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The impact of variation in reporting practices on the validity of recommended birdstrike risk assessment processes for aerodromes

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ABSTRACT

Birdstrikes are a major hazard to aviation; costing millions of pounds a year in damage and delays, as well as occasional hull losses and loss of life. The numbers and species of birds on and around airfields therefore need to be managed. To aid this process, airport staff often use risk assessments to identify which bird species cause the greatest risk and use the outcome to target their bird control effort. To this end, a number of national and international regulators, airports and other organisations recommend, or use, a derivation of a risk assessment process first published in 2006. This was developed using the UK Civil Aviation Authority's birdstrike database, employing data collected between 1976 and 1996. The risk assessment process relies on using the proportion of reported strikes that cause damage to the aircraft as a proxy for the likely severity of the outcome of strike incidents, so any change in the relative level of reporting of damaging and non-damaging strikes may significantly bias the results. The implementation of mandatory birdstrike reporting by the UK CAA in 2004 led to a significant increase in the number of strikes reported. If this involved a disproportionate increase in the number of non-damaging compared to damaging incidents reported, it may have impacted on the accuracy of the risk assessment process. This paper examines how differential reporting of damaging and non-damaging strikes can impact on the risk assessment process. It shows that changes in reporting practices since the original risk assessment was developed have impacted on the apparent birdstrike risk at UK airports, giving a false impression of increasing risk over the period. It makes recommendations for how the process can be better adapted to cope with such changes in the future, and how it should be modified for use in countries with different reporting regimes to that in the UK.

1. Introduction

Collisions between aircraft and wildlife, mostly birds, (hereinafter referred to as birdstrikes) are a serious hazard to all forms of aviation and have resulted in the loss of at least 108 aircraft and 276 lives in civil aviation (Thorpe, 2012). Less serious birdstrikes cause significant operational costs to the aviation industry as a result of repairs to damaged aircraft, delays and cancellations, insurance claims etc. The total cost to world commercial aviation has been conservatively estimated at 1.5 billion US$ per year (Allan, 2002). In order to manage these risks, the International Civil Aviation Organisation (ICAO) requires national aviation regulators to ensure the implementation of effective bird management policies on the airfields under their control via a number of Standards And Recommended Practices (SARPS) (ICAO, 2012). The guidance material provided by ICAO in support of these SARPS includes a recommended risk assessment process to help aerodrome operators target their bird management effort and resources at those species that cause the greatest risk. This process derives from a paper published in 2006 (Allan, 2006) which has subsequently been adopted, with minor modifications, by International Birdstrike Committee (IBSC, 2006) Airports Council International (ACI, 2013) and a number of national regulators such as the UK Civil Aviation Authority (CAA, 2014a).

Other birdstrike risk assessment techniques have also been developed. Most of these employ a variety of ranking processes, usually combining factors such as numbers of a particular species

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on or around the airfield, their location, their movement in relation to aircraft flight-paths, presence of single birds or flocks, mass of the species, tendency to be involved in strikes etc. The various factors are combined mathematically and weighted to provide a more or less real-time measure of risk that bird controllers can immediately respond to (Allan, 2000; Shaw and McKee, 2008; Soldatini et al., 2010; Yang et al., 2010, Zakrajsek and Bissonette, 2005). These techniques rely on regular and accurate data gathering by bird control staff, who frequently have other duties to perform leaving them unable to devote the time needed to ensure that the necessary data are gathered with the accuracy required. Although having the advantage of providing immediate tactical advice concerning if and when birds need to be dispersed, they have not generally found favour with regulators.

The process developed by Allan (2006) provides a longer term strategic view of the risk levels at a particular airport. This, combined with a 'live risk register' (a real-time dynamic assessment of immediate risks), provides both strategic and tactical guidance for bird control staff and resource managers. Allan's process relies on combining, an estimation of the probability of a strike occurring with a particular bird species (using the airports strike record over the past five years) with an estimation of the likely severity of the outcome of the strike incident (using the proportion of strikes with that species resulting in aircraft damage). The data used came from the UK Civil Aviation authority's birdstrike database for those strikes reported over the period 1976–1996.

Since 1996, the number of strikes reported at most UK airports each year has risen, with markedly more strikes reported following the UK CAA's mandating of birdstrike reporting in 2004 *(see Table 3)*. If this represents a real increase in strike numbers, the number of damaging and non-damaging strikes would be expected to rise by a similar proportion and the proportion of strikes resulting in damage would remain the same. Other studies produced before the introduction of mandatory reporting have shown that strikes that damage an aircraft were more likely to be reported than non-damaging ones (Linnell et al., 1999; Milsom and Horton, 1995). An unintended consequence of mandatory reporting could, therefore be the more frequent reporting of previously unreported non-damaging strikes. If this is the case the number of non-damaging strikes reported should increase by a greater proportion than the number of damaging strikes. This would reduce the proportion of strikes causing damage for a particular species, which, in turn, would balance the increase in overall strike numbers, thus giving no overall increase in risk. If the proportion of strikes causing damage is not recalculated, as has been the case in the UK, the same change in reporting behaviour would give a false impression of increasing risk.

This paper assesses whether the increase in reported strikes at UK airports has involved a differential increase in the numbers of non-damaging strikes reported, and whether these changes in reporting practices have impacted on the risk assessment process at UK airports. It then determines whether the methodology needs to be adjusted to ensure that the risk assessment outcomes remain valid, both for use in the UK and in other countries where reporting regimes may differ from those on which the technique was originally based.

2. Materials and methods

2.1. *Detailed description of the current birdstrike risk assessment methodology*

Table 1 shows the risk assessment matrix published by Allan (2006). The probability categories are based on a 5 year rolling mean of the number of strikes reported per year with a particular bird species at the airport being risk-assessed. The severity categories are based on national data combining all strikes for the species concerned and determining the proportion of those strikes that resulted in damage to the aircraft involved. There is a problem when calculating the severity measure for rarely struck bird species because the proportion of strikes resulting in damage varied widely due to random chance. In order to control this variation, a linear regression of proportion of strikes causing damage against mass, weighted according to the number of strikes recorded for each

Table 1
Showing the category boundaries for the probability and severity measures used to position bird species in the risk assessment matrix (after Allan (2006)).

(a) Probability categories					
5-year rolling mean of no. of strikes per year for each species (airport data)	>10	3–10	1–2.9	0.3–0.9	0–0.2
Probability category	Very high	High	Moderate	Low	Very low
(b) Severity categories					
Percentage of strikes with a species causing damage (national data)	>20%	10–20%	6–9.9%	2–5.9%	0–1.9%
Severity category	Very high	High	Moderate	Low	Very low

Table 2
The risk assessment matrix developed by Allan (2006) showing the three levels of response required from the airport depending on the position of each bird species defined by its probability and severity categories.

SEVERITY	*PROBABILITY*				
	Very High	**High**	**Moderate**	**Low**	**Very Low**
Very High	Action	Action	Action	Action	Review
High	Action	Action	Action	Review	Review
Moderate	Action	Action	Review	Accept	Accept
Low	Review	Review	Accept	Accept	Accept
Very Low	Accept	Accept	Accept	Accept	Accept

species (expressed as a percentage), was calculated. This used only species struck more than 5 times during the period in question. Assuming that different bird species of similar mass caused similar damage, the proportion of strikes resulting in damage (i.e. the measure of severity in the matrix) could then be read directly from the graph for any species for which the body mass was known. Re-examination of the data shows that the fit of the data to the linear regression model is poor, with high residual values (i.e. a poor fit to the line). It was not possible, however, to find an alternative, more complex, model that provided a good fit to the data. Because any risk assessment model needs to be easy to use and understandable by the airport staff involved, and because Allan (2006) used a simple weighted linear regression in the original methodology, this paper has kept to the same process for the purposes of this re-evaluation.

Once the probability and severity figures for a particular species are determined for the airport being risk assessed, they are placed in one of 5 categories: very low, low, moderate, high and very high (see Table 1) which allows each species to be placed within a particular box in a risk matrix of a type commonly used in a variety of risk assessment processes (see Table 2). The matrix is divided into 'accept', 'review' and 'action' categories, and the airport then develops an action plan to manage species that fall into the different categories. Most airports focus their bird control effort on those species that fall into the 'action' category.

3. Calculation

3.1. Determining if the number of strikes and the proportion of damaging strikes reported has changed over time

Data from 1976 to 1996, the final 7 years of the period used by Allan (2006), is still available for analysis. This can be compared with the following 8 years (1997–2004) during which the reporting requirements were similar, and for the 9 years after the mandating of birdstrike reporting in 2004 (2005–2013). Table 3 below shows the overall total and number per year of all confirmed strikes identified to species and all damaging strikes identified to species that were reported during these three time periods.

The data show that between 1990–96 and 1997–2004 the total number of confirmed strikes identified to species per year increased by 39 percent, whilst the number of damaging strikes reported per year fell by 14 percent. The proportion of strikes resulting in damage fell from 6% to 3.7% over the same period.

Between 1997-2004 and 2005–2013 (i.e. comparing the periods before and after reporting was made mandatory) the total number of reported strikes per year identified to species rose by 92% and damaging strikes identified to species per year rose by 21%. The proportion of strikes causing damage fell from 3.7% to 2.3% over the same period.

It is possible that the increase in total reported strikes identified to species shown in Table 3 occurred due to factors other than reporting behaviour. The most obvious of these might be changes in aircraft movement rates with increasing number of flights leading to an increased number of birdstrike incidents. Table 4 below shows the UK aircraft movement rate data for the period 1990 to 2013 (CAA, 2014b).

The data in Tables 3 and 4 and Fig. 1 above, show that a 92% increase in the number of reported strikes identified to species occurred after mandating of reporting in 2004 and that this cannot be explained by a change in the number of air transport movements over the same period. The number of damaging strikes reported also increased (by 21%) over the same period, suggesting that mandating of reporting has resulted in a disproportionate increase in the reporting of non-damaging strikes. This has resulted in the proportion of strikes causing damage falling from 3.7% to 2.3%. This shows that the severity measure in the risk assessment (the proportion of strikes causing damage for each species) needs to be recalculated in order to avoid the risk being over-estimated following the increase in reported strikes that occurred after mandating of reporting in 2004.

3.2. Recalculation of the proportion of strikes causing damage

The predictive graph for the proportion of strikes causing damage was recalculated using the same method as used by Allan (2006) for each of the three periods (Fig. 2). The gradient of the line in the three time periods decreases, showing that in the later time periods the proportion of reported strikes causing damage to aircraft for a bird species of given mass is reduced. There is still considerable scatter around the line for all periods, and the fit of the model after 2004 was particularly poor ($R^2 = 0.288$).

Table 3
The total number and number per year of strikes identified to species in the three time periods.

	Total confirmed strikes identified to species	Number of confirmed strikes identified to species per year	Total number of damaging strikes identified to species	Number of damaging strikes identified to species per year	Proportion of strikes identified to species resulting in damage (%)
All years	13582	565.92	453	18.88	3.3%
1990–1996	2256	322.29	136	19.43	6.0%
1997–2004	3581	447.62	134	16.75	3.7%
2005–2013	7745	860.56	183	20.33	2.3%

Table 4
UK Air Traffic Movement (ATM) Rates 1990 to 2013.

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
ATM (millions)	3.22	2.88	2.82	2.83	2.95	3.10	3.10	3.24	3.39	3.38	3.39	3.39
Year	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
ATM (millions)	3.60	3.46	3.61	3.67	3.80	3.78	3.80	3.67	3.38	3.11	3.12	3.03

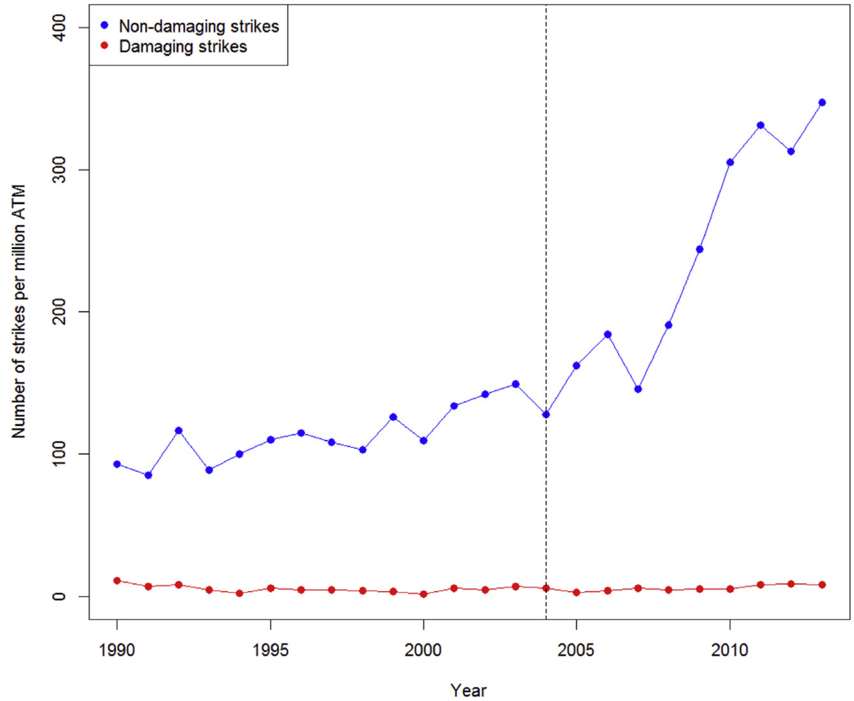

Fig. 1. The number of damaging and non-damaging strikes identified to species per million air traffic movements (ATM) in each year. The vertical dotted line represents when mandatory reporting was introduced in 2004.

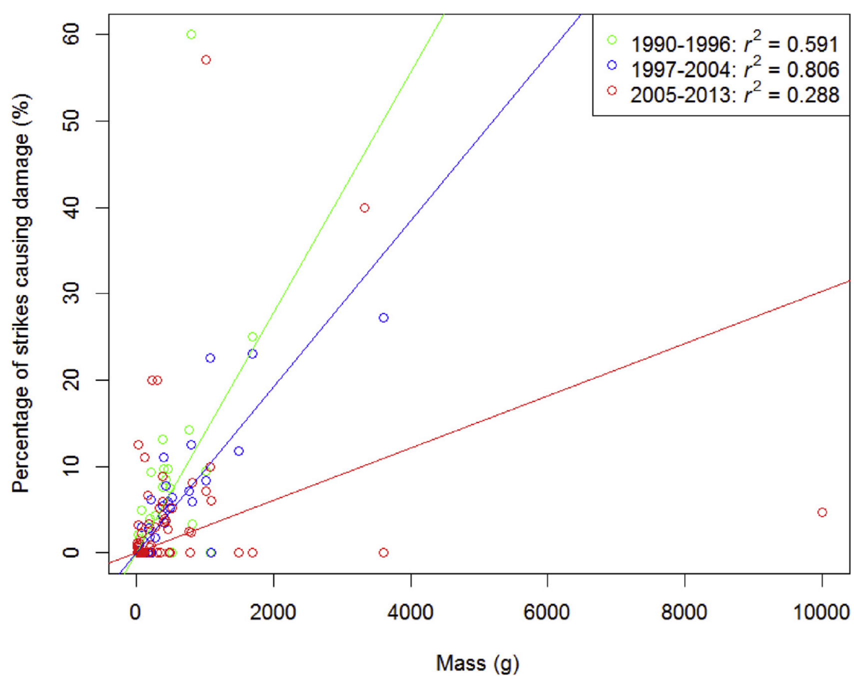

Fig. 2. Linear regression, weighted by the number of strikes per species, of species mass against the proportion of reported strikes causing damage to an aircraft for the three time periods. Species struck more than 5 times are included in the analysis.

In an effort to improve fit of the relationship, the analysis was repeated including only species struck more than 100 times in the whole period. This change had relatively little impact on the relationship in 1990–96 or 1997–2004, but greatly improved the fit of the model in the 2005–13 period, increasing the R^2 value from 0.28 to 0.87. Fig. 3 shows the graphical representation of the relationship between mass and proportion of strikes causing damage calculated using species with more than 100 strikes recorded in each period. The number of outliers is reduced.

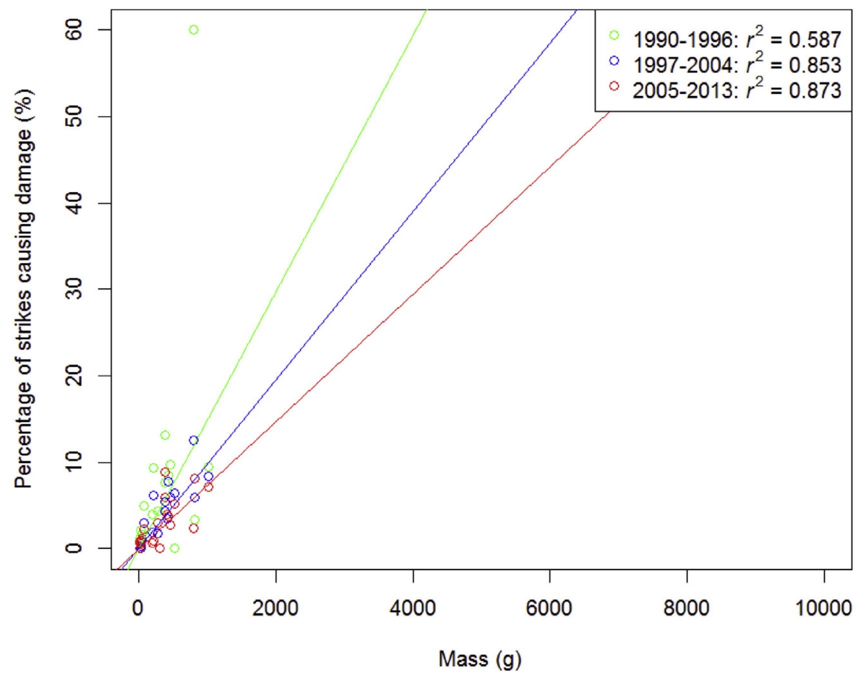

Fig. 3. Linear regression, weighted by the number of strikes per species, of species mass against the proportion of reported strikes causing damage to an aircraft for the three time periods using only bird species struck more than 100 times during the period concerned.

Table 5
The number of species that changed their risk category between the three time periods considered when the proportion of strikes causing damage from Allan (2006) was applied and when the proportion of strikes causing damage was adjusted to take account of changes in reporting rates, either using species struck more than 5 times or species struck more than 100 times as a cut-off for inclusion in the calculation.

	Number of Species Increasing In Risk Category	Number of Species Decreasing In Risk Category
Severity Measure Not Adjusted	28	7
Severity Measure Adjusted using species struck more than 5 times	7	31
Severity Measure Adjusted using species struck more than 100 times	11	22

3.3. Determining the impact of recalculating the relationship between mass and proportion of strikes causing damage on the risk assessment outcome

In order to assess whether re-calculating the proportion of strikes causing damage over the three periods changes the outcome of the risk assessment process, the risk assessment matrices for the 20 most commonly struck bird species for the five UK aerodromes with the greatest number of reported birdstrikes between *1990 and 2013* were calculated. The position of each bird species on the airport's matrix in the three time periods being considered was first calculated using the proportion of damaging strikes from 1976 to 96 calculated by Allan (2006) without any adjustment made for changes in reporting rates that have occurred in subsequent years. The data for 1997–2004 and 2005–13 were then re-calculated using the proportion of damaging strikes specific to the period concerned.

Table 5 shows the number of species that changed in risk category (i.e. moved from ‘accept’ to ‘review’ or ‘review’ to ‘action’ or vice versa) between the three time periods when the proportion of damaging strikes used by Allan (2006) was not adjusted (the current situation) and when the proportion of damaging strikes was re-calculated for the time period concerned. The analysis was repeated using 5 strikes (Fig. 2) or 100 strikes (Fig. 3) in each period as a cut-off for including a species in the calculation of the relationship between mass and proportion of strikes causing damage. The data show a clear difference, with far more species increasing in risk category if the proportion of strikes causing damage is not adjusted and more decreasing in risk category if it is recalculated. The difference between the numbers increasing and decreasing in category is less marked when 100 strikes per species is used as a criterion for inclusion in the calculation than when 5 strikes is used.

4. Discussion

The analysis presented here shows that the outcome of the risk assessment protocol developed by Allan (2006) is susceptible to variation depending on the levels of reporting efficiency that exist at the airport or in the country involved. The broadly static numbers of damaging strikes recorded in the UK over the 23 years for which data are now available suggest that overall national risk levels have not changed greatly.

Increasing rates of reported non-damaging birdstrikes between 1990–96 and 1997–2004 cannot be explained by increasing numbers of air transport movements, and the fact that the number of reported damaging strikes fell over the same period suggests that the overall risk at UK aerodromes fell between the two periods. However, because the proportion of damaging strikes used in the risk assessment process has not been recalculated, the increasing number of non-damaging strikes reported has given a false impression of an increase in overall birdstrike risk in that period.

The mandating of birdstrike reporting in 2004 resulted in a large increase in the total number of reported birdstrikes that cannot be explained by changes in air transport movements. There was a corresponding, but smaller, increase in the number of damaging birdstrike reports, but overall the proportion of damaging birdstrikes fell. Because this proportion has not been recalculated, a number of bird species have risen in risk category at the UK's main airports primarily as a result of increased reporting rates for non-damaging strikes rather than any actual increase in risk. There is clearly a need to recalculate the proportion of damaging strikes for use on UK airports in order to avoid airport managers investing scarce resources in managing risks unnecessarily.

The sensitivity of this risk assessment process to reporting culture means that care also needs to be taken when applying this method around the world. Individual countries have different reporting requirements in their regulations, and from personal experience at hundreds of airports around the world, the authors are aware that these regulations are applied with very different levels of rigour when the reporting of birdstrikes is concerned. It is therefore most important that individual countries undertake a calculation of the relationship between bird mass and percent damage using their own data, rather than relying on data collected from other countries where reporting behaviour may be significantly different. Similarly, where any country's reporting regulations change, or where there is reason to assume that reporting behaviour may have changed for other reasons (e.g. a publicity campaign or pressure from safety auditors to improve reporting of strikes), the proportion of damaging strikes should be re-calculated to allow for the impact of changes in reporting behaviour that may otherwise give a false impression of the true level of risk.

The poor fit of the data to the simple linear regression model used by Allan (2006) poses further problems. The low number of strikes recorded for some species make a simple percent damaging strikes measure prone to fluctuation caused by random chance. Examination of the residual variation suggests that the true relationship between mass and proportion of damaging strikes is not simply linear. Nevertheless, the risk assessment methodology has worked well in practice since its publication, and, at present, we recommend continuing with this technique in the future, but revising the calculation of mass vs. proportion of damaging strikes as needed to allow for changes in reporting rates. We would also encourage the use of the largest possible sample size when deciding whether or not to include a species in the calculation. The choice of sample size will inevitably be a trade-off between having enough species included in the analysis to make it meaningful and having a statistically valid relationship not unduly influenced by outliers. This, in turn, will depend on the numbers of strikes in the available national dataset that are both reported and identified to species. Alternatively, more complex methods could be used to model the relationship between damage and bird mass, however this requires an understanding of factors such as how reporting effort varies between aerodromes, which is not currently available.

5. Conclusion

The risk assessment developed by Allan (2006) has proved a very useful tool in practice and it, or derivatives of it, have been adopted by a large number of regulators and airport operators around the world. This analysis shows that the methodology is susceptible to changes in reporting efficiency within a country or differences in reporting culture between countries. In the UK, for example, the current recommendation is to use the relationship between mass and proportion of strikes causing damage calculated by Allan (2006) which uses the data from 1976 to 1996 and includes species struck at least 5 times. This line has a slope of 0.014, so in practice one would multiply the mass in grams of a species by 0.014 to obtain the proportion of damaging strikes for that species and hence a strike severity measure for use in the risk assessment. The increase in reporting frequency since the mandating of strike reporting in 2004 means that the recalculated slope of the line, using species struck more than 100 times to improve the fit, is now 0.003 (the line shown for 2005–2013 in Fig. 3). Failing to apply this recalculation is in parallel to the increase in reporting of non-damaging strikes following mandating of strike reporting is resulting in a substantial over-estimation of the risk at individual aerodromes in the UK. We therefore recommend the new relationship between mass and proportion of strikes causing damage is applied in the UK with immediate effect and that individual countries calculate the relationship between mass and proportion of strikes causing damage using their own data. Routine recalculation of the relationship should be undertaken at least every 5 years, or more frequently if there is reason to believe that a change in reporting practices may have occurred. Further studies to develop a better understanding of the relationship between bird mass and the number of reported damaging strikes could help to make the risk assessment more statistically robust.

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