-Headed Gull	39	2.6
	Swallow	30	0.0
	Herring Gull	29	17.2
	Pigeon	29	0.0
Taxi	Pigeon	7	0.0
	Woodpigeon	4	0.0
	Lapwing	3	0.0
	Kestrel	2	0.0
	Grey Partridge	2	0.0

Appendix E: Flying Hours Data

	Million Flying Hours																		
	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	Total
CS-25 Aircraft																			
US	11.05	11.34	11.64	11.94	12.26	12.58	12.91	13.25	13.56	14.36	15.35	15.22	15.59	17.95	19.31	19.86	19.70	20.12	**267.97**
UK	1.444	1.38	1.527	1.547	1.624	1.706	1.823	1.859	2.14	2.289	2.442	2.505	2.408	2.473	2.626	2.736	2.908	2.996	**38.43**
Total	12.49	12.72	13.16	13.49	13.88	14.28	14.73	15.11	15.70	16.65	17.79	17.73	18.00	20.42	21.94	22.60	22.61	23.12	**306.41**
CS-23 Aircraft																			
US	24.08	24.08	24.08	21.63	21.2	23.2	23.4	24.11	24.39	27.05	26.13	23.62	23.49	23.64	24.02	22.31	22.76	22.86	**426.04**
UK	0.962	0.844	0.801	0.81	0.854	0.841	0.831	0.854	0.854	0.839	0.808	0.802	0.795	0.798	0.775	0.828	0.843	0.857	**15.00**
Total	25.04	24.92	24.88	22.44	22.06	24.04	24.23	24.97	25.25	27.89	26.94	24.42	24.28	24.44	24.80	23.14	23.61	23.71	**441.03**
CS-29 Helicopters																			
US	0.316	0.316	0.316	0.316	0.359	0.406	0.249	0.429	0.497	0.422	0.335	0.322	0.31	0.411	0.481	0.576	0.57	0.55	**7.18**
UK	0.166	0.145	0.129	0.129	0.123	0.136	0.135	0.135	0.127	0.117	0.118	0.128	0.136	0.132	0.128	0.136	0.143	0.145	**2.41**
Total	0.48	0.46	0.45	0.45	0.48	0.54	0.38	0.56	0.62	0.54	0.45	0.45	0.45	0.54	0.61	0.71	0.71	0.70	**9.59**
CS-27 Helicopters																			
US	1.38	1.38	1.38	1.38	1.42	1.56	1.87	1.66	1.85	2.21	1.86	1.63	1.57	1.72	2.05	2.48	2.88	2.70	**32.97**
UK	0.164	0.144	0.14	0.137	0.152	0.117	0.124	0.138	0.151	0.152	0.153	0.149	0.159	0.162	0.169	0.183	0.19	0.203	**2.79**
Total	1.55	1.53	1.52	1.52	1.57	1.67	2.00	1.79	2.00	2.36	2.01	1.78	1.73	1.89	2.22	2.66	3.07	2.90	**35.75**
Total all aircraft	**39.56**	**39.62**	**40.01**	**37.90**	**37.99**	**40.54**	**41.35**	**42.43**	**43.57**	**47.43**	**47.19**	**44.38**	**44.45**	**47.29**	**49.56**	**49.11**	**49.99**	**50.42**	**792.78**

Blue text: Estimated values

Sources: FAA General Aviation and Part 135 Activity Surveys – CY 2007 Table 1.5
US Bureau of Transport Statistics System Revenue Aircraft Hours (Airborne) (Jan 1996 - Dec 2007)
CAP 701, 763, 780 CAA Aviation Safety Review 1990 -1999, 2005, 2008

Appendix F: Accident Data

Date	Location	Aircraft	Altitude (ft)	Indicated Airpeed (Knots - KIAS)	Bird Species as Reported	Est Mass (Kg)	Data Source	Category	Est Impact KE	KE Ratio	Synopsis
1981	Australia	Callair A9		70	Black Kite	0.78	1	CS-23	506		While glider towing, a Black Kite became lodged between the strut and the left wing top surface causing loss of aileron control. The aircraft was forced into a turn, descending into woodland where it was destroyed by fire.
Mar 1963	Bakersfield, USA	Beech 35 Bonanza		130	Common Loon	3.7	1	CS-23	8,274		Collision with a Common Loon (3.7kg) removed the tailplane. Note does not appear in NTSB database.
15-Aug-62	Lahore, Pakistan	Douglas DC3	8,000	130	"Vulture"	5	1	CS-25 (Prop)	15,046	6.64	Indian Airlines flight was in the cruise between Kabul and Amritsar when the crew spotted a vulture (up to 10 Kg) above and to one side. The co-pilot was killed when it "attacked" the aircraft and

Date	Location	Aircraft	Altitude (ft)	Indicated Airpeed (Knots - KIAS)	Bird Species as Reported	Est Mass (Kg)	Data Source	Category	Est Impact KE	KE Ratio	Synopsis
											penetrated the windshield.
23-Nov-62	Maryland, USA	Vickers Viscount	6,000	282	Whistling Swan	6	1	CS-25 (Prop)	79,201	4.61	Loss of control after separation of left horizontal stabilizer due to collision wit two whistling swans. Aircraft was in the cruise at 6,000ft.
01-Feb-64	Belfast, UK	D31 Turbulent	5,000	81	Gull		1	CS-23			Single seat open-cockpit aircraft spun into the ground after windshield strike by a gull.
16-Apr-72	Atlantic City, USA	Mitsubishi MU2		260	"Geese"	1	1	CS-23 (Commuter)	8,945	3.79	Evidence that geese hit windshield, possibly incapacitating one or both pilots. Fog bank along shore..
26-Jul-78	St Elena, Guatemala	DC3	0	0			1	CS-25 (Prop)			Aircraft was taking off when it hit a flock of birds. Forced landing attempted but aicraft overran the runway, ending in a swamp.
02-Mar-81	Vancouver, Canada	Bell 206 Jetranger		150	Raven	1.2	1	CS-27	3,573		At least one Raven struck the plexiglass windshield and probably entered the cockpit.

Date	Location	Aircraft	Altitude (ft)	Indicated Airpeed (Knots - KIAS)	Bird Species as Reported	Est Mass (Kg)	Data Source	Category	Est Impact KE	KE Ratio	Synopsis
07-Apr-81	Cincinnati, USA	Lear 23	3,800	184	Common Loon	3.7	1	CS-23	19,108		Common loon struck co-pilot's windshield at 3,800ft msl. Copilot killed, pilot seriously injured, engine 2 damaged by windshield debris and shut down.
06-Aug-81	Musiars, Kenya	Cessna 402		140	Ruppel's Griffon Vulture	7.5	1	CS-23	19,452		Vulture penetrated the windshiled, killing the pilot
11-Jul-83	Texas USA	Boeing Stearman	50	75			1	CS-23			The pilot stated that before flying under wires a bird struck and broke a plastic fuel gauge mounted under the upper wing. Fuel sprayed onto the windshield and the pilot's face restricting his visibility. In an effort to miss the power lines the aircraft was flown into trees.
21-Jul-84	Seboomook, USA	Piper PA18	50	100	Cormorant	2.4	1	CS-23	3,182		The aircraft was on final for a water landing at approximately 50 feet when a bird hit the windshield according to the pilot's statement. A dark object (thought to be a cormorant, since several were seen in the area before & after the

Date	Location	Aircraft	Altitude (ft)	Indicated Airpeed (Knots - KIAS)	Bird Species as Reported	Est Mass (Kg)	Data Source	Category	Est Impact KE	KE Ratio	Synopsis
											accident) was seen floating away from the aircraft wreckage. There was a large hole in the windshield and cuts of the pilot's face.
30-Aug-84	Minnesota, USA	Boeing Stearman	15	55	Red-tailed Hawk	1.1	1	CS-23	441		Aircraft struck a bird (believed to be a Red Tailed Hawk) during spray run. The impact broke the canopy, distracting the pilot, resulting in crash. Aircraft overturned, killing the pilot.
21-Jan-85	Honolulu, USA	Hughes 369	400	130			1	CS-27			While flying over water at about 400 ft agl, the pilot saw a large flock of white birds. He reported that he flared to a stop, but was unable to avoid the birds. After the helicopter struck bird(s), an extreme vibration developed. The helicopter touched down on the water, rolled over & sank, but the pilot escaped & swam to shore without injury.

Date	Location	Aircraft	Altitude (ft)	Indicated Airpeed (Knots - KIAS)	Bird Species as Reported	Est Mass (Kg)	Data Source	Category	Est Impact KE	KE Ratio	Synopsis
24-Nov-87	Cape Liptrap, Australia	Osprey Homebuild	20	70			1	CS-23			At 70 kts, shortly after take-off, the windsield was shattered by a bird. The aircraft caught fire on landing and was destryed. Bird believed to have damaged a fuel line.
11-Feb-88	New York, USA	Cessna 172		90	N/K		1	CS-23			Shortly after take off the pilot transmitted that he had struck some birds and could not maintain control of the aircraft. There as no further transmission as to his location, and the aircraft crashed in the ocean. The only part of the aircraft recovered to date is the head rest. The aircraft crashed about 1 mile offshore.
30-May-90	Louisiana, USA	Schweizer 269	800				1	CS-27			During cruise flight at 800 feet agl the pilot inadvertently flew into a flock of birds. The aircraft developed severe vertical vibrations and the pilot attempted a precautionary landing. During the flare prior to landing the main

Date	Location	Aircraft	Altitude (ft)	Indicated Airpeed (Knots - KIAS)	Bird Species as Reported	Est Mass (Kg)	Data Source	Category	Est Impact KE	KE Ratio	Synopsis
											rotor blade flexed down and struck the tail boom resulting in the aircraft becoming uncontrollable. The aircraft struck the ground in a nose low attitude and rolled on its left side.
26-Dec-91	Musiara, Kenya	Piper PA31	250	100	White-backed Vulture	5.4	1	CS-23	7,217		At 250ft and high speed, the aircraft struck a White-backed Vulture resulting in crash killing the 9 occupants
25-Jan-92	Masai Mara, Kenya	Cessna 401		200	Marabou Stork	5.9	1	CS-23	31,229		A Ruppell's Griffon Vulture holed the windshield killing the pilot
05-Jun-92	Texas, USA	SA.300 Starduster			"Large Black Bird"		1	CS-23			The pilot was viewed by several witnesses manoeuvring at low altitude over open pasture land. The airplane impacted with a large black bird and directional control was lost. The airplane descended out of control and impacted into a field. A post impact fire consumed the airframe. The bird's carcass was located under the cockpit of the inverted airframe.

Date	Location	Aircraft	Altitude (ft)	Indicated Airpeed (Knots - KIAS)	Bird Species as Reported	Est Mass (Kg)	Data Source	Category	Est Impact KE	KE Ratio	Synopsis
13-Oct-92	Kiev, Russia	Antonov 124	19,700	330	Not identified, but weight estimated 1.8Kg	1.8	2	CS-25 (Jet)	50,405		At about 19,700 ft in a high-speed descent (estimated at 330 kts), a bird (about 1.8Kg) was struck, holing the nose. Ram air pressure caused further structural damage resulting in fatal crash and loss of this prototype aircraft.
29-Jan-93	Vancouver, Canada	Bell 47	15	45	N/K	-	1	CS-27	-		Flying at 15 ft and 45 kts when a bird entered via the door opening. Pilot struck on right temple, aircraft crashed in the sea.
24-Mar-93	USA	Bell 47	100	60			1	CS-27			During cruise the pilot heard a loud bang and felt a vibration in the rudder pedals; then all yaw control was lost. The pilot thought the tail rotor struck a large sea bird as many birds were in the area. One passenger leapt from the aircraft and was killed. The pilot subsequently made a running landing on the water, and was rescued. The t/r blades exhibited impact damage.

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Date	Location	Aircraft	Altitude (ft)	Indicated Airpeed (Knots - KIAS)	Bird Species as Reported	Est Mass (Kg)	Data Source	Category	Est Impact KE	KE Ratio	Synopsis
24-Feb-94	Lake Ontario, Canada	Piper PA28		120			1	CS-23			Pilot reported a windshield penetration (assumed to be a bird) and that he could hardly see. The aircraft is presumed lost at sea.
15-Jul-94	Florida, USA	Cessna 172	200	110	Pelican	7	1	CS-23	11,298		The airplane was observed to be flying about 200 ft above the water along the beach. A bystander videotaped the airplane as what appeared to be a large bird collided with the airplane in the windshield area. The airplane rolled inverted and impacted the water. The videotape shows numerous pelicans in flight prior to the impact. The pilot's facial injuries were consistent with a windshield shattering.
18-Oct-94	Indiana, USA	Beech B58		130	Goose	1.5	1	CS-23	3,354		The airplane was departing runway 23, and had just reached flying speed when the pilot saw a flock of geese approaching from his right. The geese struck the airplane, breaking the windshield and hitting the

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											pilot. The pilot said he cut power to the engines and landed off the end of the runway.
22-Oct-95	Bole, Ethiopia	DHC-6 Twin Otter	5,000	154	White Backed Vulture	5.8	1	CS-23	22,024		While in the cruise, the aircraft struck a White-backed vulture causing both windshileds to colapse into the cockpit. The aircraft was destroyed during off runway landing.
04-Apr-96	Ushhuaia, Argentina	SA227	0	120			1	CS-23 (Commuter)			While landing, the aircraft was struck by several large birds, one breaking the windshield, others striking an engine. Control was lost and the aircraft departed the runway, being damaged beyond repair.
18-Jul-96	Pamplona, Spain	Robin DR380	2,800	61	Griffon Vulture	8	2	CS-23	4,393		10 minutes after take-off the aircraft crashed in woods after apparently striking a vulture

Date	Location	Aircraft	Altitude (ft)	Indicated Airpeed (Knots - KIAS)	Bird Species as Reported	Est Mass (Kg)	Data Source	Category	Est Impact KE	KE Ratio	Synopsis
04-Sep-97	Hectorspruit, South Africa	Beech B95 Travel Air	1,250	170	White Backed Vulture	5.8	2	CS-23	23,303		While flying from Komatipoort to Nelspruit at low level beneath cloud at about 1,000 to 1,500 ft agl and 170 kts, the aircraft collided with a vulture, believed to be a white-backed (Gyps africanus, wt 5.8kg). It penetrated the windshield, the aircraft crashed killing both occupants. First at the scene was a local pilot who reported there were many vultures in the vicinity.
04-Mar-98	New Jersey, USA	Piper PA23	1,500	146			1	CS-23			The aircraft was cruising at about 1,500 feet AGL, when a witness saw the vertical stabilizer start to oscillate and then separate from the airplane. An impact mark on the left outboard leading edge of the horizontal stabilizer was consistent with a soft bodied impact prior to ground impact. Although one witness reported seeing several birds flying in the area at the time of the accident,

Date	Location	Aircraft	Altitude (ft)	Indicated Airpeed (Knots - KIAS)	Bird Species as Reported	Est Mass (Kg)	Data Source	Category	Est Impact KE	KE Ratio	Synopsis
											examination failed to find any evidence of bird remains. No evidence was found to indicate that any of the attach points were unsecured prior to the accident.
27-Jan-00	Panama City, Panama	Bell 407 Longranger	1,500	90	Black Vulture	1.7	1	CS-27	1,933		At about 1500 ft and 90 kts, a black vulture pebetrated the windshield, knocking the pilot unconscious.
19-Mar-00	California, USA	Bell 212	500	100			1	CS-27			The helicopter was the second in a flight of two and trailed the lead helicopter by a short distance. The lead pilot noticed the second helicopter wreckage after the pilot did not receive a radio response from the accident pilot; he reported receiving no distress transmissions from the accident pilot. The first helicopter pilot reported they were in cruise flight between

Date	Location	Aircraft	Altitude (ft)	Indicated Airpeed (Knots - KIAS)	Bird Species as Reported	Est Mass (Kg)	Data Source	Category	Est Impact KE	KE Ratio	Synopsis
											400 - 500 feet agl at 100 knots. He said that he encountered a large bird about 1 mile before the accident.
28-May-00	Montana, USA	Cessna 310R	600	107	Geese		2	CS-23			At about 600 ft agl shortly after taking off the aircraft collided with a number of geese. The pilot heard 3 or 4 loud bangs just before the windshield shattered. The aircraft subsequently collided with the ground and was destroyed by fire. The pilot was unable to recall any other details.
04-Feb-02	Priaia, Mozambique	Piper PA28		70	Vulture	5	1	CS-23	3,242		On final approach, the aircraft struck a vulture. The bird penetrated the windshield, beaking the pilots neck.

Date	Location	Aircraft	Altitude (ft)	Indicated Airpeed (Knots - KIAS)	Bird Species as Reported	Est Mass (Kg)	Data Source	Category	Est Impact KE	KE Ratio	Synopsis
03-May-03	Alabama, USA	Cessna 150G	4,500	107	Geese		3	CS-23			During cruise flight at 4.500 feet amsl, the airplane collided with a flock of geese and began to vibrate violently. Whilst attempting an emergecy landing, the landing gear and left wing clipped trees. The airplane came to rest on the ground about 30 feet beyond the trees, inverted.
08-Jul-03	Texas, USA	Cessna 172	800	116	Vulture	1.7	2	CS-23	3,125		The pilot (CFI) made a distress call stating they had hit a bird and were going down. A witness reported seeing the airplane fly over erratically at 500 to 1,000 feet agl. Witness marks at the accident site and airplane crush angles were consistent with the airplane stalling prior to impacting the ground.
28-Oct-03	French Guayana	AS360 Ecuriel					2	CS-27			The Heli Inter Guayana helicopter was flying low over the jungle when it suffered a bird strike. The bird enterd the cabin through the left hand windshield

Date	Location	Aircraft	Altitude (ft)	Indicated Airpeed (Knots - KIAS)	Bird Species as Reported	Est Mass (Kg)	Data Source	Category	Est Impact KE	KE Ratio	Synopsis
											resulting in the left rear door opening. A passenger fell from the helicopter and was killed.
28-Nov-04	Schiphol, Netherlands	B 737-400	0	150	Buzzard	0.8	2	CS-25 (Jet)	2,382	0.09	Bird strike occured shortly after take off from Schipol. On landing at Barcelona the pilots were unable to keep the aircraft on the runway by use of rudder, differential reverse or nose wheel steering. The aircraft left the runway at about 100 kts into an area of work-in-progress. The bird remains were found in the nose gear jamming the steering cables to one side.
30-Dec-05	Los Angeles, USA	Bell 206 Jetranger	500	104	Large Buzzard	2	5	CS-27	2,920	N/A	At approximately 500 feet MSL and 120 mph, a large buzzard collided with the right windshield and struck the pilot's face. leaving him temporarily blinded.The pilot elected to execute a emergency landing. During the descent, the pilot was forced to use both hands and was unable to clear his

Date	Location	Aircraft	Altitude (ft)	Indicated Airpeed (Knots - KIAS)	Bird Species as Reported	Est Mass (Kg)	Data Source	Category	Est Impact KE	KE Ratio	Synopsis
											vision. The pilot lost sight of the ground and the helicopter impacted on the aft portion of the left landing skid and rolled over .
26-Sep-06	Botswana	Cessna 206	2,500	142	White Backed Vulture	5.8	3	CS-23	17,062		The aircraft was flying at 2,500 ft agl over the Okavango nature reserve when a vulture smashed through the pilot's windshield destroying some of the instruments panel and becoming entangled in the flight controls. The pilot managed to shove the bird aside and regain control but the excessive drag from the holed windshield prevented the aircraft from maintaining height. The pilot force landed in a swamp
02-Oct-06	Pinheiros, Brazil	Piper PA32		109	Black Vulture	1.7	3	CS-23	2,673		As the aircraft was approaching to land after an air taxi flight transporting money for the Brazil Central bank from dense forest 100 metres from the airfield

Date	Location	Aircraft	Altitude (ft)	Indicated Airpeed (Knots - KIAS)	Bird Species as Reported	Est Mass (Kg)	Data Source	Category	Est Impact KE	KE Ratio	Synopsis
											killing the 3 occupants. The airfield is near a garbage dump and it is common to have birds swarming around.
27-Jan-07	Orlando, USA	Cessna 172	1,300	90	Vulture	10	4	CS-23	11,283		The pilot stated that after exiting class C airspace, as he initiated a climb, a turkey buzzard impacted the airplane's right wing causing damage. The damage caused the airplane to turn to the right and severely limited his ability to control the airplane. During the forced landing the nose wheel dug into the ground and separated.
04-Feb-07	Nadergul, India	Cessna 152		74	Eagle		3	CS-23	0		Whilst returning to the airfield an ‘eagle’ struck the windshield smashing it and causing the aircraft to ‘spin out of control’. The aircraft crash landed in a field, the student suffering a deep cut on her forehead. The aircraft was very badly damaged in the forced landing.

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Date	Location	Aircraft	Altitude (ft)	Indicated Airpeed (Knots - KIAS)	Bird Species as Reported	Est Mass (Kg)	Data Source	Category	Est Impact KE	KE Ratio	Synopsis
20-Jul-07	California, USA	Cessna 150	1,000	85	"Large Hawk"	1.1	5, 3	CS-23	1,094		Shortly after take off on a student training flight a ‘hawk’ came through the windshield causing minor injuries. The drag prevented the aircraft from maintaining level flight resulting in a forced landing in a field. The aircraft overturned in the soft ground and was damaged such as to be a write off.
23-Oct-07	Minn. USA	Piper PA44		155	Canada Goose	3.6	3	CS-23	11,445		The aircraft was on a routine late evening night training flight when according to stored memory on cockpit devices (GPS?) it went out of control and crashed. The Preliminary NTSB Report states it was likely to have been struck by two or more Canada Geese. There was a large dent on the left wing along with Canada Goose DNA and another on the tail section which when peeled back revealed goose remains.

COMMERCIAL-IN-CONFIDENCE

Date	Location	Aircraft	Altitude (ft)	Indicated Airpeed (Knots - KIAS)	Bird Species as Reported	Est Mass (Kg)	Data Source	Category	Est Impact KE	KE Ratio	Synopsis
04-Mar-08	Oklahoma City, USA	Cessna Citation 500	3,200	200	Pelican	9	4	CS-25 (Jet)	53,930	2.72	The NTSB determines that the probable cause of this accident was airplane wing-structure damage sustained during impact with one or more large birds (American white pelicans), which resulted in a loss of control of the airplane.
02-May-08	California, USA	Vans RV-7A	50	90	Canada Goose	3.6	3	CS-23	3,866		During takeoff initial climb, a large bird impacted the leading edge of the left wing slightly outboard of the fuel tank. The airplane immediately yawed and banked to left. The left wing struck the ground and the airplane cart wheeled. Examination revealed structural damage to the outboard sections of both wings and empennage, and large dead goose was found in the debris.
11-Sep-08	Western Cape, South Africa	Air Tractor AT-502B		116	Blue Crane	4	3	CS-23	7,122		During an agricultural spraying operation a Blue Crane (Anthropoides paradisea wt. 4 kg) struck the windshieldand

Date	Location	Aircraft	Altitude (ft)	Indicated Airpeed (Knots - KIAS)	Bird Species as Reported	Est Mass (Kg)	Data Source	Category	Est Impact KE	KE Ratio	Synopsis
											apparently incapacitated the pilot as feathers were found in the cockpit. The aircraft flew into the ground, bounced and overturned.
04-Jan-09	Lousiana, USA	S76++	700	138	Red Tailed Hawk	1.1	4	CS-29	2,850	1.05	Flight data recorder data indicates that the helicopter was cruising at 138 knots at about 700 feet agl. The cockpit voice recorder indicates a loud noise followed by a substantial increase in the background noise level . About one second after the loud noise, the torque of both engines dropped simultaneously to near zero. A visual examination did not detect any evidence of bird strike, but a swab taken from the pilot-side windshield from showed that microscopic remains of a hawk variety DNA were present. The swab was taken from an area of the windshield that exhibited concentric ring fractures

Date	Location	Aircraft	Altitude (ft)	Indicated Airpeed (Knots - KIAS)	Bird Species as Reported	Est Mass (Kg)	Data Source	Category	Est Impact KE	KE Ratio	Synopsis
01-Feb-09	Los Angeles, USA	Schweizer G-164B	20	70	Cormorant	2.4	5	CS-23	1,557		While on short final, the bi-wing airplane impacted a flock of birds. Bird residue penetrated the windshield and impacted the pilot in the face. Temporarily blinded, the pilot attempted a go-around manoeuvre, but the airplane impacted the runway, nosed over, and came to rest in an inverted position. The airplane's fuselage sustained structural damage during the accident.

:Outside scope of bird strike data.

Refs

1 Fatalities and Destroyed Civil Aircraft due to Bird Strikes, 1912 to 2002 John Thorpe IBSC26/WP-SA1 Warsaw 5-9 May 2003

2 Fatalities and Destroyed Civil Aircraft due to Bird Strikes, 2002 to 2004 John Thorpe IBSC27/WP-II3 Athens 23-27 May 2005 Revised July 2005

3 Fatalities and Destroyed Civil Aircraft due to Bird Strikes, 2006 to 2008 John Thorpe IBSC28/WP Brasilia 24-28 November 2008

4 Accident Synopses by month, NTSB Website - www.ntsb.gov/ntsb/Month.asp

5 Bird Strike Committee - USA Significant Bird and Other Wildlife Strikes

6 AAIB Website

Appendix G: Serious Incident Data

G1 General

G1.1 These serious incident data have been extracted from the UK Mandatory Occurrence Reports [26.] and US Significant Bird Strikes [27.] reports. A serious incident is defined (for the purpose of this report) as one that could have led to an accident. i.e. an accident was prevented by an external event such as good airmanship or good fortune.

DATE	Aircraft	Assigned Altitude (ft)	TAS (Kts)	Bird Species	Synopsis
04/09/1981	Fokker F28	8000	348	N/K	AT 8000FT & APPROX 300KTS THE A/C COLLIDED WITH A 1.5KG OSPREY WHICH PENETRATED THE FUSELAGE ABOVE THE RH FRONT WINDSCREEN, DAMAGING THE FLIGHT DECK CEILING & SOME WIRING LOOMS. CONTROL OF THE A/C WAS RETAINED & A SAFE LANDING MADE. (SWEDISH BOARD OF ACCIDENT INVESTIGATION REPORT 22/81).
12/09/1982	B707	400	161	STORK	STRIKE OCCURRED AT 400FT, 160KTS. LH WINDSCREEN OBSCURED BYBLOOD. A/C RETURNED. RADOME SEVERELY HOLED & ILS GLIDESLOPE AERIAL BROKEN. (NOTE: SOME STORKS WEIGH UP TO 7KG).
30/01/1984	Concorde	<2000	N/K	N/K	AFTER GEAR RETRACT GREEN CONTENTS FELL TO ZERO. FUEL DUMPED, A/C RETURNED. AFTER LANDING YELLOW FELL TO FIRST LOW LEVEL. BIRD, BELIEVED TO BE SEAGULL, ENTERED MLG BAY DURING 15 SECS DOORS ARE OPEN FOR RETRACTION, PUNCTURED STRUCTURAL DIAPHRAGM & DAMAGED HYDRAULIC LINES. CAA CLOSURE: GREEN HYD SYS LOSS DUE TO SEVERENCE OF PIPE TO RH LG DOOR. YELLOW HYD SYS LOSS DUE TO SEVERENCE OF BRAKE PRESS SUPPLY PIPE. TYRE DEBRIS GUARD INTRODUCED AS PART OF MAND MOD TO IMPROVE HYD SYS INTEGRITY. ALTHOUGH NOT ADEQUATE, IN THIS INSTANCE, TOTAL HYD SYS SEGREGATION OR PROTECTION IS IMPRACTICAL. NO FURTHER CAA ACTION POSSIBLE. HOWEVER, BLUE SYS NOT COMPROMISED ON THIS OCCASION SINCE BLUE PIPES ARE NOT ROUTED THROUGH LANDING GEAR BAYS.

COMMERCIAL-IN-CONFIDENCE

DATE	Aircraft	Assigned Altitude (ft)	TAS (Kts)	Bird Species	Synopsis
11/02/1984	B707	2500	168	N/K	AT 2500FT IN CLIMB ACCELERATING TO 250KTS LARGE BIRD STRUCK WING L/E. HOLE 18IN BY 12IN VISIBLE FROM CABIN. FLIGHT CONTINUED TO DOHA AT 250KTS AND 16000FT. NR2 GENERATOR ALSO TRIPPED. TEMPORARY REPAIR FOR FERRY TO LHR WITH NR2 GEN INOP. SLIGHT NICK ON NR2 ENG THREE PHASE CABLE.
01/06/1984	DHC6	500	96	Gull	AT 95KTS 500FT TWO TO THREE GULLS APPEARED IN FRONT OF A/C.ONE GREAT BLACK BACKED GULL (WEIGHT 1.7KG) STRUCK.STRUCTURE DEFORMED,DE ICE BOOT HAD TO BE RENEWED. CAA CLOSURE.NO FURTHER ACTION NECESSARY.
29/09/1984	B727	11000	342	BLUE CRANE	A/C STRUCK BLUE CRANE AT 280KIAS. REMAINS PENETRATED TO THE FLIGHT DECK DOOR AFTER PASSING THROUGH THE PRESSURE BULKHEAD & INSTRUMENT PANEL. A/C RETURNED. AVERAGE WEIGHT OF BLUE CRANE IS 3.5KG.
17/02/1985	B737	0	N/K	PARTRIDGE	BIRDSTRIKE DAMAGED AIR/GROUND SENSOR ON RH MAIN GEAR. WHILE CLEARING RUNWAY THERE WERE LARGE PRESSURISATION SURGES.FOUND SENSOR BRACKET DAMAGED.SENSOR AFFECTS REVERSER SYSTEM,ANTI-ICE,GEAR RETRACTION,T/O WARNING SYSTEM AND SPOILERS.BIRD WAS PARTRIDGE WEIGHING 400 GM. CAA CLOSURE-NO FURTHER CAA ACTION REQUIRED.
29/03/1986	PA23	20	85	PIGEON	FLOCK OF PIGEONS DAMAGED WING LEADING EDGE AND BRAKE HOSE ON RH GEAR. AT ABOUT 20FT AND 85KTS.BIRDS ALSO STRUCK NOSE,WINDSCREEN AND FUSELAGE.
07/04/1986	B747	2000	312	CUCKOO	RADOME SCANNER AND FRONT PRESSURE BULKHEAD DAMAGED BY CUCKOO. INTERMITTENT PICTURE ON BOTH RADAR SYSTEMS ON DESCENT AND APPROACH.BIRD REMAINS IDENTIFIED AS CUCKOO FROM MIDDLE EAST.
24/07/1986	CESSNA 152	100	74	N/K	BIRD STRUCK PROPELLER BOUNCED OFF AND BADLY DAMAGED WINDSCREEN. AT 100 FT PIGEON CAUSED ABOUT 2 SQ FT OF WINDSCREEN TO ALMOST SEPARATE.
30/06/1987	BELL 212	100	45	Gannet	GANNET PENETRATED TOP RH CORNER OF CAPT's WINDSHIELD. MINOR INJ. THE BIRD WAS SEEN APPROX 100YDS AHEAD. AVOIDING ACTION ATTEMPTED. PILOTS WIND SHIELD WAS TOTALLY STARRED. CO-PILOT LANDED THE A/C. CREWMAN IN REAR SUFFERED SMALL GLASS PARTICLES IN THE EYE BUT NO PERMANENT INJURY
10/08/1989	A320	2500	263	BENGAL VULTURE	ENGINE LOSS DUE SHOCK EFFECT ON RELAY BY BIRD STRIKE AT TOP OF P1 WINDSCREEN. INFORMATION ON 4 OF THE 6 CRT SCREENS WAS LOST.BIRD WAS IDENTIFIED AS A 5.5KG BENGAL VULTURE. COLLISION OCCURRED AT 2500FT AND 250 KTS.INVESTIGATION SHOWED THAT THE ENGINE SHUTDOWN PUSH-BUTTON SWITCHES COULD BE MOVED TO A STABLE (BUT UNLOCKED) INTERMEDIATE POSITION DURING MAINTENANCE FOR EXAMPLE WHERE RELATIVELY SLIGHT KNOCKS COULD RESULT IN CLOSURE OF THE LOW PRESSURE FUEL VALVES.
18/04/1990	BAC111	0	140	N/K	ON SELECTING LG UP RH MLG REMAINED LOCKED DOWN.ONE RE-SELECTION FAILED TO CHANGE SITUATION & IT WAS THEN NOTICED THAT NR1 HYDRAULICS CONTENTS WERE FALLING RAPIDLY.LG SELECTED DOWN BY FREE FALL.SUBSEQUENT INVSTGN REVEALED DAMAGE TO HYD PIPES & A/C STRUCTURE.

DATE	Aircraft	Assigned Altitude (ft)	TAS (Kts)	Bird Species	Synopsis
08/04/1993	A310	400	176	N/K	DURING THIS INCIDENT THE 'GREEN' HYDRAULIC SYSTEM FAILED DUE TO LOSS OF FLUID VIA A LOOSE 'B-NUT'. THIS REQUIRED MANUAL EXTENSION OF THE LANDING GEAR & CAUSED A LOSS OF NOSEWHEEL STEERING. ONE FAN BLADE WAS FOUND BROKEN WITH FRAGMENT IMPACTS TO THE REMAINING BLADES, THE FAN CASE & INLET NACELLE
04/10/1994	DO228	N/K	200	N/K	Pan call due bird strike. Damage to windscreen area & electrical systems. Diverted.
22/12/1994	B737	800	234	N/K	Multiple strike at 800ft. Extensive damage. Damage found to nr1 engine intake cowling (top outer lip). Also evidence of nr1 engine bird ingestion. Flap boat fairing dented, delaminated and internal guide rails broken. Radome damaged
29/01/1996	BN2 TRISLANDER	250	131	GANNET	Leading edge of left wing dented & 2ft diameter hole made. Reporter believes bird was Gannet. Occurred at 250ft/130kts.
09/01/1998	B727	6000	297	Snow Geese	A/C climbing through 6000ft whenflock of Snow Geese encountered. 3-5 birds injested. Radome torn from A/C and leading edges of both wings damaged, pitot tube torn off. Intense vibration & & high level of noise in cockpit made communication dificult. Emergency decrlared.
01/09/1998	B767	500	232	Canada Geese (10)	Multiple bird strike on approach to LHR R/W09L. Damage to nose cone, LH engine & flaps/leading edge slats on LH wing. Birds identified as Canada geese, evidence of 10 strikes. Subject to AAIB AARF invstgn.
04/09/1998	BAE 146	2000	161	CORMORANT	At approx 2000ft during climb out, large bird (later identified, from feathers, as cormorant) seen to dive towards a/c. Bird impacted just above RH flight deck window - very loud bang & shudder, then feathers appeared in flight deck & a/c immediately depressurised. Emergency declared & a/c returned for normal landing with emergency vehicles in attendance. During engine shutdown, reporter noted that nrs 1 & 4 fire handles had been displaced by approx 1in due to impact. A/c subsequently flown unpressurised to maintenance base where damaged frame 6A (p/n HC537L0053-000) & cracked LH & RH brackets (p/n HC251H0177-001) on forward face of frame 9 were changed. Additionally, severely cracked fwd canopy intercostal (p/n HC537L0053-000) was replaced with p/n HC537H1275-001. Investigation found that a/c skin at main point of impact was of an early build standard - skin was replaced with new skin (p/n HC537H1274-000 & HC537H1210) of a later standard which offers greater resistance to bird impact.
22/01/2000	BO 105	200	80	Gull	5 to 10 seagulls observed ahead of a/c. Avoiding turn made but one gull struck LH windscreen, shattering the perspex, & entered the cockpit. Pan call. A/c returned & landed safely. Observer in front LH seat received cuts to face.
19/01/2001	Fokker F100	500	253	Canada Geese	Multiple birdstrike (Canada geese) descending through 500ft. Radome severely damaged, both engines ingested birds
02/04/2001	B747	14000	422	N. SHOVELER	Struck a flock of N Shovelers causing dents & 11 punctures. One bird entered cockpit causing depressurisation. Crew had to use oxygen masks. A/C returned sfely to departure airport.
21/02/2002	BE-1900	400	146	Northern pintail	Bird penetrated RH wing and was rapidly leaking fuel. Emergency landing made. Passengers safely de-planed. Bird identified by Smithsonian.
09/03/2002	BAe146	800	122	Wild Turkey	One shattered the wind shield, spraying cockpit with glass fragments & remains. Another hit the fuselage & was injested. 14in x 4in section of fuselage skin damaged below windshield seal.

DATE	Aircraft	Assigned Altitude (ft)	TAS (Kts)	Bird Species	Synopsis
11/04/2002	Cessna 208	2500	147	Horned Grebe	Bird penetrated wind shield, injuring the pilot.
06/06/2002	Cessna 172	1000	102	Turkey Vulture	Vulture smashed through the windshield and the RH side door blew open. The instructor's headset departed through the open door. Bird ended up in the baggage compartment. Both studet and instructor were cut on the face and arms.
26/06/2002	BEAGLE PUP	N/K	N/K	N/K	At 200ft and 80kts at commencement of climb (following a runway flypast inspection), a large bird (either a crow or a rook) flew into the windscreen from the left. The bird shattered the screen adjacent to the clear vision panel and entered the cockpit in front of the pilot. The cockpit was covered in blood and bird remains with some remains hanging on shards of perspex and flapping in the airflow through the hole in the windscreen. After the initial impact, handling was found to be normal, therefore the bird remains on the windscreen were pushed out and a tight circuit was flown, followed by an uneventful landing. No injuries to aircraft occupants but the windscreen was destroyed and perspex shards damaged a handheld GPS unit.
14/10/2002	Dash 8	3000	159	CANADA GOOSE	Pilot tried to avoid a large flock of birds. A/C handled normally and landed without incident. On landing, a bird was found protruding from the wing, with fuel leaking out. Another large hole was found in the harizontal stabiliser.
08/01/2003	Dash 8	1000	204	Duck	Aircraft was transporting a heart patient to Bernes-Jewish Hospital, when a duck crashed through the windshiled ending up in patient's lap. Pilot slightly injured and partially incapacitated.
09/03/2003	PA34 Seneca	800	122	Red-breasted Merganser	Aircraft struck two birds. One penetrated the right windshield, the other shattered the left.
28/04/2003	GAZELLE	300	144	GULL	Aircraft was struck by an adult seagull 10 minutes prior to reaching destination, striking the aircraft on the top RH front perspex windscreen and creating a 2ft x 1ft hole. The pilot, who was unhurt, narrowly missed being showered with perspex and bird remains. Further engineering inspection revealed the outside temperature probe to be bent and feathers on the tailplane stabilisers.
10/06/2003	AEROSTAR 601	1500	129	BLACK VULTURE	Pilot saw bird just prior to ompact. Bird came through the windshield on RH side, injuring the co-pilot. Emergency declared. Windshield wad destroyed anlong with right side of fuselage forward of the window.
22/10/2003	Cessna 152	1000	92	BLACK VULTURE	Windshield knocked out and pilot could not maintain altitude on full throttle. Aircraft hit nose first in a field and came to a stop inverted.
03/11/2003	MUSTANG II	1000	N/K	N/K	Damage to forward fuselage in front of windshield and to RH side instrument panel. Pasenger hit in face and required hospitalisation.
22/01/2004	AW109S	500	136		Osprey crashed into windshield, forcing the pilot to land. Windshield shattered & caused minor injuries to plot, the only person on board. Most of the windshield departed the aircraft and the interior was "quite a mess".
17/04/2005	Bell 407	1000	122	TEAL	Helicoptrer was hit by three ducks. The windshield was shattered and the pilot temporarily blinded by bird remains. Crew helped direct the pilot to a safe landing area.

DATE	Aircraft	Assigned Altitude (ft)	TAS (Kts)	Bird Species	Synopsis
25/05/2005	MD900	400	111	BUZZARD	Kestrel/Buzzard in high hover and camouflaged by the background struck the aircraft as it was flying straight and level at 400ft agl and 110kts. Immediate landing carried out. Perspex chin bubble and nose of aircraft damaged. The bird remains entered the flight deck striking the pilot's legs and cyclic. PAN declared and aircraft landed immediately.
17/08/2005	Cessna 421	2000	162	BLACK VULTURE	Collision ripped the A/C wing, punctured a fuel tank and caused fuel to spray out. Strike also damaged the light/sensor the confirmed landing gear down & locked. Pilot declared an emergency but landed safely.
23/08/2005	MD 520	400	151	COOT	Bird hit LH side windshield injuringthe pilot. Emergency landing made.
30/12/2005	Bell 206B3	500	152	Vulture	Pilot looked up from instrument to see a large vulture crashing in to the windshield. He was temporaily blinded by blood and wind. After regaining control, the pilot tried to land in a bean field nearby, but blood was hampering his vision and the left skid hit the ground first causing the aircraft to tip on its side. Pilot was taken to hospital and had several surgeries to repair face, teeth and eye. Cost of aircraft repairs was $1.5 million.
21/01/2006	Cessna 210	2000	135	BLACK VULTURE	Bird crashed through the windsheild. The instructor was cut by plexiglas on head and face. Aircraft landed safely. Time out fo service was 24 hours. Cost was $3,500
28/02/2006	Cessna 172	2500	95	Ring-billed Gull	While on traffic enforcement detail, the windsheild was shattered by a gull. The pilot was forced to make an emergency landing in a cow pasture. During the landing, the aircraft clipped a fence. Pilot was taken to hospital, treated and released. ID by Smithsonian, Division of Birds from photograph
08/03/2006	CESSNA 172	2500	95	N/K Duck	Birdstrike caused the windshield to implode; the doors blew open, and the plane went into a spin and a spiral. Aircraft recovered at 500ft AGL. Pilot was able to land safely at KTPH. Wings were damaged by the force of the plane in the spin. Aircraft was out of service for 7 months. Costs estimated at $15,700 plus medical bills for cuts and hypothermia which burned the lungs, throat and eyes of one of the passengers. Injuries reported for three people.
16/05/2006	Bell 206B3	3000	159	DUCK	During a patient transfer to Abilene Regional Hospital, we hit a flock of what I believe were ducks. I saw 5-6 medium sized birds just before they hit the windshield. The cockpit instantly became noisy, and debris was strewn about. A large piece of the windshield was in my lap. The arircraft was vibrating. I delcared an emergency and landed at the nearest airport, 10 miles away. The patient was transferred to a land unit for care until another helicopter arrived to finish the flight. We found large amounts of remains in the cowling, cross tubes, flight steps and bent antennas. This was determined to have been damaged by the windsheild. Time out fo service was 1 week. Cost of repairs was estimated at $48,100
26/05/2006	Beech 58 Baron	2500	137	N/K	-
26/05/2006	Beech 55	2500	163	RED TAILED HAWK	The hawk shattered the windshield and hit the pilot in the right eye, knocking is headset and glasses off. The pilot had difficulty seeing, due to swollen right eye and need for glasses in his left eye. Pilot was treated and released from hospital.

DATE	Aircraft	Assigned Altitude (ft)	TAS (Kts)	Bird Species	Synopsis
16/05/2006	Bell 206B3	3000	159	DUCK	Helicopter hit a fllock of ducks. 5 or 6 seen to strike windshield. Cocpit became noisy and stewn with debris. A large piece of winshield laned in the pilots lap. Aircraft vibrating. Emergency landing carried out. Large amounts of bird remains in cowlig, cross tubes, flight steps and bent antennae. Grove, caused by damaged windshield found in main rotor blade.
14/12/2006	HUGHES 369	500	65	RING BILLED GULL	The birdstrike occurred about 6 miles away from Fresno Airport. The Sheriff was in pursuit of a theft in progress when a gull shattered the windshield on the obcerver's side. The observer had minor bruises and was flown to a medical centre. The aircraft was put on a flatbed and taken to the Fresno Airport. The gull was either a ring billed or California, based on photos.
14/03/2006	Homebuild	N/K	N/K	N/K	Pilot reported a birdstrike and intended return to departure aerodrome. Subsequently reported making a forced landing in a field with damage to propeller
02/06/2007	SCHWEIZER 300	800	66	BALD EAGLE	Eagle crashed through the widshieldand strick the chest of a passenger. Passenger lost consciousness and suffered a fractured shoulder and several other injuries.
01/08/2007	CESSNA 180	0	65	CANADA GEESE	The aircraft was substantially damaged when it impacted terrain during an aborted landing attempt. The pilot was lowering the tail wheel when he hit 2 geese. The plane started turning right and the pilot tried to correct using left brake and rudder and right aileron controls. He then added full power to get back in the air. The left wing hit the runway and aircraft flipped over on to its back. NTSB investigated.
25/08/2007	B737	12000	360	MARBLED GODWIT	A loud bang was heard in the cockpit during climb, followed by rushing air as the cabin began to depressurise. The cabin alt horn sounded and oxygen masks were put on as the aircraft decsended to 10,000 feet. After landing at El Paso, two large holes were found; one under the captain's side by his foot and the other in the left horizontal stabiliser. The cockpit on the first officer's side was dented. Blood and feathers were found. No birds were seen in flight. Ground crew said "turkey buzzards" were in area. ID by Smithsonian Division of Birds. Cost of repairs was $144,000. Time out of service was 2 days.
28/08/2007	CRJ700	2300	262	BLACK VULTURE	The pilot declared emergency after a vulture smashed in the front fuselage between the radome and windshield. The strike ripped the skin, broke the avionics door, broke a stringer in half and bent 2 bulkheads. Maintenance made temporary repairs, then aircraft was ferried out for permanent repairs. ID by Smithsonian, Division of Birds. Cost of repairs was $200,000. Time out of service was 2 weeks.
27/09/2007	EC130	600	132	GOLDEN EAGLE	An eagle broke through the pilots windshield, hitting a passenger in the head. The pilot and two passengers were injured with cuts and scratches. Time out of service was three months. Cost was $800,000. NTSB investigated. ID by Smithsonian, Division fo birds.
29/09/2007	B737	3000	307	CANADA GOOSE	Several geese were struck. Windshield shattered, injuring the co-pilot. An emergency landing was made. One bird removed from radome.
07/10/2007	A319	7400		N/K	Birdstrike during descent at 7400ft. Nose cone punctured. Bird penetrated radome and radar.

DATE	Aircraft	Assigned Altitude (ft)	TAS (Kts)	Bird Species	Synopsis
29/10/2007	BO117	1400	139	WOOD DUCK	The aircraft disappeared during a night training flight. The instructor and student pilot did not report any difficulties or anomalies prior to the accident . Wreckage was found 36 hours later, partially submerged upside down in a bog. The NTSB sent part of a wing with some remains inside the Smithsonian. The damage that crippled the aircraft was to the left horizontal stabilator. ID by Smithsonian, Division fo Birds. NTSB investigated. Two fatalities.
04/12/2007	B767	3000	244	SNOW GOOSE	Geese penetrated the radome, damaged the radar and then penetrated the fuselage into the aircraft. The vertical stabilizer was dented. Pilot requested emergency equipment to stand by. ID by Smithsonian.
14/12/2007	B737	100	230	N/K	Loud bang heard from NLG although there was no change to aircraft handling or engine performance, with all indications normal. During taxi, flaps were retracted with the flap gauge indicating 'Up' but with 'LE Flap Transit' light illuminated. The overhead light indications showed 'Flaps 3 in Transit'. Subsequent inspection revealed nr1 engine bird ingestion, nr2 pack intake bird ingestion and the RH wing inner LE flap damaged by bird impact.
12/03/2008	BELL 407	600	132	TURKEY VULTURE	Helicopter hit bird over Biscayne Bay about 6 miles east of MIA. It landed safely at MIA. Pilot was tranported to hospital by Fire and Rescue due to cuts and lacerations to his face caused by the broken windshield. Bird remains entered cockpit. ID by Smithsonian, Division of Birds.
08/04/2008	CL 600	3000	138	WHITE PELICAN	Shortly after departure. The aircraft had multiple, large birdstrikes. One bird penetrated the nose area just below the windsheild and continyed through the forward occkpit bulkhead. Bird remains were sprayed throughout the cockpit. No injuries reported. Both engines ingested at least 1 bird. The #1engine had fan damage ; the #2 engine lost power and had a dented
26/09/2008	CR-22	2500	158	ANHINGA	The bird entered the cockpit, striking the piolet's face. He required stitches. The deice boot on two prop blades received damage. The ledt engine cowl had damaged paint and fibreglass. Id by Smithsonian.
18/11/2008	AS 350	2000	125	CANADE GOOSE	Helicopter was over Hudson River near West Point Military Academy. Report indicates a hole in center left nose area about 21" by14". New canopy was ordered from France. Cost reported as over $91,000. Time out fo service was about 3 months.
17/01/2009	AS 350	1200	123	SNOW GOOSE	Helicopter hit a flock of birds around the Forrest City area and made an emergency landing. The pilot suffered some minor injuries and everyone was shaken up. The crew members were not wearing helmets and were fortunate the pilot's vision remained intact to land teh aircraft. Aircraft was trailered for repairs.
01/02/2009	G-164B Ag Cat	20	90	CORMORANT	While on short final, the bi-wing aircraft hit a flock of birds which penetrated the windscreen and impacted pilot in the face, temporaily blinding the pilot. The pilot attempted a go-around but the aircraft impacted the runway, nosed over and came to rest inverted. The fuselage sustained strutural damage. NTSB investigated. Aircraft was destroyed.
16/02/2009	Cessna 402	600	111	BLACK VULTURE	Pilot had just taken off when he saw a flock of vultures ahead. One smashed through the windshield, hitting the pilot in the face injuring him. Blood splattered all over the cockpit. Firefighters were on hand for the landing. Pilots in the area have reported a growing vulture problem.

DATE	Aircraft	Assigned Altitude (ft)	TAS (Kts)	Bird Species	Synopsis
05/03/2009	AW109	700	142	DUCK	A duck shattered the windshield and entered the cockpit. The pilot received cuts and an eye injury. A trauma patient was on board as they approached the rooftop helipad at Shands Hospital. The bird broke switches and circuit breaksers on the overhead instrument panel before landing on the foot of a crewmember. The aircraft landed at the ShadsCair helipad, rather than the hospital roof. Patient was tranported by ambulance. ID by Smithsonian, Division of Birds based on photo.

Appendix H: Damage Rates to Aircraft Parts

H1 Introduction

H1.1 This appendix presents data showing the percentage of bird strikes to individual parts of the aircraft resulting in damage to that part. The data is presented by aircraft category and by bird mass range for each part.

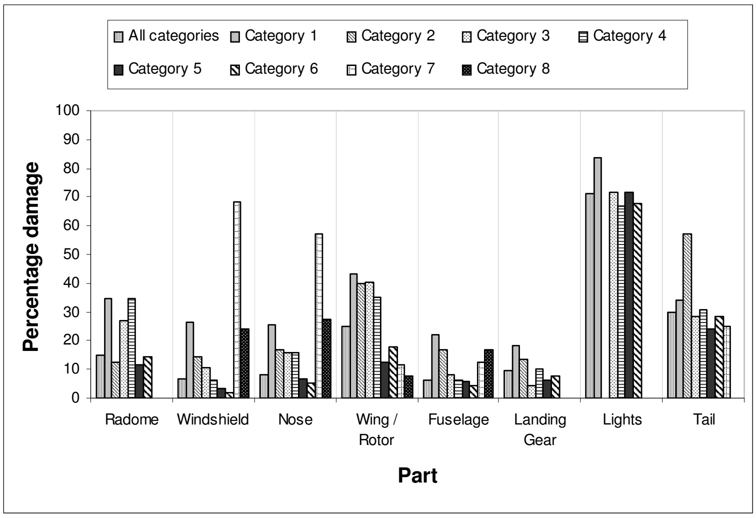
H2 Damage to Aircraft Parts by Aircraft Category

Table H-1 Number of Strikes and Percentage Causing Damage, by Aircraft Part and Aircraft Category

Aircraft Cat.	Radome		Windshield		Nose		Wing / Rotor	
	n	*% Damage*	*n*	*% Damage*	*n*	*% Damage*	*n*	*% Damage*
1	26	34.6	289	26.6	222	25.7	697	43.2
2	8	12.5	14	14.3	12	16.7	35	40.0
3	30	26.7	95	10.5	69	15.9	186	40.3
4	26	34.6	49	6.1	57	15.8	108	35.2
5	156	11.5	309	3.6	301	6.6	341	12.3
6	1564	14.5	1723	1.8	1833	5.4	1523	17.9
7	0		38	68.4	7	57.1	26	11.5
8	1	0.0	29	24.1	11	27.3	90	7.8

Aircraft Cat.	Fuselage		Landing Gear		Lights		Tail	
	n	*% Damage*	*n*	*% Damage*	*n*	*% Damage*	*n*	*% Damage*
1	168	22.0	275	18.5	37	83.8	111	34.2
2	12	16.7	15	13.3	0		7	57.1
3	73	8.2	66	4.5	7	71.4	28	28.6
4	33	6.1	40	10.0	9	66.7	13	30.8
5	304	5.9	211	6.2	21	71.4	46	23.9
6	1454	4.2	983	7.9	108	67.6	166	28.3
7	8	12.5	1	0.0	0		4	25.0
8	18	16.7	4	0.0	1	0.0	6	0.0

Figure H-1 Percentage of strikes causing damage split across aircraft category and part.



H2.1 Note that this data includes incidents where more than one bird was struck, hence a single strike report can be included more than once if more than one part was hit.

H3 The effect of bird weight on the outcome of a bird strike

Table H-2 The percentage damage caused to the radome by bird weight for each aircraft category, with total number of strikes for each category in brackets.

Aircraft Cat.	Weight Range (kg)					
	< 0.1	*< 0.45*	*< 0.9*	*< 1.8*	*< 3.6*	*> 3.6*
1	50.0 (2)	25.0 (12)	0.0 (1)	0.0 (4)	71.4 (7)	
2	0.0 (2)	0.0 (5)			100.0 (1)	
3	22.2 (22)	27.3 (11)	0 (3)	25.0 (4)	66.7 (3)	
4	0 (7)	37.5 (8)	0 (1)	50.0 (6)	66.7 (3)	100.0 (1)
5	0 (48)	6.1 (66)	7.1 (14)	14.3 (14)	80.0 (10)	75.0 (4)
6	3.7(656)	8.7 (552)	31.0 (113)	41.6 (132)	59.2 (98)	53.9 (13)
7						
8				0 (1)		

Figure H-2 Percentage damage to the radome split by bird weight and aircraft category.

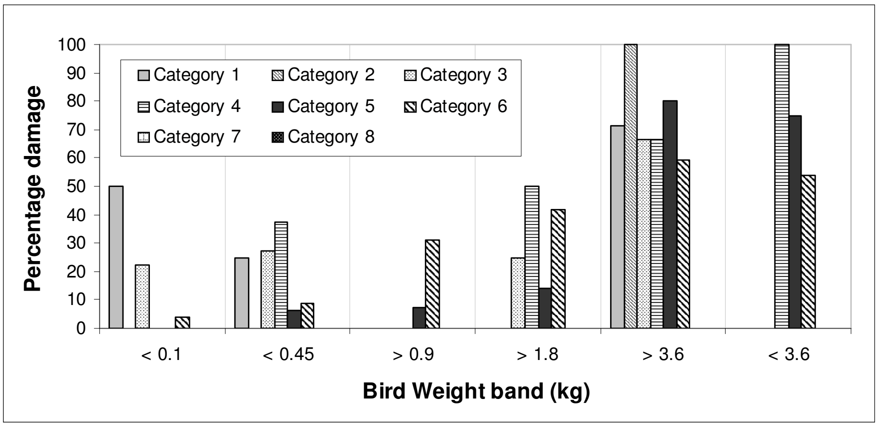


Table H-3 The percentage damage caused to the nose by bird weight for each aircraft category, with total number of strikes for each category in brackets.

Aircraft Cat.	Weight Range (kg)					
	< 0.1	*< 0.45*	*< 0.9*	*< 1.8*	*< 3.6*	*> 3.6*
1	3.0 (66)	9.9 (111)	33.3 (18)	67.3 (49)	55.3 (38)	57.1 (7)
2	0.0 (2)	16.7 (6)	0.0 (2)		25.0 (4)	
3	0 (43)	0 (26)	14.3 (7)	40.0 (10)	62.5 (8)	0 (1)
4	0 (20)	0 (21)	33.3 (3)	50.0 (2)	33.3 (3)	
5	0 (137)	2.7 (112)	11.8 (17)	0 (21)	30.0 (20)	0 (2)
6	0.4 (848)	1.0 (584)	2.1 (97)	3.7 (107)	17.7 (79)	25.0 (8)
7	0 (6)	55.6 (9)	87.5 (8)	100.0 (9)	75.0 (4)	100.0 (2)
8	0 (7)	0 (10)	50.0 (2)	50.0 (6)	100.0 (2)	50.0 (2)

Figure H-3 Percentage damage to the nose split by bird weight and aircraft category.

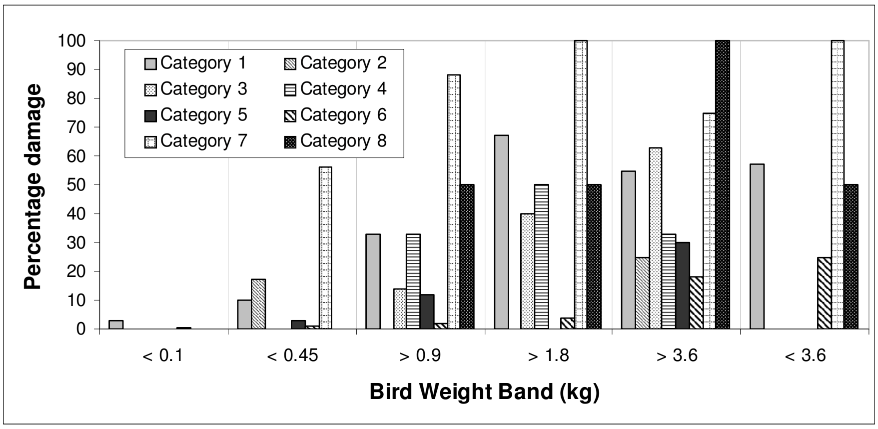


Table H-4 The percentage damage caused to the windshield by bird weight for each aircraft category, with total number of strikes for each category in brackets.

Aircraft Cat.	Weight Range (kg)					
	< 0.1	*< 0.45*	*< 0.9*	*< 1.8*	*< 3.6*	*> 3.6*
1	11.1 (36)	5.1 (78)	23.1 (26)	34.5 (29)	64.3 (42)	54.5 (11)
2	0 (3)	0 (5)		0 (1)	66.7 (3)	
3	0 (20)	0 (19)	0 (6)	60.0 (10)	33.3 (12)	50.0 (2)
4	4.8 (21)	5.3 (19)	0 (1)	22.2 (9)	66.7 (6)	100.0 (1)
5	1.7 (121)	4.1 (121)	13.6 (22)	8.7 (23)	75.0 (8)	33.3 (6)
6	1.0 (797)	2.1 (664)	9.2 (130)	13.2 (136)	45.6 (90)	37.5 (16)
7	0 (1)	100.0 (2)	0 (1)	100.0 (2)	0.0 (1)	
8	0 (3)	0 (4)	50.0 (2)	100.0 (2)		

Figure H-4 Percentage damage by Bird Weight Band & Aircraft Category

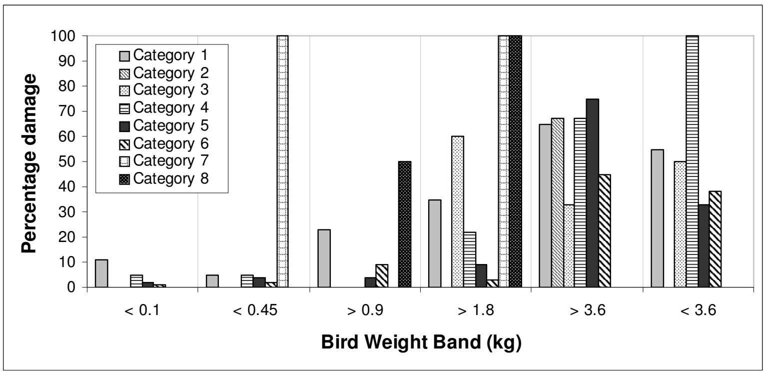


Table H-5 The percentage damage caused to the wing / rotor by bird weight for each aircraft category, with total number of strikes for each category (n) in brackets.

Aircraft Cat.	Weight Range (kg)					
	< 0.1	*< 0.45*	*< 0.9*	*< 1.8*	*< 3.6*	*> 3.6*
1	12.5 (64)	24.5 (257)	36.5 (74)	58.8 (148)	76.3 (131)	69.6 (23)
2	0 (6)	25.0 (16)		50.0 (6)	100.0 (7)	
3	6.9 (29)	17.5 (63)	55.6 (18)	65.6 (32)	71.4 (42)	50.0 (2)
4	11.8 (17)	16.7 (42)	50.0 (4)	61.5 (13)	62.1 (29)	33.3 (3)
5	3.28 (61)	4.1 (146)	3.2 (31)	17.2 (58)	53.8 (39)	33.3 (6)
6	2.6 (426)	6.7 (505)	23.0 (152)	28.0 (211)	59.6 (203)	46.2 (26)
7	0 (4)	0 (13)	0 (3)	50.0 (2)	33.3 (3)	100.0 (1)
8	16.7 (12)	1.8 (55)	18.2 (11)	18.2 (11)		0 (1)

Figure H-5 Percentage damage to the wing/rotor split by bird weight and aircraft category.

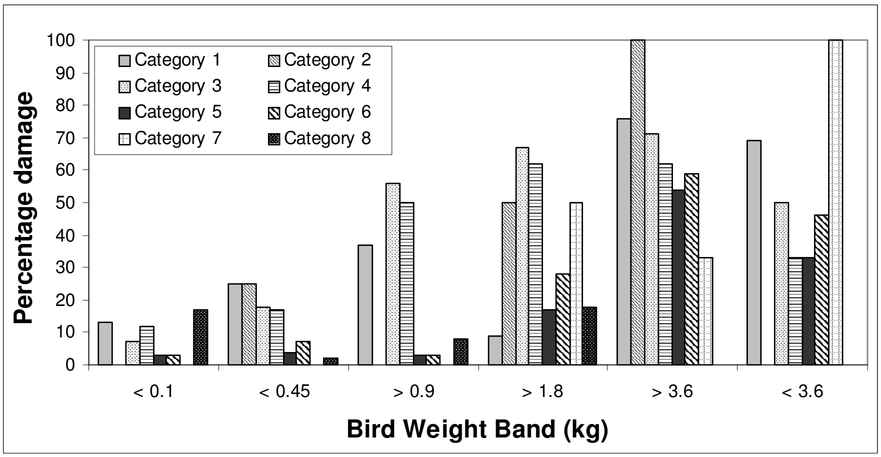


Table H-6 The percentage damage caused to the fuselage by bird weight for each aircraft category, with total number of strikes for each category (n) in brackets.

Aircraft Cat.	Weight Range (kg)					
	< 0.1	*< 0.45*	*< 0.9*	*< 1.8*	*< 3.6*	*> 3.6*
1	0 (15)	7.0 (71)	14.3 (14)	36.0 (25)	44.4 (36)	71.4 (7)
2	0 (3)	0 (6)		0 (1)	100.0 (2)	
3	0 (21)	0 (27)	25.0 (4)	14.3 (7)	30.8 (13)	0 (1)
4	0 (9)	0 (9)	0 (2)	14.3 (7)	16.7 (6)	
5	3.3 (91)	1.6 (126)	4.2 (24)	2.9 (35)	41.7 (24)	25.0 (4)
6	0.7 (571)	1.9 (535)	4.1 (98)	8.9 (146)	29.7 (91)	23.1 (13)
7	0 (1)	0 (5)	50.0 (2)			
8	0 (5)	0 (7)	50.0 (2)	66.7 (3)		0 (1)

Figure H-6 Percentage damage to the fuselage split by bird weight and aircraft category.

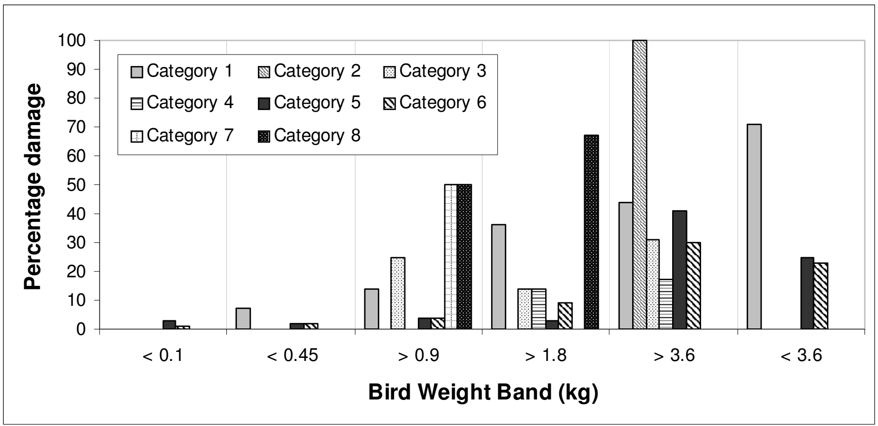


Table H-7 The percentage damage caused to the landing gear by bird weight for each aircraft category, with total number of strikes for each category (n) in brackets.

Aircraft Cat.	Weight Range (kg)					
	< 0.1	*< 0.45*	*< 0.9*	*< 1.8*	*< 3.6*	*> 3.6*
1	5.0 (20)	5.1 (98)	5.0 (40)	24.0 (50)	45.8 (59)	50.0 (8)
2	0 (3)	25.0 (4)	0 (2)	0 (3)	33.3 (3)	
3	16.7 (6)	0 (28)	0 (6)	8.3 (12)	7.7 (13)	0 (1)
4	0 (5)	6.3 (16)	0 (1)	0 (6)	30.0 (10)	0 (2)
5	2.6 (38)	3.1 (98)	0 (27)	7.4 (27)	23.1 (13)	50.0 (8)
6	1.9 (215)	3.9 (385)	10.7 (103)	13.2 (167)	23.5 (98)	20.0 (15)
7				0 (1)		
8		0 (2)		0 (2)		

Figure H-7 Percentage damage to the landing gear split by bird weight and aircraft category.

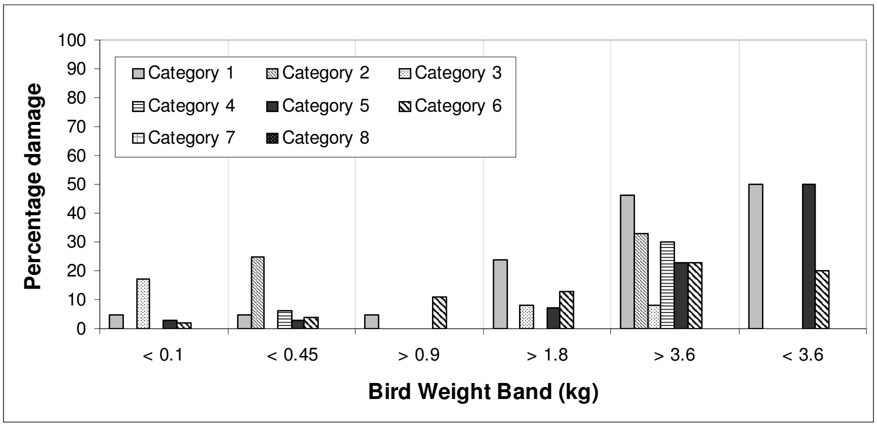


Table H-8 The percentage damage caused to the lights by bird weight for each aircraft category, with total number of strikes for each category (n) in brackets.

Aircraft Cat.	Weight Range (kg)					
	< 0.1	*< 0.45*	*< 0.9*	*< 1.8*	*< 3.6*	*> 3.6*
1	0 (1)	75.0 (8)	40.0 (5)	100.0 (10)	100.0 (11)	100.0 (2)
3	100.0 (1)	50.0 (2)	100.0 (1)		66.7 (3)	
5	50.0 (6)	60.0 (5)	100.0 (4)	80.0 (5)	100.0 (1)	
6	40.7 (27)	75.0 (28)	73.3 (15)	75.0 (20)	83.3 (18)	
8		0 (1)				

Figure H-8 Percentage damage to the lights split by bird weight and aircraft category.

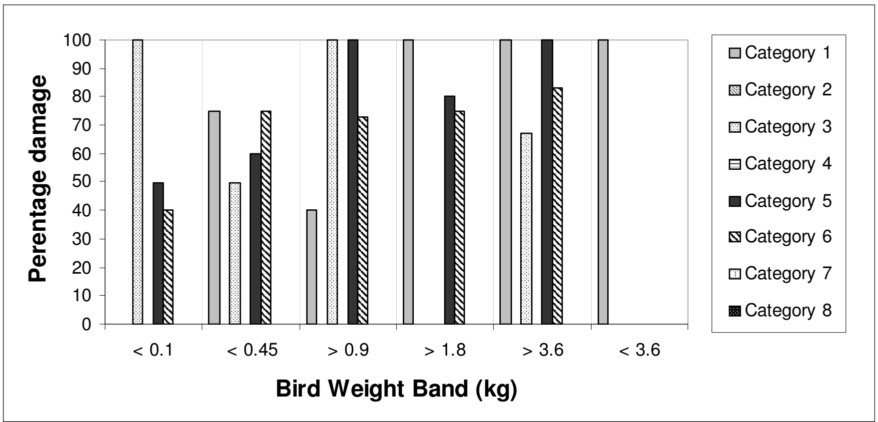
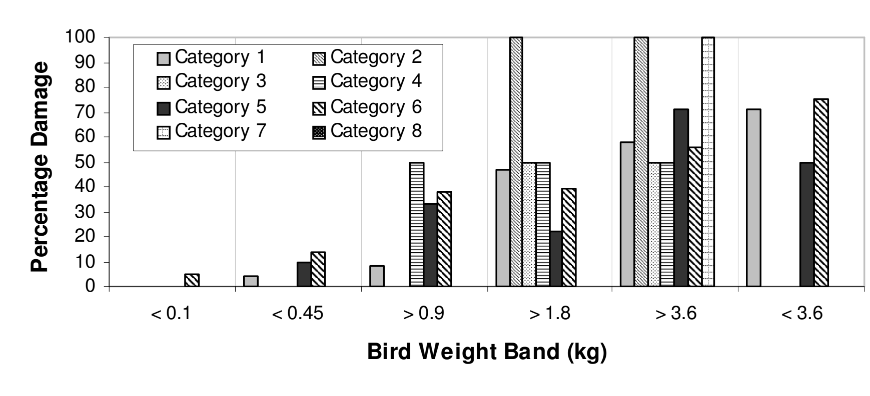


Table H-9 The percentage damage caused to the tail by bird weight for each aircraft category, with total number of strikes for each category (n) in brackets.

Aircraft Cat.	Weight Range (kg)					
	< 0.1	*< 0.45*	*< 0.9*	*< 1.8*	*< 3.6*	*> 3.6*
1	0 (10)	4.0 (25)	8.3 (12)	47.1 (17)	57.5 (40)	71.4 (7)
2	0 (1)	0 (1)	0 (1)	100.0 (2)	100.0 (2)	
3	0 (2)	0 (8)	0 (2)	50.0 (6)	50.0 (10)	
4	0 (1)	0 (4)	50.0 (2)	50.0 (2)	50.0 (4)	
5	0 (5)	10.0 (20)	33.3 (3)	22.2 (9)	71.4 (7)	50.0 (2)
6	4.8 (42)	14.3 (42)	37.5 (16)	39.3 (28)	55.9 (34)	75.0 (4)
7		0 (2)	0 (1)		100.0 (1)	
8	0 (1)	0 (2)	0 (1)	0 (1)	0 (1)	

Figure H-9 Percentage damage to the tail by bird weight and aircraft category .



H4 Kinetic Energy causing damage to aircraft parts for each aircraft category.

Table H-10 The percentage damage caused to the radome by Kinetic Energy (Joules) for each aircraft category, with total number of strikes for each category (n) in brackets.

Aircraft Cat.	Kinetic Energy (Joules) Range							
	<50	*<100*	*<250*	*<500*	*<1000*	*<5000*	*<10000*	*>10000*
1	0 (1)	50 (2)	33.3 (3)	0 (1)	50 (2)	33.3 (6)		100 (2)
2			0 (4)	0 (1)	0 (1)			100 (1)
3		0 (1)	0 (6)		16.7 (6)	40 (5)	0 (1)	
4	0 (1)		0 (6)	0 (1)	50 (2)	71.4 (7)	100 (1)	
5	0 (10)	0 (8)	0 (21)	0 (18)	5.9 (17)	33.3 (18)	50 (4)	83.3 (6)
6	0.9 (107)	1.0 (99)	2.2 (272)	3.7 (161)	15.3 (131)	29.4 (187)	59.2 (49)	64.6 (48)

Figure H-10 Percentage damage to the radome at different kinetic energy bands for all aircraft categories.

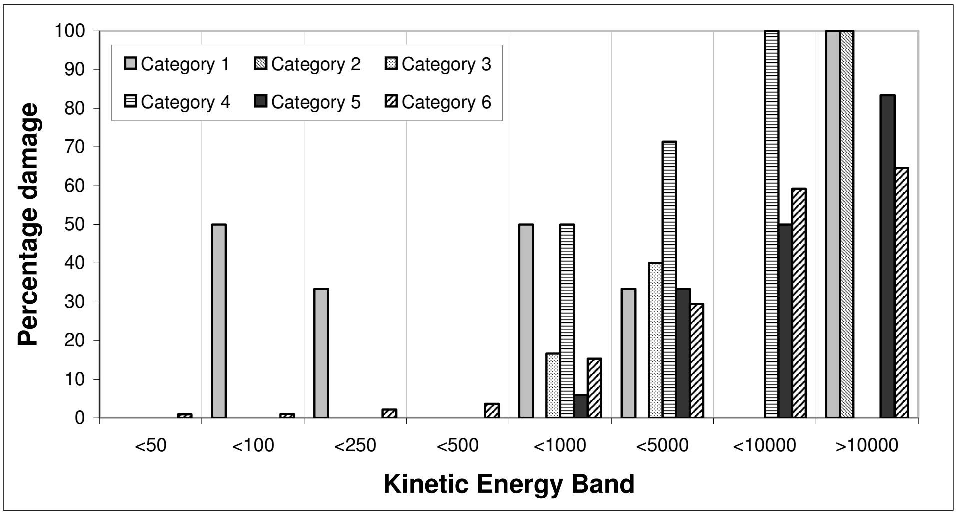


Table H-11 The percentage damage caused to the windshield by Kinetic Energy (Joules) for each aircraft category, with total number of strikes for each category (n) in brackets.

Aircraft Cat.	Kinetic Energy (Joules) Range							
	<50	*<100*	*<250*	*<500*	*<1000*	*<5000*	*<10000*	*>10000*
1	0 (35)	4.8 (21)	8.6 (58)	18.2 (33)	26.3 (19)	65.4 (52)	75 (20)	100 (2)
2			0 (3)	0 (1)	100 (1)	0 (1)	0 (1)	0 (1)
3	0 (5)	0 (4)	0 (23)	0 (6)	0 (8)	45.5 (11)	33.3 (6)	100 (2)
4	0 (2)	0 (2)	0 (13)	0 (3)	0 (3)	50 (4)	50 (2)	0 (1)
5	0 (36)	0 (28)	2.2 (45)	3.1 (32)	6.3 (32)	11.5 (26)	12.5 (8)	37.5 (8)
6	0 (138)	0 (121)	0.6 (330)	1.1 (188)	0 (140)	1.9 (160)	11.4 (35)	27.0 (37)
7	0 (5)	0 (1)	50 (6)	100 (2)	100 (5)	92.3 (13)	100 (2)	
8	0 (11)		0 (3)	0 (1)	0 (3)	50 (4)	100 (2)	

Figure H-11 Percentage damage to the windshield at different kinetic energy bands for all aircraft categories.

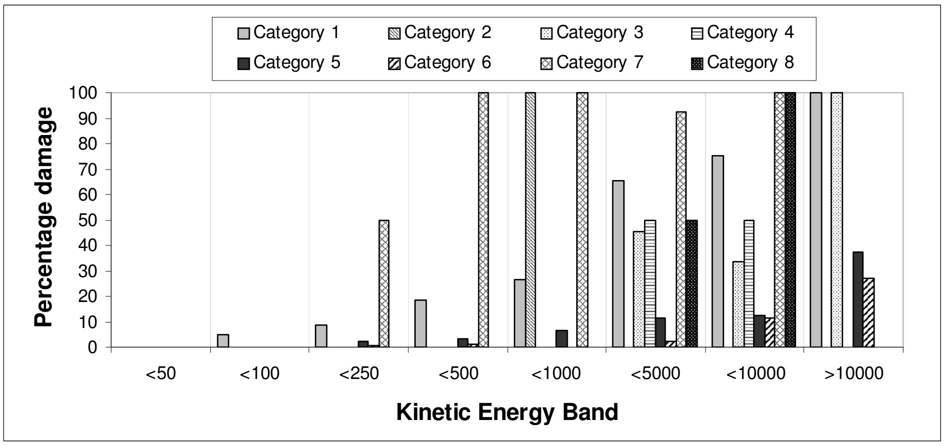


Table H-12 The percentage damage caused to the nose by Kinetic Energy (Joules) for each aircraft category, with total number of strikes for each category in brackets.

Aircraft Cat.	Kinetic Energy (Joules) Range							
	<50	*<100*	*<250*	*<500*	*<1000*	*<5000*	*<10000*	*>10000*
1	0 (15)	13.3 (15)	6.7 (45)	0 (26)	23.8 (21)	54.8 (42)	72.7 (11)	100 (5)
2			0 (4)		0 (2)	0 (1)	100 (1)	50 (2)
3	0 (2)	0 (2)	0 (16)	0 (2)	0 (8)	50 (8)	62.5 (8)	0 (1)
4	0 (3)	0 (3)	7.1 (14)	0 (3)	0 (1)	42.9 (7)	100 (3)	0 (1)
5	0 (25)	0 (20)	1.6 (61)	2.5 (40)	15.2 (33)	4.5 (22)	33.3 (6)	100 (4)
6	0 (120)	0.8 (131)	0.9 (339)	1.1 (176)	6.4 (157)	7.0 (215)	25.7 (35)	59.6 (47)
7	50 (2)				50 (2)	50 (2)		
8	0 (2)		0 (3)	0 (1)	0 (2)	100 (3)		

Figure H-12 Percentage damage to the nose at different kinetic energy bands for all aircraft categories.

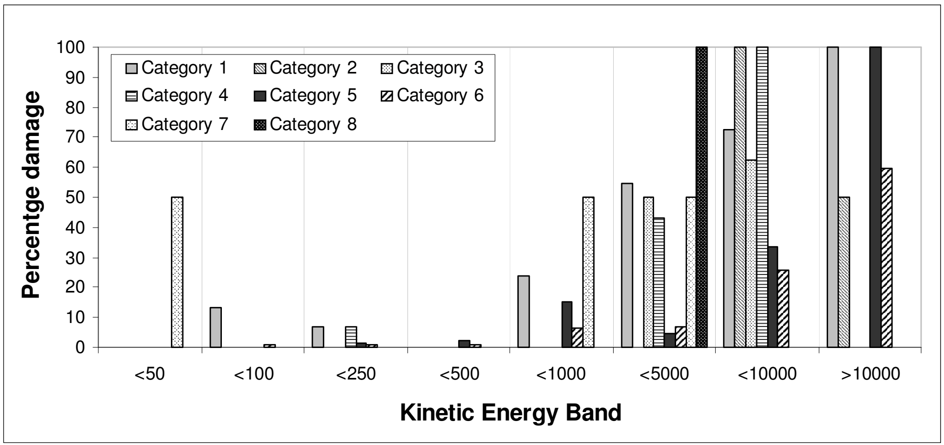


Table H-13 The percentage damage caused to the wing or rotor by Kinetic Energy (Joules) for each aircraft category, with total number of strikes for each category in brackets.

Aircraft Cat.	Kinetic Energy (Joules) Range							
	<50	*<100*	*<250*	*<500*	*<1000*	*<5000*	*<10000*	*>10000*
1	12.5 (32)	19.5 (41)	23.8 (126)	33.7 (86)	45.2 (62)	74.5 (157)	84.6 (26)	72.7 (11)
2	0 (1)	0 (1)	28.6 (7)	25 (4)	100 (1)	100 (4)	100 (3)	100 (1)
3	0 (4)	0 (6)	12 (25)	20 (20)	54.2 (24)	63.2 (38)	85.7 (14)	100 (8)
4		0 (2)	12.5 (32)	33.3 (6)	33.3 (9)	70.6 (17)	46.2 (13)	80 (5)
5	7.1 (14)	0 (14)	6.1 (33)	7.8 (51)	4.8 (42)	20.4 (49)	36.8 (19)	87.5 (8)
6	0 (53)	2.0 (51)	2.4 (168)	2.8 (108)	8.7 (149)	22.5 (204)	55.6 (90)	71.0 (69)
7	0 (13)		0 (2)	0 (1)		25 (4)	100 (1)	
8	5.3 (57)	0 (6)	33.3 (3)	0 (3)	0 (2)	100 (1)	0 (1)	

Figure H-13 Percentage damage to the wing/rotor at different kinetic energy bands for all aircraft categories.

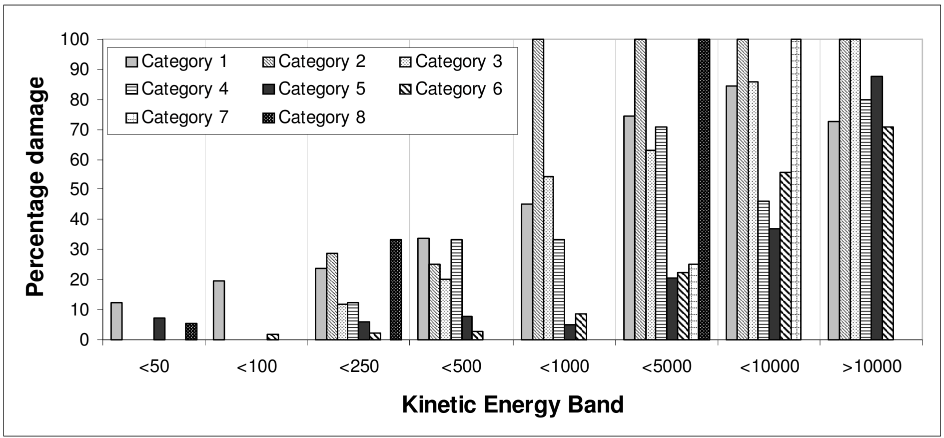


Table H-14 The percentage damage caused to the fuselage by Kinetic Energy (Joules) for each aircraft category, with total number of strikes for each category in brackets.

Aircraft Cat.	Kinetic Energy (Joules) Range							
	<50	*<100*	*<250*	*<500*	*<1000*	*<5000*	*<10000*	*>10000*
1	0 (11)	0 (8)	5.6 (36)	14.3 (14)	27.3 (11)	37.5 (32)	30 (10)	100 (6)
2	0 (1)		0 (5)		0 (2)	100 (1)		100 (1)
3	0 (2)	0 (2)	0 (25)	0 (10)	0 (7)	33.3 (9)	50 (4)	25 (4)
4		0 (3)	0 (7)	0 (2)	0 (1)	20 (5)	50 (2)	0 (1)
5	4 (25)	0 (15)	2 (50)	0 (40)	3.4 (29)	0 (31)	40 (10)	57.1 (7)
6	1.1 (91)	0 (62)	0.9 (231)	0 (124)	0.7 (153)	3.6 (167)	14.3 (42)	46.2 (39)
7	0 (4)		0 (1)	0 (1)	100 (1)	0 (1)		
8	0 (8)	0 (2)	0 (1)	0 (1)	0 (2)	100 (3)	0 (1)	

Figure H-14 Percentage damage to the fuselage at different kinetic energy bands for all aircraft categories.

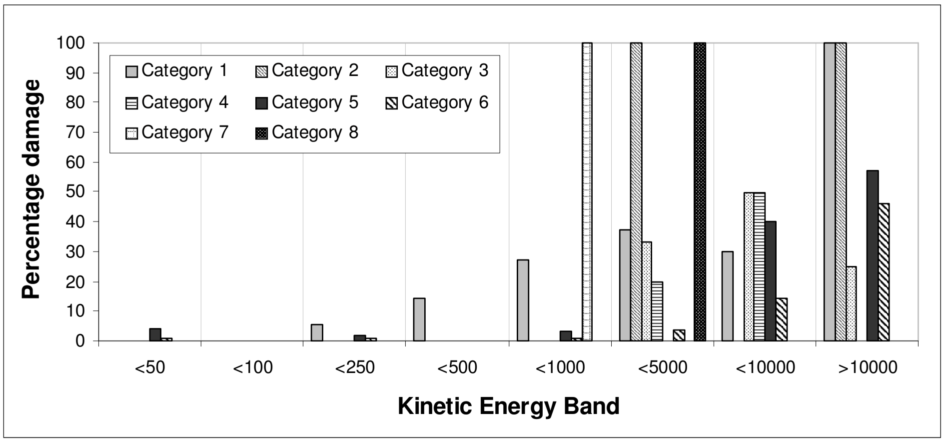


Table H-15 The percentage damage caused to the landing gear by Kinetic Energy (Joules) for each aircraft category, with total number of strikes for each category in brackets.

Aircraft Cat.	Kinetic Energy (Joules) Range							
	<50	*<100*	*<250*	*<500*	*<1000*	*<5000*	*<10000*	*>10000*
1	0 (11)	0 (8)	5 (60)	4.8 (42)	29.2 (24)	45.8 (59)	28.6 (7)	100 (1)
2	0 (1)	0 (1)	0 (1)	0 (2)	25 (4)	100 (1)	0 (1)	0 (1)
3	0 (1)		6.7 (15)	0 (5)	0 (8)	8.3 (12)	0 (4)	
4			0 (10)		20 (5)	14.3 (7)	25 (4)	0 (1)
5	0 (9)	0 (7)	0 (25)	2.9 (35)	5.7 (35)	10 (20)	40 (5)	80 (5)
6	3.4 (29)	0 (29)	3.9 (102)	1.4 (71)	5.6 (107)	13.7 (161)	29.5 (44)	22.2 (18)
7						0 (1)		
8	0 (1)			0 (1)		0 (2)		

Figure H-15 Percentage damage to the landing gear at different kinetic energy bands for all aircraft categories.

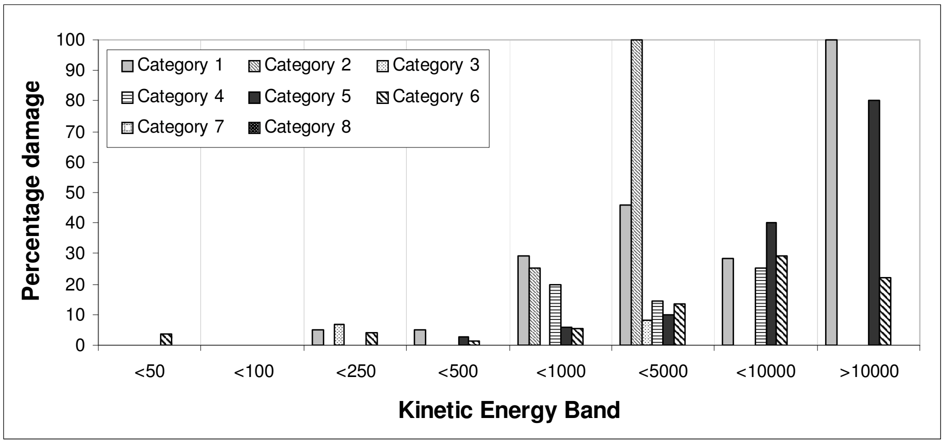


Table H-16 The percentage damage caused to the lights by Kinetic Energy (Joules) for each aircraft category, with total number of strikes for each category in brackets.

Aircraft Cat.	Kinetic Energy (Joules) Range							
	<50	*<100*	*<250*	*<500*	*<1000*	*<5000*	*<10000*	*>10000*
1	0 (1)	50 (2)	75 (4)	25 (4)	100 (2)	100 (9)	100 (4)	100 (1)
2								
3			50 (2)	100 (1)	100 (1)	100 (1)	100 (1)	
4			100 (1)			75 (4)	0 (1)	
5	50 (2)	0 (1)	75 (4)	50 (2)	100 (3)	50 (2)	100 (1)	
6	100 (1)	33.3 (3)	46.2 (13)	60 (5)	66.7 (12)	72.7 (22)	100 (5)	40 (5)
7								
8					0 (1)			

Figure H-16 Percentage damage to the lights at different kinetic energy bands for all aircraft categories.

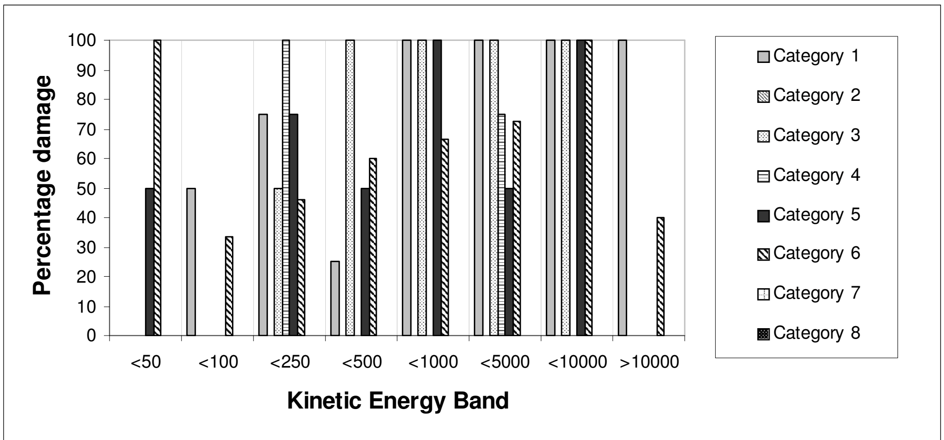
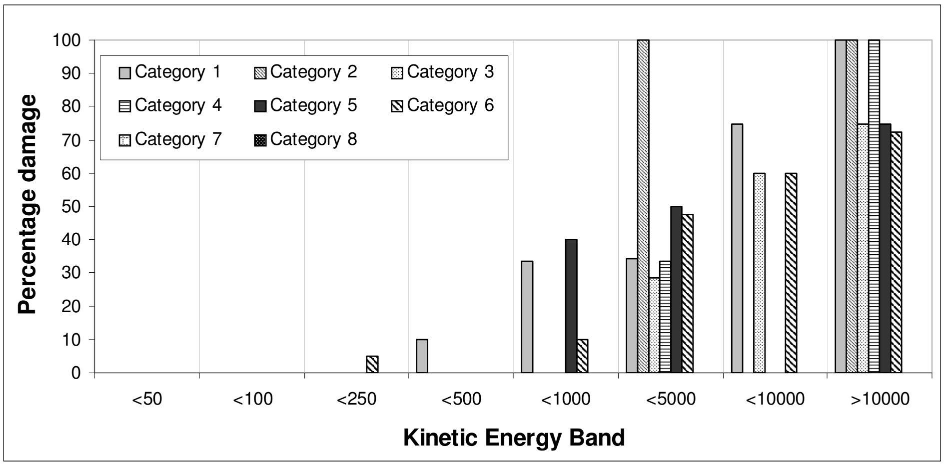


Table H-17 The percentage damage caused to the tail by Kinetic Energy (Joules) for each aircraft category, with total number of strikes for each category in brackets.

Aircraft Cat.	Kinetic Energy (Joules) Range							
	<50	*<100*	*<250*	*<500*	*<1000*	*<5000*	*<10000*	*>10000*
1	0 (6)	0 (4)	0 (17)	10 (10)	33.3 (6)	34.4 (32)	75 (12)	100 (5)
2			0 (2)			100 (2)		100 (1)
3	0 (1)	0 (1)	0 (1)	0 (3)	0 (3)	28.6 (7)	60 (5)	75 (4)
4			0 (2)		0 (4)	33.3 (3)		100 (1)
5	0 (2)	0 (1)	0 (4)	0 (7)	40 (5)	50 (2)	0 (1)	75 (4)
6	0 (8)	0 (5)	4.8 (21)	0 (14)	10 (10)	47.6 (21)	60 (15)	72.2 (18)
7	0 (2)							
8	0 (4)		0 (4)					

Figure H-17 Percentage damage to the tail at different kinetic energy bands for all aircraft categories.



Appendix I: Detailed Bird Strike Trends Data

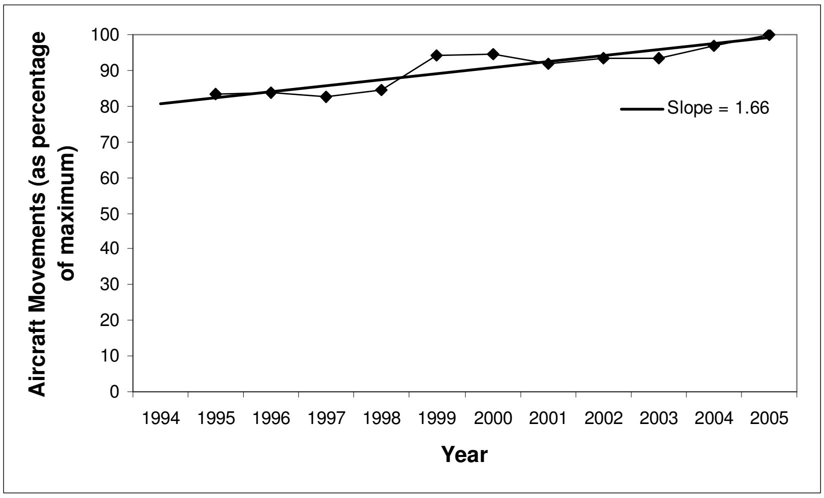
I1 Trends in bird populations and bird strike rate

I1.1 Trends in bird strike rate are increasing for most species (42 out of 51). One is remaining stable and seven are decreasing. However, aircraft traffic rates have also increased in this same period. To see whether the change in bird population is reflected in the bird strike record, it is necessary to correct for aircraft movement rate.

I1.2 The trend in aircraft movements in shown in Figure I-1 , and the trends in bird strikes are shown in Figures I-2 to I-15. Note that bird species have been grouped according to the direction and degree of their trend line.

I1.3 Table 35 lists the slope of the trend lines for each species. As stated above, these slopes should be compared to the change in aircraft movements (slope: 1.66 - Data from ICAO. Refers to category 3 to 6 aircraft.). For a species to show an increase in bird strikes over and above that due to the increase in air traffic, the slope for that species has to be greater than 1.66. Similarly, for a species to demonstrate a decrease in bird strikes, the slope could actually be positive, but below 1.66.

Figure I-1 Trend in aircraft movements between 1995 and 2004.



I2 Trends in UK Bird Populations

Table I-1 The population trends in commonly struck or high weight UK species.

Species	Weight (g)	Strikes	Population trend
Black-headed Gull	275	932	Increase
Buzzard	800	76	Increase
Canada Goose	3600	20	Increase
Carrion Crow	530	115	Unknown
Common Gull	420	432	Increase
Gannet	2900	3	Increase
Great Black-backed Gull	1690	37	Decrease
Grey Heron	1500	40	Increase
Greylag Goose	3325	7	Increase
Herring Gull	1020	671	Stable
House Martin	17	151	Unknown
Kestrel	204	450	Increase
Lapwing	215	897	Decrease
Lesser Black-backed Gull	820	110	Increase
Mallard	1080	59	Unknown
Mute Swan	10000	4	Increase
Oystercatcher	500	125	Unknown
Pheasant	1100	63	Unknown
Rook	430	360	Unknown
Skylark	39	651	Decrease
Starling	80	372	Decrease
Swallow	19	721	Decrease
Swift	41	623	Stable
White-fronted Goose	2350	2	Decrease
Whooper Swan	10000	2	Increase
Woodpigeon	465	627	Unknown

I3 Trends in US Bird Populations

Table I-2 The population trends in commonly struck or high weight USA species.

Species	Weight (g)	Strikes	Population trend
American Coot	615	27	Decrease
American Crow	476	177	Increase
American Kestrel	105	990	Stable
Bald Eagle	5140	65	Increase
Barn Owl	315	268	Stable
Barn Swallow	19	302	Decrease
Canada Goose	3600	926	Increase
Common Loon	3700	9	Stable
Double-crested Cormorant	2000	35	Increase

Species	Weight (g)	Strikes	Population trend
Eastern Meadowlark	86	251	Decrease
European Starling	80	1376	Decrease
Great Blue Heron	2700	141	Increase
Herring Gull	1020	423	Decrease
Horned Lark	37	343	Decrease
Killdeer	85	576	Decrease
Mallard	1080	325	Decrease
Mourning Dove	126	1591	Decrease
Northern Pintail	840	31	Decrease
Osprey	1525	100	Increase
Pacific Golden-Plover	130	277	Decrease
Peregrine Falcon	790	77	Increase
Red-tailed Hawk	1100	592	Increase
Ring-billed Gull	485	535	Increase
Rock Pigeon	393	1119	Decrease
Sandhill Crane	4240	52	Increase
Snow Goose	2450	38	Increase
Snowy Owl	1875	55	Decrease
Tundra Swan	7200	5	Decrease
Turkey Vulture	1450	219	Increase
Wild Turkey	6440	31	Increase

Table I-3 Comparison of bird population and bird strike trends. (UK and US Combined)

Species	Slope of trend of strike rate	Population trend
American Coot	3.15	Decrease
American Crow	1.84	Increase
American Kestrel	5.47	Stable
Bald Eagle	3.55	Increase
Barn Owl	5.14	Stable
Black-headed Gull	-0.57	Increase
Buzzard	2.55	Increase
Canada Goose	2.78	Increase
Carrion Crow	3.54	Unknown
Common Gull	1.41	Increase
Common Loon	4.35	Decrease
Double-crested Cormorant	1.88	Increase
Eastern Meadowlark	3.01	Decrease
Gannet	-2.33	Increase
Great Black-backed Gull	3.24	Stable
Great Blue Heron	5.41	Increase
Grey Heron	-0.07	Stable
Greylag Goose	2.42	Increase
Herring Gull	3.64	Decrease
Horned Lark	5.61	Decrease
House Martin	4.03	Unknown

Species	Slope of trend of strike rate	Population trend
Kestrel	2.46	Increase
Killdeer	4.68	Decrease
Lapwing	-5.36	Decrease
Lesser Black-backed Gull	1.00	Increase
Mallard	4.05	Decrease
Mourning Dove	5.17	Decrease
Mute Swan	-1.19	Increase
Northern Pintail	4.94	Decrease
Osprey	5.19	Increase
Oystercatcher	-1.65	Unknown
Pacific Golden-Plover	5.59	Decrease
Peregrine Falcon	4.22	Increase
Pheasant	1.67	Unknown
Red-tailed Hawk	4.91	Increase
Ring-billed Gull	5.29	Increase
Rock Pigeon	3.16	Decrease
Rook	1.55	Unknown
Sandhill Crane	3.09	Increase
Skylark	4.83	Decrease
Snow Goose	2.38	Increase
Snowy Owl	-0.08	Decrease
Starling	3.95	Decrease
Swallow	3.90	Decrease
Swift	3.23	Fluctuating
Tundra Swan	0.60	Decrease
Turkey Vulture	3.89	Increase
White-fronted Goose	0.00	Decrease
Whooper Swan	2.02	Increase
Wild Turkey	3.95	Increase
Woodpigeon	4.16	Unknown
American Coot	3.15	Decrease

Table I-4 Annual bird strikes for top five most frequently struck species for each weight category, UK and North American data combined.

Species	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Starling	33	38	35	34	43	30	50	53	45	66	71	48	80	78	89	33	101	88
Mourning Dove	5	7	16	26	36	15	23	27	32	34	55	63	84	67	52	12	63	83
Rock Pigeon	19	34	29	23	30	31	32	29	39	32	47	70	56	52	57	25	50	53
Herring Gull	12	13	15	9	16	15	25	15	20	18	20	19	31	32	42	18	33	33
Swallow	1	2	27	31	19	23	20	31	23	34	21	37	30	34	56	32	53	76
American Kestrel		2	3	5	5	7	4	13	3	13	15	17	25	15	33	6	39	34
Canada Goose	15	20	27	28	41	36	33	34	58	64	62	56	52	58	40	16	50	34
Black-headed Gull	20	10	33	23	14	19	21	15	16	18	13	15	25	14	13	17	13	25
Lapwing	57	49	52	29	38	40	40	19	11	13	13	25	8	8	12	5	6	3
Skylark	3	5	4	4	8	11	10	13	13	19	12	18	17	18	20	14	15	22
Woodpigeon	7	5	14	5	7	6	11	6	6	7	11	22	17	20	23	28	21	27
Swift			11	19	16	19	15	26	12	28	16	21	27	16	23	11	22	16
Red-tailed Hawk		5	3	6	8	14	7	8	8	18	25	13	17	27	25	17	38	44
Killdeer	2	4	4	8	10	8	5	13	12	14	17	17	24	17	26	2	39	45
Ring-billed Gull	2			4	5		9	19	14	8	14	9	14	16	21	8	20	26
Kestrel	5	3	6	4	4	9	7	6	7	7	4	9	9	9	4	10	12	26
Common Gull	5	3	11	9	9	13	8	11	6	7	10	5	7	7	3		13	23
Mallard	4	2	5	10	15	9	9	8	9	18	12	14	10	18	19	11	16	16

Species	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Rook	8	3	6	4	7	7	4	4	5	7	7	5	6	7	8	5	15	6
Horned Lark		1			2	1	1	1			1	7	16	18	22	8	32	29
Pacific Golden-Plover	1			2	2	2	7	9	12	13	4	12	13	8	13	1	16	12
Barn Owl	1	1	2	1	3	2	1	8	4	9	7	6	10	8	14	6	21	22
Eastern Meadowlark		1	4	1	1	5	4	3	1	3	1	11	3	8	7	2	3	7
Turkey Vulture	2	4	6	5	7	4	3	7	6	5	13	16	9	14	15	13	14	26
American Crow	4	2	3	5	3	10	2	5	4	6	7	12	5	12	2	1	8	4
House Martin	1				4	1		4	5	3	1	1	4	5	8	11	9	7
Great Blue Heron		1		2	1	3	1	5	5	4	7	5	3	6	8	3	5	8
Oystercatcher	3	5	5	2	4	9	5	3	3	1	4	2	8	2	4	4	2	
Carrion Crow	2		1				1	1	1	2	2	5	2	1		6	9	7
Lesser Black-backed Gull	2		1	3	1	3	4	1	3		2	4	2	7		2	1	3
Osprey	1	3			1		1	4		5	6	4	4	3	8	2	6	8
Peregrine Falcon					1		1				2	1	4	1	2	1	2	5
Buzzard	4		1	1	2	1	1	1		1	1	1	3	3	3	2	8	4
Bald Eagle	1	2	2		7	2	2	2	5	2	4	5	1	3	5		12	11
Pheasant	1			3	2		1	2	1			4	3	1	2	3	1	2
Snowy Owl			1	2	1		1						1	2	1	9		
Sandhill Crane		1	2	3	1	2	4	1	3	4	4	2	4	2	1	2	5	4
Grey Heron	1			2	1	2		1		2		1	1		2			1

COMMERCIAL-IN-CONFIDENCE

Species	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Snow Goose	2	2	1	4	1	1	2	1	2	5	7	2	6	3	5		1	5
Great Black-backed Gull	1			2	1	1	1	2	1	1	2	1	2	4	3	1	1	3
Double-crested Cormorant	1		2	1			1		1			1	6	1	1		4	1
Northern Pintail					1							1	4	5	5	4	4	1
Wild Turkey							1	2	3	2	2		4	1	1		2	3
American Coot			1		1						1	1	2	3		1	1	5
Common Loon												1	1		1		1	2
Greylag Goose					1										1			1
Tundra Swan					1					1					1			
Mute Swan					1			1								1		
Gannet	1						1											
White-fronted Goose																		
Whooper Swan																		1

COMMERCIAL-IN-CONFIDENCE

Figure 1-2 Trends in strike occurrence from 1990 to 2007 for starling, mourning dove, rock pigeon and herring gull.

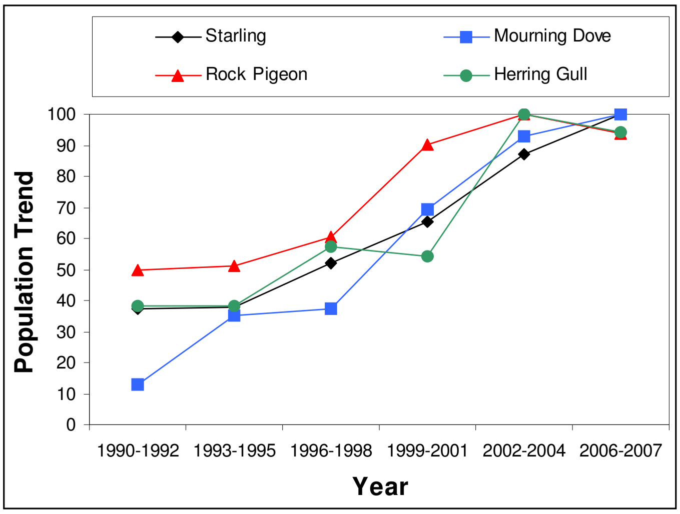


Figure I-3 Trends in strike occurrence from 1990 to 2007 for kestrel, mallard, horned lark and pacific golden plover.

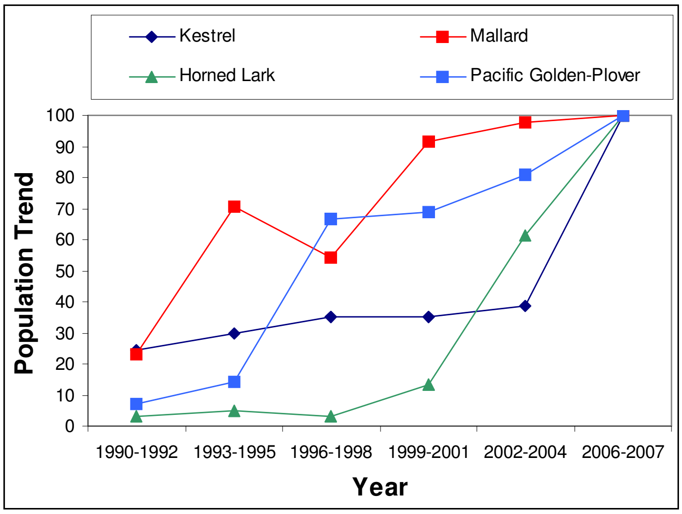


Figure I-4 Trends in strike occurrence from 1990 to 2007 for bald eagle, sandhill crane, snow goose and great black backed gull.

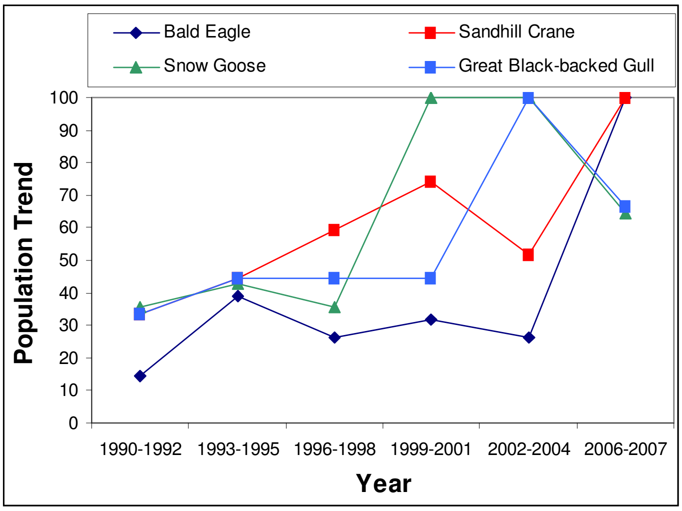


Figure I-5 Trends in strike occurrence from 1990 to 2007 for swallow, American kestrel, skylark and woodpigeon.

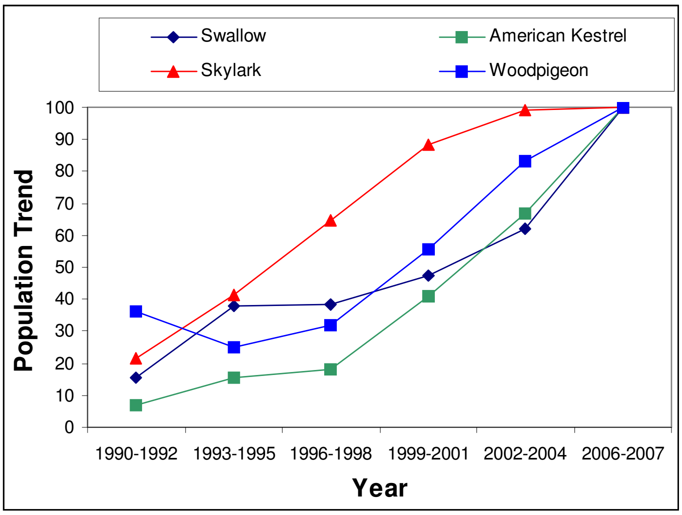


Figure I-6 Trends in strike occurrence from 1990 to 2007 for barn owl, turkey vulture, house martin and great blue heron.

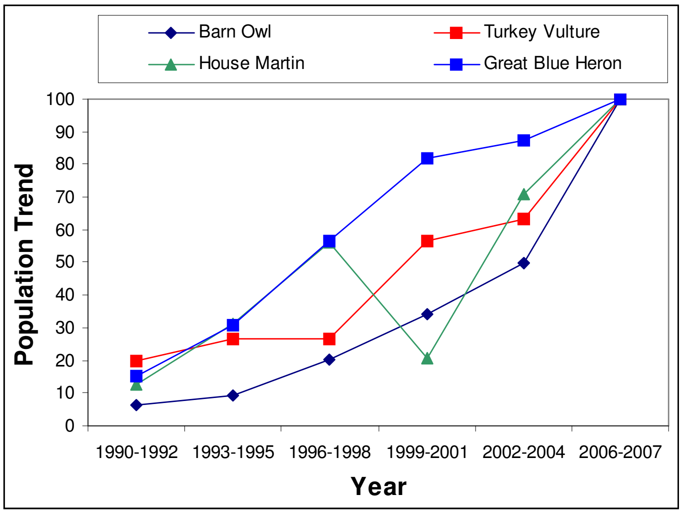


Figure I-7 Trends in strike occurrence from 1990 to 2007 for northern pintail, wild turkey, american coot and common loon.

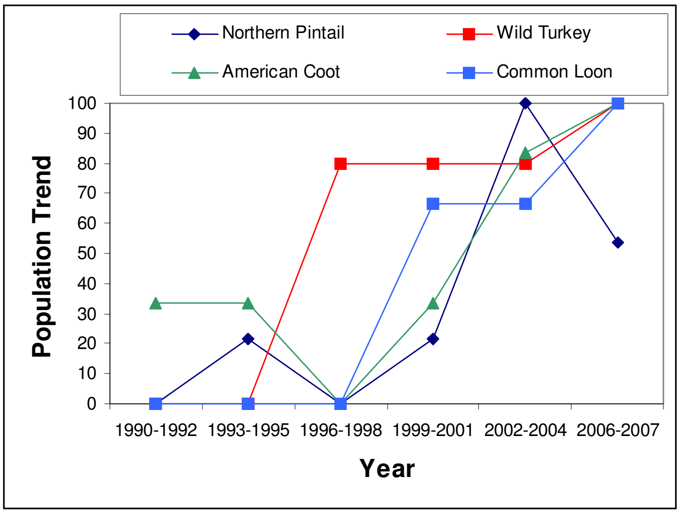


Figure I-8 Trends in strike occurrence from 1990 to 2007 for swift, red-tailed hawk, killdeer and ring-billed gull.

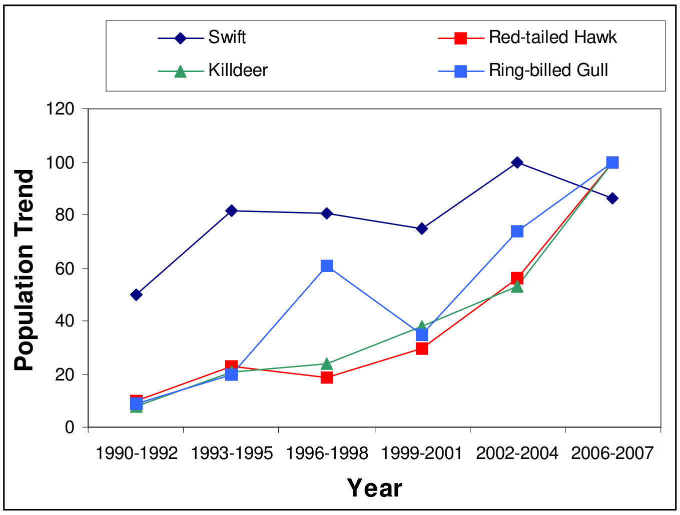


Figure I-9 Trends in strike occurrence from 1990 to 2007 for carrion crow, peregrine falcon, osprey and buzzard.

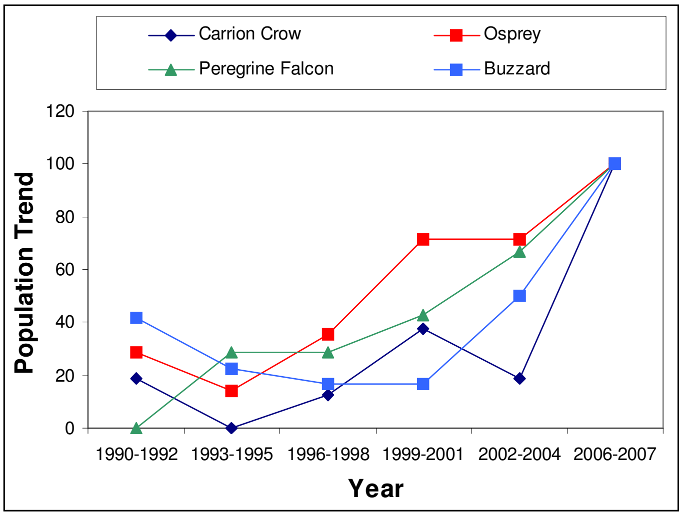


Figure I-10 Trends in strike occurrence from 1990 to 2007 for Canada Goose.

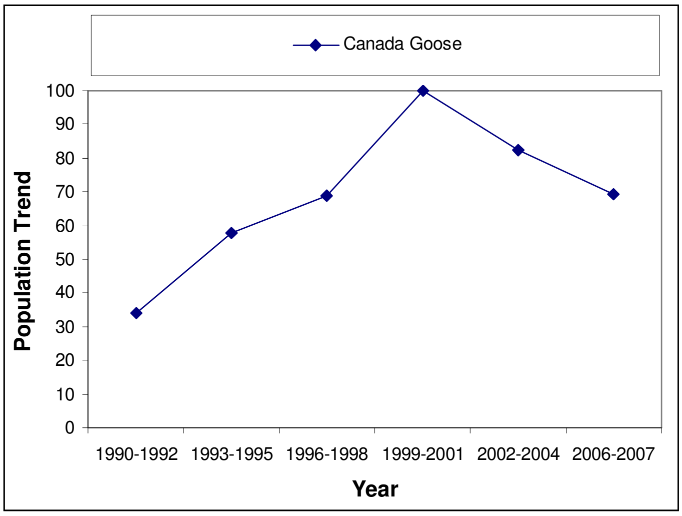


Figure I-11 Trends in strike occurrence from 1990 to 2007 for black-headed gull, lapwing and oystercatcher.

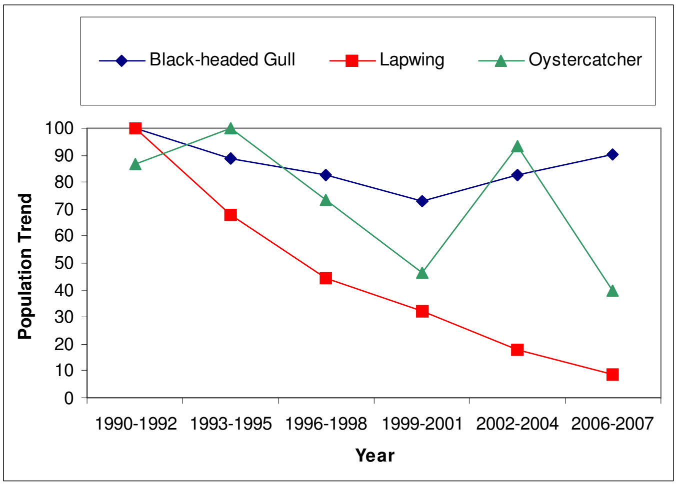


Figure I-12 Trends in strike occurrence from 1990 to 2007 for common gull, rook and double-crested cormorant.

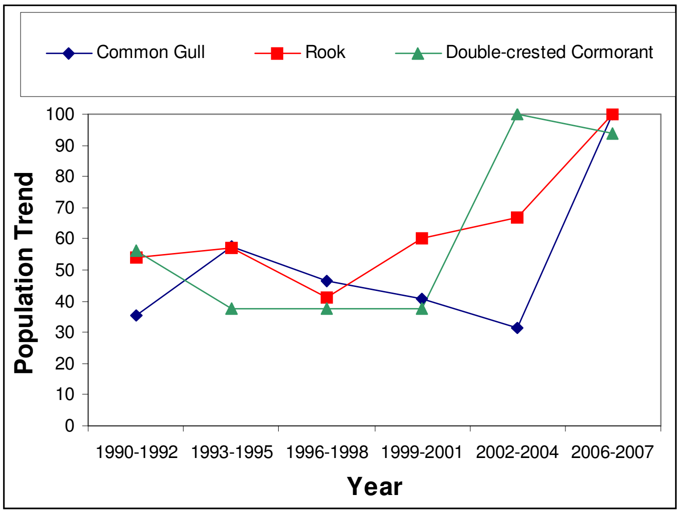


Figure I-13 Trends in strike occurrence from 1990 to 2007 for eastern meadowlark, american crow, lesser black-backed gull and pheasant.

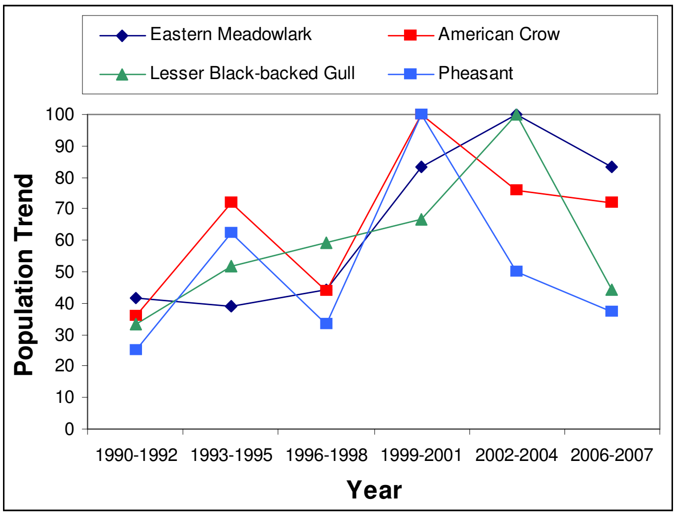


Figure I-14 Trends in strike occurrence from 1990 to 2007 for snowy owl and grey heron.

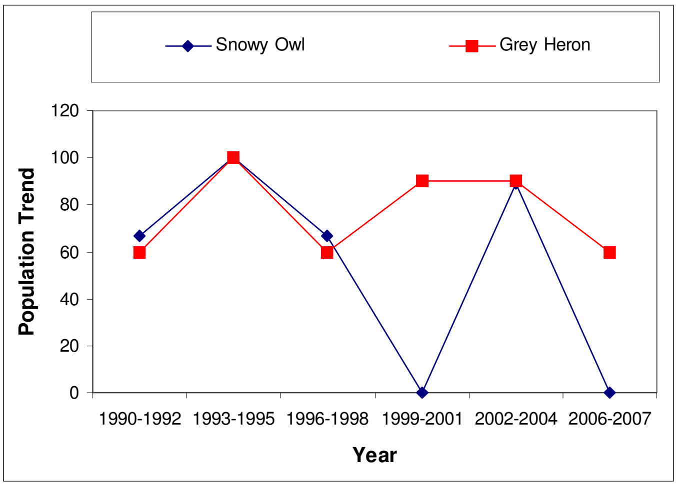
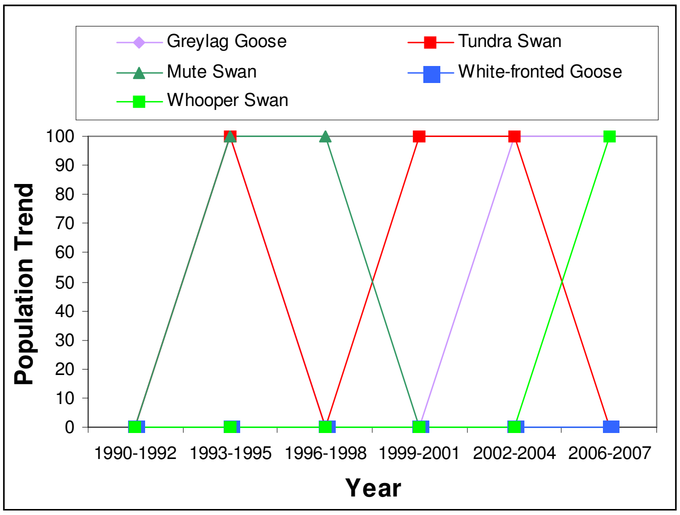


Figure I-15 Trends in strike occurrence from 1990 to 2007 for tundra swan, mute swan, whooper swan, gannet and greylag goose.



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