

REDUCING THE INCIDENCE OF BIRD STRIKES INVOLVING HIGH RISK SPECIES AT MELBOURNE AIRPORT, AUSTRALIA

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ABSTRACT

Wildlife strike records have been kept at Melbourne Airport since March 1986. These records show a marked increase in reported strike-rate from 2004—when data from airline operators began consistently to be captured—and therefore only data from 2004 onwards are considered to be comparable. A total of 906 wildlife strikes were reported at Melbourne Airport between 2004 and 2009, inclusive. Of these reports only 438 occurred at or near the airport (i.e. <13 Km from the runway intersection), involved flying animals, and were confirmed through carcasses or physical evidence of a strike on the aircraft.

Annual risk assessments using this dataset identify high-risk species of bird/bat at the airport and management actions are then focused on these species. Initially the Australian Magpie (*Cracticus tibicen*) represented by far the greatest risk of a strike to aircraft at Melbourne Airport, being responsible for around one-fifth of all bird/bat strikes, and one-quarter of all strikes in which the bird/bat species involved was identified. The Masked Lapwing (*Vanellus miles*) was the third most frequently struck species of bird/bat and also ranked high in risk assessments. Other high-risk species include ibis (*Threskiornis* spp.), Rock Dove (*Columba livea*) and Grey-headed Flying-Fox (*Pteropus poliocephalus*).

Melbourne Airport maintains an active and varied wildlife hazards management program that emphasizes habitat management and the elimination of bird attractions. However, restricting food resources available to ground-foraging species of bird across the 750 ha of airside area currently presents an intractable problem. Soil conditions and drought prevent the cultivation of dense grass swards and the cracking black clay soil supports large densities of invertebrates. Therefore, bird harassment aimed at reducing bird numbers at the airport and targeting ground-foraging species remains an important part of the airport's strategy to address the risk of bird strikes. Harassment is not seen as merely reducing bird numbers on the airside but also increasing birds' vigilance and state of alertness, which should somewhat reduce the chance of them being surprised by an aircraft movement.

Since 2007 Melbourne Airport has instituted an intensive harassment program, with one officer dedicated to bird harassment on duty each day and two officers on duty during the periods of greatest risk, autumn and spring. Three high-risk taxa of ground-foraging bird have been particularly targeted: Australian Magpie, Masked Lapwing and ibis. The harassment program includes culling of these species, particularly the naïve subadult birds, displaying ibis carcasses on stakes, and the destruction of Masked Lapwing nests. In addition, since 2008 insecticide has been sprayed close to runways to reduce prey populations ahead of the high-risk spring and autumn periods.

Results have been encouraging. While the reported and confirmed strike-rates do not differ significantly between 2004–06 and 2007–09 (i.e. before and after implementation of the intensive harassment program) the average number of damaging strikes per year has declined from 6.0 to 3.3 between these two periods. The estimated mass of birds/bat struck by aircraft per year averaged over these two three-year periods also shows a slight decline, from 20.7 Kg to 18.9 Kg.

The average number of Australian Magpies counted on the airside has declined from 62.2 during 2004–06 to 32.3 during 2007–09. The number of strikes involving this species has similarly declined by almost half, from an average of 21.3 strikes/yr over 2004–06 to 11.0 strikes/yr during 2007–09. The average number of strikes per year also declined for the Masked Lapwing (from 6.7 per year to 3.0 per year) and ibis (from 4.0 to 1.0).

Key Words: Bird strike, risk management, Melbourne Airport, southeastern Australia, *Cracticus tibicen*

INTRODUCTION

Although bird strikes are not common events—an investigation of bird strikes in Europe between 1981 and 1985 found there was an average of 5.7 bird strikes per 10,000 aircraft movements (Thorpe 1990)—they do present a real hazard to aircraft and exact a significant cost in terms of both human lives and money. In one 1994 estimate the U.S. Federal Aviation Administration assessed that birds and other wildlife caused U.S. \$35 million worth of damage to aircraft in the United States every year, with U.S. \$5 million additional costs due to dumped fuel, flight delays, aircraft schedule changes and loss of revenue (Porter 1994). A more recent estimate attributes direct costs to the U.S. civil aviation industry of damaging strikes at U.S. \$500 million per year, with over 500,000 hours of aircraft down time (Cleary & Dolbeer 2005). One comprehensive review of wildlife strike costs to commercial aviation worldwide (excluding military, general aviation and helicopters) concluded these were in the order of U.S. \$1.2 billion per annum (Allan 2001).

The problem of wildlife strikes is likely to become greater in the future as the volume of air traffic increases. Between 1964 and 1974, wildlife strikes cost the U.S. Air Force over U.S. \$10 million, together with the loss of 11 pilots and 19 aircraft (Burger 1983). By 1993 the annual cost of wildlife strike damage to the U.S. Air Force was U.S. \$15 million (E&SS 1994). A further exacerbation of the problem seems likely since it has been suggested that modern commercial aircraft, which are quieter and have larger engine air-intakes than older models, are involved in proportionately more bird strikes than older aircraft because birds are less able to detect them in time to avoid collisions (Chilvers *et al.* 1997). Finally, there are concerns, particularly in North America, that populations of high risk species of bird are increasing.

While commercial aircraft generally fly too high to be at risk of colliding with birds, many military and light aircraft utilise the same air space as birds, and all aircraft are exposed to the risk of a bird strike when landing or taking off at airports. The threat of bird strikes in the vicinity of an airport is increased because several bird species congregate at these sites (e.g. Blokpoel 1976; Burger 1983). Between 75% and 90% of all wildlife strikes in the United States and Western Europe have occurred at airports (Burger 1983; E&SS 1994), while up to 98% of wildlife strikes in Canada are thought to occur at airports (E&SS 1994). Around 50% of all high-speed rejected take-offs (i.e. those in excess of 120 kts) are due to bird strikes (MacKinnon *et al.* 2001). Thus the management of wildlife at airports—particularly bird populations—to reduce the risk of wildlife strikes is becoming increasingly important to airport operators, including those in Australia (e.g. ATSB 2003).

The worst bird strike incident to have occurred in Australia took place on 29 September 1977, when a Royal Australian Air Force General Dynamics F-111 'Aardvark' struck Australian Pelicans (*Pelecanus conspicillatus*) whilst flying off Evans Head, New South Wales; resulting in the deaths of both crew members and the loss of the aircraft (Directorate of Flying Safety 1997). But there are limited published studies addressing the issue of bird strikes from the Australasian region. In Australia, van Tets published a number of papers during the 1960s and 1970s (van Tets 1969a, 1969b; van Tets *et al.* 1969, 1977) and there is a small number of other peer-reviewed papers (e.g. Lavery 1969; Woodall 1999). From New Zealand there are published studies from Christchurch Airport (Moeed 1976; Chilvers *et al.* 1997), Auckland (Saul 1967), and Wellington and Gisborne Airports (Caithness 1968). The Australian Transport Safety Bureau—and, before its formation, the Bureau of Air Safety Investigation—has maintained records for Australia and published occasional assessments of these

data (BASI 1996; ATSB 2003, 2010; Stanton 2008). There are, of course, also many notes in the 'grey literature', such as those by Steele (1997, 2001) and Giese *et al.* (2000) on work done at Melbourne Airport.

During 1997 Melbourne Airport authorities initiated a program to decrease the site's attractiveness to birds and so reduce the risk of a bird strike on aircraft using the airport. While it is impossible to eliminate all wildlife strikes at an airport from 2007 onwards an intensive harassment program was launched in a targeted effort to reduce the incidence of damaging strikes at Melbourne Airport.

METHODS

Study site

Melbourne Airport, in Victoria, is Australia's second largest in terms of aircraft and passenger movements. The airport operates two major runways: a north-south runway 3.7 Km long and an east-west runway 2.3 Km in length; with an airside manoeuvring area of some 750 ha (Fig. 1). During 2009/10 the airport saw a total of 180,082 air traffic movements (ATMs), including 37,234 movements by aircraft over 136 tonnes (Airservices Australia 2010). Both Melbourne Airport and Launceston Airport, Tasmania, are operated by Australia Pacific Airports Corporation Ltd under a 50-year lease agreement with the Australian Federal Government.

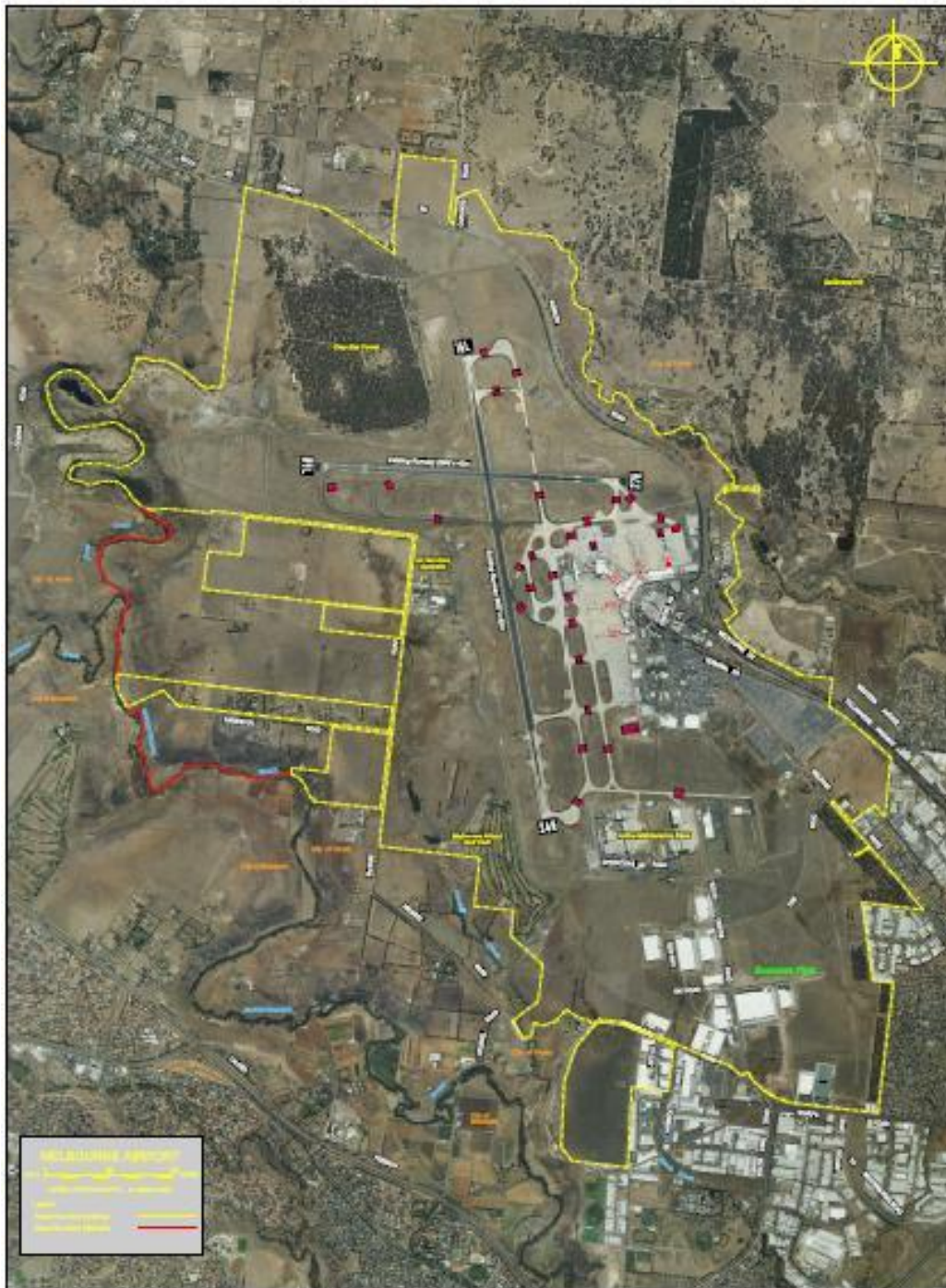


Figure 1. Melbourne Airport.

Melbourne Airport lies on the flat Newer Volcanic Plains which extend to the west of Melbourne, between 100 and 120 m above sea level (Duncan 1982). It is bounded by Moonee Ponds Creek to the east and Deep Creek—which runs through a deeply incised valley some 40 to 50 m below the level of the plain—to the west. To the northwest of the airport lies a small remnant woodland dominated by Grey Box (*Eucalyptus microcarpa*) trees, while the banks of Deep Creek support River Red Gums (*Eucalyptus camaldulensis*) with an understorey of both native and exotic shrubs (Peake *et al.* 1995). Much of the remaining area is pasture with predominantly exotic grasses, although there are windbreaks of trees alongside most of the northern half of the airport's perimeter fence (e.g. KTRI 1995).

Data collection

Reports of wildlife strikes at Melbourne Airport were obtained from a number of sources: Melbourne Airport records, the Australian Transport Safety Bureau (and, before that, the Bureau of Air Safety Investigations), Qantas (including Jetstar), Virgin Blue Australia, and the former Ansett Australia (e.g. Operational Safety Department 1997). In total, 1539 reports of wildlife strikes at the airport from March 1986 to October 2009 are included in the airport's Wildlife Hazards Management Database. Of these reports, 1475 related to flying birds or bats and were classified as 'bird strikes' (as opposed to those strikes involving terrestrial animals).

These records were then further classified as 'on airport', 'near airport' or 'off airport'. A strike 'on airport' was any strike within the confines of the airport's perimeter fence and within the airspace up to 200 ft above ground level on approach and up to 500 ft above ground level on take-off (following E&SS 1994; Manktelow 2000).

Cleary and Dolbeer (2005) recommend a minimum 'separation distance' of 10,000 ft (3 Km) between an airport's perimeter fence and any known wildlife attractant, such as waste disposal facilities and landfills. This separation distance is increased to 5 miles (8 Km) for any facility that attracts wildlife movement into or across approach and departure airspace. Canadian guidelines also give 8 Km as the preferred distance around an airport where no new wildlife attracting development should be permitted (Mackinnon *et al.* 2001; Transport Canada 2002). However, the standard glide slope for aircraft descending for an instrument landing is 3°. The vast majority of bird strikes occur at very low altitudes or even at ground level, and at Melbourne Airport the number of collisions above 2500 ft is negligible. The combination of these two facts leads to the conclusion that bird communities and their flight lines in an area within a 13 Km radius around Melbourne Airport are of potential concern to aircraft traffic. Therefore, a wildlife strike was deemed to be 'near airport' if it occurred outside the area defined as 'on airport' but within an area within a 13 Km radius from the runway intersection.

Of the 1475 reported bird/bat strikes 58 occurred at some distance from Melbourne Airport and 1417 are classified as on, or near, the airport. But, of these reports, only 949 were confirmed through animal carcasses or physical evidence of a strike on the aircraft. These 949 confirmed bird/bat strike reports on or near Melbourne Airport represent a valuable data set that gives us the opportunity to investigate the factors behind strikes and to identify trends over time.

The records show a marked increase in reported strike-rate from 2004—when data from airline operators began consistently to be captured—and therefore only data from 2004 onwards are considered to be comparable. A total of 906 wildlife strikes were reported at Melbourne Airport between 2004 and 2009 (inclusive). Of these reports only 438 occurred at or near the airport, involved flying animals, and were confirmed through carcasses or physical evidence of a strike on the aircraft.

The 64 terrestrial animal strikes reported at Melbourne Airport since 1986, of which only 39 are confirmed, form a smaller and less significant dataset. Strikes on terrestrial animals occur at ground level, and generally at lower speeds which means that they present less of a risk to aircraft than do strikes on flying animals.

Recording of damaging strikes is not yet well standardized across organizations. Airline operators consider any incident incurring a monetary cost, including flight delays and missed landings, to be 'damaging'. This has the result that, in some organization's datasets, strikes that inflict no physical damage to the aircraft are recorded as 'damaging' because there is a cost incurred in inspection and cleaning. In other cases an incident in which it is known that no actual strike occurred is recorded as a damaging strike because aircraft were delayed. From an airport's perspective it is impossible to eliminate strikes altogether and the important thing is to reduce as far as possible the risk of a strike

involving any species which is likely to cause physical damage to an aircraft. Thus, for our purposes here, only strikes reported as causing physical damage to an aircraft are considered as 'damaging' strikes.

During the 23-year period for which we have records—1986 to 2009—there have been 42 bird/bat strikes at Melbourne Airport that are reported to have caused some physical damage to an aircraft. To date no terrestrial animal strikes have been reported to have caused significant physical damage to the aircraft involved.

Table 1. Wildlife species involved in confirmed bird/bat strikes at Melbourne Airport, 1986 to 2009.

Species	No. of strikes	% of strikes	Species	No. of strikes	% of strikes
Unidentified bird	233	24.55	Banded Lapwing	3	0.32
Australian Magpie	171	18.02	Black Kite	3	0.32
Eurasian Skylark	90	9.48	Galah	3	0.32
Masked Lapwing	36	3.79	Ibis	3	0.32
Australasian Pipit	36	3.79	Unidentified owl	3	0.32
Rock Dove	33	3.48	Pacific Black Duck	3	0.32
Nankeen Kestrel	31	3.27	Peregrine Falcon	3	0.32
Grey-headed Flying-fox	27	2.85	Unidentified raptor	3	0.32
Brown Falcon	22	2.32	Whistling Kite	3	0.32
Barn Owl	20	2.11	Wedge-tailed Eagle	3	0.32
Unidentified corvid	20	2.11	Chocolate Wattled Bat	2	0.21
Welcome Swallow	18	1.90	Spotted Turtle-Dove	2	0.21
Unidentified hawk	17	1.79	Unidentified swift	2	0.21
Silver Gull	16	1.69	Barking Owl	1	0.11
Unidentified bat	13	1.37	Black Swan	1	0.11
Black-shouldered Kite	13	1.37	Crested Pigeon	1	0.11
House Sparrow	12	1.26	Common Greenfinch	1	0.11
Common Starling	10	1.05	Hoary-headed Grebe	1	0.11
White-faced Heron	9	0.95	Latham's Snipe	1	0.11
Unidentified kite	8	0.84	Little Eagle	1	0.11
Gould's Wattled Bat	7	0.74	Long-billed Corella	1	0.11
Tree Martin	7	0.74	White-striped Mastiff-bat	1	0.11
Australian Wood Duck	6	0.63	Lesser Long-eared Bat	1	0.11
Australian Hobby	5	0.53	Pink-eared Duck	1	0.11
Little Raven	5	0.53	Pacific Golden Plover	1	0.11
Magpie-Lark	5	0.53	Little Red Flying-fox	1	0.11
Common Bent-wing Bat	5	0.53	Red-browed Finch	1	0.11
Unidentified duck	4	0.42	Straw-necked Ibis	1	0.11
Unidentified eagle	4	0.42	Song Thrush	1	0.11
Sulphur-crested Cockatoo	4	0.42	Stubble Quail	1	0.11
Southern Boobook	4	0.42	Unidentified swallow	1	0.11
Australian White Ibis	3	0.32	Willie Wagtail	1	0.11

A total of 284 counts of the birds on the airport grounds have been conducted by an ornithologist between January 1997 and August 2009. Results of these bird counts were recorded by 200-m grid square across the airside.

Melbourne Airport keeps a record of the number of animals culled at the airport, incident reports of wildlife hazards observed by staff, and maps on which are plotted notable hazardous behaviour by wildlife. Monthly ATMs at Melbourne Airport were ascertained from the Airservices Australia website (Airservices Australia 2010).

Identification of high-risk species

It is usual to discuss wildlife strikes at airports in terms of the rate of strikes per 10,000 ATMs, which allows standardized comparison between years and between airports. For the purposes of analysis and evaluation we here consider only confirmed bird/bat strikes at, or near, Melbourne Airport.

At least 65 taxa of birds/bats have been confirmed in strikes (Table 1). The species of animal involved in only 716 of the 949 confirmed bird/bat strikes at Melbourne Airport were identified. To assess the risk presented by different species of bird/bat at Melbourne Airport a risk assessment procedure, based on that of Allan (Allan 2001; Allan *et al.* 2003), was followed. This method has been used to assess species risk rankings at Melbourne Airport over several years (Steele 2002 to 2009).

Risk is defined as the consequence of a hazard, measured in terms of likelihood and severity (MacKinnon *et al.* 2001). Likelihood was determined for each of the 100 species of bird or bat recorded at Melbourne Airport from the average number of strikes, per year, over the past five years at the airport. Each species was then allocated a likelihood rating using Allan's method (Allan 2001; Allan *et al.* 2003).

Likelihood Rating					
No. strikes per annum	>10	3–10	1–2.9	0.2–0.9	0–0.1
Category	Very high	High	Moderate	Low	Very low

Severity was estimated for each species using the percentage of strikes that have resulted in damage to the aircraft. The largest possible database was used in determining the proportion of strikes by each species to have resulted in damage. For example, for some cosmopolitan species the published U.S. and Canadian records include very large sample sizes, and provide the best available data (e.g. Carter 2001). For Australian species a 2002 review by the ATSB often provides the best data set (ATSB 2003).

Severity Rating					
% strikes causing damage	>20	10–20	6–9.9	2–5.9	0–1.9
Category	Very high	High	Moderate	Low	Very low

Finally, the likelihood and severity ratings for each species were combined in Allan's (2001) matrix to determine what level of risk each bird species at Melbourne Airport presents to aircraft operations (Table 2).

Table 2. Matrix to determine overall risk ranking of each bird/bat species recorded at Melbourne Airport, 1986 to 2009.

Severity	Likelihood				
	<i>Very high</i>	<i>High</i>	<i>Moderate</i>	<i>Low</i>	<i>Very low</i>
<i>Very high</i>	Risk	Risk	Risk	Risk	Review
<i>High</i>	Risk	Risk	Risk	Review	Review
<i>Moderate</i>	Risk	Risk	Review	Accept	Accept
<i>Low</i>	Review	Review	Accept	Accept	Accept
<i>Very low</i>	Accept	Accept	Accept	Accept	Accept

This risk assessment process identified a number of species as representing a particular risk at Melbourne Airport. Until recent years the Australian Magpie (*Cracticus tibicen*) represented by far the greatest risk of a strike to aircraft at Melbourne Airport, being responsible for around one-fifth of all bird/bat strikes, and one-quarter of all strikes in which the bird/bat species involved was identified. The Masked Lapwing (*Vanellus miles*) was the third most frequently struck species of bird/bat and also

ranked high in risk assessments. Other high-risk species include ibis (*Threskiornis* spp.), Rock Dove (*Columba livea*) and Grey-headed Flying-Fox (*Pteropus poliocephalus*).

Targeted management

Melbourne Airport maintains an active and varied wildlife hazards management program that emphasizes habitat management and the elimination of bird attractions. However, restricting food resources available to ground-foraging species of bird across the 750 ha of airside area currently presents an intractable problem. Soil conditions and drought prevent the cultivation of dense grass swards and the cracking black clay soil supports large densities of invertebrates. Therefore, bird harassment aimed at reducing bird numbers at the airport and targeting high-risk, ground-foraging species remains an important part of the airport's strategy to address the risk of bird strikes. Harassment is not seen as merely reducing bird numbers on the airside but also increasing birds' vigilance and state of alertness, which should somewhat reduce the chance of them being surprised by an aircraft movement.

From 2007 Melbourne Airport instituted an intensive harassment program, with one officer dedicated to bird harassment on duty each day and two officers on duty during the periods of greatest risk—autumn and spring. Three high-risk taxa of ground-foraging bird were targeted: Australian Magpie, Masked Lapwing and ibis. The harassment program includes deployment of two to three fixed bird deterrents (i.e. Bird-Gard and gas-cannons); direct harassment and firing of Bird-frite cracker-shells; culling of these species, particularly the naïve subadult birds; displaying ibis carcasses on stakes; and the destruction of Masked Lapwing nests. In addition, since 2008 insecticide has been sprayed close to runways to reduce prey populations ahead of the high-risk spring and autumn periods.

We then compared 2004–06 data on confirmed bird/bat strikes at, or near, Melbourne Airport, before intensive targeted harassment, with the 2007–09 data. The mass of animals struck by aircraft was calculated from the average mass of each species reported in the literature (e.g. Higgins & Davies 1996) multiplied by the number of individuals reported struck.

RESULTS

The *reported* average strike-rate per 10,000 ATMs during 2004–06 – 7.8 ± 0.55 ($n = 419$ records)—was lower than that reported during 2007–09: 8.4 ± 2.64 ($n = 487$ records) although not significantly so ($F = 23.31$, $p < 0.05$, d.f. = 4; $t = 0.37$, d.f. = 4.; Table 3). This increase in reported strike rate is thought to be due to continuing improvements in reporting and data capture in recent years.

The *confirmed* strike-rate before intensive harassment, 4.1 ± 0.37 ($n = 221$ records), was higher, but similar, to that recorded during the three-year period of targeted intense harassment of the larger, ground-foraging species of bird, 3.7 ± 1.28 ($n = 217$ records), with no statistically significant difference between these periods ($F = 12.11$, $p < 0.05$, d.f. = 4; $t = 0.51$, d.f. = 4).

Table 3. Bird/bat strike data at Melbourne Airport before (2004–06) and after (2007–09) intensive harassment program targeting large ground-foraging species of bird.

Year	ATMs	Reported bird/bat strikes	Confirmed bird/bat strikes	Damaging bird/bat strikes	Estimated mass of animals struck(Kg)
2004	175,000	127	72	10	17,557
2005	180,278	142	68	3	19,101
2006	179,732	150	81	5	25,337
2007	184,492	101	42	1	14,671
2008	199,586	183	86	8	23,148
2009	191,869	203	89	1	18,934

However, the average number of *damaging* strikes per year declined from 6.0 to 3.3 between these two periods. This equates to a reduction in damaging strike-rate from 0.34 ± 0.21 ($n = 18$ records) during 2004–06 to 0.17 ± 0.20 ($n = 10$ records) during 2007–09. This difference is not statistically significant ($F = 0.92$, $p < 0.05$, $d.f. = 4$; $t = 1.01$, $d.f. = 4$).

There was also a slight decrease in the average estimated mass of birds/bats struck per year: 20.7 Kg during 2004–06 to 18.9 Kg during 2007–09 (Table 3).

Results are somewhat clearer when considering only those species targeted. The average number of Australian Magpies counted on the airside declined from 62.2 during 2004–06 to 32.3 during 2007–09 (Figure 2). The number of strikes involving this species has similarly declined by almost half, from an average of 21.3 strikes/yr over 2004–06 to 11.0 strikes/yr during 2007–09 ($F = 0.23$, $p < 0.05$, $d.f. = 4$; $t = 1.46$, $n.s.$, $d.f. = 4$). The average number of strikes per year also markedly declined for the Masked Lapwing (from 6.7 per year to 3.0 per year) and ibis (from 4.0 to 1.0).

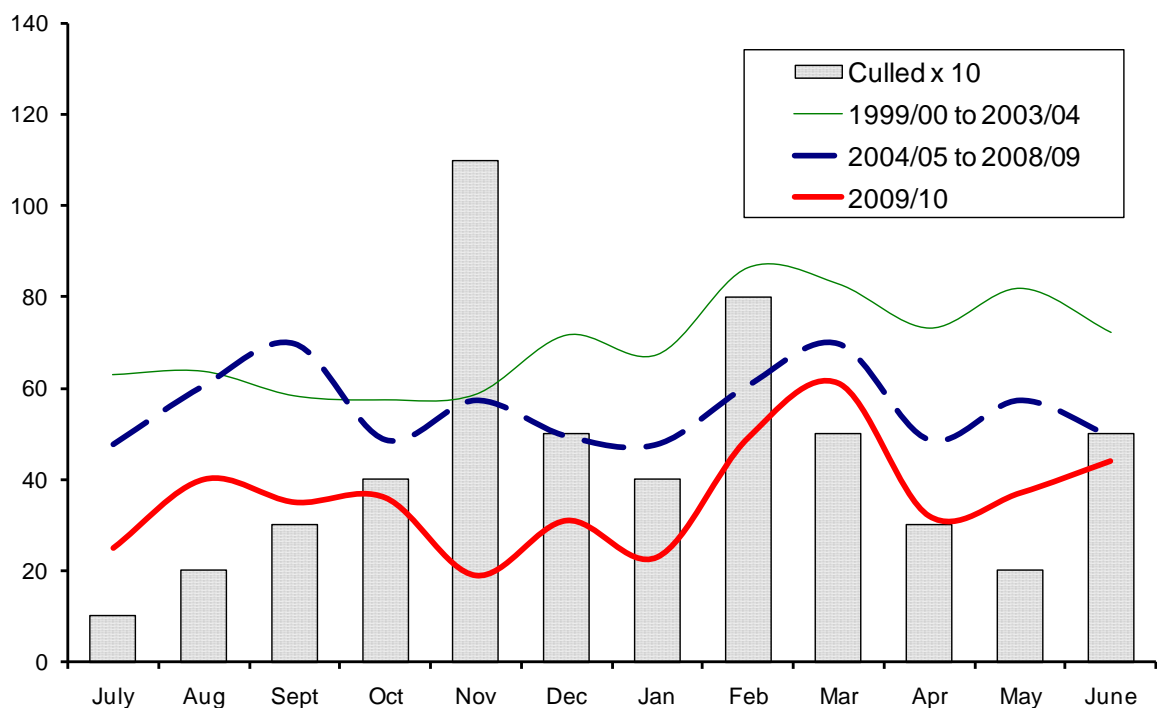


Figure 2. The decline in numbers of Australian Magpies recorded at Melbourne Airport in response to targeted harassment and culling. (Note: figures for magpies culled refer to 2009/10).

The average number of Masked Lapwings counted during daytime surveys has always been very low and for many years has been close to zero. The species is reported to occur at the airport on some nights but the count data for this species are too sparse to analyse. Similarly, ibis numbers fluctuate enormously on an hourly basis and these birds are chased from the airport as soon after they land as possible. Therefore, lapwing and ibis count data are not presented for interpretation here.

DISCUSSION

At Melbourne Airport the incidence of bird strikes appears not to be related simply to bird numbers at the airport. The risk of bird strikes is increased by certain weather conditions—for example on days of rain and high wind (Steele 2001). The risk also varies between species and times of the year, seemingly independent of species' numbers on the airside, with Masked Lapwings being particularly aggressive and prone to collision with aircraft during December when they have young chicks. Similarly, Australian Magpies are particularly susceptible to bird strikes during December (when they have young) and March/April (when young may be dispersing from natal territories). Surges in

harassment activity that are not sustained over many weeks have resulted in increased incidences of bird strikes despite decreases in bird numbers at the airport. This is probably explained by increased aggressive interactions among birds competing for territories left vacant by birds killed or displaced by management activity, and also by young and naïve birds moving onto the airport to take advantage of disrupted territories/ flock structures.

There is no single solution to the problem of wildlife hazards at Melbourne Airport, and an integrated management plan, which incorporates a wide range of actions, is needed to address the problem adequately. Of these actions, long-term pre-emptive measures to reduce the airport's attractiveness to birds (e.g. habitat management) are preferable to short-term reactive measures to move birds settled at the airport. Long-term measures include: exclusion (which is practical only for small areas and buildings), habitat management to remove all those features which might attract wildlife to the airport, and population control of offending species across the wider area surrounding the airport when this is necessary and appropriate. While physically excluding birds is the nearest to a complete solution but this is only a viable option in limited circumstances, such as specific buildings and in general habitat management contributes the most towards wildlife hazards reduction.

However, despite the best efforts at long-term measures to dissuade wildlife from frequenting the airport, there will always be a need for short-term (or reactive) measures to disperse or remove wildlife. These short-term measures include: deterrence, through the deployment of fixed scares and other devices; active harassment through human, vehicle and/or dog activity, or the application of chemical agents, etc.; and removal through trapping and relocation, or shooting, when necessary.

Attempting to simply remove all birds from an airport's grounds by shooting or trapping is both time consuming and expensive, and almost always a waste of time and money because other birds will simply move in from neighboring areas to replace those removed. Although in some situations, the shooting of birds can reduce the number of birds using a site and so reduce the incidence of wildlife strikes (Dolbeer *et al.* 1993), this is generally the exception rather than the rule. At one Canadian airport where owls and other raptors presented a hazard to aircraft, a total of 543 owls and hawks were trapped and removed from the airport over three years—without any significant decrease in the number of birds at the airport or in the bird hazard (Burger 1983). Nevertheless, bird harassment aimed at reducing bird numbers at the airport and targeting specific species and high-risk times of the year remains an important part of any strategy to address the risk of bird strikes. Harassment should not be seen as merely reducing bird numbers on the airside but also increasing birds' vigilance and state of alertness, which should reduce somewhat the chance of them being surprised by an aircraft movement.

Melbourne Airport maintains an active and varied wildlife hazards management program that emphasizes habitat management and the elimination of bird attractions. However, restricting food resources available to ground-foraging species of bird across the 750 ha of airside area currently presents an intractable problem. Soil conditions and drought prevent the cultivation of dense grass swards and the cracking black clay soil supports large densities of invertebrates. Therefore, bird harassment aimed at reducing bird numbers at the airport and targeting ground-foraging species remains an important part of the airport's strategy to address the risk of bird strikes. Harassment is not seen as merely reducing bird numbers on the airside but also increasing birds' vigilance and state of alertness, which should somewhat reduce the chance of them being surprised by an aircraft movement.

While the data from Melbourne Airport to date are inadequate for rigorous statistical analysis there is some evidence that intense harassment, targeting larger, high-risk species of ground-foraging bird has contributed to a decline in the number of strikes by these species on aircraft operating there. The Australian Magpie, once responsible for up to one quarter of all reported bird strikes at Melbourne Airport, is now struck infrequently.

The number of bird strikes causing physical damage to an aircraft has practically halved since the instituting of intense and targeted harassment. While the overall strike rate at Melbourne Airport has not decreased since intense harassment commenced it would seem that the majority of strikes reported now comprise the smaller grassland species, such as the Australasian Pipit (*Anthus novaehollandiae*) and Eurasian Skylark (*Alauda arvensis*), which very rarely cause damage and which, in the past, were probably largely overlooked in the strike record.

The use of insecticide spray to limit the food resources and attractiveness of grasslands for birds is thought to have assisted in reducing the numbers of large ground-foraging species close to runways at Melbourne Airport. But the data are not yet available to test this.

There are other measures to reduce the risk of bird strike from ground-foraging birds attracted to the airport's large grassland areas. Trained dogs would likely be effective as a reactive measure but the surest pre-emptive action is habitat management to promote a dense sward of monospecific grass, reducing broad-leaf weed cover and reducing Onion Grass (*Romulea* sp.), which is fed upon by cockatoos and corellas. Eliminating trees from the immediate vicinity of the airside, removing all unnecessary posts and signs, and installing anti-perch spikes on all remaining structures to deny the bird safe perches across the airside and within 100 m of the perimeter fence would also reduce the attractiveness of the airside. However, all of these suggestions are difficult to implement and targeted harassment seems likely to be needed for the foreseeable future. Therefore it is reassuring to know that – although limited – this targeted harassment does serve to reduce the incidence of strikes on large species of bird that are most likely to cause damage to aircraft.

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