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THE EFFECT OF LOCAL WEATHER CONDITIONS ON BIRD-AIRCRAFT COLLISIONS AT BRITISH AIRPORTS

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Abstract

The majority of birdstrikes occur at or around airfields. Study into birdstrike prevention has focused on the control of bird numbers on airfields, and the success of control measures at this level has been mixed and difficult to assess. In order to properly assess the effectiveness of control measures it is necessary to have an understanding of the factors that contribute to birdstrikes and their relative importance. This study investigates the role of weather at and around the time of birdstrikes using birdstrike and meteorological data from nine British airports. Several variables were tested including wind speed and direction, rainfall, temperature, visibility and cloud cover. The results show that higher rainfall and temperature are associated with an increased chance of a birdstrike occurring and when studied in conjunction with bird behaviour would suggest that these conditions increase the number of birds on airfields. This supports research and observations from other workers in the field. Visibility was better at the time of birdstrikes indicating that poor visibility is not a major factor. Wind direction was a factor only for two of the airports studied. The other weather variables tested had no relationship to birdstrike frequency.

Keywords: Environmental, Forecasting, Guidance, Weather

1. Introduction

Collisions between birds and aircraft are commonly reported and although the number of incidents is low compared to the amount of air traffic (5.7 incidents in 10,000 aircraft movements in Europe (Thorpe 1990)), the financial and health costs associated with them can be considerable. In a report of the costs of wildlife damage in the United States (Cleary, Wright & Dolbeer 1999), it was estimated that around 22,247 birdstrikes to civilian aircraft occurred between 1990 and 1998 with costs of $167.63 million and 97,813 hours of aircraft down time. There has been considerable effort to reduce the number of birdstrikes, particularly those that produce serious accidents (Milsom & Horton 1995).

Over 90% of birdstrikes occur below 700 metres (2,300 feet) (Eschenfelder 1998) and more than three quarters on or around airfields below 305 metres (1,000 feet) (Milsom & Horton 1995). Therefore effort to reduce the number of birdstrikes should be concentrated at this level.

Control requires a large commitment from the airfield in both finance and time and therefore airfields require information as to the level of success that their control is achieving. The success of control is difficult to measure as improved bird control and bird survey methods may increase the number of reported birdstrikes or the number of birds recorded as present on the airfield because of more efficient data gathering and not because of an actual increase in numbers (Harris & Davis 1998).

Does the risk of birdstrike increase in line with the number of birds on airfields or is it also increased by conditions that alter the ability of birds to detect and escape from approaching aircraft? Several studies have addressed this issue for example Burger (1983) and Linnell, Conover & Ohashi (1996).

Understanding the factors which contribute to birdstrikes will help to more accurately assess the risk from birds on runways.. Environmental factors such as weather conditions are thought to be involved, for example wind speed effects the flight speed of birds, which fly more slowly if they are flying into the wind than if they were flying with the wind (Burger 1983). This could be especially important when birds face into the wind as they commonly do when resting (Burger 1983; Eschenfelder 1998). Ambient noise at airfields may mask the sound of an approaching aircraft (Burger 1983) suggesting that environmental factors can affect the birds' ability to detect or escape from aircraft.

Weather can have indirect affects as well as direct ones. It has been shown that flying insects are scrubbed to the lower levels of the atmosphere after storms and subsequent rainfall (Russell 1999). Insects are also attracted to runway lights at night (Vantets, Vestjens & Slater 1969) and these may attract birds to feed. A significant portion of the food of gulls and waders is earthworms (Lumbricidae) and other soil invertebrates (Allan & Watson 1990; Cramp & Simmons 1983). These creatures may rise to the surface during wet weather because of a rise in the level of the water table and may move out of the grassland and onto tarmac areas. Some airfields need to employ sweepers to clear the hard standing of worms (J. Allan, pers. com.). Feeding and other forms of distraction affect the ability of the birds to detect and avoid any vehicle as noted in Blokpoel (1976). Pools of standing water on the runways have also been shown to encourage birds onto them (Buckley & McCarthy 1994). A previous study was inconclusive on whether this affects birdstrike occurrence (Gabrey & Dolbeer 1996), as the effect on birdstrikes was significant at one location but not another.

Visibility may be important as low visibility can alter flight patterns and may reduce the ability of birds and aircrew to detect each other but may also cause aircrew and airfield staff to be more vigilant and detect birds before they are a threat.

Despite many indications that weather conditions can affect the probability of birdstrikes there is little analytical evidence to support this and most of the existing research has been confined to one or two locations. This study uses data collected on birdstrikes from nine civilian airports in the United Kingdom for the years 1976 to 1995 and uses meteorological data from these locations to compare weather conditions at the time of birdstrikes and on comparable days of the year when there were no birdstrikes. The aim was to look at several weather variables and to further clarify the extent to which weather conditions contribute to the birdstrikes risk at airfields, either by influencing bird behaviour or affecting bird numbers.

2. Methods

Birdstrike data were provided by the Central Science Laboratory of the Ministry of Agriculture, Fisheries and Food (MAFF) of Great Britain[1], and covers 20 years of birdstrikes occurring on civil airfields in Britain from 1976 to 1995. The data was analysed in regard to season, time of day and species composition by Milsom & Horton (1995). The records are of strikes reported by aircrew and bird control staff at the individual airports. They include the dates and times of the strikes and the altitude and phase of flight.

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[1] Birdstrike Avoidance Team, Central Science Laboratory, Sand Hutton, York, YO41 1LZ.

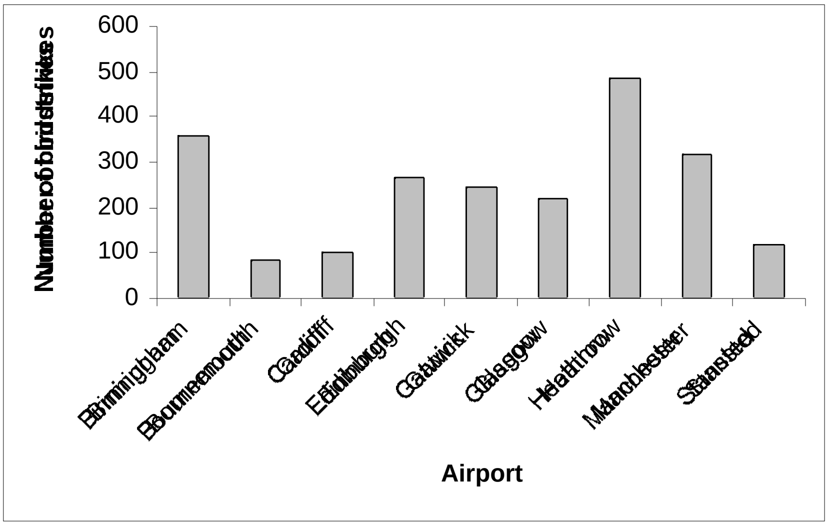

Figure 1. The distribution of birdstrikes among the nine airports included in the analysis.

The airports used in the analysis were those that had the most complete meteorological data available. The sample size of birdstrikes at each of the airports is shown in Figure 1.

In order to ensure that the study only included birdstrikes that occurred at the airport rather than en-route, birdstrike data were only included if they met the International Bird Strike Committee location criteria of 'on airport' (Thorpe 1986). They state that this is birdstrikes occurring below 152 metres (500 feet) for take off and 61 metres (200 feet) for approach. The data include birdstrikes on aircraft that were taxiing or parked. Any record without a known time or date was excluded from the analysis, as was any record for which the altitude or the phase of flight of the aircraft was unknown. Records for all bird species or where the species of bird was unknown were included and all species were combined in the analysis.

The Meteorological Office of England and Wales[2] provided meteorological data and a list of parameters tested is given in Table 1. These parameters were included because they could potentially affect the ability of birds to detect approaching aircraft, affect their escape ability or may encourage birds onto the airfield and runways.

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[2] The Meteorological Office, Academic Research, JG9 Johnson House, London Road, Bracknell, Berkshire, UK, RG12 2SY.

Table 1: Meteorological data used in the analysis.

Parameters	**Frequency of recordings** Hourly	Daily
Rainfall totals	✓	✓
Dry bulb temperature on the hour	✓	
Minimum / Maximum air temperature		✓
Visibility on the hour	✓	
Total cloud cover on the hour	✓	
Height of low cloud on the hour	✓	
Sunshine amount in hours		✓
Mean wind speed	✓	✓
Mean wind direction	✓	

Conditions at the time and on the day of birdstrikes were studied. Variables are either recorded as an average value over an hour or as a spot measurement on the hour. Daily measurements contain totals, maximum and minimum values, or averages as shown in Table 1. Data chosen for the analysis were the spot measurements taken closest to the time of the birdstrike, and the average/total data on the hour or day. Mean daily temperature was calculated from the maximum/minimum values.

Rainfall measurements include any precipitation such as snow and hail. The number of days of snow fall in the UK is low (an average of 21 days for the winter months October through to May from 1961 and 1990) and the number of days of hail is also low (4 days on average per year) (Met. Office 1999). The majority of precipitation falls as rain and therefore for the purposes of this study precipitation will be classed as rainfall.

Days around the birdstrike dates were studied to confirm if weather conditions on the start of the day are important and if the day of the birdstrike was different to prevailing conditions at the time.

Conditions during birdstrikes were compared to those on days when there was no birdstrike. The month, date and time of the birdstrikes were reciprocated in these non-birdstrike dates to control for the seasonal differences in general weather patterns aircraft movement frequencies and bird abundance. These reciprocal dates were obtained by taking a date 364 days before the day of the birdstrike.

Weather conditions on the resultant non-birdstrike dates were compared to those when birdstrikes occurred. If a birdstrike occurred on this new date, the date was rejected and a date 364 days prior to that was selected instead. The process was continued until a date where no birdstrike was reported was found. An exception was made with seven dates occurring in 1974 for which no birdstrike records were available for comparison. It was assumed that no birdstrikes occurred on these dates because the level of birdstrikes during the year is low and the sample was unlikely to coincide with birdstrike dates. The time distance between the paired dates ranged from one to four years and the majority were one or two years apart. This range was not large enough to span significant changes in aircraft movements, aircraft type or bird control measures.

Weather variables on these data pairs were compared using Wilcoxon matched pair's tests. In addition to comparing the level of rainfall, the presence and absence of rain on the times and dates were compared.

In order to test whether particularly adverse weather conditions are a factor, weather on the day of a strike was compared to the monthly average values where conditions were found to be different between birdstrike and non-birdstrike dates in the previous analysis. Monthly averages were calculated from the daily meteorological data. For rainfall, data were compared only where rainfall occurred.

The data for wind direction was treated separately from the remaining variables because of the circular nature of the distribution. Analysis of wind direction variables between strike and non-strike times was conducted using Moore's test for directionality for paired data. This procedure is described in Zar (1996). Airports were analysed individually as well as together to enable comparison with runway bearing at each airport because wind direction may be more important when in line with runway direction. Runway bearings were taken from Ginsberg (1997). Non-parametric tests were chosen because the shape of the distribution varies between sites. The meteorological office measures wind direction in ten-degree intervals.

Data manipulation was carried out in Microsoft Access 97 and Microsoft Excel 97 for Windows. SPSS versions 8.0 and 9.0.1 for Windows[3] and Microsoft Excel 97 were used for the statistical analysis.

[3] SPSS Inc. 1997 and 1999.

3. Results

3.1 Rainfall

A relationship between rainfall and birdstrike occurrence was suggested from graphical representation of the data as shown in a section of results from Birmingham airport in Figure 2. Birdstrikes tend to occur around dates of rainfall with periods of no rain characterised by the lack of birdstrikes. Wilcoxon matched pairs tests showed that rain was more likely on the day before birdstrike dates than non-birdstrike dates ($Z = -2.37$, $n = 2150$, $p < 0.05$) and that the amount of rain that fell was also greater ($Z = -5.30$, $n = 2150$, $p < 0.001$). These conditions would maximise the likelihood of standing water on airfields.

Rainfall on days of birdstrikes is both more likely ($Z = -3.65$, $n = 2150$, $p < 0.001$) and greater ($Z = -2.40$, $n = 2150$, $p < 0.05$) than dates without birdstrikes. Further indication that wet weather has a major influence on birdstrike occurrence is that rain is both more likely to occur ($Z = -3.65$, $n = 2104$, $p < 0.001$) and fall in greater amounts ($Z = -3.61$, $n = 2104$, $p < 0.001$) at the time of a birdstrike than no birdstrike.
When compared to monthly average rainfall, results showed that days before birdstrikes have more rain than average ($Z = -11.89$, $n = 1322$, $p < 0.001$) whereas those before non-birdstrike dates have less than average ($Z = -4.12$, $n = 1222$, $p < 0.001$).

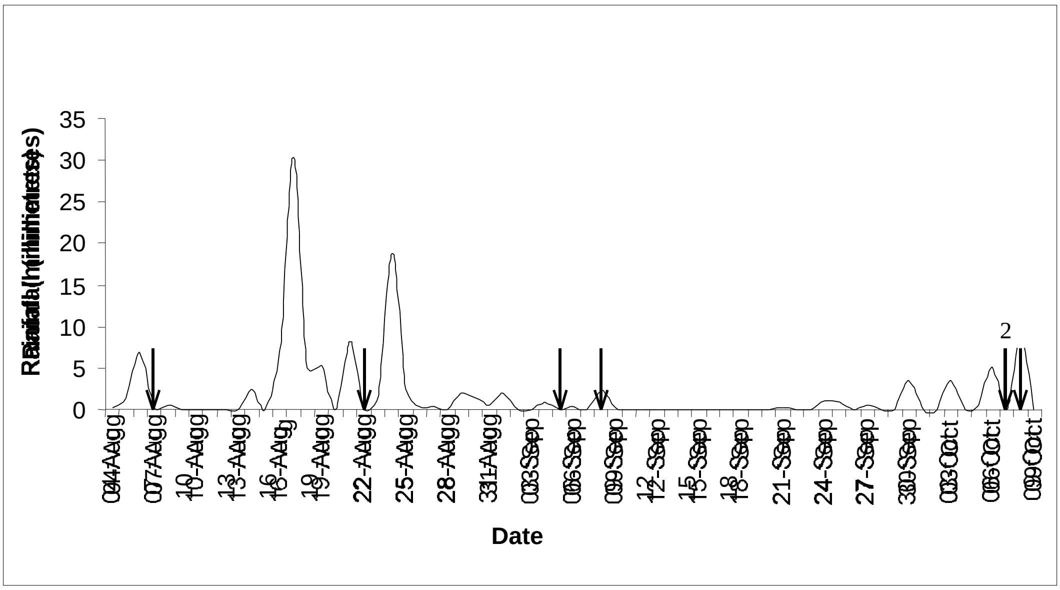

Figure 2: Two months daily rainfall data at Birmingham airport in 1977 showing positions of birdstrikes (↓). A number above the arrow indicates multiple birdstrikes of that number occurring on the same date.

3.2 Temperature

Mean daily temperature on the days of birdstrikes was higher than the day before (Z = -2.86, n = 2150, p < 0.01) and two days before (Z = -3.38, n = 2150, p < 0.01) indicating that temperature was higher than prevailing conditions during that time (see Figure 3). Days without incidents did not show this rise in temperature (Z = -1.46, n = 2150, NS; Z = -1.42, n = 2150, NS). Temperature was higher around the date and time of birdstrikes compared to non-birdstrike dates and times. This applies to both the temperature at the time (Z = -3.84, n = 2150, p < 0.001) and the maximum/minimum daily temperatures (Z = -2.78, n = 2150, p < 0.01; Z = -2.03, n = 2150, p < 0.01).

When compared to the monthly average temperature, both the day of the birdstrike and the preceding day where higher (Z = -4.35, n = 2150, p < 0.001; Z = -2.59, n = 2150, p = 0.01).

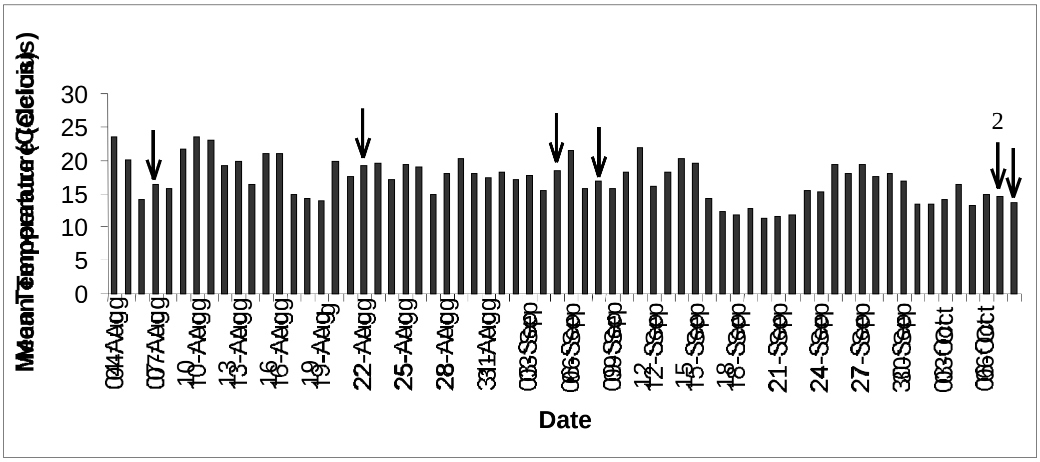

Figure 3: Two months daily temperature data at Birmingham airport in 1977 showing positions of birdstrikes (↓). A number above the arrow indicates multiple birdstrikes of that number occurring on the same date.

3.3 Visibility

Visibility at the time of the birdstrike incidents was greater than when no birdstrike occurred (Z = -2.57, n = 2150, p < 0.05).

3.4 Cloud cover

The amount and height of cloud cover did not differ between times that had birdstrikes and those that did not (Z = -0.10, n = 1338, NS;

Z = -0.50, n = 2150, NS). This indicates that visibility may not play a significant part in birdstrikes.

3.5 Sunshine

There was no difference in the number of hours of sunshine on days with or without birdstrikes incidents (Z = -1.46, n = 2034, NS). This supports the above findings regarding cloud cover.

3.6 Wind speed

There were no differences in the wind speed at the time or on the day of birdstrikes (Z = -0.57, n = 2142, NS; Z = -1.00, n = 2147, NS). This indicates that although wind speed may reduce the flight and take off speed of birds, this may not be a disadvantage in their escape.

3.7 Wind direction

The general distribution of wind direction for birdstrikes and non-birdstrike times was south-westerly and over all the airports there was no difference in wind direction between the times with or without birdstrikes
(R′ = 0.25, n = 2087, NS).

When the airports were analysed separately, Cardiff
(R′ = 1.02, n = 99, $p < 0.05$) and Stansted (R′ = 1.18, n = 112, $p < 0.05$) were significantly different. All the airports shared similar runway bearings to Cardiff and Stansted but did not show any difference (the maximum difference in runway bearings between other airports and Cardiff was 60 degrees and for Stansted was 40 degrees). These results indicate that any differences are due to the wind direction and not runway bearing. However, there is no obvious pattern that emerges for the reason of the significance of wind direction at these two airports.

4. Discussion

From the results of this study, it is clear that local weather conditions do have an effect on birdstrike frequency. Although this has been suggested as a factor in collisions in the past this is the first known study with evidence on many aspects of weather conditions taken together over a number of different airfields.

A major finding in this study is that rainfall plays a large role. The presence of rain on the day of and during birdstrikes and the fact that larger amounts of rain fell on these and preceding days than when no birdstrikes occurred indicates conditions that produce standing water on airfields and heavy falling rain both increase the chance of birdstrikes. This supports the results obtained by Gabrey & Dolbeer (1996) that heavy rainfall increases the probability of a birdstrike on the following day and suggests that the phenomenon may be more widespread than as tested by that study.

Rainy conditions may lead to an increase in the total number of birds on an airfield for instance by increasing that attractiveness of the site. For example, worms may be encouraged to the surface in wet weather and other soil living invertebrates may be forced to the surface when the water table rises. Worms and other soil invertebrates form a significant part of the diet of gulls and waders (Allan & Watson 1990; Cramp & Simmons 1994), which are often involved in birdstrikes. Wet weather may encourage these birds onto airfield grassland to feed.

Bird numbers may also be locally increased on the runway during and immediately after rain as they seek out the relatively dry tarmac instead of grass during periods of rain in order to keep their feathers from getting water logged.

Another suggestion that the number of birds on airfields is important is the high temperatures associated with birdstrike dates and times compared with other times and average conditions for the time of year. High temperatures may encourage birds onto the runways to sunbathe and dry off after rainfall but further evidence is required to support this.

Visibility was greater when birdstrikes occurred but the height and amount of cloud were not significant. This indicates that weather conditionsassociated with low visibility are not as important as may be intuitively thought at influencing strikes. It may be that in low visibility conditions, birds avoid the aircraft movement areas and seek shelter elsewhere. This may be a sensible strategy especially as low visibility reduces the birds ability to sense predators in general. Visibility was shown to be important in detection of danger when studied by Bruderer, Peter & Steuri (1999) who showed that birds in flight avoid a bright light beam. It is also possible that, at times of low visibility, aircraft operating patterns may be changed with fewer flights operating in very poor visibility or that birdstrikes may go undetected.

Prior to this study it was postulated that wind direction would influence birdstrike probability because when it is in line with the runway bearing birds would face into the wind and the aircraft would approach the bird from behind making detection of the aircraft more difficult. The only airports showing any effect of wind direction were Cardiff and Stansted. Here the wind direction at the time of birdstrikes was different from non-birdstrike times but no reasons for this were apparent.. In cases where the bird will have its back to the aircraft the it is more likely to rely on hearing. Burger (1983) found that by the time aircraft noise rose higher than ambient noise there is little time (9-14 seconds) for birds to escape. This time is reduced in wider bodied aircraft because they make less noise.

The high number of incidents when the wind was in a south-westerly direction corresponds to the common winds that occur in Britain (Shellard 1976). South-west winds often indicate the presence of warm and wet weather and strong winds (Hardy 1996). The differences shown in this study suggest an additional effect over and above the effect of the prevailing south-westerly winds as both birdstrikes and non-birdstrike days have the same overall distribution of wind directions.

Burger suggested that as birds fly more slowly against the wind they would be significantly slowed and prevented them from escaping (Burger 1983). From this it may be expected that wind speed would be a factor in determining birdstrike probability. This study has not shown this to be the case and further work on the way that birds perceive and avoid aircraft would be needed to determone the precice roles of wind speed and direction in the process that results in a birdstrike.

These results support the view that rainfall can influence birdstrike occurrence by attracting birds onto airfields or close to the runways. The influence of rainfall suggests that measures should be taken to improve the drainage on airfields where standing water is a problem and to manage the grassland around the runways to limit the availability of food.

5. Acknowledgements

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