THE USE OF BIRDSTRIKE STATISTICS TO MONITOR THE HAZARD AND EVALUATE RISK ON UK CIVIL AERODROMES

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SUMMARY

Birdstrike statistics are widely perceived as the primary instrument for monitoring the hazard and evaluating risk on individual aerodromes. However, those currently in use are not very informative and they are susceptible to variations in reporting standards. A number of new statistics are proposed to rectify these problems. The use of other sources of information on the birdstrike hazard at individual aerodromes is examined.

1. INTRODUCTION

In the UK, case histories of birdstrikes to civil aircraft have been compiled by the regulatory authority for civil aviation since 1951 and statistics derived from these data comprise the primary instrument for monitoring the hazard and evaluating birdstrike risk on civil aerodromes. Serious doubts about the validity of the civil birdstrike statistics currently in use, in the UK and elsewhere, have been voiced on several occasions, most recently at the 19th Meeting BSCE (Bruderer 1988, Thomas 1988), but the problems that were highlighted remain unaddressed.

One solution would be to use additional methods of monitoring and, indeed, the birdstrike record is only one of three sources of information on the birdstrike hazard on UK aerodromes. The others are field surveys, which have been carried out by the CAA on all major UK civil aerodromes since the early 1980s, and the record in aerodrome bird control logs of bird numbers and the application of control measures. Their purpose is rather different from that of the birdstrike recording scheme and they should be regarded as complementary sources of information (Milsom and Horton, in prep). However, in spite of any short-comings, the birdstrike recording scheme remains the most useful source of information for remote monitoring because it is the only one of the three that is centrally co-ordinated by the regulatory authority, continuous in its sampling operation, computerized and published.

In the light of the foregoing, this paper addresses three questions:

(i) how much do the birdstrike statistics currently in use tell us about the hazard at individual aerodromes?

(ii) could the range of statistics be expanded to produce a more informative picture?

(iii) should we continue to regard birdstrike statistics as the primary instrument for monitoring the hazard and evaluating risk on individual aerodromes?

2. EVALUATION OF CURRENT USAGE OF CIVIL BIRDSTRIKE STATISTICS IN THE UK

The sole published statistic for each UK civil aerodrome is the annual birdstrike total for UK registered transport aircraft above 5,700 kg (Thorpe 1978). As this statistic is frequently compared with those published for other aerodromes, where aircraft movement rates are different, it is usually expressed as a fraction of the annual aircraft movement total (x 10,000). The justification for this weighting procedure is that if all other factors (aircraft, bird, bird control and birdstrike reporting parameters) were equal then the birdstrike and aircraft movement statistics would vary in exact proportion.

Both the annual birdstrike total and the corrected rate are widely perceived as useful indicators of the hazard at individual aerodromes. However, neither statistic imparts much information nor are they appropriate for monitoring the hazard, evaluating risk or assessing the performance of remedial measures. This application can be criticised on at least three counts: reliability of the statistics, lack of calibration against a recognised standard and unrealistic weighting of each birdstrike report.

With the exception of those incidents covered under the CAA Mandatory Occurrence Reporting Scheme, all birdstrike reports are submitted voluntarily in the UK, and the vagaries of this arrangement, combined with the known difficulties of detecting certain classes of incidents, continues to give rise to doubts about the standards of reporting (Thorpe 1978, Thomas 1988). There is considerable uncertainty over whether reporting standards at a given aerodrome remain constant through time or whether standards are, on average, equivalent across all aerodromes. This, in turn, raises serious doubts about the validity of comparing the annual birdstrike totals both within and between aerodromes, particularly as there is no straightforward and exact means of adjusting the data to correct for reporting biases.

The second difficulty with the annual birdstrike total or corrected rate arises when they are used for risk assessment because neither statistic is calibrated against a recognised standard of acceptable risk. It has been common practice to compare the annual statistic for a given aerodrome against an average annual value for all aerodromes, in the belief that the average level is somehow acceptable. However, the basis of this procedure is unsound because the average is neither an acceptable nor a fixed standard.

Thirdly, there is an implicit assumption that the individual birdstrike record is the unit of currency in the assessment of the hazard. This needs to be challenged. All birdstrike records do not have equal weight, in the statistical sense, because the hazard posed by birds varies between species in relation to their mass and behaviour. It is unrealistic to treat an incident involving a single small passerine, such as a Skylark *Alauda arvensis*, as being of no greater or lesser significance than one involving a large flock of gulls *Larus*. Equal weighting of records is also inappropriate for the assessment of the performance of control measures because not all bird species on aerodromes are equally responsive to existing control techniques. Consequently, an uncritical examination of trends in the unweighted annual strike total or rate at a particular aerodrome could result in a mistaken conclusion about their cause or significance. For example, the sharp rise in the annual strike total at London Heathrow in the early 1980s did not signify a dramatic decline in the efficiency of bird control at that airport because it was due mainly to an increase in the number of strikes involving small birds, such as swifts *Apus apus* swallows *Hirundo rustica* and martins *Delichon urbica*/*Riparia riparia*, which do not respond to existing scaring techniques (Fig. 1). Moreover, the rise in the annual strike total did not automatically imply that the risk of a serious incident had increased because it was due mainly to species that rarely cause damage to aircraft.

Of course, the principal users of the birdstrike recording scheme will also have access to the case histories of each strike. These records contain much more information than the published annual summaries. Nonetheless, no recognised procedure exists for the interpretation of their contents, and the foregoing observations about the use of published summary statistics apply equally well to the original data.

Given that the existing arrangements are unsatisfactory what, if any, improvements are feasible? The content of each birdstrike record is such that it is practicable to expand the range of statistics that is currently available. However, if the new statistics are to be useful we have to be clear about what is required of them. The principal users of the birdstrike recording scheme are aerodrome managers, who have responsibility for bird control (CAP168, Sharp 1988), and the regulatory authority. Both parties require statistics to assess the hazard, to evaluate birdstrike risk and to monitor the performance of remedial measures on individual aerodromes.

3. MONITORING OBJECTIVES

To evaluate birdstrike risk or assess performance of remedial measures, a given statistic has to be compared against an explicitly defined standard. This is currently lacking. As the level of acceptable risk remains unspecified, the only goal against which it is practicable to assess performance from the annual strike total or rate is the prevention of all birdstrikes on each aerodrome. However, this goal appears to be unattainable even by those UK aerodromes where standards of control are known to be very high. Clearly, the application of such a demanding criterion is not very helpful, and assessment against lesser but operationally significant goals would be more appropriate.

3.1 The primary goal

The primary goal of bird control on aerodromes should not be to prevent all birdstrikes but to minimize the likelihood of an incident that results in damage to the aircraft. Progress towards the primary goal can be monitored in several ways depending upon which control strategy is chosen (Table 1). I aim to show that strategy B (Table 1) is a practicable option by demonstrating that there is a clear link between bird parameters, which bird controllers can manipulate, and the risk of a damaging strike. Strategy B is not only more direct than Strategy A but it also enables performance to be assessed from the frequency of those classes of strikes where the risk of damage is high. This is a more useful measure of performance than the frequency of incidents that have resulted in damage.

On theoretical grounds, we would expect that, all other things being equal, the probability of damage resulting from a birdstrike will increase with the mass of the bird species involved and with the number of birds struck. These predictions were tested using a sample of records from the CAA dataset where both the mass of the species and number of birds involved were known (Table 2). The first analysis showed that the occurrence of damage of any kind was correlated with both the numbers of birds hit and the mass of the bird species involved (see Table 2 for statistical details). As power-plant damage and failure is a major area of concern, the analysis was repeated with the occurrence of damage to aero-engines as the dependent factor. The results were less clear cut because the interaction term between the explanatory variabled was just significant at the 2% level. (see Table 2 for statistical details). Reporting biases probably led to errors of estimation within and between the categories shown in the tables (see footnotes Table 2). However, the main results of the analyses remain valid in spite of these confounding factors because correction for reporting biases would tend to strengthen the correlations (see footnote Table 2).

The uncertainty in the outcome of strikes within flock size and weight categories will have been due partly to chance and partly to variation in the aircraft parameters, such as flight speed and the resistance of

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It is now realistic to attach scaring priorities to bird species on the basis of their mass and flocking habit. In particular, the presence on aerodromes of flock forming species, especially those of medium and large mass (as defined in Table 2), must be regarded as especially hazardous, and top priority should be given to their control. In the UK, as in western Europe, the commonest bird species on aerodromes tend to be those that not only form large flocks but also fall into the higher weight ranges (Table 3). These species should comprise the **priority group** in any bird control strategy. As all respond to existing aerodrome habitat management and scaring methods, a multiple strike involving any of these species should be regarded as a warning that bird control standards are falling, or perhaps have fallen, to an unacceptably low level.

3.2 A minimum acceptable standard for bird control on aerodromes

A minimum acceptable standard for bird control has not been formally defined but the criteria proposed in Table 4 form the basis for discussion in the UK. They are based upon the frequency of multiple strikes involving bird species from the priority group. This statistic is less sensitive to fluctuations in reporting standards than the annual strike total because it is derived from the class of birdstrikes which is the least likely to go undetected or unreported.

Although the occurrence of multiple strikes involving birds from the priority group may signify that bird control standards are falling to an unacceptably low level, the converse, a lack of these strikes, does not automatically indicate that the situation is satisfactory. This is especially the case on aerodromes with low aircraft movement rates where the combination of factors (aircraft and bird) necessary for a multiple strike is likely to occur only at infrequent intervals. Expressed in another way, the potential for a serious strike may exist more or less continuously on an aerodrome that is used freely by large flocks of birds but that potential may only be realised during the rare occasion when, for example, a jet transport aircraft movement occurs. The circumstances leading up to a major birdstrike on an unlicenced UK aerodrome illustrate this point very well. At this aerodrome, the movement rate of jet and turbo-prop transport aircraft and the birdstrike rate were both very low: on average <1000 and <1 per annum respectively. Only one multiple strike (2-10 Lapwings hit) was reported between 1975 and 1983, but in 1984, a notifiable accident occurred as a result of a multiple strike involving at least 17 Lapwings. If the hazard had been assessed by the frequency of multiple strikes alone, then their paucity before 1984 may well have suggested that the situation was satisfactory up until then. However, a simple analysis of bird counts from the aerodrome, and scrutiny of the case histories of each strike that occurred prior to the accident, especially the numbers of birds estimated by aircrew prior to impact, would have shown that this was not the case.

3.3 Secondary goals

The definition of secondary goals is less clear cut. To some extent, they are determined by what birdstrike parameters are measurable. However, the relationship between the probability of damage and the mass of the bird species involved forms a sound basis for proposing that the next logical goal from the minimum acceptable standard should be to prevent any strike involving species of medium, or large mass (as defined in Table 2). The following goal in the series could be to prevent all strikes involving species that respond to existing control measures. Beyond that goal lies the aim of the bird-free aerodrome and the prevention of all birdstrikes, except for those caused by extraneous factors. This remains the ultimate and, probably, unattainable objective (Horton, this conference).

Monitoring the performance of bird control in relation to these secondary goals is not straightforward because of uncertainty over whether the observed trend in the frequency of a given class of birdstrikes is real or an artifact caused by a variation in reporting standards. This applies to both the bird weight and the controllable species statistics.

3.4 The bird weight statistic

To overcome the problem arising from variations in reporting standards, I have assumed that the biases in reporting vary in a predictable manner across the weight range of the birds involved in strikes. *A priori* we would expect that birdstrikes involving small birds are less likely to be detected and reported than those involving large species. No empirical data are available to test this assumption directly, but Thomas (1988) provides circumstantial evidence to indicate that it is true.

On basis of these assumptions, trends in the frequency of birdstrikes involving medium or large species can be monitored indirectly by comparison with the frequency of the class of incidents that is least likely to be reported - those involving the smallest species. Thus, the aim is to detect a change in the composition of the annual birdstrike sample from one that is dominated by incidents involving medium or large species to one that is dominated by those involving small species. Given that the latter are the least likely to be reported, we can be certain that our goal has been reached when this class of birdstrikes makes up the entire annual sample. The bird weight statistic is, therefore, the proportion of the annual sample of birdstrikes, for a specified aerodrome, which involved small bird species. Small bird species are defined as those with a mass of less than 110g. This is the lightest weight category considered by the CAA in their statistics (Thorpe 1978, 1987).

Interpreting the significance of intermediate values of the bird weight statistic is less straightforward because they can reflect changes in the standards of reporting as well as those of the remedial measures. Nonetheless, if this statistic is compared with the annual strike total it is feasible, under certain circumstances, to infer which of the two factors (reporting standards and efficiency of control) has had the greater influence (Milsom and Horton, in prep). The indicators that signify a net improvement either in control or reporting standards are summarized in Table 5. Other permutations are possible, and a full set will be published elsewhere (Milsom and Horton, in prep).

3.5 The controllable species statistic

Similar logic has been applied to the design of the statistic to assess performance in relation to the goal of preventing all strikes with controllable species. In this case, the statistic is the proportion of the annual sample of birdstrikes that involved bird species that are responsive to existing control measures.

The fact that some species are more difficult to control on aerodromes than others has already been mentioned. With very few exceptions, it is practicable, on the basis of current knowledge, to assign all bird species that commonly occur on UK aerodromes to one of two categories: (i) those that respond to existing scaring methods and habitat management techniques (CAA 1981) - the 'contollable species' - and (ii) those that are unresponsive - the 'uncontrollable species'. Birds in the controllable category (gulls, lapwings, pigeons, corvids, for example) tend to be the most numerous on UK aerodromes and, where bird control is poor, it is likely that they will be involved in most birdstrikes. As control efficiency improves, the proportion of incidents involving 'controllable species' should decline.

As before, I shall assume that reporting biases vary in a predictable manner, and that incidents involving 'controllable species' are more likely to be reported than those from the 'uncontrollable' group. 'Controllable species' tend to be conspicuous because they are medium or large in size, many form flocks, and bird controllers on training courses, run by the ABU and CAA, are alerted to their significance. In contrast, species from the 'uncontrollable' group tend to be rather less conspicuous, because they are small and/or solitary, and comparatively little attention is given to them on the training courses.

The philosophy behind the controllable species statistic is similar to that for bird weight, in that the frequency of strikes involving the controllable species (those more likely to be reported) is compared with that for the uncontrollable species (those less likely to be reported). As before, we can be certain that the goal has been reached when the annual sample of birdstrikes consists solely of the latter group. The relative effects of variation in reporting standards and control efficiency upon intermediate values of the statistic are distinguishable using the criteria shown in Table 5.

4. REVIEW OF PROPERTIES OF NEW STATISTICS

Collectively, the new statistics impart considerably more information about the birdstrike hazard on a given aerodrome than the old, and their scales are calibrated against operationally significant goals. The specification of these goals enables us to make assessments at a range of levels from the ideal of no birdstrikes at all down to the minimum acceptable level. Two of the three statistics have finite scales, whose extremes mark the worst and best possible situations, whereas the third, the frequency of multiple strikes, can be judged against set criteria. Consequently, the performance of one aerodrome can be assessed without recourse to comparison with others. This was not possible previously. The new statistics possess another major advantage over the old in that, with certain qualifications, they allow one to distinguish between the effects of variation in reporting standards and the performance of the remedial measures; previously there was no way of doing this.

5. PRACTICAL APPLICATION OF NEW STATISTICS

To illustrate how the statistics work in practice, I shall use those for two regional aerodromes in the UK, A and B, which have similar transport aircraft movement rates (30-40,000 p.a.). Bird control operations at both aerodromes have been surveyed repeatedly over the last 15 years (Milsom and Horton, in prep). The initial surveys, which were carried out during the late 1970s, showed that standards of bird control were very poor at both aerodromes. More recent surveys indicated that the standard at B had risen only slightly, whereas those at A detected a very major improvement. The difference in the field assessments are reflected in the statistics.

The trends in the statistics for A comprise a textbook example of how improvements in the application of control measures can dramatically affect the types of strikes that occur (Fig. 2). The annual frequency of multiple stikes involving species from the priority group was relatively high in the early 1980s, but it fell markedly after 1984 and, if the criteria shown in Table 4 are applied, the aerodrome met the minimum acceptable standard annually after 1985. Also there was a very marked rise in small bird statistic and a corresponding fall in controllable species statistic. When viewed against a more or less steady annual total, the trends in both statistics suggest that effects of improvements in control and reporting standards were approximately balanced.

The statistical picture for B is very different from that for A (Fig. 3). The annual frequency of multiple strikes was much higher than that at A and B failed to meet the minimum acceptable standard in all but one of the years of the survey. Moreover, there is little evidence of much progress towards either of the secondary goals as the values of both measures remained at the poor end of their respective scales throughout the survey period.

It is interesting to note that the old methods would have drawn rather different inferences from the statistics. At B, a slight improvement may well have been inferred from the gradual decline in the annual birdstrike total whereas, at A, the level trend would have suggested that no changes had occurred!

6. USE OF OTHER SOURCES OF INFORMATION ON THE BIRDSTRIKE HAZARD

There is no doubt that statistics derived from the birdstrike record for a given aerodrome can be useful indicators of the hazard and of the performance of remedial measures at that aerodrome. However, they also have short-comings, in the light of which it is appropriate to question whether birdstrike statistics merit being the primary monitoring instrument. Some specific problems with interpreting the statistics in isolation have already been highlighted. Others will be detailed in a forthcoming publication (Milsom and Horton in prep). A more general problem arises from the retrospective property of the statistics. As birdstrikes are relatively infrequent events, a particular statistic may be meaningful only when it is computed from data that cover a period spanning several years. Consequently, the statistical picture tends to lag behind the current situation. Where the time lag is considerable, it is clearly inadvisable to draw any firm inferences from the statistics alone. Under such circumstances, other monitoring systems have an essential role to play.

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Systematic counts of birds on aerodromes are a valuable source of information because they can provide a more up to date picture of the hazard than that which can be inferred from the birdstrike record. Unfortunately, they comprise the least organized and exploited monitoring system (Milsom and Horton in prep). A centrally organized scheme would ensure that the counts were done in a systematic and standardized manner to provide an additional and valuable remote monitoring instrument. Such a scheme has been suggested in the past but the proposal has yet to be adopted in the UK. Nonetheless, the experience of the British Trust for Ornithology with the Common Bird Census and other monitoring schemes (Hickling 1983, Baillie 1990), the Wildfowl and Wetlands Trust with the Wildfowl Counts scheme (Owen et al 1986), and the Aviation Bird Unit with the Airfield Lapwing Enquiry (Milsom and Rochard 1987), indicates that a monitoring scheme of bird numbers on all major civil aerodromes in the UK would be feasible.

7. ACKNOWLEDGEMENTS

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Table 1. Cont
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Table 1. Control strategies for achieving primary goal of minimizing frequency of birdstrikes that result in damage to aircraft.

	Assumption: Relationship between bird parameters and risk of damage	
	No	Yes
Control Strategy	(A) Make no distinction between bird groups	(B) Target bird groups most likely to cause damage
Criteria for monitoring performance of remedial measures	Frequency of damaging strikes	Frequency of damaging strikes OR Frequency of classes of strikes where risk of damage is high

Table 2. Relationship between the probability of damage arising from birdstrikes in relation to the numbers of birds involved and their mass.

	Number of birds hit[1]					
	1	2-10	11-100 & >100 pooled	Chi sq	d.f.	P
% strikes where damage occurred:	8.12	14.6	40.32	57.41	2	<0.001
% strikes where engine damage occurred:	2.1	4.6	22.6	43.67	2	<0.001
N of strikes:	1453	720	62			
	Mass of bird species involved[2]					
	<100g	101-1000g	>1000g	Chi sq	d.f.	P
% strikes where damage occurred:	2.7	12.0	22.7	59.45	2	<0.001
% strikes where engine damage occurred:	0.7	3.96	4.97	13.31	2	<0.01
N of strikes:	414	1640	181			

Notes: 1 - categories determined by those used on CA1282 birdstrike report form (Thorpe 1978) ; 2 - species assigned by their average weights, data from Brough 1983; 3 - sample relates to UK registered aircraft: 1976-87.

Statistical models: generalized linear model (GLIM) for logits (McCullagh & Nelder 1983, Healy 1988) fitted to (i) proportion of damaging strikes as response variable with flock size and mass of species involved as explanatory variables, (ii) proportion of strikes resulting in aero-engine damage as the response variable, explanatory variables as before. Test statistic = Chi sq. [Interaction term between explanatory variables: Model (i) NS, Model (ii) Chi sq - 12.74; d.f.= 4; P<0.02>0.01].

Sources of error: The probability of a strike being detected and reported is not independent of either explanatory variable. It is likely to rise as the number of birds involved increases and as the mass of the species involved becomes greater. Within flock size and weight categories, damaging incidents are more likely to be detected and reported than non-damaging ones. Therefore, we can place greatest confidence in the estimate of the number of damaging strikes involving the largest flocks and/or the largest species, and least confidence in the estimate of the number of non-damaging strikes involving the smallest species and/or solitary birds. Correction for these reporting biases would lengthen the odds against damage across all levels of both explanatory variables but by the greatest amount in the single bird and smallest weight categories, thereby exagerating the correlations as shown.

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Herring Gull
Great Black-back

Feral Pigeon
Stock Dove
Woodpigeon

Jackdaw
Rook

Note 1 - for stati
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Table 3. The priority group: bird species, of medium to large mass, that form large flocks and which are widespread and numerous on UK aerodromes.[1]

		Mass (g)[2]	Range
Oystercatcher	*Haematopus ostralegus*	500	335-800
Golden Plover	*Pluvialis apricaria*	185	88-230
Lapwing	*Vanellus vanellus*	215	112-303
Black-headed Gull	*Larus ridibundus*	275	119-390
Common Gull	*Larus canus*	420	300-555
Lesser Black-backed Gull	*Larus fuscus*	820	584-1180
Herring Gull	*Larus argentatus*	1020	600-1800
Great Black-backed Gull	*Larus marinus*	1690	1140-2275
Feral Pigeon	*Columba livia var.*	393	194-570
Stock Dove	*Columba oenas*	345	217-567
Woodpigeon	*Columba palumbus*	465	258-739
Jackdaw	*Corvus monedula*	234	123-265
Rook	*Corvus frugilegus*	430	282-595

Note 1 - for status of the these species on aerodromes see Bridgman 196[illegible], Hilsom and Rochard 1987, ADAS unpublished. Note 2 - data from Brough 19[illegible].

Table 4. Proposed definition of a mimimum acceptable standard of bird control on UK civil aerodromes based upon frequency of multiple birdstrikes involving species from the priority group[1]

Nos birds hit	Nos birds seen by aircrew/ATC prior to impact	Birdstrike category
2-10	11-100 or >100	(i)
11-100	Not applicable	(ii)
>100	Not applicable	(iii)

The occurrence of 3 or more category i strikes on a given aerodrome in any year, or a single categeory ii or category iii incident should indicate that the standard of bird control on that aerodrome has fallen below the acceptable minimum.

Note: 1 - (see Table 3 for species list).

Table 5. Guide

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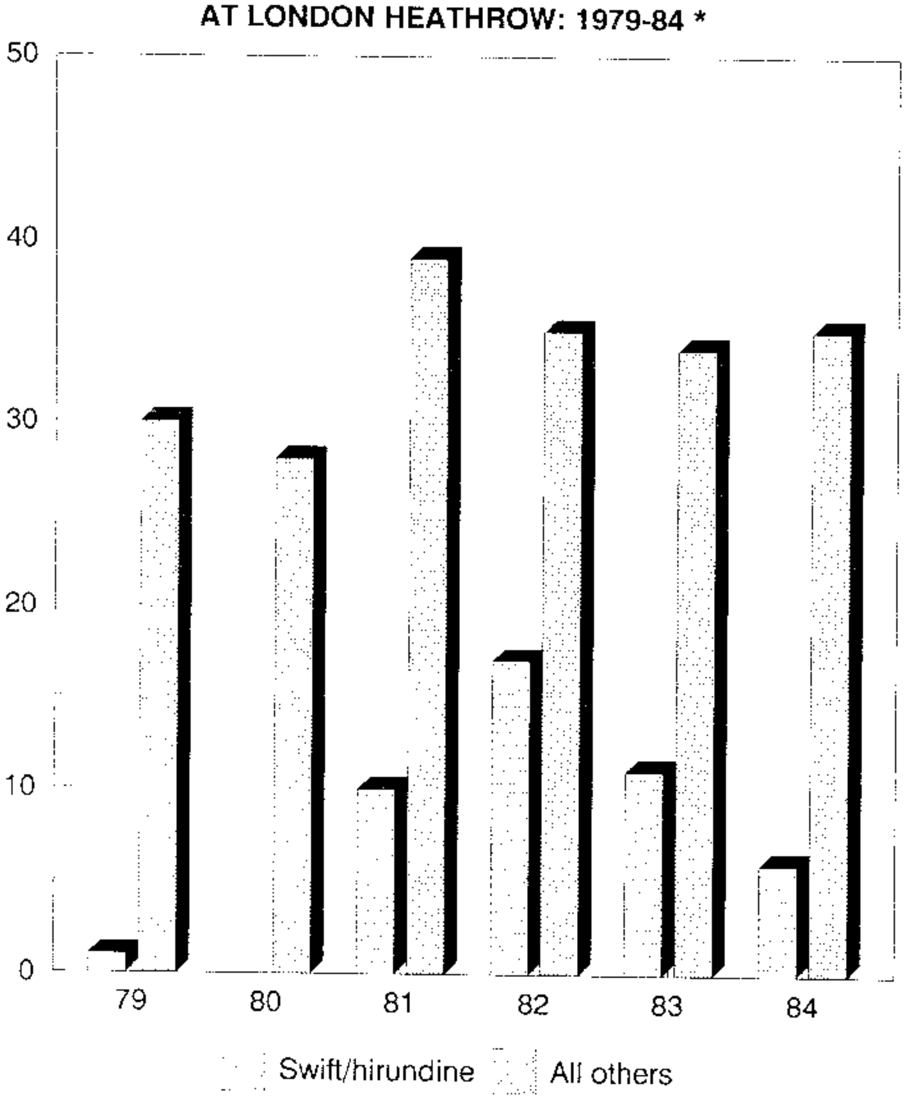
Table 5. Guide to interpretation of bird weight and controllable statistics.

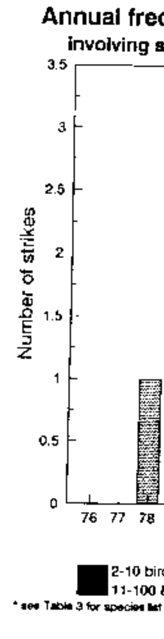
Trends			
Annual birdstrike total	% strikes involving species (<110g)	% strikes involving controllable species	Inference
Rising	Rising	Falling	Effects of improvement in control< reporting
Level	Rising	Falling	Effects of improvement in control & reporting balanced
Falling	Rising	Falling	Effects of improvement in control> reporting

Figure 1

CHANGES IN ANNUAL TOTAL OF BIRDSTRIKE REPORTS AT LONDON HEATHROW: 1979-84 *



* - Data from CAA database; UK and foreign registered aircraft, all weights.



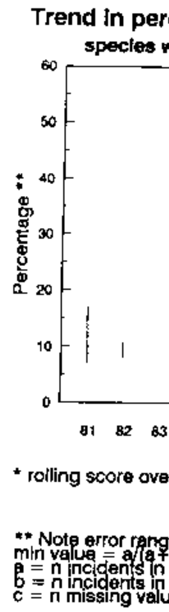
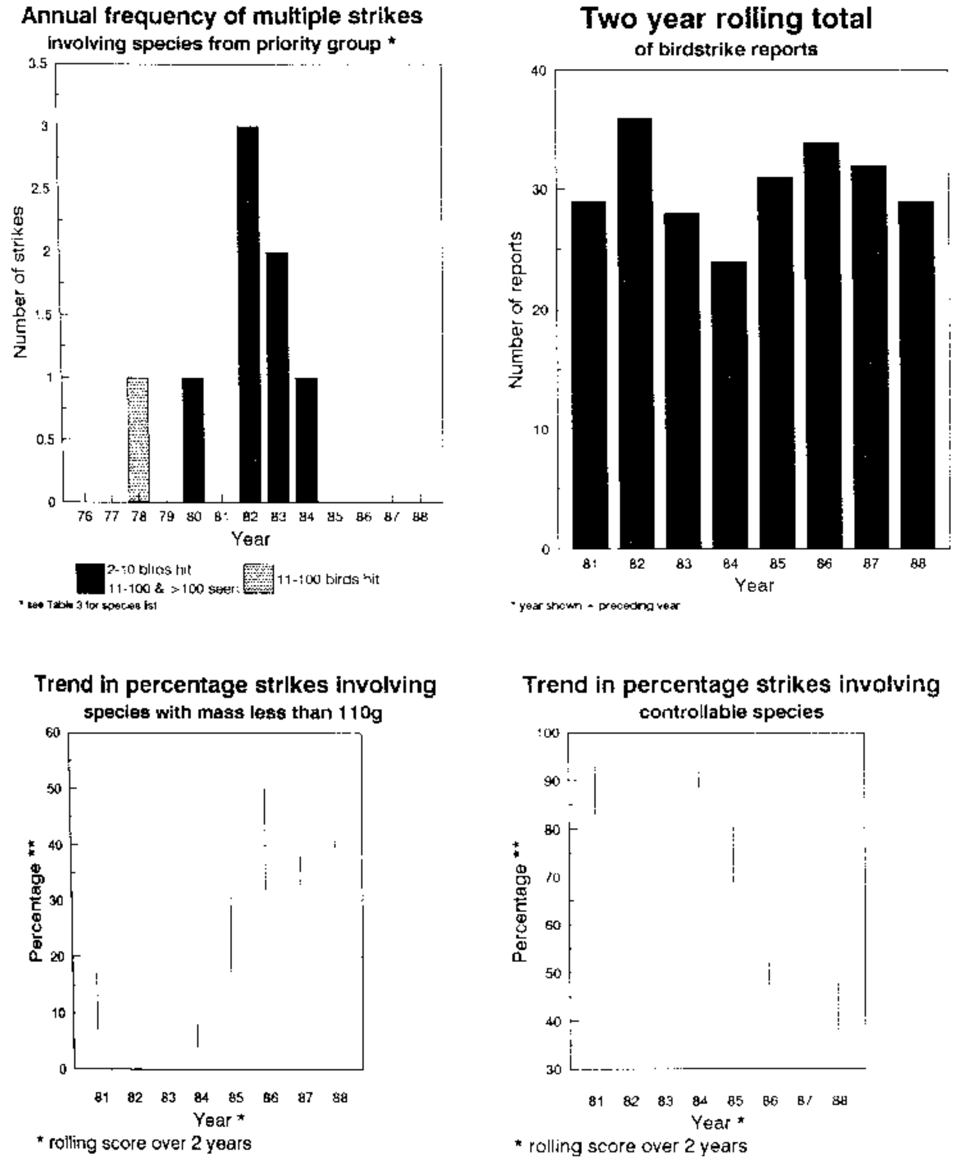
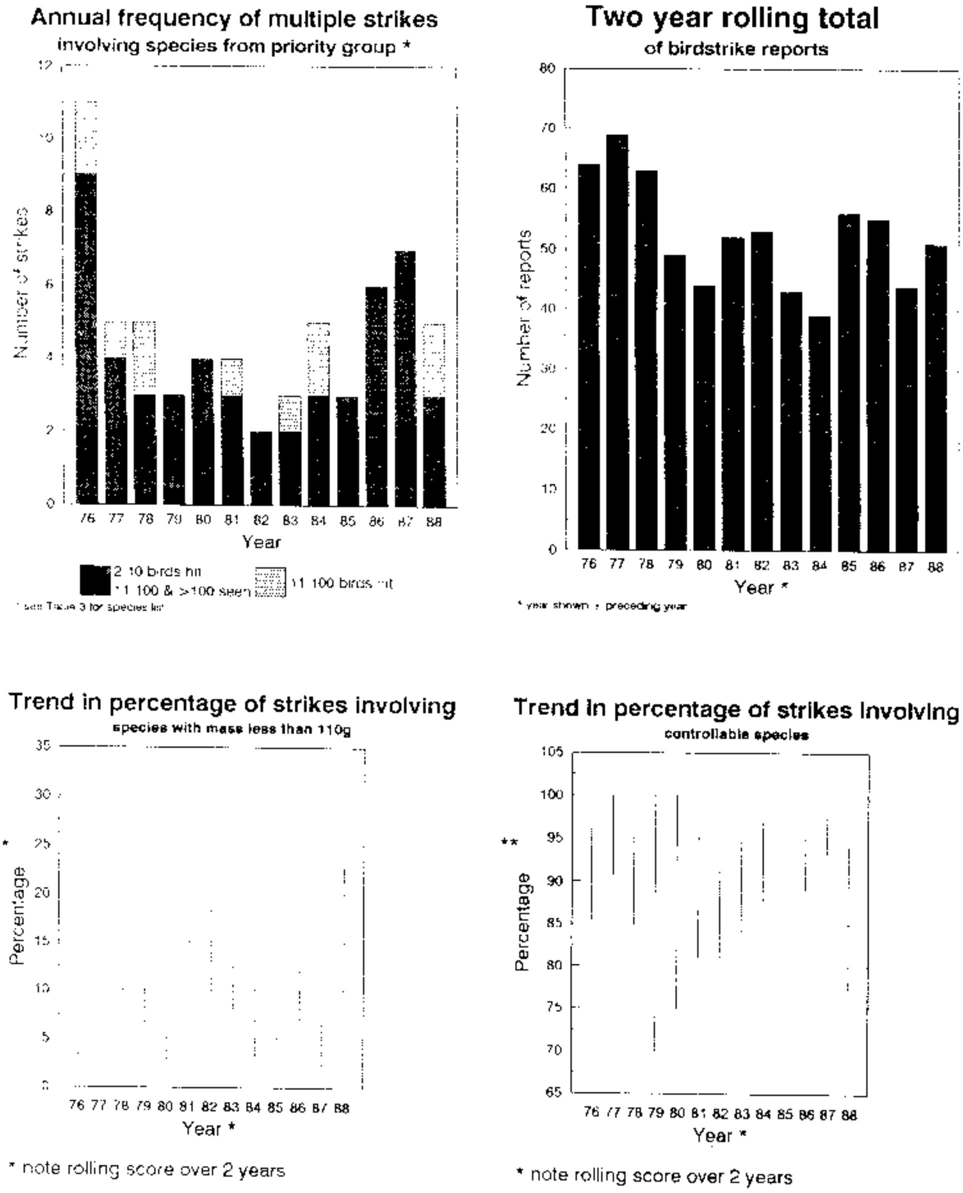


Figure 2
Aerodrome A



** Note error ranges showing minimum & maximum values
min value = a/(a+b+c)*100, max = (a+c)/(a+b+c)*100
a = n incidents in category of interest
b = n incidents in other category
c = n missing values

Figure 3
Aerodrome B



** See footnote to Fig. 2.

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