ATSB
Australian Transport Safety Bureau

AUSTRALIAN TRANSPORT SAFETY BUREAU

RESEARCH PAPER

AVIATION SAFETY

The Hazard Posed to Aircraft by Birds

COMMONWEALTH DEPARTMENT OF TRANSPORT AND REGIONAL SERVICES

Department of Transport and Regional Services

Australian Transport Safety Bureau

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The Hazard Posed to Aircraft by Birds

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EXECUTIVE SUMMARY

Birdstrikes continue to be a problem for aviation worldwide, costing approximately $US3 billion annually. Increasingly, funds are being directed towards research which focuses on bird control and avoidance methods. Two such methods which are proving to be successful, are the use of hand held laser devices to scare birds from the airport environment, and the use of the US developed Avian Hazard Advisory System (AHAS), which allows aircraft to avoid high-risk birdstrike areas.

This study investigated the Australian birdstrike data for the period 1991 to 2001. Although limited, the available data was able to be used to investigate birdstrike rates, species involvement and hazard potentials, as well as providing a time of day and phase of flight analysis. Additionally, the current study highlights the magnitude of some of the impact forces exerted during a birdstrike. The data suggest that there has been a significant increase in the rate of birdstrikes being recorded in Australia since 1992 (most notably between 1998 and 2001). It is unclear whether this is the result of an increasing strike hazard or an improving reporting culture. Both the International Civil Aviation Organisation (ICAO) and Australian data indicate that the majority of strikes occur on, or in the vicinity of, the airport environment, during the take off, approach or landing phases of flight.

An analysis of the strike data revealed that birdstrikes are most common during the earlier months of the year (January to May) and are at their lowest between June and August. The specific monthly pattern varies between locations, particularly between airports in the north and south of Australia: with airports in the north of Australia generally recording higher strike rates. The data also suggests that strikes are most common at dawn, and during the early morning and late afternoon periods of the day. However, this may be an artefact of aircraft activity levels during these times.

The hawk and the galah are the most commonly struck birds in Australia. However, the eagle and the ibis pose the most serious hazard to aircraft if struck. Development of ‘most struck’ and ‘potential hazard’ lists allow airport owners and operators to develop and prioritise control methods to suit their specific area.

All birdstrikes and bird hazards, no matter how insignificant they might appear, must be reported to the Australian Transport Safety Bureau (ATSB). An improved reporting culture will allow a more thorough and comprehensive understanding of the bird hazard situation, which should in turn lead to the implementation of more effective control and management strategies.

The production of regular, standardised, educational and promotional material, regarding the birdstrike problem within Australia is recommended. This will not only increase awareness of the issues and the importance of reporting, but it will also help individuals and organisations in the industry to take the necessary steps to minimise the occurrence of birdstrikes.

It is also recommended that an Australian Birdstrike Working Group consisting of industry representatives from Australia be established. Such a body may not only enhance awareness of the safety issues surrounding birdstrikes, but may also determine directions for future research, regulations and procedures to minimise the risk posed to aircraft.

1 INTRODUCTION

1.1 Objectives of this study

This study was prompted by the chronic nature of birdstrikes worldwide; increasing legal implications; the minimal reporting culture; and the lack of Australia-wide monitoring of bird hazards.

The study had several objectives:

- To review the available Australian birdstrike data for the period 1991– 2001;
- To provide a comparative analysis of ICAO and Australian birdstrike data;
- To develop a hazard ranking for the most struck species;
- To provide an analysis of the impact forces involved in a collision between an aircraft and a bird; and
- To consider any safety actions that may be warranted.

1.2 Background information

Birdstrikes, collisions between an aircraft and one or more birds, are not a new phenomenon. The first recorded fatal aircraft accident resulting from a birdstrike occurred in the United States in 1912 (Lewis, 1995). Since that time, birdstrikes have caused the loss of 52 civilian aircraft and around 190 lives worldwide (Allan, 2000). Fortunately, the majority of birdstrikes cause little or no damage.

Occurrence Number 199503813

Birdstrike

At 100 – 200 feet above ground level, on final approach, the aircraft encountered a flock of starlings. Several birdstrikes were experienced as the aircraft continued for a normal landing. An investigation revealed a dent in the left wing leading edge, and a bird carcass in the right engine air intake.

However, the consequences of a birdstrike are not always so mild.

Birdstrike (NTSB, 1999).

In September 1995, all 24 people on board a US Air Force (USAF) Boeing E-3B, were killed, when the aircraft crashed. The E-3B had suffered a multiple birdstrike on take-off from Elmendorf Air Force base in Alaska.

The USAF investigation determined that a flock of Canada geese had flown in front of the aircraft as it became airborne. Birds were ingested into two of the aircraft's four engines, causing them to lose power. Investigators found the remains of nearly three dozen birds on the runway after the accident.

It is estimated that more than 30,000 birdstrikes occur to civilian aircraft each year (ICAO, 2001). Despite efforts to reduce the problem, birdstrikes continue and are estimated to cost the worldwide aviation fleet in excess of $US3 billion annually. Direct costs can include hull loss or damage. However, a substantial proportion of these costs are associated with cancelling commercial flights and making alternative travel arrangements for fare paying passengers (Short, Kelley, Speelman & McCarty, 2000).

Sophisticated aircraft engines, of the type used in modern airline fleets can cost millions of dollars to repair or replace, and are particularly vulnerable to damage from bird ingestion, despite vast improvements in design standards. In one incident, a Boeing 747 ingested several gulls into the number-2 engine, which subsequently failed. The aircraft made a safe landing, however the cost of the incident was estimated to be $US1.4 million (ICAO, 1991).

1.3 Design standards

ICAO Annex 8, stipulates the design standards for civilian aircraft. For the certification of engines designed in the USA, ingestion limitation standards are set out in Federal Aviation Regulation (FAR) 33.76. These regulations for the weight and number of birds which an engine must be capable of ingesting without immediate catastrophic failure vary, according to the size of the engine inlet throat area. For example, the engines used on a Boeing 777 are required to simultaneously ingest four 1.125kg birds and continue to produce at least 75 per cent of full rated thrust (Lewis, 1995).

Despite these design standards, even the most robust engine designs may fail if a heavy bird, or large number of birds are ingested. Modern jet engines are relatively delicate and can experience considerable damage, if not destruction by ingesting foreign objects such as birds, particularly if the ingestion design limitations are exceeded. Figure 1 illustrates the damage that can result from bird ingestion.

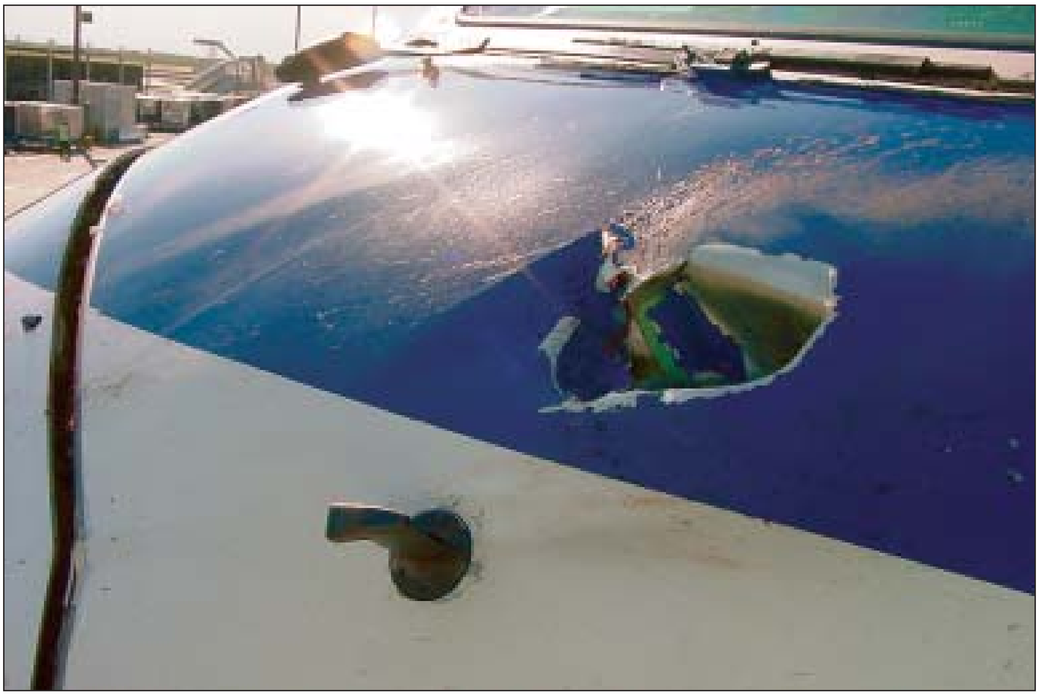
FIGURE 1.
Engine damage from bird ingestion

The United Kingdom Civil Aviation Authority (CAA) is currently working on developing new engine design requirements for large jet engines. Although this process is still in its infancy, it appears that some aircraft engines will be required to be able to sustain strikes from heavier birds, while maintaining longer run-on periods[1], than those currently stipulated. The process appears to have become necessary due to the apparent increase in the numbers of large flocking birds such as Canada geese.

The proposed run-on times will ensure that the engine is capable of providing sufficient thrust and operability after ingestion to continue a take-off, initial climb and perform a safe return for landing. The specification also ensures that if an ingestion results in engine malfunction during take-off, flight crews are able to concentrate on flying the aircraft to at least 400ft without throttle manipulation. This is considered consistent with current aircraft manufacturer and regulator recommended procedures (UK CAA, unpublished). However, due to the nature of the industry, it may be 2008 before engines conforming to these proposed standards enter service.

Engines are not the only aircraft parts vulnerable to damage from birdstrikes. Windshields, surrounding structures and the empennage of transport category aircraft are designed to withstand some impact (for example, as stipulated in FAR 23.775 and FAR 25.775 in the case of US designed aircraft). However, these sections of the aircraft are not impregnable and are particularly susceptible to damage at high speeds. The fact that large flocking birds, such as geese, are often encountered at altitudes where an aircraft's speed is greatest, compounds the danger. This creates the potential for catastrophic damage. Figure 2 shows the damage inflicted to the nose area of an American Airlines Boeing 767 as a result of a birdstrike during 2001.

FIGURE 2.
Birdstrike damage (B767)



1 Run-on period refers to the length of time, subsequent to an ingestion, where an engine is designed to operate safely without experiencing catastrophic failure, and without causing further damage.

Bird populations worldwide are increasing. According to some estimates, the Canada geese population of the USA has quadrupled since 1987 and the Snow geese, gull and cormorant populations have also increased (Eschenfedler, 2000). In the UK, Canada geese and greylag numbers have increased to such proportions that they can be found in flocks of up to 1,000 birds. Conservation efforts, and the birds' ability to adapt to human environments have been factors in increasing bird numbers.

The use of aircraft as a means of transportation is also increasing. If the trends of increasing bird populations and increasing aircraft numbers continue, the occurrence of birdstrikes with catastrophic outcomes are likely to continue to rise. The raising of certification standards for aircraft engines, while useful, will not be sufficient to reduce this risk, due to the large fleet of current technology engines which may remain in service for up to 25 years. Worldwide, this has led to greater emphasis on the development of bird control and management techniques.

1.4 Why control birds?

Examination of the available birdstrike statistics reveal that, although possible at all altitudes, the likelihood of a birdstrike appears to substantially increase within, or in close proximity to the airport[2] environment (ICAO, 1998). Accordingly, the majority of bird control techniques are focused on or around these areas.

Birds are attracted to airports for numerous reasons. The large, open grassed areas found on most airports provide perfect feeding, resting and nesting areas for many types of birds. Short grass provides protection against predators such as snakes, cats and foxes. However, short grass also attracts predatory birds such as raptors, in search of rodents and other food sources. Water, lying in drains and spillways on the airports provides a perfect environment for waterfowl such as ibis and ducks. Large open hangars and other flat roofed buildings provide excellent nesting areas for gulls and other small birds such as starlings. The environment surrounding airports can also attract birds. It is not uncommon for airports to be located near coastal waterways, lakes, landfill and agricultural sites; all of which can attract birds. Areas more remote from an airfield can also pose problems. Birds can transit across airports and flight paths while travelling between nesting and feeding sites.

Currently, ICAO Annex 14 has recommended practices that relate to bird and wildlife control on and around the airport environment. However, there is now a strong movement for these to be raised to standards, to enhance operational safety (ICAO, 2001).[3] Airport owners and operators will be required to ensure that hazards to aircraft on airports (including those posed by birds) are kept at a minimum.

There is an increasing tendency for airlines to seek to retrieve costs arising from serious birdstrike incidents through the courts. Additionally, the costs arising from litigation that may occur should a fatal aircraft accident result from a birdstrike could be immense. This would be particularly true if the airport authority could not demonstrate that it had taken reasonable steps to assess and minimise, the risk posed to aircraft by birds in the vicinity of the airport.

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2 The term airport is used generically in this report to describe both an airport and an aerodrome. Refer to the Macquarie dictionary for an accurate definition of both terms.

3 *Recommended Practices* are any specification to which Contracting States will endeavour to conform in accordance with the Convention. *Standards* are any specification to which Contracting States will conform in accordance with the Convention.

Birdstrike liability (FAA, 2002)

On 3 June 1993, an Air France Concorde ingested a Canada goose into the number 3 engine on landing at New York's JFK airport. The engine suffered an uncontained failure, causing parts to go into the number 4 engine. Subsequently, both engines were destroyed. The aircraft was out of service for 5 days while repairs were made. The airport operator (the New York Port Authority) paid $5.3 million in compensation to Air France for losses incurred.

Accordingly, airport owners and operators may wish to consider an appropriate risk assessment, encompassing not only the airport environment but also surrounding areas. This, together with detailed records of bird species, numbers and hazard rankings, may form the basis of a measured and effective control program aimed at reducing the risk to aircraft. It would be useful to conduct such a program in conjunction with local councils, land owners and other authorities to ensure that surrounding land use is not an attractant to bird populations. Formal control evaluation procedures, such as those illustrated in Appendix J of the ICAO Bird Strike Manual (Attachment A) are valuable, and could be used by airport authorities on a regular basis.[4]

1.5 Bird control and management

Within Australia, the majority of large airports have wildlife management plans, which often incorporate a number of conventional bird control techniques. These may include methods such as:

- minimising the nesting areas available;
- reducing the amount of water lying on the airport grounds;
- maintaining the grass at a length which deters birds;
- minimising available food; and
- harassing birds using cracker shot and/or live shotgun rounds.

However, despite the continued efforts of airport staff, birds continue to be a problem on and around the airport environment.

Extensive research has been conducted on all aspects of the birdstrike phenomenon. The USA, Canada, and the UK, have carried out research in areas ranging from bird migratory pattern prediction and warning, through to distress call determination and simulation. The majority of research has been conducted through the military, whose high-speed aircraft are particularly vulnerable to damage if birdstrikes occur. The US Air Force, for example, reports approximately 3,000 birdstrikes to its aircraft each year. These incidents cost around $US50 million per year (Defusco, 2000). Similar problems are encountered by the Australian military.

4 Please note that Attachment A is an ICAO document and as such has some aspects which are not relevant to the Australian context. It is provided only as a guide to the types of control evaluation procedures which may be used.

Birdstrike (Directorate of Flying Safety, 1997)

On 19 August 1987, a Royal Australian Air Force (RAAF) F-111 took off from Townsville for a return flight to Amberley. While flying at 400 feet AGL and accelerating to 450kts, the pilot spotted an eagle and pulled the aircraft's nose up.

The bird impacted the radar nose cone and all pitot-static instruments were rendered useless. The crew were able to continue to Amberley and landed without further incident. Damage to the front of the aircraft was extensive. After landing, the remains of an eagle and rabbit were found in the wreckage of the radome.

The US Avian Hazard Advisory System (AHAS) was first designed and tested in 1998. AHAS uses radar, historical bird migratory data and weather patterns to provide close-to-real-time monitoring and predictions of potentially hazardous bird activity. It has proved to be very accurate in providing strike hazard data for aircraft in US airspace (Kelley, 1999). AHAS was developed by the US military to reduce the risk of birdstrikes to low flying military aircraft. Pilots and operation controllers are able to use the information provided by AHAS to alter or cancel missions where a high risk of birdstrikes has been identified. It also has the potential to provide useful information to large civilian transport aircraft and may be formally extended to this role. The AHAS webpage (www.ahas.com) is already available for civilian use and currently provides birdstrike risk information for almost 67 per cent of the airspace over the US continent. AHAS coverage will continue to expand as the relevant information is compiled. Such a program may prove to be useful in Australia.

Several studies have investigated the relationship between the frequency and volume of aircraft engine noise and the distress calls of some bird types (Short et al., 2000). The evidence suggests that some birds are able to detect and avoid some aircraft more easily than other birds, due to the engine sounds produced. Other studies have investigated the possibility that certain radar frequencies induce searching behaviour in birds. With further research the acoustical control of birds may be a valid method for reducing the occurrence of birdstrikes (Short et al. 2000).

Several other recently developed bird control techniques are being trialed with varying degrees of success:

- Hand-held laser devices have been found to be useful in deterring birds from staying on airfields, although the effectiveness of such devices appears to vary according to species (Short et al., 2000).
- Remote bird sensing is becoming more widely used by operation controllers for detection and avoidance of birds on military airfields during night operations (Short et al., 2000).

1.6 Reporting

For all countries, an overarching issue concerning birdstrikes to aircraft is the lack of comprehensive incident data. Canada, for example, estimates that only 30 per cent of all strikes are reported, while the USA estimates as low as 15 per cent are reported. While there is no conclusive evidence available, it is reasonable to assume that the birdstrike reporting rate in Australia is likely to be less than 50 per cent. Between November 1993 and April 1998, the then Bureau of Air Safety Investigation (BASI)[5] only recorded

[5] BASI became part of the newly formed Australian Transport Safety Bureau (ATSB) in July 1999.

details of birdstrikes if they resulted in damage to the aircraft. Consequently, a large gap exists in the Australian birdstrike data over the past decade.

Prior to 1991, the Australian Civil Aviation Authority (CAA)[6] had its own Bird Hazard Investigation Unit (BHIU). This unit was responsible for:

- monitoring bird and other animal hazards to aircraft;
- assessing the performance of aerodrome operators and others in addressing bird hazards to aircraft and;
- ensuring compliance with the appropriate standards.

The BHIU also had additional functions including:

- assisting the BASI during accident investigations;
- educating aerodrome operators and other sections of the aviation industry to assist them to minimise the risk of birdstrikes;
- representing the CAA at ICAO and other international meetings on birdstrike hazards and;
- developing and coordinating innovative research activity into relevant areas of applied ornithology, including oversight of consultant research.

While active, the BHIU produced numerous airport specific studies which focused on highlighting the most hazardous bird species, strike rates and possible control methods. They also evaluated new control techniques and provided feedback to those individuals and organisations involved in aviation.

In 1991 the BHIU was disbanded. As a result, bird hazard monitoring on a national scale was substantially reduced within Australia.

6 As a result of 1995 legislation, the CAA was split between Airservices Australia and the Civil Aviation Safety Authority (CASA) from 1996.

2 METHOD

Incidents, serious incidents and accidents reported to the ATSB are recorded on the Occurrence Analysis and Safety Investigation System (OASIS) database. For this study, the OASIS database was searched for all birdstrikes to aircraft within Australia, between 1991 and 2001. Details such as location, species, number of birds struck, aircraft part struck and part damaged were collated. Because only birdstrikes resulting in damage to the aircraft were recorded on the OASIS database between November 1993 and April 1998, this study is limited by the data available. Some military data was also obtained from the Directorate of Flying Safety (DFS) of the Australian Defence Force (ADF).

To determine impact forces associated with a birdstrike, the ATSB contracted Associate Professor John O'Connor of the University of Newcastle, a specialist in impact physics. For details on impact force calculations and an explanation of the methodology used in this study, refer to Attachment B.

3 RESULTS AND DISCUSSION

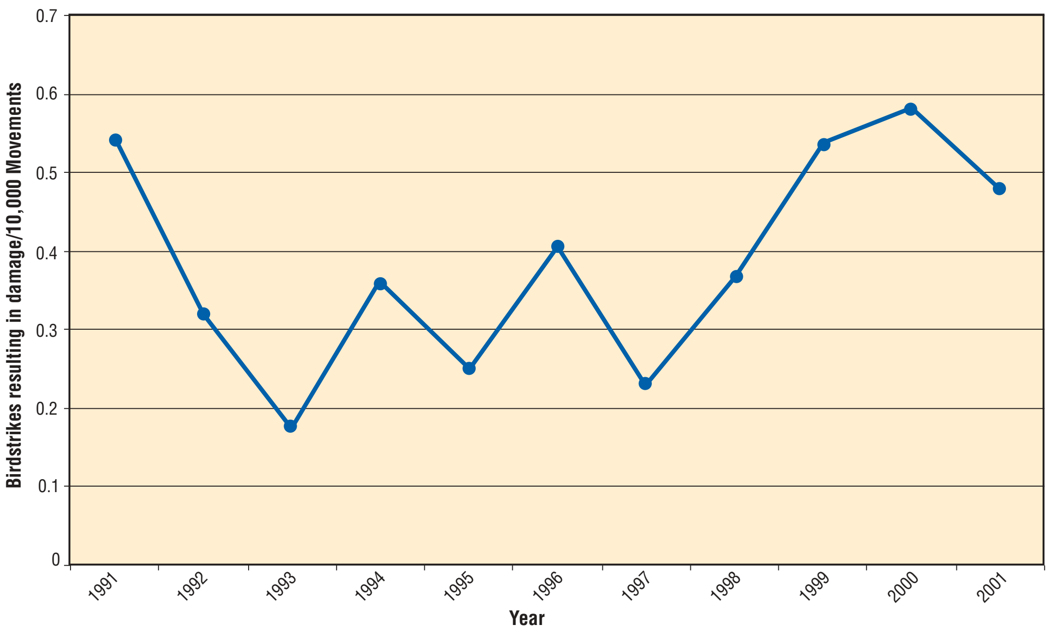
3.1 Overview

A search of the OASIS database identified a total of 3,319 birdstrikes recorded by the ATSB between 1991 and 2001. The majority of those (67 per cent) were reported by the Regular Public Transport (RPT) sector. This could be the result of a higher involvement of RPT category aircraft in birdstrikes. However, it is likely, to a substantial extent, to be the product of higher reporting rates in that sector. The reporting rate of birdstrikes is likely to vary between operational sectors, with different workloads and reporting cultures being contributing factors. As a result, the data recorded by the ATSB may not be representative of the actual strike rates. An improvement in reporting rates for all sectors of the industry is needed to allow a more accurate analysis of the problem within Australia.

3.2 Reported birdstrikes by year and month

An analysis was conducted on those birdstrikes which resulted in damage to the aircraft. Given the more severe nature of such strikes, the reporting rates are likely to be more consistent over time. Figure 3 indicates the rate of birdstrikes resulting in damage to the aircraft per 10,000 aircraft movements for the period 1991– 001.[7]

FIGURE 3:
Damage birdstrikes rates within Australia by year (1991–2001)



7 In the absence of any accurate figures indicating total aircraft movements within Australia, RPT aircraft movements within Australia were used as a proxy. Movement data for 2001 is an estimate based on movement trends over the previous ten years.

An increase in the rate of birdstrikes resulting in damage to the aircraft occurred between 1992 and 2001. This increase is most notable over the last four or five years of the decade. Statistical analysis[8] revealed a significant linear trend up from 1992 to 2001. The 1991 data was excluded from the analysis to minimise the effect of any increased reporting rates which may have occurred as a result of the operational BHIU.[9]

Two, two-year periods (1991 and 1992; 2000 and 2001) were used to investigate any change in the rate of total birdstrikes. Movement data for these years were obtained and the rate of birdstrikes per 10,000 aircraft movements was calculated. 1991 data was included in this instance to allow an analysis of two equal time periods which where not influenced by recording policies.

Table 1.
Birdstrikes per 10,000 aircraft movements.

Years	*Total Birdstrikes*	*Birdstrikes Resulting in Damage*	*Aircraft Movements (10,000)*	*Strike Rate (Strikes per 10,000 Movements)*	*Damage Strike Rate (Strikes per 10,000 Movements)*
1991/1992	765	90	211.2	3.6	0.43
2000/2001	1381	142	267.8	5.2	0.53
%Change	80.5%▲	57.8%▲	26.8%▲	44.4%▲	23.3%▲

A significant increase in the rate of reported birdstrikes between 1991/1992 and 2000/2001 occurred.[10] It could not be conclusively determined whether the increase was a result of an actual increase in the rate of birdstrikes or a product of an improving reporting culture within the Australian aviation community. A similar increase in the rate of total occurrences reported to the ATSB suggests that this increase is an artefact of an improving reporting culture within the Australian aviation industry. However, given that there was no significant change in the proportion of strikes that resulted in damage to the aircraft between 1991 and 2001[11], it can be assumed that at least part of the increase can be accounted for by an increase in the actual number of strikes occurring. An increase resulting purely from reporting tendencies would likely see an increase in total strikes recorded but not damage strikes.

Analysis of the strike data by month was also conducted. Figures 4 illustrates the average total birdstrike rates and Figure 5 illustrates the damage birdstrike rates for each month between 1991 and 2001.[12]

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8 For statistical purposes a Chi-square analysis was used to determine whether a difference in observed and expected frequencies occurs as a result of chance. By convention, a probability (p) less than 0.05 indicates a statistically significant difference.

9 χ^2=28.3, df=1, p<.005

10 χ^2=11.95, df=1, p<.005,

11 χ^2=0.89, df=1, p>.05

12 In this case, total birdstrike rates are calculated using damage strikes for the years 1993–1998, to avoid any monthly bias that may exist due to the change in recording requirements.

FIGURE 4:
Total Australian birdstrike rates by month (1991–2001)

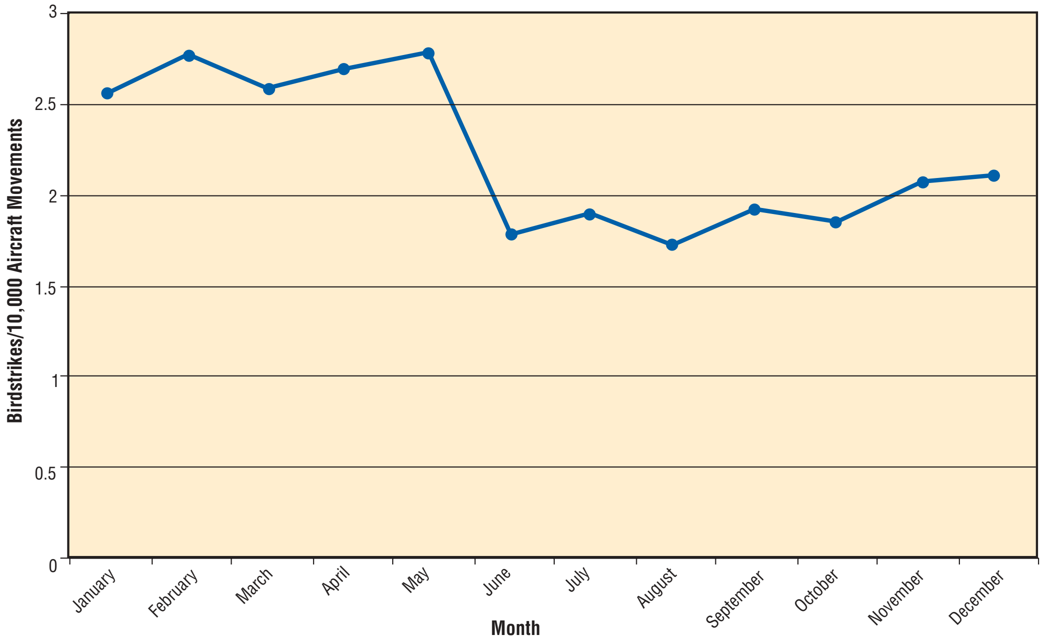
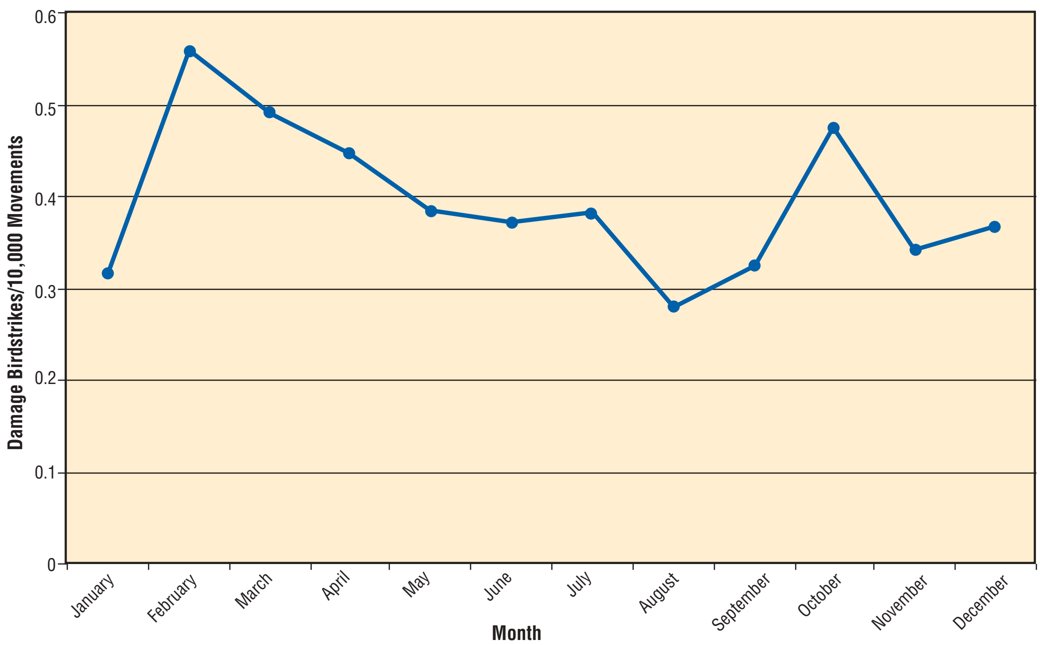


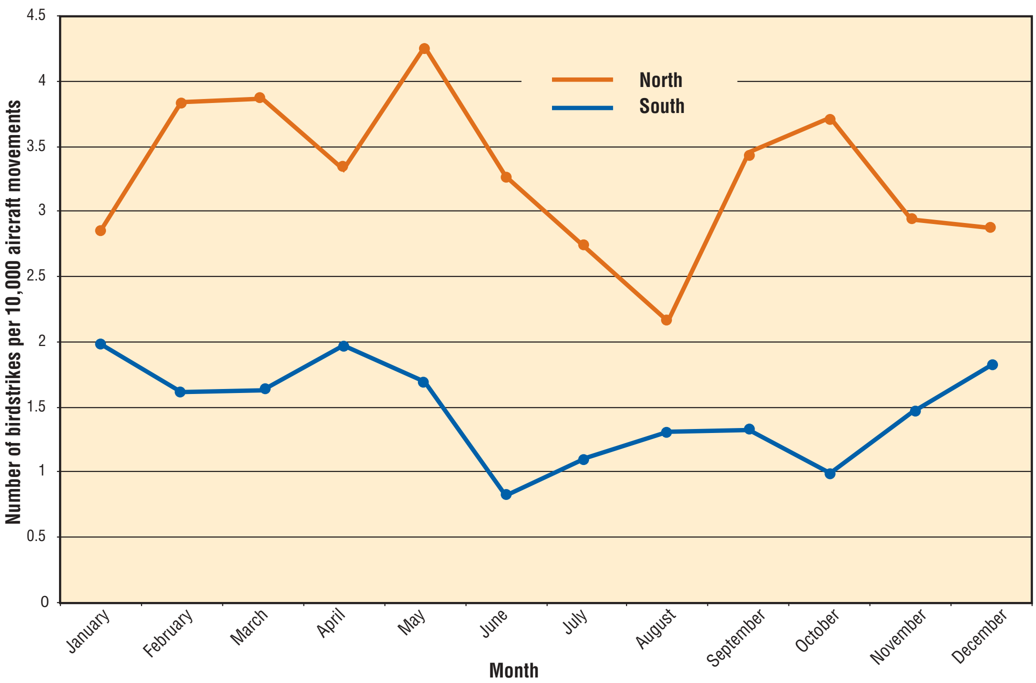
FIGURE 5:
Damage birdstrike rates by month (1991–2001)



Total recorded birdstrike rates peak in Australia during February and May, and are at their lowest during August. The rate of recorded birdstrikes resulting in damage peaks in February and again in October and has a low in August.

Individual airports have varying patterns of seasonal variation in birdstrikes, which most likely reflect the levels of bird activity in those areas during different times of the year. Figure 6 illustrates the monthly total strike rates in the north[13] and south[14] of Australia. These figures were calculated using strike information recorded for some of Australia's major airports.

FIGURE 6:
Birdstrike rates by month for major northern and southern Australian airports (1991–2001)



Northern strike rates peak during February, May and October, with a low during August. Alternately, southern strike rates peak during December and January, with a low during June. Overall, northern airports appear to have a higher strike rate, with greater seasonal variation than those in the southern half of Australia.

The frequency of birdstrikes also varies markedly among different individual airports. Table 2 lists the total number of strikes and strike rates recorded for 2001, for some of the major airports around Australia.[15]

13 Airports used to calculate these figures include Alice Springs, Brisbane, Broome, Cairns, Darwin, Mackay and Townsville.

14 Airports used to calculate these figures include Adelaide, Canberra, Hobart, Launceston, Melbourne, Perth and Sydney.

15 These rates are based on those strikes reported to the ATSB and, as such, may not reflect the actual rate of birdstrikes at these airports.

Table 2.
Strike rates per 10,000 movements by airport (2001).

Airport	*Strikes Recorded by ATSB*	*Strike Rate (Strikes/10,000 Movements)*
Alice Springs	34	10.97
Hobart	16	8.33
Launceston	14	6.03
Adelaide	43	3.87
Townsville	24	3.66
Mackay	13	3.56
Cairns	36	3.48
Darwin	28	3.11
Melbourne	42	2.37
Brisbane	39	2.27
Canberra	22	1.89
Sydney	54	1.82
Perth	14	1.45

According to DFS data, Townsville and Richmond are the two military airfields with the highest frequency of reported birdstrikes over the last 15 years. These two airfields have been found to have approximately three times the number of reported strikes than any other military airfield within Australia.

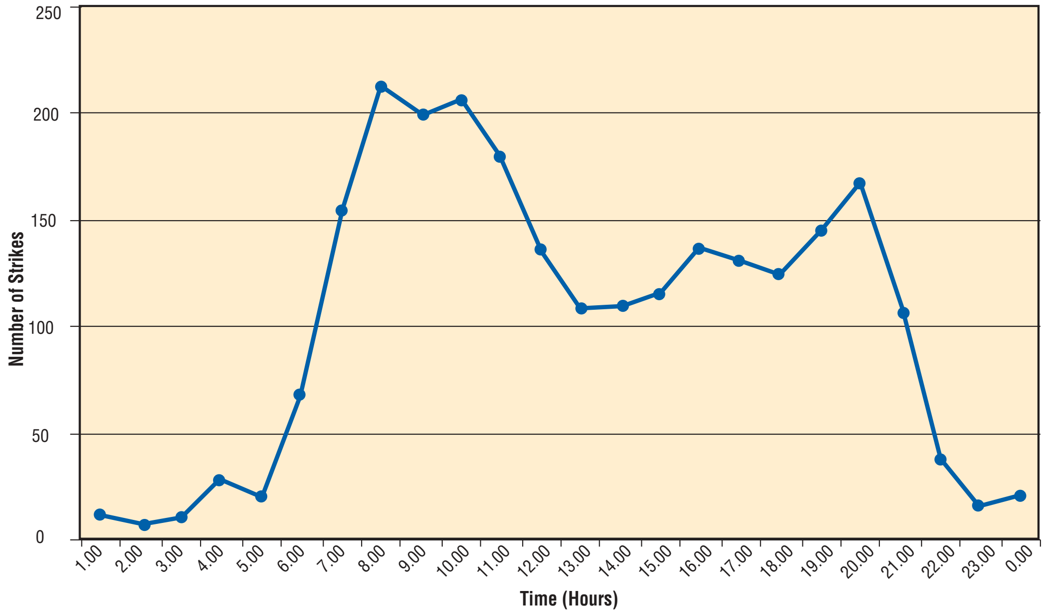
Bird behaviour and migratory patterns are likely to have a strong influence on the location and seasonal variations in strike rates. There are many ornithological materials available that deal with these patterns. Some useful references are listed in the Further reading section of this report.

3.3 Time of day

Analysis of the available data also revealed that the occurrence of birdstrikes varies according to the time of day. Figure 7 graphs the total number of strikes that occurred during each hour of the day for the years 1991–2001.[16]

[16] Figures were calculated by rounding the time of occurrence to the nearest hour. Figures based on those strikes recorded by the ATSB, in which a time of strike was given.

FIGURE 7:
Total birdstrikes by time of day

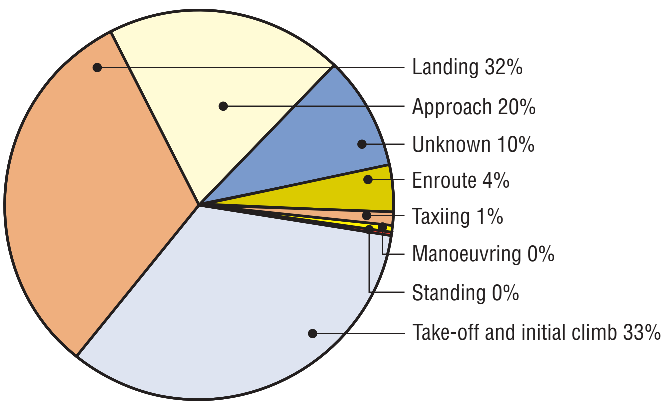


As can be seen, birdstrikes are most frequent between seven and eleven in the morning and again between 7 and 9 at night. This suggests that birdstrikes are most common during the dawn, early morning and dusk periods. However, caution must be used when interpreting these figures, as they may predominantly represent the level of aircraft activity at those times.

3.4 Phase of flight

The majority of birdstrikes occur on or near the airport environment. This corresponds to several critical phases of flight – approach, landing, take off and climb. ICAO statistics reveal that 55.2 per cent of strikes occur during the approach and the landing roll, while 39.4 per cent occur during take-off or initial climb. The Australian statistics between 1991 and 2001 reveal a similar picture.

FIGURE 8:
Birdstrikes within Australia by phase of flight (1991–2001)



Overall, 52 per cent of recorded birdstrikes in Australia occur during the approach and landing phase, while 33 per cent occur during the take off or initial climb phase. These results are in accordance with ICAO findings that the majority of birdstrikes (64.5 per cent) occur below 100 feet above ground level. ICAO figures also indicate that almost 51% of strikes occur with an airspeed of between 101 and 150 kts (ICAO, 1999).

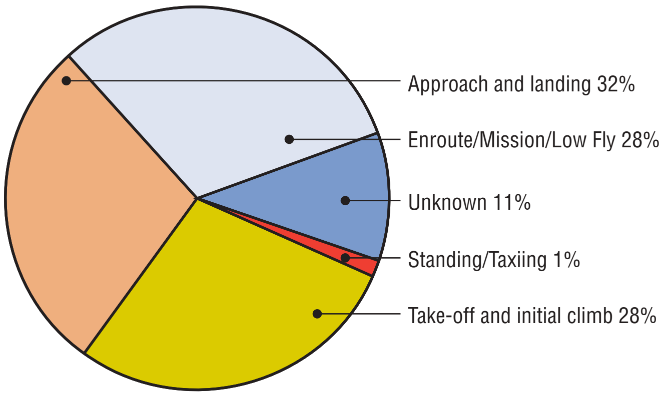
The occurrence of birdstrikes during the takeoff, approach and landing phases of flight raises several flight safety issues. A strike during these critical phases of flight gives flight crew little time to recognise, plan and react. For example, a strike during a take-off roll may leave the flight crew only seconds to determine whether to abort the takeoff. Hence, every effort should be made to minimise bird activity on and around airport environments.

Birdstrike (ICAO, 1991)

During the take-off roll, a gull was ingested by one of the engines on a B737. The affected engine lost power, at which point the pilot decided to abort the takeoff. The pilot applied the brakes at the last minute and tried to stop the aircraft. As a result, the aircraft skidded off the runway and sank to a halt in a swampy area. All fifty eight passengers were evacuated.

DFS data show similar trends. The primary difference between civilian and military data is the higher number of strikes which occur to military aircraft during the enroute/mission/low-flying phase of flight. This is primarily due to the higher number of military flights conducted at low levels, and the high-speed operations involved. Figure 9 illustrates this trend.

FIGURE 9:
Military birdstrikes within Australia by phase of flight (1986–2001)



Strikes during high speed, low level military operations leave little time for crews to react and recover.

Birdstrike (DFS, 1990)

On 29 September 1977, the crew of an RAAF F-111 were killed when their aircraft suffered a multiple birdstrike. Investigation of the wreckage revealed that three separate birdstrikes with pelicans had occurred. All of these hit the forward cockpit windscreen and at least one penetrated into the cockpit area. Pieces of windscreen, canopy, helmet visor cover and helmet visor were found from 1500m to 2750m prior to the aircraft impact position. The aircraft position, altitude and airspeed were calculated to be approximately 2000ft AMSL and at an airspeed of approximately 465kts at bird impact.

Investigations revealed that the instructor pilot initiated the ejection sequence approximately ten seconds after the initial impact. Actual separation occurred 0.35 seconds later at about 700ft AMSL and at a speed of 520kts. The escape module was out of the ejection envelope at that time, The aircraft mainframe crashed in a 30 degree dive angle and right wing low. The module travelled 298ft past the primary crater and broke up on ground impact.

3.5 Species involvement and hazard potential

An understanding of the species most frequently involved in birdstrikes to aircraft is vital for the development of sound control and avoidance procedures and practices. Table 3 outlines the top twenty most struck birds[17] in Australia between 1991 and 2001, the percentage of strikes which resulted in damage to the aircraft and the percentage of strikes which had an adverse effect on the planned flight. By summing these two percentages, a hazard ranking for each species can be calculated (Dolbeer, Wright & Clery, 1998). The ranking does not take into consideration the number of strikes involving any particular species, and as such, does not consider the probability of a strike occurring with a particular species. However, the hazard ranking method is a useful tool in developing control priorities, based on the potential to cause damage or interrupt flights.

TABLE 3.
Species and hazard rankings for the 20 most struck Australian birds (1991–2001).

Species	*Number of Strikes Recorded*	*% Resulting in Damage to Aircraft*	*% Having Effect on Planned Flight*	*Composite Hazard Ranking*
Eagle	38	55.3	13.2	1
Ibis	39	41.0	17.9	2
Duck	52	26.9	19.2	3
Bat	72	25.0	13.9	4
Galah	154	17.5	14.9	5
Gull	136	15.4	3.7	6
Kite	90	14.4	4.4	7
Hawk	156	12.8	5.1	8
Pigeon	53	16.9	0	9
Owl	19	5.3	10.5	10
Lark	16	12.5	0	11
Starling	17	11.8	0	12
Magpie	117	5.1	5.9	13
Plover	143	6.9	2.8	14
Curlew	31	9.7	0	15
Peewee	18	0	5.6	16
Falcon	18	0	5.6	17
Swallow	66	4.6	0	18
Kestrel	92	1.1	0	19
Sparrow	38	0	0	20

[17] Due to the nature of birdstrike reporting, general terms are often used to identify the species of bird struck. Therefore, a number of sub-species may be listed under the one common generic name. These generalisations should be taken into account when interpreting the following figures.

Table 3 includes only the top twenty most struck Australian bird species. Birds such as pelicans and cockatoos, for example, may have a higher hazard ranking, but as strikes with these birds did not occur very often, they do not appear in this list. Refer to Attachment C for a full listing of species struck. Individual airport operators can make an area specific hazard list by keeping thorough records of species struck (when identifiable), the percentage of strikes resulting in damage and the percentage of strikes having an effect on a flight (such as an aborted takeoff). Such a list can then be used to develop control methods and priorities for that airport. However, this does not obviate the requirement to report all birdstrikes to the ATSB.

For the current study, the top five most struck birds (hawk, galah, plover, gull and magpie) correspond closely to those species found in a study by the BHIU in 1984 to be most struck (plover, gull, hawk, kite and galah). This suggests some consistency over time in regard to the species most commonly struck.

Over 50 per cent of strikes reported do not identify the species involved. This may be the result of flight crew not noticing the strike, or there not being sufficient facilities available to identify the carcass. The above lists, therefore, should be interpreted accordingly.

According to the Australian statistics between 1991 and 2001, 87.5 per cent of birdstrikes involved only one bird, which is similar to ICAO statistics which suggest that 79.1per cent of recorded birdstrikes involve only one bird.

3.6 Damage and impact forces

Occurrence Number 199804451

Birdstrike

Whilst taxiing for departure, the left propeller was struck by a large bird resulting in the separation of one propeller blade. The ensuing vibration caused substantial damage to the engine mountings and firewall before the engine could be shut down.

ICAO data indicates that 22.8 per cent of birdstrikes cause some form of damage to the aircraft. The Australian birdstrike figures between 1991 and 2001 indicate that 13.8 per cent of birdstrikes result in damage to the aircraft. An analysis of the parts most commonly damaged during a strike found:

- 35.1 per cent of damage strikes (or 4.8 per cent of total strikes) caused some form of damage to the wing or main rotor;
- 24.4 per cent of damage strikes (or 3.4 per cent of total strikes) caused some form of damage to one or more of the aircraft's engines; and
- 7.9 per cent of damage strikes (or 1.1 per cent of total strikes) caused some form of damage to the windshield or surrounding structures.

Occurrence Number 9601590

Birdstrike

The Dash 8, with a crew of three and 14 passengers, was passing 4,800ft on descent to Broome at 243kts when it struck a wedge-tailed eagle. The bird impacted the leading edge at the root of the left wing. The wing-to-fuselage fairing was punctured and the forward wing spar and the electrical components attached to the spar were damaged.

The left engine instrumentation failed and the master caution panel indicated multiple systems failures. The crew shut down the left engine 2 minutes and 9 seconds after the birdstrike. The left main landing gear unsafe warning light illuminated when the landing gear was extended. The crew discontinued the landing approach and elected to hold between 5nm and 10nm northwest of the aerodrome while they checked the aircraft systems.

Thirty-seven minutes after the birdstrike, the aircraft was landed on runway 10. During the latter part of the landing roll, the pilot in command was unable to maintain directional control through the nosewheel steering. He attempted to slow the aircraft using reverse thrust on the right engine and the normal brakes, but the brakes failed. The aircraft veered off the sealed runway to the right before the pilot stopped it using the emergency brake system.

Many studies that have attempted to investigate the impact force of birdstrikes, have made the assumption that the force of impact is equal to half of the mass of the bird, multiplied by the square of the speed of the aircraft ($E=\frac{1}{2}$ x Mass x Velocity^2). However, this formula does not take into account the shape of the bird, the speed and direction which the bird is flying, nor the extent to which the birds' body deforms during the collision. The following figures were prepared by Associate Professor John O'Connor at the University of Newcastle to address these inadequacies. As there are so many variables involved in a birdstrike, it is not possible to provide one number to quantify the possible effect. In the following table, a range of variables have been used reflecting the range of possible collisions suffered in a strike. For a more detailed explanation of the methods used, refer to Attachment B. The references to FAR requirements relate to the airspeeds at which certain aircraft structures are currently tested.

TABLE 4.
Physical parameters associated with birdstrikes on aircraft.

Bird size	***Small***	***Medium small***	***Small medium***	***Large medium***	***Medium large***	***Large***
Typical Species	Starling	Cattle Egret	Eastern Curlew	Duck	Ibis	Pelican
Weight (kg)	.085	.300	.700	.900	1.800	5.000
Diameter (m)	.035	.054	.071	.078	.098	.138
Density (gm/cc)	1.026	.992	.969	.962	.943	.915
Aircraft speed 140kts (FAR 23.775 & FAR 33.77)						
Impact speed (m/s)	58-86	58-86	58-86	58-86	58-86	58-86
Impact force (tonnes)	0.1-0.9	0.3-2.1	0.4-3.7	0.5-4.4	0.8-6.9	1.6-13.7
Aircraft speed 250 kts						
Impact speed (m/s)	115-143	115-143	115-143	115-143	115-143	115-143
Impact force (tonnes)	0.4-2.5	1.0-5.8	1.7-10.2	2.0-12.0	3.2-19.0	6.0-38.0
Aircraft speed 350 kts (FAR 25.775 & FAR 25.571)						
Impact speed (m/s)	166-194	166-194	166-194	166-194	166-194	166-194
Impact force (tonnes)	0.9-4.6	2.1-10.7	3.6-18.8	4.3-22.3	6.7-35.3	13-70

Note: In the foregoing, it is assumed that the bird is travelling at a speed of 50 kilometres per hour (14m/s)

As can be seen from Table 4, birdstrikes can result in substantial forces being exerted on an aircraft. Even small birds such as starlings can exert up to 4.6 tonnes of force on an aircraft if struck at high speeds. Table 4 illustrates why large birds, such as pelicans and eagles, are very hazardous to aircraft. If a large eagle is struck by an aircraft travelling at approximately 140kts, the impact force could be up to 13.7 tonnes. Figure 10 illustrates the destructive forces that are often involved during a birdstrike.

FIGURE 10:
Birdstrike damage

4 CONCLUSIONS

- Birdstrikes continue to be a problem despite various individual efforts to reduce their occurrence. Increasing bird populations and an expanding world aviation fleet ensure that birdstrikes will remain a safety issue.
- Worldwide, birdstrikes are estimated to cost the civilian aviation fleet $US3 billion annually. The majority of these costs are associated with disruptions to commercial operations.
- In addition to the traditional bird control techniques, such as live and cracker shotgun rounds, airport authorities (particularly those involved in military aviation) are now investigating new ways of deterring birds from airports. Among other techniques, the US developed Avian Hazard Advisory System (AHAS) is proving to be a successful method of reducing birdstrikes.
- Higher birdstrike reporting rates would enable a more thorough understanding of the problem, and would allow for the development of more effective bird control and management techniques. It is important that all strikes are reported to the ATSB to enable more thorough data analysis and information to be released back into the aviation industry. This can now be done through a reporting form on the ATSB website (www.atsb.gov.au).
- The available data suggests that there has been a significant increase in the rate of both total birdstrikes and damage birdstrikes recorded between 1991 and 2001. The evidence suggests that this is a result of an increasing number of strikes occurring, although a proportion of the increase could be a result of an improving reporting culture.
- Both Australian statistics and ICAO reports suggest that the majority of birdstrikes occur on or near the airport environment. This corresponds to several critical phases of flight – approach, landing, take off and climb, and the statistics show that birdstrikes are most common at these stages of flight. Australian military statistics indicate that whilst the majority of strikes to military aircraft also occur on or near the airport, over one quarter of strikes occur during low level operations.
- Birdstrike rates appear to vary according to the time of day. The available data suggests that strikes are most common in Australia during dawn, early morning and dusk. This may be due to a combination of bird and aircraft activity at these times. Birdstrikes also vary by month and location. These variations are likely to reflect bird movements within Australia throughout the year.
- The most struck bird species in Australia between 1991 and 2001 include the hawk, galah, plover, gull and magpie. These are similar to the findings of a 1984 Bird Hazard Investigation Unit study. A composite hazard ranking allows airport authorities to assess which species pose the greatest threat to aircraft if struck, and to prioritise control methods accordingly. The results of the current study suggest that the top five most hazardous species in Australia between 1991 and 2001 were the eagle, ibis, duck, bat and galah.
- Birdstrikes are capable of exerting very large forces on an aircraft. According to the ATSB data, the most commonly damaged sections of an aircraft following a

birdstrike include (not unexpectedly) the wings or main rotor, the engine(s) and the windshield.

This study aimed to provide an outline of the Australian birdstrike statistics, and to remind all those involved in the industry of the potential hazard posed by birds. It also highlights the importance of reporting birdstrikes giving as much detail as possible to the ATSB.

5 SAFETY ACTIONS

Airport owners and operators should look to develop a measured control program aimed at reducing the risk posed to aircraft by birds and may wish to consider formal control evaluation procedures to evaluate current bird control techniques.

Priority should be given to the development of an Australian Birdstrike Working Group. Such a group should include industry representatives from Australia, and should liase with other such groups and industry representatives from the surrounding regions. Such a body may enhance awareness of the safety issues surrounding birdstrikes; provide an opportunity for birdstrike information, knowledge and advice to be shared; and may also determine directions for future research, regulations and procedures to mitigate the risk posed to aircraft by birds. This may include:

- a review of the need for the development of a system similar to the US AHAS for use within Australia;
- investigating the need for improved avian control measures, based on current programs, operations and risk at various Australian airports.

The Civil Aviation Safety Authority, Department of Defence and ATSB may wish to consider cooperatively producing regular, standardised reports and educational material focusing on strike rates and bird hazard potentials, as well as presenting other birdstrike-related data and new control methods.

6 FURTHER READING

The following articles and websites regarding various aspects of birdstrikes may be of interest to those researching the topic, or for those who wish to find out more about the issues raised in this paper.

- *Handbook of Australian, New Zealand and Antarctic Birds (HANZAB)*. Birds Australia.
- *Airport Wildlife Management: Most Hazardous Species*. Transport Canada Safety and Security, Bulletin No. 26, Spring, 2000.
- *Bird Strike Prevention: Applying Aero-Science and Bio-Science*. International Bird Strike Committee, 2000.
- *The Avian Hazard Advisory System (AHAS)*. Flying Safety, April 2000.
- *General Aviation Safety Sense 10A: Bird Avoidance*. UK Civil Aviation Safety Authority, 2000.
- *A Protocol for Bird Strike Risk Assessment at Airports*. International Bird Strike Committee, 2000.
- *Reported Bird Strikes in Australia*. Australian Transport Safety Bureau (BASI), 1996.
- *Bird Strikes: Managing Birds at Airports to Improve Aviation Safety*. Airliner, Jan-Mar 1995.
- http://birdstrike.bcrescue.org/birdlinks.html
- http://www.int-birdstrike.com/
- http://www.ahas.com/
- http://www.icao.int/
- http://www.birdsaustralia.com.au/
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Lewis, C.M. (1995). *Engine Bird Ingestion.* Airliner, Jan–Mar, 17-19.

National Transportation Safety Board (1999). *Safety Recommendation A–99–86 through – 94.* November

Short, J.J., Kelley, M.E., Speelman, R.J. & McCarty, R.E. (2000). *Birdstrike Prevention: Applying Aeroscience and Bio-Science.* International Bird Strike Committee.

ATTACHMENTS

Attachment A

Note: As stated above, this attachment is taken directly from the ICAO Bird Strike Manual, and as such will have some parts which are not relevant to the Australian context. It should be used as a guide only, or adapted as necessary for use within Australia.

Assesing wildlife hazard management plans at airports

This appendix describes a system (modified from Seubert 1941) for objectively assessing the implementation of wildlife hazard management plans at civil airports. Five assessment categories, each with a list of elements to be evaluated, are used to indicate how well airport wildlife hazard management plans are being implemented.

Category 1. **Management functions related to wildlife hazards at or in the vicinity of the airport.**

Category 2. **Bird control at or in the vicinity of the airport.**

Category 3. **Mammal control at or in the vicinity of the airport.**

Category 4. **Management of habitat and food sources on airport property related to wildlife hazards.**

Category 5. **Land uses and food sources off airport property potentially related to wildlife hazards at the airport.**

The elements described in Categories 1-4 are assessed as to the degree that management programs are being implemented. The elements in Category 5 are rated as to the degree of hazard posed. Elements within each category are not intended to cover every possibility – they can be modified or expanded to meet situations unique to an airport. During an assessment, each element in Categories 1-4 is examined and classified as one of the following:

S = Satisfactory. If an assessor finds that an airport has initiated action to reduce a wildlife hazard according to plan and is on schedule, the action would be considered ‘satisfactory’.

U = Unsatisfactory. If no measures have been taken or inappropriate measures taken, the assessment would be ‘unsatisfactory’.

NI = Needs improvement. If implementation of a control measure is behind schedule or only partially accomplished, the assessment would be either ‘needs improvement’, or ‘unsatisfactory’, depending on the seriousness of the hazard.

NA = Not applicable. If it is apparent that certain listed techniques or items are not applicable to the airport, the assessment would be ‘not applicable’.

If an assessment is either 'NI' or 'U', a comment by an assessor is required on the Assessment Summary Form (last page). Examples of assessments requiring comments are as follows:

Category 1. Management functions related to wildlife hazards at or in the vicinity of the airport.

- If permits have not been obtained (Code 1.1) for shooting or trapping birds or mammals, the assessment would be U'.
- If animal remains found on runways are being counted to document bird strikes, but are not being identified by species (Code 1.13), the assessment would be 'NI'.

Category 2. Bird control at or in the vicinity of the airport.

- If bioacoustics are not being used (Code 2.2), the assessment would be 'U'.
- If the installation of wires (Code 2.9) over an airport pond is behind schedule, the assessment could be 'NI' or 'U', depending on the degree of potential hazard.
- If raptors are not being trapped and relocated (Code 2.22), the assessment would be 'U'.

Category 3. Mammal control at or in the vicinity of the airport.

- If fencing (Code 3.2) is in need of repair, the assessment would be 'NI'.
- If rodenticides (Code 3.12) are not being used to control a rodent population attracting raptors, the assessment would be 'U'.

Category 4. Airport habitat and food sources related to wildlife hazards.

- If airport litter control is inadequate (Code 4.9), the assessment would be 'NI'.
- If trees used as a roost site (Code 4.3) are not being eliminated or thinned to be made unattractive, the assessment would be 'U'.

Categories 1-4 focus on actions that can be taken on the airport to reduce wildlife hazards.

Category 5 provides a list of off-airport land uses and food sources that may be attractive to birds or other wildlife. The assessor should review this list and score each element on a scale of 0 to 3:

0 = land use or food source not present;

1 = present but no wildlife problems noted or anticipated;

2 = site attracts some hazardous wildlife creating possible or potential problem, site should be monitored;

3 = site creates significant wildlife hazard for airport, action should be taken.

Wildlife hazards at airports frequently are attributable to these off-site attractants, but airport managers have no authority over the use of private property. However, airport managers can initiate programs to reduce the hazards of these off-airport wildlife attractants (e.g., garbage dumps, certain agricultural activities) by informing local jurisdictions and landowners of the hazards, and suggesting ways of alleviating them (Code 1.12).

Catergory 1. Management functions related to wildlife hazards at or in the vicinity of the airport.

ASSESSMENT CODE ITEMS S NI U NA

1.1 Acquiring wildlife control permits from federal, state, and local agencies

1.2 Arranging for wildlife hazard assessments and other studies, as needed, to evaluate hazard potential of wildlife attracted by habitats, land uses, and food sources on or in vicinity of airport.

1.3 Developing Wildlife Hazard Management Plan based on Wildlife Hazard Assessment and other studies and factors.

1.4 Defining and delegating authority and responsibility for Wildlife Hazard Management Plan.

1.5 Supervising, implementing, and coordinating airport Wildlife Hazard Management Plan.

1.6 Evaluating Wildlife Hazard Management Plan at least once a year.

1.7 Training personnel responsible for implementing airport Wildlife Hazard Management Plan, especially field personnel.

1.8 Operating wildlife patrol system with a trained field staff, conducting surveillance/inspections of critical airport areas, and effecting wildlife control when needed or requested.

1.9 Establishing a communication capability between wildlife control and ATC personnel.

1.10 Maintaining a system for warning pilots about wildlife hazards (e.g., NOTAMS, ATC, Radar observations).

1.11 Ensuring that airport habitats are managed to reduce or eliminate wildlife attractions.

1.12 Ensuring that airport policy prohibits feeding of wildlife and exposure of food wastes.

1.13 Interacting with local jurisdictions and landowners about zoning, land use, and the resolution of wildlife hazard problems in vicinity of airport.

1.14 Maintaining log book with daily record of wildlife control activities, wildlife activity, and reported wildlife strikes and wildlife remains found on runways identified by species.

1.15 Reporting all wildlife strikes to FAA.

Catergory 2. Bird control at or in the vicinity of the airport.

ASSESSMENT CODE TECHNIQUES S NI U NA

DISPERSE, DETER, EXCLUDE, REPEL

2.1 Bird patrols in vehicle

2.2 Bioacoustics (distress calls)

2.3 Electronically generated noise

2.4 Propane cannons

2.5 Pyrotechnics

2.6 Shooting to scare

2.7 Netting hangar rafters, ponds etc.

2.8 Perching deterrents (e.g., stainless steel needles)

2.9 Overhead wires for ponds, ditches, roofs etc.

2.10 Chemical repellents

2.11 Falconry

2.12 Dogs

2.13 Radio-controlled aircraft

2.14 Thinning or eliminating roosting trees and shrubs

2.15 Grass management

2.16 Scarecrows

2.17 Dead bird effigies

REMOVE

2.18 Chemical capture (alpha chloralose)

2.19 Nest and egg destruction

2.20 Poisoning

2.21 Predators to remove eggs (foxes, pigs, etc.)

2.22 Shooting

2.23 Trapping and relocation (e.g., raptors)

Catergory 3. Mammal control at or in the vicinity of the airport.

ASSESSMENT CODE TECHNIQUES S NI U NA

DISPERSE, DETER, EXCLUDE, REPEL

3.1 Cattle guards

3.2 Fencing

3.3 Vehicle patrols

3.4 Propane cannons

3.5 Pyrotechnics

3.6 Rodent-resistant sheathing on electrical cables

REMOVE

3.7 Controlled hunting (e.g., deer)

3.8 Den destruction (e.g., coyotes)

3.9 Fumigants (e.g., woodchucks)

3.10 Kill trapping (e.g., beavers, muskrats)

3.11 Live trapping and relocation or euthanasia (e.g., dogs)

3.12 Rodenticides (e.g., mice, ground squirrels)

3.13 Shooting (e.g., deer, woodchucks, hares)

Catergory 4. Management of habitat and food sources on airport property related to wildlife hazards.

ASSESSMENT CODE ITEMS S NI U NA

Agriculture/vegetation managemant

4.1 Agricultural crops (especially grains)

4.2 Plowing, mowing, harvesting (rodents, insects,worms)

4.3 Landscaping (fruits & roost sites attractive to birds)

4.4 Brush, shrubs, wood lots (cover, browse for deer)

4.5 Misc. nesting sites (e.g., trees) for egrets, raptors, etc.

Waste management/sanitation

4.6 Feeding birds and mammals (by people)

4.7 Food waste storage (e.g., cafeterias, catering services)

4.8 Garbage dumps

4.9 Litter

4.10 Sewage treatment ponds/lagoons/outfalls

4.11 Weeds, construction debris, junk yards

4.12 Animal carcasses (dead livestock, bird strike remains)

Water sources

4.13 Aquatic vegetation

4.14 Canals, ditches, creeks, waterways

4.15 Low areas on pavement/ground that collect water

4.16 Retention ponds (water, de-icing fluid)

4.17 Water fountains

Miscellaneous attractants

4.18 Earthworms along runways

4.19 Insects hatches from vegetation or soil

4.20 Seed-producing vegetation.

4.21 Flat roofs (e.g., gull nesting and loafing sites)

4.22 Structures (hangars, towers, signs, poles, etc.)

Catergory 5. Land uses and food sources off airport property potentially related to wildlife hazards at the airport.

CODE ITEMS SCORE and COMMENTS

0 = not present;

1 = present but no wildlife problems noted or anticipated;

2 = site attracts some hazardous wildlife creating possible or potential problem, site should be monitored;

3 = site creates significant wildlife hazard for airport, action should be taken.

Agriculture

5.1 Agricultural crops (especially grains)

5.2 Aquaculture facilities

5.3 Livestock feedlots

5.4 Grain storage or grain mills

Commercial/recreational land uses

5.5 Drive-in theaters, amusement parks etc.

5.6 Restaurants (esp. outdoor eating areas)

5.7 Picnic areas, parks

5.8 Marinas

5.9 Golf courses

5.10 Flat roofs (gull nesting sites)

Waste management

5.11 Garbage barges

5.12 Garbage dumps

5.13 Garbage transfer stations

5.14 Fish processing plants

5.15 Sewage lagoons, outfalls

Water sources

5.16 Retention ponds (water, feedlots, etc.)

5.17 Canals, creeks, ditches

5.18 Reservoirs, lakes, natural ponds

Nesting/loafing/feeding areas

5.19 Wildlife refuges/nature preserves

5.20 Misc. nesting sites (egrets, raptors, etc.)

5.21 Roosting trees (starlings, egrets, etc.)

5.22 Marshes, swamps, mud flats

SUMMARY FORM

(Wildlife Hazard Assessment): Comments are required for all elements in Categories 1-4 assessed as 'Unsatisfactory' or as 'Needs Improvement' or with a score of 2 or 3 in Category 5.

Airport: **Date:**

Manager or wildlife supervisor:

Phone:

Fax:

E mail:

Assessor:

Phone:

Fax:

E mail:

Assessors comments for elements rated 'unsatisfactory' or 'needs improvement' in Categories 1-4 or for elements scored 2 or 3 in Category 5.

Element code Assessment symbol Comment Assessor's general comments (use back if needed):

Attachment B

Physical parameters associated with bird strike on aircraft

Prepared by John O'Connor, Associate Professor, Physics, University of Newcastle ©

Assumptions and Equations Associated with the Bird Strike Table

The accompanying table on the physical parameters associated with bird strikes on aircraft have been calculated using 'model' bird parameters based on the common characteristics of over 100 birds which have been parameterised [1].

As there are so many variables in a birdstrike, it is not possible to provide one number to quantify the effect. In the following table a range of variables have been used reflecting the range of possible collisions suffered in the strike. In all cases where there are unknowns, conservative figures have been used so that the accompanying tables should be read as lower limits.

In deriving the table the following assumptions have been made:

- In all calculations only average forces, pressures etc have been calculated. Thus the figures quoted must be viewed as lower limits to the peak values which will occur. To do otherwise would require serious measurement of the time dependence of impact parameters which could only be obtained by 'sacrificing' many birds in a detailed series of measurements. This would not ultimately improve the predictive capability sufficiently to warrant such expenditure and suffering on the part of laboratory animals.
- The bird is travelling at a speed of 50 km/hr at the time of the impact. This speed is typical of most birds in this mass range. An account has been taken of the fact that the bird may be heading either in the same direction, across the path of or head on to the aircraft. This leads to a range of outcomes which is reflected in the table.
- The duration of the impact depends on how much the bird's body deforms during the collision. As this information is not currently available then some assumptions can be made. The most extreme is that the body is compressed to zero dimension (flat) in the direction of the plane's travel and this would give again a lower estimate to the parameters listed on the table. A more realistic estimate is for the distance to be half the thickness of the bird's body which consequently increases the magnitude of the force of impact and the pressure. However one could get embroiled in a meaningless argument about whether it is half, 40 per cent, 65 per cent etc so in keeping with the principle outlined above, the assumption of being squashed flat is made as it will provide a lower limit to the real values.
- It was assumed that in the collision the bird did not suffer an glancing blow. The modelling is done on the basis that the collision is head on with a structure which brings the bird to the same speed as the aircraft.
- The 'shape' of the bird affects the outcomes of the prediction process. To be as comprehensive as possible, three different shapes have been used in keeping with previous studies [1]. The shapes of the birds have been idealised as a simple cylinder, a cylinder with hemispherical ends and an ellipsoid.
- In all calculations the parameters associated with 'plucked birds' have been used to reflect the physical characteristics of the model birds. This choice has been made as there is greater variability in bird types when feathers are included. Also any

‘cushioning’ effect in the collision has been more than accounted for by the assumption that the bird is squashed flat in the collision.

Details Associated with the Calculation of Collision Parameters

Mass and Density:

From a database of over 300 species of birds the relationship between mass and density (for plucked birds) has been assessed to be:

$$\text{Density(plucked)} = 1.148 - 0.063 \log_{10} \text{Mass}$$

where density is in gm/cc and mass is in gms. This can also be expressed as:

$$\text{Density(plucked)} = 959 - 63 \log_{10} \text{Mass}$$

where density is in kg/m^3 and mass is in kg.

Mass and Torso Diameter:

From the same database as above, the relationship between mass and torso diameter is:

$$\log_{10} \text{Diameter} = 0.900 + 0.335 \log_{10} \text{Mass}$$

where diameter is in mm and mass is in gms. This can also be expressed as:

$$\log_{10} \text{Diameter} = -1.095 + 0.335 \log_{10} \text{Mass}$$

or

$$\text{Diameter} = 0.0804 \text{ Mass}^{0.335}$$

where diameter is in metres and mass is in kg.

Collision Parameters:

Energy:
The collision is assumed to be perfectly inelastic and thus the kinetic energy lost is given by:

$$\text{Kinetic Energy Loss} = \tfrac{1}{2}m\,(V - v)^2 / (1 + (m/M))$$

where m is the mass of the bird, M is the mass of the aircraft, v is the velocity of the bird and V is the velocity of the aircraft. As the mass of the bird is much less than the mass of the aircraft, the term (1 + m/M) can be dropped as it is negligible.

Time:
The duration of impact, T, is taken to be the length of the bird divided by the relative speed for both a head-on or tail-on collision. For a side on collision the time is taken to be the diameter of the bird divided by the speed of the plane.

Force:
The force is calculated as the change in kinetic energy loss divided by the time taken. This provides an average force which will be less than the peak value. Thus

$$\text{Average Force} = \text{Kinetic Energy Loss / Time of Collision}$$

As units of force are not used in everyday situations, they have been converted to the equivalent force exerted by a mass under gravity. This provides a gauge of the magnitude which is more readily appreciated by non-technical readers.

Pressure:
The pressure is defined as the force per unit area. To calculate the average pressure in this table, the force is divided by the end on cross sectional area for a head-on or tail-on collision and the side on cross sectional area for the side-on collision. This is also an average for the duration of the collision and will have peak values which are much greater than those listed.

As a guide to the magnitude of pressures involved, a G size industrial gas cylinder is designed to hold a pressure of in excess of 5 M Pa and a standard scuba diving tank holds a pressure of 20 M Pa.

Volume and Density:
The volume and density are linked by the mass of the bird in that density is the mass divided by volume. There are three different models of bird shape so the parameters for each have been used. From the equations given above, once the mass is known, the bird's diameter and density are provided. Then the volume and length can be determined.

Cylindrical Model Bird:
If the diameter, D, of the bird, and its volume, V, calculated from its mass, M, and density, D, then the length of the bird, L, is derived from:

$$V = B\ (D/2)^2\ L$$

$$\triangle = M / V = 4\ M / (B\ D^2\ L)$$

$$L = 4\ M / (B\ \triangle\ D^2\ )$$

Head on cross sectional area = $B\ (D/2)^2$

Side on cross sectional area = D L

Cylindrical Model Bird with Hemispherical Ends:

$$V = (4/3)\ B\ (D/2)^3 + B\ (D/2)^2\ L$$

$$V = B\ D^2\ (\ D/6 + L/4)$$

$$\triangle = M / V = M / (B\ D^2\ (\ D/6 + L/4))$$

$$L = 4\ (M/(B\ \triangle\ D^2) - D/6)$$

Where L is the length of the straight cylinder section.

Head on cross sectional area = $B\ (D/2)^2$

Side on cross sectional area = $D\ L + B\ (D/2)^2$

Ellipsoidal Model Bird:

If the ellipsoid has a cigar shape with a diameter D and a length L, then

$$\text{Volume} = V = B\ D^2\ L\ /6$$

$$\triangle = M\ /\ V = 6\ M\ /\ (B\ D^2\ L)$$

$$L = 6\ M\ /\ (B\ D^2\ \triangle)$$

Head on cross sectional area = $B\ (D/2)^2$

Side on cross sectional area = $B\ (D\ L\ /\ 4)$

References

[1] 'Artificial Bird Proposal', report of the International Birdstrike Research Group.

Attachment C

Birdstrike species information

Species	*Strikes Recorded*	*Multiple Strikes*	*% Resulting in Damage to Aircraft*	*% Having Effect on Planned Flight*
Hawk	156	7	12.8	5.1
Galah	154	77	17.5	14.9
Plover	143	24	7	2.8
Gull	136	37	15.4	3.7
Magpie	117	7	5.1	5.9
Kestrel	92	5	1.1	0
Kite	90	8	14.4	4.4
Bat	72	12	25	13.8
Swallow	66	25	4.5	0
Pigeon	53	18	16.9	0
Duck	52	16	26.9	19.2
Ibis	39	7	41	17.9
Sparrow	38	4	0	0
Eagle	38	0	55.3	13.2
Curlew	31	2	9.7	0
Owl	19	0	5.3	10.5
Peewee	18	2	0	5.6
Falcon	18	1	0	5.6
Starling	17	4	11.8	0
Lark	16	1	12.5	0
Cockatoo	14	6	50	14.3
Herren	14	1	7.1	0
Turkey	12	0	25	16.7
Pratincole	11	3	9.1	0
Tern	10	1	10	20
Crow	9	3	55.6	0
Martin	9	2	0	0
Finch	9	2	0	11.1
Pelican	9	1	77.8	22.2
Bustard	9	0	22.2	33.3
Whimbrel	8	4	0	0

Species	*Strikes Recorded*	*Multiple Strikes*	*% Resulting in Damage to Aircraft*	*% Having Effect on Planned Flight*
Raven	8	0	0	0
Egret	7	0	28.6	0
Sandpiper	7	0	0	0
Skylark	6	0	16.7	0
Pipit	6	0	0	0
Swift	5	0	40	20
Magpie Goose	4	2	25	25
Goose	3	2	66.7	33.3
Emu	3	0	33.3	0
Crane	3	0	33.3	33.3
Courser	3	0	0	0
Lorikeet	3	0	0	0
Dove	3	0	0	0
Osprey	2	1	50	50
Harrier	2	1	0	0
Brolga	2	1	0	0
Cormorant	2	0	50	0
Dotterel	2	0	0	0
Sanderling	2	0	0	0
Willy Wagtail	2	0	0	0
Robin	2	0	0	0
Mutton Bird	1	1	0	0
Prantel	1	1	0	0
Kookaburra	1	0	100	0
Kingfisher	1	0	0	0
Stint	1	0	0	0
Albatross	1	0	0	0
Cuckoo	1	0	0	0
Grebe	1	0	0	0
Swamphen	1	0	0	0
Nanking	1	0	0	0
Corsair	1	0	0	0
Godwit	1	0	0	0
Wren	1	0	0	0
Buzzard	1	0	0	0
Blackbird	1	0	0	0
Unknown	1753	126	13.2	5.2

Note: Due to the nature of birdstrike reporting, general terms are often used to identify the species of birds struck. It is therefore not possible to provide any more species detail than those listed above. Unfortunately, this may cause some confusion.

For example, in most cases, the generic term 'plover' may refer to the species 'Vanellus miles' which was previously known as the Spurwing Plover but is now known as the Masked Lapwing. There are 12 other species of plover which are very different is size, behaviour, distribution and abundance to the Masked Lapwing (Birds Australia, 2002). These generalisations should be taken into consideration when interpreting the above figures.

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