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QUANTITATIVE METHODS IN BIRD HAZARD CONTROL: PRELIMINARY RESULTS

Thomas C. Kelly,[1,2] John Murphy,[1] Raymond Bolger[1]

[1]Aer Rianta, Dublin Airport, Ireland
[2] Department of Zoology, University College Cork, Ireland

SUMMARY

This study presents a preliminary report on the development of quantitative methods in assessing the effectiveness of bird hazard control at Dublin Airport. Yearly totals of bird strikes since the base year 1978 are indexed using the recently developed Underhill method. The numbers of birds involved in individual incidents are analysed using the variance to mean ratio of a frequency distribution. It will be shown that while there has been an increase in the annual index of bird strikes since 1990, the variance of the numbers of birds being struck has remained less than the mean. The results are discussed in the general context of monitoring bird hazard control.

Key words: Statistics, Aerodrome Survey, Country

INTRODUCTION

The task of monitoring the effectiveness of bird hazard control around airfields relies heavily, though not exclusively, on the analysis of bird strike statistics. Nevertheless, it is widely recognised that these data suffer from a number of limitations, and an uncritical analysis may produce misleading patterns and unwarranted conclusions (Thomas 1986). Many of the difficulties arise from human error in that both pilots and ground staff have problems in correctly identifying all the bird species (due to differences in their detectability), involved in strike incidents (Thomas 1988).

However, an earlier analysis of statistics from a large sample of airports in the UK by Rochard and Horton (1980) identified the species most frequently struck and also the seasonal pattern of these strikes. More recently Horton (1994) has shown that relevant statistics can be generated if the culpable birds are correctly identified. In particular, useful quantitative information can be obtained on two of the most important factors associated with the risk of damage to aircraft - namely the numbers and weights of the birds being struck (Horton 1994).

This study has two main objectives: (i) to employ a recently developed index method to establish the trend in the variation in the annual numbers of bird strikes and (ii) to apply conventional statistical analysis of frequency distributions to data involving the numbers of birds being struck by aircraft.

STUDY AREA

Dublin Airport is Ireland's largest and busiest aerodrome. Passenger numbers have grown strongly since the mid-1980s, increasing from 2.6 million in 1984 to approximately 8 million in 1995. For several years the air traffic has been dominated by wing-mounted twin-engined commercial jet aircraft.

METHODS

This study encompasses an 18-year period, from January 1978 to December 1995, during which detailed records of bird strikes were kept. From a bird hazard control point of view, the study can be further subdivided in to three six-year segments during which major changes in management procedures, or to the airfield itself, occurred (Table 1). Relevant information was extracted from the airport database (known by the acronym "DABHAND"- Dublin Airport Bird Hazard and Numeric Database; Paradox V.5 for Windows) containing all available information relating to bird strikes.

Table 1. Bird hazard control policies: Dublin Airport 1978-95 *.

Period	Habitat management	Bird Hazard Committee	Expert identification of bird remains	Principal runway
1978-1983	No	No	No	05/23
1984-1989	Yes from 1985 onwards	Yes from 1986 onwards	Yes from 1986 onwards	05/23
1990-1995	Yes	Yes	Yes	10/28

* New runway 10/28 opened 1989 (Sept.). Runway 05/23 closed 1990 (June)

Confirmed bird strikes are defined as incidents in which a report has been received from the flight crew, ATS or the fire station and either;

(a) a carcass has been located which was relevant to the flight or
(b) there was evidence of impact on the aircraft or a carcass has been found which, following specialist examination, was deemed to have been involved in a bird strike.

While all the information on bird strikes was recorded on the database, only incidents complying with the above-mentioned criteria were included in this analysis (n = 412). Since 1989 all carcasses or fragments of birds involved in putative strikes were labelled, placed in polythene bags and stored in a deep freeze until examined by an ornithologist.

TREND IN THE ANNUAL NUMBER OF STRIKES

While there has been much discussion of the temporal variability of abundances (e.g. Gaston 1994; Gaston and MacArdle 1994) the approach in this study has been to experiment with the recently developed index - known as the Underhill method (Underhill and Prys-Jones 1994). For the purposes of this study, the Underhill method has been reworded: an index number of bird strikes for a particular year is defined as the ratio of the total number of bird strikes that year to the total number in the base year. The base year taken for this study is 1978.

Following Underhill and Prys-Jones (1994) x_{ijk} is the total count of bird strikes at location i in year j and month k where i = 1, 2; I the number of localities. j = 1, 2; J the number of years and k = 1, 2; K the number of months. The base year is designated as b, so that $1 \le b \le J$.

Then the population = bird strike index for year j relative to the base year b using km months is

$$P_j(b)(km) = \frac{\sum_{i=1}^{I}\sum_{k=1}^{K} x_{ijk}}{\sum_{i=1}^{I}\sum_{k=1}^{K} x_{ibk}}$$ Equation 1.

However in this study, unlike Underhill and Prys-Jones (1994), all twelve months of the year are included in the computation of the index, so km = 12.

Therefore the bird strike index for year J = $$\frac{\sum_{k=1}^{12} x_{jk}}{\sum_{k=1}^{12} x_{bk}}$$ Equation 2

Note that I = 1 in all years, since only one location was studied and j = b for base year = 1978 used here.

NUMBERS OF BIRDS INVOLVED IN STRIKES

In the annual total, most strikes will have involved only one or a few birds. However, several incidents may have resulted from aircraft striking larger numbers, that is, flocks of birds. Such a pattern of bird strikes will produce the well known, long-tailed frequency distribution which is also clumped (Southwood 1966; Elliot 1977; Krebs 1989; Fowler and Cohen 1990). Horton (1994) noted that the risk of damage to aircraft increases non-linearly with the number and weight of the birds being struck. It was also suggested that where an aircraft strikes a large number of birds, there has probably been a breakdown in the control procedures. An analysis, therefore, of the number of birds being struck by aircraft may be useful in assessing the efficiency of bird hazard control procedures.

The degree of clumping (that is, the probability of flocks of birds being struck) is determined by the relationship between the mean $\bar{x}$ and the variance S^2 of the frequency distribution. Thus if x is the number of birds involved in individual strikes and f their frequency of occurrence then $\sum f = N$ and $\frac{\sum fx}{N} = \bar{x}$ the mean of the frequency distribution (Elliot 1977; Krebs 1989).

The variance of the frequency distribution (Elliot 1977) is found by:

$$S^2 = \frac{\sum(fx^2) - \bar{x}\sum fx}{N-1} \qquad \text{Equation 3}$$

Statistically, the distribution is clumped if the variance S^2 is greater than the mean $\bar{x}$. Therefore, following the calculation of the variance to the mean ratio $S^2/\bar{x}$ a chi squared test, $\chi^2 = \frac{S^2(n-1)}{\bar{x}}$ (Elliot 1977), can be performed to establish if S^2 is statistically greater than the mean. Confirmation of this fact will show that some strikes involve relatively large flocks of birds.

RESULTS

It can be seen from Fig. 1 that there has been considerable variation in the index number of bird strikes for the period of consideration. Thus the index number climbed well above the base year in the period 1979-85. As shown in Table 1, this was a period when bird hazard control relied exclusively on bird scaring without habitat management. However, after a long grass policy (together with extensive drainage of the airfield) commenced in 1986, the annual index declined well below that of the base year in both 1988 and 1989. It might be expected that with the increase in the annual index number of bird strikes, there would be a higher probability of flocks of birds being struck. Table 2 shows that the variance-to-mean ratio was high in the period 1978-80 and also in the period 1984-89. In both cases the variance is statistically greater than the mean. This in turn is associated with incidents involving some very large flocks of birds.

Fig. 1. Index numbers of bird strikes from base year 1978.

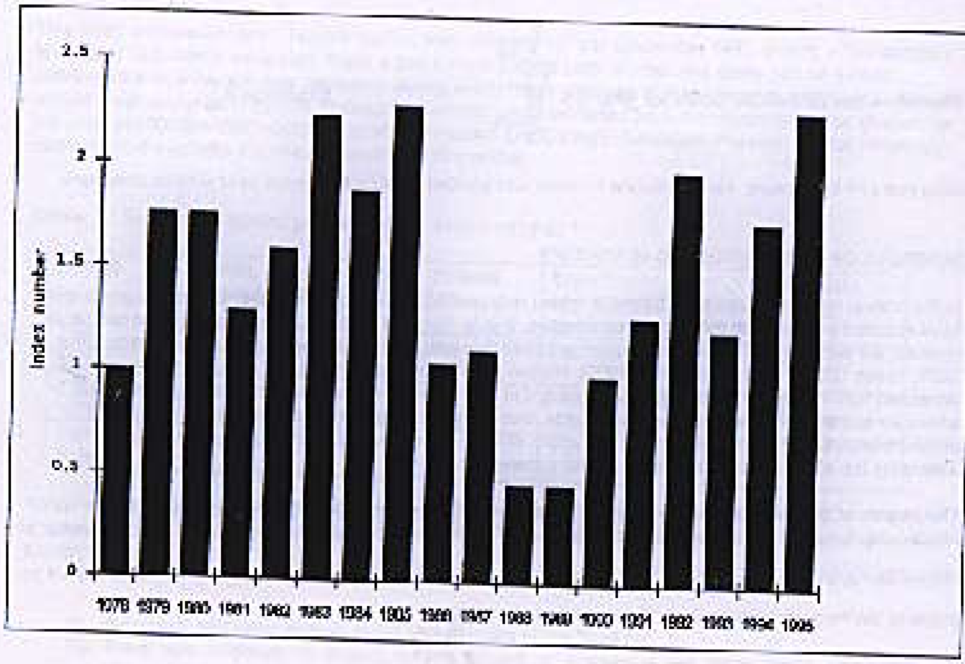

Table 2. Variance-to-mean ratios of numbers of birds involved in strikes at Dublin airport: 1978-95.

Period	Number of strikes	Max. frequency class	Mean number of birds per strike	Variance	S^2 > mean	$S^2/\bar{x}$	Chi Square	Probability
1978-1983	163	30	1.76	6.14	Yes	3.49	565.15	P<0.001
1984-1989	99	37	2.5	19.92	Yes	7.96	780.86	P<0.001
1990-1995	155	7	1.28	1.14	No	-	-	NS

However, despite an increase in the annual index number of bird strikes between 1990 and 1995, there has not been a corresponding expansion of the variance-to-mean ratio (Table 2). In fact, the mean number of birds being struck has reduced and the variance is less than the mean. In 1993, the variance (all species pooled) was greater than the mean but not significantly (Table 3). Nevertheless, a strike incident involving seven lapwings is notable for its effect on the ratio as this species averaged less than one strike per annum over that period. Likewise, although gulls have been struck every year since 1990, the variance has been consistently less than the mean (Table 4).

Table 3. Variance to-mean ratios of the numbers of birds struck by aircraft at Dublin airport (all species pooled) 1990-95.

Year	N*	Max. X	mean	S^2	var > mean	$S^2/\bar{x}$	Chi-square	Probability
1990	15	3	1.47	0.55	No	-	-	-
1991	29	3	1.30	0.36	No	-	-	-
1992	33	5	1.44	0.89	No	-	-	-
1993	20	7	1.65	2.45	Yes	1.48	28.21	NS
1994	30	2	1.30	0.23	No	-	-	-
1995	37	4	1.32	0.50	No	-	-	-

* Denotes number of strikes for which details on the number of birds involved is known.

Table 4. Variance-to-mean ratios of gull strikes at Dublin airport: 1990-95.

Species	Period	N*	Max frequency class	Mean	S^2	S^2>mean	Chi Square	Probability
Black Headed Gull	1990-95	42	3	1.086	0.67	No	-	-
Herring/ Lesser Black Backed Gull	1990-95	18	5	1.94	1.57	No	-	-

* Refers to number of strikes for which details of numbers of birds involved is known.

DISCUSSION

In bird hazard control it is obviously important to identify the cause or causes of an increase in the number of bird strikes. Questions which have to be addressed include whether or not the increase is due to a failure in control methodology and application or is caused by problems associated with prescribed habitat management. Alternatively, there is the possibility that the rise in the number of strikes can be explained by sustained increases in the populations of culpable bird species.

The Underhill method has been developed to identify trends in one of the largest biological databases in the world, namely the count data collected by the British Trust for Ornithology (BTO) during their Birds of the Estuary Enquiry (BoEE), which commenced in the early 1960s. Therefore its use in this study is profoundly different to that defined by Underhill and Prys-Jones (1994). Firstly, only one location is examined here, however for the BoEE many sites were studied. Secondly, whereas the index has been developed for monitoring trends in individual wading bird and waterfowl species, it is used here on an annual total of bird strikes. This in turn represents a pooled total, representing the incidents involving a number of different species.

Nevertheless, as defined, - "Index numbers, sometimes simply called indices, are used to measure changes between different circumstances in the values of some quantity or quantities" - (Crawford 1991), it appears appropriate to apply the index method to bird strike totals. The Underhill method is of particular interest because it is being used to identify population trends in species such as the Lapwing, Golden Plover and Oystercatcher (Underhill and Prys-Jones 1994) which are frequently involved in bird strikes (Rochard and Horton 1980; Milsom and Rochard 1987; CAA 1990). The technique does not appear to have been applied to monitoring wintering European gull populations, possibly because they are not censused to the same extent as wildfowl and waders.

The advantage of using the Underhill method on bird strikes would obviously be far greater if a number of different airfields could be included in the annual totals. This would permit regional, national and international trends to be established for the strike rates of different bird species which in turn could be compared with their Underhill index numbers based on census data (see for example Prys-Jones *et al.* 1994). In addition the bootstrapping requirement (for missing months and other data) and particularly the "strong assumptions" upon which it is based (Kirby *et al.* 1995) would not be a difficulty for bird strike data which is normally collected systematically over a 12-6month period.

In this study, following a decline in the annual index number of bird strikes below the base year level in 1988 and 1989 , it began to increase again in 1990 and since then has remained above the base year (Fig. 1). This increase is associated with the opening of Runway 10/28 which also resulted in the addition of 300 acres of grassland to the airfield. However, the major change resulted from the fact that the runway projects like a narrow peninsula into the surrounding countryside, which is mostly intensively farmed or used for sporting activities. It is believed therefore, that most of the strikes have involved birds overflying the airport. There is, in addition, some evidence to suggest that gull numbers in the region are increasing and the wintering population of Lapwing appears to fluctuate in response to the severity of weather in both the United Kingdom and continental Europe.

Despite the increase in the annual index number of bird strikes in the 1990s the variance has been mostly less than the mean. While this gives no grounds for complacency it does suggest that the bird hazard control strategy is having a protective effect. Ideally there would be no bird strikes at all, but if they do occur they should involve one individual only.

This analysis has not addressed the important question of the weights of the birds being struck. As pointed out by Horton (1994) there is a very large difference in the potential risk of damage to an aircraft if it is a flock of 5 Herring Gulls as compared to 5 Skylarks which has been struck. Perhaps a transformation of the frequency distribution values into something like "Black Headed Gull" equivalents would result in a more rigorous analysis of the variance-to-mean ratios. Thus a strike involving 5 Herring Gulls would be equivalent to (in weight terms) 16.6 *L. ridibundus*, whereas one resulting from a collision with 5 Skylarks would be approximately equal to 0.66 Black Headed Gulls. A more realistic approach to the transformation of bird strike frequency distribution values for different species will have to await detailed quantification of the relative risks of damage to aircraft in relation to weight.

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