BSCE 21 / WP 19
Jerusalem, 23-27 March 1992

COLLECTING EFFORTS AND IDENTIFICATION STANDARDS IN RELATION TO BIRD STRIKE STATISTICS

Tim G. Brom

Institute of Taxonomic Zoology (Zoological Museum)
University of Amsterdam
P.O. Box 4766, 1009 AT Amsterdam
The Netherlands

ABSTRACT

Different methods of feather identification are discussed and evaluated, such as macroscopical comparison with bird skins, microscopical examination of feather structure, and biochemical analysis of feather proteins. The results of the microscopical investigation of feathers as applied to bird strike analysis in the Netherlands are evaluated. It is demonstrated in which ways accurate identification procedures may affect bird strike statistics. The main conclusion is that proper identification of bird remains is fundamental and essential to bird strike statistics. Aviation authorities should direct their efforts towards the improvement of the general reporting and collecting standard, whereas biologists should optimize and standardize their identification methods, advertise the possibilities of different identification techniques, and make their expertise available.

Key Words: Collecting of bird remains, identification methods, reliability of bird strike statistics.

INTRODUCTION

One of the first steps in reducing the risk collisions between birds and aircraft establishing which species are most likely to cause an accident. Only when a detail insight regarding the species most frequently involved in bird strikes has been obtaine the most adequate preventive measures may be taken, in both bird control and aircr design. Especially during the last decade, the notion that an adequate assessment this problem by keeping accurate bird strike statistics is indispensable for taking most appropriate preventive measures, has become generally accepted.

REPORTING AND COLLECTING

Internationally, bird strike reporting systems have been set up to get an insight into bird hazard. However, due to different factors, in most data sets the number of cases which the bird has been identified is low in comparison to the total number of strikes. some analyses, the number of unidentified birds is given (Table 1), but in others the are fully ignored. In either case, both conclusions and preventive measures are oft based on an extremely limited number of cases and possibly biased statistics.

TABLE 1. Percentage of unidentified birds in bird strike statistics*

source, year, reference	N	unknown
Civil, world-wide, 1972-1975 (Thorpe 1977)	3806	48%
Civil, world-wide, 1976-1980 (Thorpe 1984)	7318	50%
Civil, world-wide, 1981-1985 (Thorpe 1990)	7544	42%
Civil, world-wide, 1989 (ICAO 1991)	4777	36%
Civil (engine ingestions), world-wide, 1981-1983 (Frings 1984)	638	50%
Civil, USA, 1978 (Harrison 1979)	788	20%
Civil, Australia, 1982 (Davidson 1984)	552	27%
Civil, Australia, 1983 (Davidson 1985)	430	21%
Military, northwestern Europe, 1981 (Leeming 1984a)	1271	64%
Military, northwestern Europe, 1982 (Leeming 1984b)	1489	62%

The total number of unknown birds involved in collisions with aircraft may be divided in four categories.

1) The first concerns strikes that occur unnoticed. No estimation exists regarding th percentage of cases that is simply not noticed, neither by pilots at the moment of impa nor by ground personnel during post-flight inspections.

---

* These data-sets have been selected as examples to illustrate the problem regarding the reporting of strikes and collecting and identification of remains. It is by no means the author's intention to criticize individual workers activ the field of bird strike prevention.

2) The secon
account for
Blokpoel 197
Control Unit
ornithological
among countr
meaningful bi
different orga
size of this ca
& Medve 199
1978, Harriso

3) The third
importance of
the position
identification
interested in
aircraft. Thus
collected than

4) Bird remai
standards dif
identified by
professional b
1984, 1990, M
remains by tr
statistics may
species, which

Although thes
number of 'un
it is evident t
coordination o
Aviation autho
reporting and
the obligatory
relevant details
1977) or the ce
emphasizing th
success of suc
unidentified bir
may be eviden
work remains t

2) The second category is due to strikes that are not reported. Several factors may account for defective reporting and hence for unreliable or biased statistics (e.g., Blokpoel 1976, Lind 1978). Bird strike reports are delivered by pilots, groundstaff, Bird Control Units, or engineers, and the quality depends on the dedication and ornithological knowledge of these people. Reporting standards vary considerably among countries, airlines, and airports, and this fact alone raises the question of how meaningful bird strike statistics are (e.g., Thomas 1988), in particular when data from different organizations or countries are combined or compared. A study to assess the size of this category indicated that 67% of the bird strikes had not been reported (Bivings & Medve 1990); others have estimated this number to be as high as 80 to 85% (Lind 1978, Harrison 1979).

3) The third category is the number of bird remains that are not collected. The importance of retaining bird remains may not be fully understood by everyone who is in the position to collect them for identification and motivation to submit remains for identification varies from person to person. Furthermore, some organizations are interested in the exact identification of the species only if damage has been done to aircraft. Thus, large birds which caused spectacular damage are more frequently collected than small remains which often cause negligible damage.

4) Bird remains that cannot be identified constitute the fourth group. Identification standards differ greatly among countries. In some countries the birds involved are identified by airfield personnel, in others identification services are provided by professional biologists who analyse bird remains. In many data sets (e.g., Thorpe 1977, 1984, 1990, Melville 1980), the identification standard ranged from the examination of remains by trained ornithologists to the fleeting glance of a pilot. Consequently, the statistics may be biased strongly by the presence of large and easily recognizable species, which, however, do not necessarily constitute the highest risk.

Although these categories are interrelated, their respective contribution to the total number of 'unknowns' probably varies among countries and organizations. In any case it is evident that the reliability of bird strike statistics can only be enhanced by the coordination of activities in two different domains, aviation and biological research. Aviation authorities should direct their efforts towards the improvement of the general reporting and collecting standard. This may be achieved by several measures, such as the obligatory use of standard reporting forms forcing reporters to pay attention to the relevant details, the establishment of Bird Control Units at airfields (Anon. 1977, Buurma 1977) or the centralization of bird strike reports (e.g., Dekker & Buurma 1990). Programs emphasizing the importance of collecting and identification can be highly effective. The success of such a campaign was demonstrated in Denmark where the percentage of unidentified birds decreased from 56% to 36% in a five-year period (Joensen 1978). It may be evident that, if bird strike statistics are to be standardized internationally, much work remains to be done, especially in the field of information and motivation of pilots, airfield personnel, and engineers. Biologists should optimize and standardize their identification methods, advertise the possibilities of different identification techniques, and make their expertise available. One possibility to achieve international standardization of identification methods is centralizing identification expertise (e.g., Brom & Wattel 1990). The only way to exclude unreliable data from the statistics is disregarding identifications done by non-biologists.

METHODS FOR IDENTIFYING BIRD REMAINS

In recent years, the search for diagnostic characters that might be used for identification purposes has been intensified (Brom 1991, and references therein). Apart from preliminary biochemical studies of blood and flesh remains (e.g., de Bont *et al.* 1986), attention has been focused on the identification of feathers and feather fragments. The most important reason for this choice is a practical one: When blood or flesh remains are available for examination, usually feathers are as well, but conversely, feathers are often found without any trace of blood or flesh.

Macroscopical comparison of feathers

The traditionally used and most straightforward way of feather identification is that of comparing unknown feathers with a reference collection. Evidently, the results strongly depend on the condition of the bird remains. Provided that the samples are large enough and contain characteristic feathers, identification rates are high at all taxonomic levels (Table 2).

TABLE 2. Identification results obtained by macroscopical examination (number of bird remains is set at 100%; small samples were omitted from these results).

country/organisation/period	N	identification results in %				
		unknown	order	family	genus	species
Estonia 1951-1988 (Shergalin 1990)	335	0	100	94	65	61
Netherlands 1960-1977 (Brom 1988)	119	0	100	92	88	74
Australia 1982 (Davidson 1984)	331	0	100	96	56	33
Australia 1983 (Davidson 1985)	392	0	100	100	44	36

The main disadvantage of this method is the fact that minute remains cannot be identified macroscopically, and, hence, that a large proportion of bird remains are being discarded, either during collecting or identification.

The advantage of the macroscopical method is that in many cases a distinction between age classes can be made, which is necessary to enable establishing whether juvenile birds are more likely to cause an accident than adults. Neither microscopical nor biochemical studies have yielded diagnostic age characters, thus confining information on the bird's age exclusively to macroscopical criteria. It should be realized that for some species hardly any differences in plumage exist between juvenile and older birds, whereas in others these differences are quite pronounced, at least during certain periods of the year. Differences in the availability of macroscopical age characters between species are clearly reflected by the ages assignment in Table 3 (compare e.g., skylark with herring gull).

TABLE 3. Age classes of 15 bird species most frequently encountered in feather remains from bird strikes (multiple strikes included), LM examination combined with macroscopical comparisons, 1960-1990.

	species		N	juvenile/ immature	adult	age unknown
1.	swift	*Apus apus*	309	1%	38%	61%
2.	lapwing	*Vanellus vanellus*	138	11%	10%	79%
3.	black-headed gull	*Larus ridibundus*	75	39%	43%	18%
4.	buzzard	*Buteo buteo*	63	2%	6%	92%
5.	skylark	*Alauda arvensis*	62	0%	2%	98%
6.	swallow	*Hirundo rustica*	58	14%	7%	79%
7.	rock dove/feral dove	*Columba livia*	44	7%	0%	93%
8.	wood pigeon	*Columba palumbus*	43	2%	2%	96%
9.	chaffinch	*Fringilla coelebs*	37	8%	5%	87%
10.	common gull	*Larus canus*	35	26%	60%	14%
11.	starling	*Sturnus vulgaris*	33	33%	3%	64%
12.	herring gull	*Larus argentatus*	28	36%	64%	0%
13.	house martin	*Delichon urbica*	25	4%	8%	88%
14.	kestrel	*Falco tinnunculus*	19	21%	21%	58%
15.	mallard	*Anas platyrhynchos*	19	0%	26%	74%

Microscopic identification in combination with macroscopical comparisons

Although the search for new diagnostic characters still continues (e.g., Dyck 1990, Perremans 1990, Frank & Brom: this meeting), downy barbs have been found to exhibit the most appropriate feather structures for identification purposes (Brom 1991). The observation that downy barbs are most frequently found in engines or on aircraft, is of equal importance to the decision that identification procedures should be based on the microscopical study of their structures. When pennaceous feathers are available for examination, downy barbs are usually present as well, but conversely, downy remains are often found without any trace of pennaceous structures. Apparently, downy barbs adhere more easily to aircraft than pennaceous ones.

The results that can be obtained with the microscopic investigation of feather remains in combination with macroscopical comparisons are illustrated by the evaluation of the results in the Netherlands in the period 1960-1990. At the Zoological Museum Amsterdam (ZMA), 83 species of birds[*] have been identified in this period (nine of which originated from collisions with civil aircraft outside Europe), belonging to 28 families and 12 orders (Table 5). Although in every case (N= 2181) bird strikes could be confirmed by the presence of feather material in the samples, it was impossible to give a more accurate identification than 'Bird' in 4% (N= 82) of all cases. The results are given in Table 4 and Fig. 1.

TABLE 4. Identification results classified per taxon, LM examination combined with macroscopical comparisons, 1960-1990.

taxon	N	%	%	%	%
class	2181	100			
order	2099	96	100		
family	1517	70	72	100	
genus	1320	61	63	87	100
species	1194	55	57	79	90

When the results of the macroscopical identification (Table 2) are compared with those of Table 4, it would appear that the microscopic method does not lead to an increase of identification rates at the taxonomic categories below the order level (Table 4, Fig. 1). However, in Table 4 minuscule feather remains have also been included, whereas these have probably been discarded in macroscopical examinations.

The species most frequently represented is the swift (Table 3), which accounts for 14% of the total number of investigated bird strikes in the period 1960-1990. Although this bird is only present in northwestern Europe from mid April to early September (the earliest collision was on 24 April, the latest on 5 September, but 91% of all strikes occurred in the period May-July), it accounts for 26% of all identifications to species level. In the identifications to family level, the Apodidae also score highest with 20%, followed by the gulls and terns (Laridae/Sternidae) with 18%. At the order level, the Passeriformes score highest with 41%, followed by the Charadriiformes with 25%.

These results are in strong contrast with other analyses. In many comparable data sets, collected either from the same geographical area or world-wide, both songbirds and swifts are represented by insignificantly small numbers. In the analysis of engine ingestions (N= 638) that occurred world-wide in the period 1981-1983, the swift was found only once (Frings 1984) whereas in the bird strikes reported to civil aircraft in 1989

---

[*] Included are only those remains that have been received by the ZMA whereas approximately 2% of the total number of remains is the result of bird strikes with civil aircraft. Therefore the data presented in the Tables 3-5 should not be interpreted as an accurate picture of the bird strike statistics of the Royal Netherlands Air Force.

er remains in
luation of the
ical Museum
(nine of which
3 families and
confirmed by
give a more
s are given in

macroscopical

%
100
90

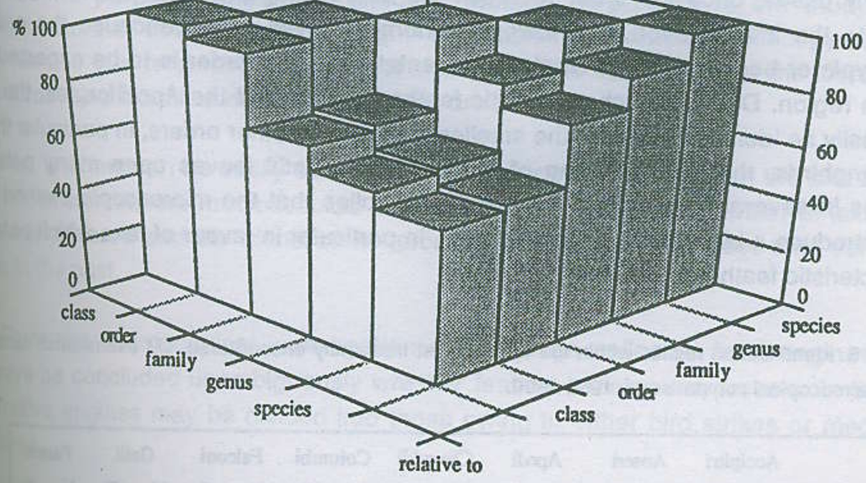
ed with those
n increase of
ble 4, Fig. 1).
led, whereas

unts for 14%
Although this
ptember (the
of all strikes
s to species
st with 20%,
der level, the
25%.

ble data sets,
ongbirds and
is of engine
he swift was
rcraft in 1989

e total number of
-5 should not be

FIGURE 1. Graphic representation of the identification results given in Table 4.



(ICAO 1991), it formed less than 1% of the total number (N= 4777) of reported cases. In the former analysis, a similar discrepancy may be observed at the level of orders: Passeriforms score only 7% of the identified remains (N= 322) which is 4% of the total number of remains (Frings 1984). Theoretically, the high number of strikes with swifts and songbirds in north-western Europe might be caused by a higher population density of these birds in this region than in other parts of the world. However, comparisons of the periods 1960-1977 and 1978-1990 have clearly demonstrated that these higher numbers are the result of the introduction of the microscopic examination of feathers in combination with a more conscientious search for even the smallest feather fragments by airfield personnel. From 1978 on, a drastic shift towards smaller birds took place. At the order level, the detection of songbirds increased from 9% in 1960-1977 to 41% in 1978-1990. At species level, swifts increased from 11% in 1960-1977 to 26% in 1978-1990. A similar trend has been observed in the United Kingdom where incidents involving species weighing 150 g or less increased from 9% in 1968 to 30% in 1976 (Rochard & Horton 1977). It may therefore safely be assumed that small birds are under-represented in bird strike statistics (see also Milsom 1990), and that microscopic examination of feather remains detects taxa that remain hidden in the high percentage of 'unknowns' in many data sets which are based exclusively on macroscopical examinations (Table 1).

The main disadvantage of the microscopical method is that it usually allows identification to the higher taxonomic categories only. Although some authors claim to have worked successfully at the species level, the differences between closely related groups and, especially, between species are so small that constructing a key at this level is not possible.

The identification rates vary considerably among different orders (Table 5), due to taxonomic and biogeographical reasons. Therefore, the identification results as classified per taxonomic category (Table 4, Fig. 1) should not be interpreted too rigidly. In many cases, once the order to which the bird belongs has been established, this leads to the identification at a lower taxonomical level, either because the order is monotypic or because only a single representative of that order is to be expected in a certain region. Due to the characteristic feather structure of the Apodiformes, the swift can easily be identified, even in the smallest remains. In other orders, in particular that of the songbirds, the determination of 'Passeriformes' still leaves open many potential species in several families and genera. This implies that the microscopic method may also introduce a bias in bird strike statistics, in particular in favour of taxa which possess characteristic feather structures.

TABLE 5. Identification results within the orders most frequently encountered, LM examination combined with macroscopical comparisons, 1960-1990.

	Accipitri		Anseri		Apodi		Charadrii		Columbi		Falconi		Galli		Passeri	
	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
order	80	100	59	100	309	100	523	100	201	100	28	100	24	100	859	100
family	80	100	59	100	309	100	443	85	201	100	28	100	24	100	357	42
genus	69	86	35	59	309	100	384	73	128	63	28	100	24	100	330	38
species	69	86	33	56	308	99	323	62	94	46	24	86	24	100	306	36

Biochemical analysis of feather remains

In recent days, electrophoresis has become a reliable and repeatable procedure for the identification of feather remnants from any source (Ouellet & van Zyll de Jong 1990). Within the family Laridae, a group of birds frequently involved in bird strikes, seven species of gulls could be distinguished., whereas little individual, sexual, or age variation was found. Thus, it seems that keratin electrophoresis is the only technique presently available that allows identification to species level. This method may be applied once the identification of downy barbs has led to the group to which the bird belonged. Since biochemical techniques are more time-consuming than microscopical investigations, they should be applied preferably in special cases, such as the investigations of accidents or the analysis of a notoriously problematic group.

CONCLUSION

Identification methods which may be applied in bird strike analysis are:

a) macroscopical comparisons of complete feathers to reference collections,

b) microscopic examinations of structures in different parts of the feather,

c) biochemical investigations of feather proteins.

For routine purp
microstructure of
with the use of a
by microscopic ex

1) Most feathers c
Hence, in subseq
to be considered
than in the past.

2) From the micr
always be conclu
defective engines
failures.

3) Even minute fe

4) For bird strike
exists that larger
1991). In this way
knowing the actua
strikes, this is of
always be disting
made between du

5) Provided that b
and demonstrate
recognizable ones
on the collecting
may lead to a mo
personnel, and, he

The need for i
standardization of
has been made cl

For routine purposes the most effective method at present is the study of the microstructure of downy barbs with light- and scanning electron microscopy combined with the use of a reference collection of bird skins. The advantages of the identification by microscopic examination of downy barbs are five-fold:

1) Most feathers can be easily assigned to the order or family to which the bird belongs. Hence, in subsequent macroscopical examinations only a limited number of taxa needs to be considered and the identification process is therefore much less time-consuming than in the past.

2) From the microscopical investigation of scrapings collected from engines it can always be concluded unambiguously whether feather remains are present. In this way, defective engines may be divided into those owing to either bird strikes or mechanical failures.

3) Even minute feather remains usually provide information at least to order level.

4) For bird strike analysis it is very useful that in several groups of birds a tendency exists that larger species have fewer nodes per mm of barbule than smaller birds (Brom 1991). In this way an indication of the weight of the bird may be obtained without exactly knowing the actual species involved. Since weight is a key factor in the analysis of bird strikes, this is of utter importance. For example, within the Passeriformes, crows can always be distinguished from small songbirds. In a similar way, a distinction can be made between ducks, geese, and swans in the family Anatidae (Horton 1990).

5) Provided that biologists clearly indicate the possibilities of their identification expertise and demonstrate that small remains should be treated as seriously as easily recognizable ones, the microscopic identification method may have a positive feed-back on the collecting efforts by airfield personnel. The introduction of microscopic methods may lead to a more conscientious search for these small feather fragments by airfield personnel, and, hence, to an increase of the number of collected remains.

The need for internationally comparable bird strike statistics is obvious, but standardization of identification results can only be achieved if the need for cooperation has been made clear to aviation authorities and professional biologists.

REFERENCES

Anon. 1977. *Bird Control Units in the RAF*. London: Ministry of Defence, United Kingdom Bird Impact Research and Development Committee.

Bivings, B. & Medve, K.A. 1990. The U.S. Navy's bird aircraft strike hazard (BASH) problem. *BSCE 20 (Helsinki):* 499-509.

Blokpoel, H. 1976. *Bird Hazards to Aircraft.* Ministry of Supply and Services, Canada.

Bont, A. de, Boomans, J.F., de Raeve, P., Hoet, E. & Verachtert, B. 1986. Strategies for the identification of bird remains from birdstrikes. Survey and advanced approach by analysis of tissues. *BSCE 18 (Copenhagen):* 113-122.

Brom, T.G. 1988. The analysis of feather remains: evaluation and perspectives. *BSCE 19 (Madrid):* 341-356.

Brom, T.G. 1991. *The Diagnostic and Phylogenetic Significance of Feather Structures.* Thesis, University of Amsterdam: 279 pp.

Brom, T.G. & Wattel, J. 1990. Proposal for the establishment of a European Centre for the identification of bird remains. *BSCE 20 (Helsinki):* 223-234.

Buurma, L.S. 1977. Establishment of Bird Control Units at 6 Dutch air bases. *BSCE 12 (Paris), WP* 27: 1-4.

Davidson, P.M. 1984. Birdstrikes to civil aircraft in Australia during 1982. *Department of Aviation, Bird Hazard Investigation Report* 3: 1-21.

Davidson, P.M. 1985. Birdstrikes to civil aircraft in Australia during 1983. *Department of Aviation, Bird Hazard Investigation Report* 4: 1-21.

Dekker, A. & Buurma, L.S. 1990. Towards a European database of military bird strikes. *BSCE 20 (Helsinki):* 105-128.

Dyck, J. 1990. The ways in which feather colours are produced and their potential for identification of feather remains. *BSCE 20 (Helsinki):* 543-548.

Frank, U. & Brom, T.G. 1992. The diagnostic significance of thickened and pronged hamuli in feathers. *(this meeting).*

Frings, G. 1984. *A Study of Bird Ingestions into Large High Bypass Ratio Turbine Aircraft Engines.* Springfield: National Techn. Inform. Service.

Harrison, M.J. 1979. Aircraft bird strikes. Summary and analysis calendar year 1978. *BSCE 14 (The Hague), WP* 6B: 26 pp.

Horton, N. 1990. Distinguishing between ducks, geese and swans by means of feather micro-biometrics. *BSCE 20 (Helsinki):* 327-337.

ICAO 1991. *IBIS World Bird Strike Statistics for 1989.* Montreal.

Joensen, A.H. 1978. *Bird Species involved in Bird-strikes with Military Aircraft in Denmark, 1968-77.* Game Biol. Station Kalø Rønde: 18 pp.

Leeming, G.H. 1984a. Military aircraft birdstrike analysis 1981. *BSCE 17 (Rome):* 147-153.

Leeming, G.H. 1984b. Military aircraft bird strike analysis 1982. *BSCE 17 (Rome):* 154-163.

Lind, H. 1978. The identification of bird remains as part of the bird strike reporting procedure. *BSCE 13 (Bern), WP* 3: 1-5.

Melville, D. 1980
Mimeograph
Milsom, T. 1990.
on UK civil
Ouellet, H. & van
protein elect
Perremans, K. 199
feathers an
30.
Rochard, J.B.A. &
76. *World C*
Shergalin, J.E. 19
183-199.
Thomas, C. 1988.
Thorpe, J. 1977.
World Conf
Thorpe, J. 1984.
BSCE 17 (
Thorpe, J. 1990.
BSCE 20 (

Melville, D. 1980. *Birdstrike Data from Kai Tak Airport Hong Kong 1974-1979.* Mimeographed report, Agricult. & Fish. Dept. Hong Kong: 1-57.

Milsom, T. 1990. The use of birdstrike statistics to monitor the hazard and evaluate risk on UK civil aerodromes. *BSCE 20 (Helsinki):* 303-320.

Ouellet, H. & van Zyll de Jong, S.A. 1990. Feather identification by means of keratin protein electrophoresis. *BSCE 20 (Helsinki):* 53-71.

Perremans, K. 1990. External surface structures of rachis, rami and rachidial barbules of feathers and their potential for determination purposes. *BSCE 20 (Helsinki):* 21-30.

Rochard, J.B.A. & Horton, N. 1977. Birds killed by aircraft in the United Kingdom, 1966-76. *World Conference on Bird Hazards to Aircraft (Paris), WP* 4: 1-17.

Shergalin, J.E. 1990. Bird strikes analysis in Estonia 1951-1988. *BSCE 20 (Helsinki):* 183-199.

Thomas, C. 1988. How meaningful are bird strike statistics. *BSCE 19 (Madrid):* 557-566.

Thorpe, J. 1977. Analysis of bird strikes reported by European airlines 1972 to 1975. *World Conference on Bird Hazards (Paris), WP* 6: 33 pp.

Thorpe, J. 1984. Analysis of bird strikes reported by European airlines 1976-1980. *BSCE 17 (Rome):* 60-87.

Thorpe, J. 1990. Analysis of bird strikes reported by European airlines 1981-1985. *BSCE 20 (Helsinki):* 263-294.