EURBASE: MILITARY BIRD STRIKE FREQUENCY IN EUROPE

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Abstract

This paper should be considered as a progress report of the EURBASE project (European Military Bird Strike Database). The contributions from participating Air Forces – as received by the summer of 2004 -- are presented and used for an analysis of the bird strike frequency of different Air Forces.

Using flying hours as provided by the Air Forces Flight Safety Committee Europe (AFSCE), ratios were calculated for 9 Air Forces over the 10 years period 1991 – 2000. Restricted to jet fighters en-route and taking into account differences in damage patterns, normalised bird strike ratios are presented. These ratios vary considerable between the different Air Forces and are used to calculate the average yearly number of non-local bird strikes with jetfighters in Europe.

Using GIS techniques on the normalised ratios a bird strike density map of Europe is calculated. Comparing this bird strike density map with a map of bird strike danger area´s (Anonymous 1979) learns that maps as a prevention tool are to coarse, to general, based on birds on the ground and to difficult to integrate in day-to-day operations. En-route bird strike prevention is far better served with dynamic models in which bird mobility is predicted in time and 3D space. The outcome of such models should be available for the pilots as end-users in their operational planning system.

Keywords: military statistics, jet fighters, en-route, bird strike ratio, geographical distribution.

1. Introduction

1.1. Background

After years of contributing bird strike summaries to the Air Forces Flight Safety Committee Europe (AFFSC(E)) it was recognised in the late 1980’s that collecting the actual details of bird strikes in one combined European Military Bird Strike Database (EURBASE) would yield much more information. At the 20th IBSC meeting in 1990 a preliminary study on the bird strike reports over the year 1988 of six Air Forces was presented (Dekker & Buurma 1990). From then on the database increased rapidly, not in the least because along with new data also data from previous years was contributed. Standardisation of data was encouraged by the introduction of EURFORM, the European Military Bird Strike Form (Dekker & Buurma 1992). The Military Agency for Standardisation (MAS) adopted EURFORM as an annex to the Standard NATO agreement 3879 FS. Over the years progress reports on the EURBASE project were presented for AFFSC(E) and IBSC (Dekker 1994, Buurma 1995 and 1996; Buurma & Dekker 1992 and 1996). In most of the progress reports some results from analyses of EURBASE data was included. At the 24th IBSC meeting in 1998 an extensive inventory of quantity and completeness of the then available database of 34,564 bird strikes was presented (Dekker 1998). During the 26th IBSC meeting an extensive analysis on the basis of the then 40,640 contributed cases was presented. This shortly dealt with seasonal patterns of bird strikes but was mainly focussed on bird species in relation to flight phase of the aircraft and in relation to damage to the aircraft (Dekker, van Gasteren and Shamoun-Baranes, 2003).

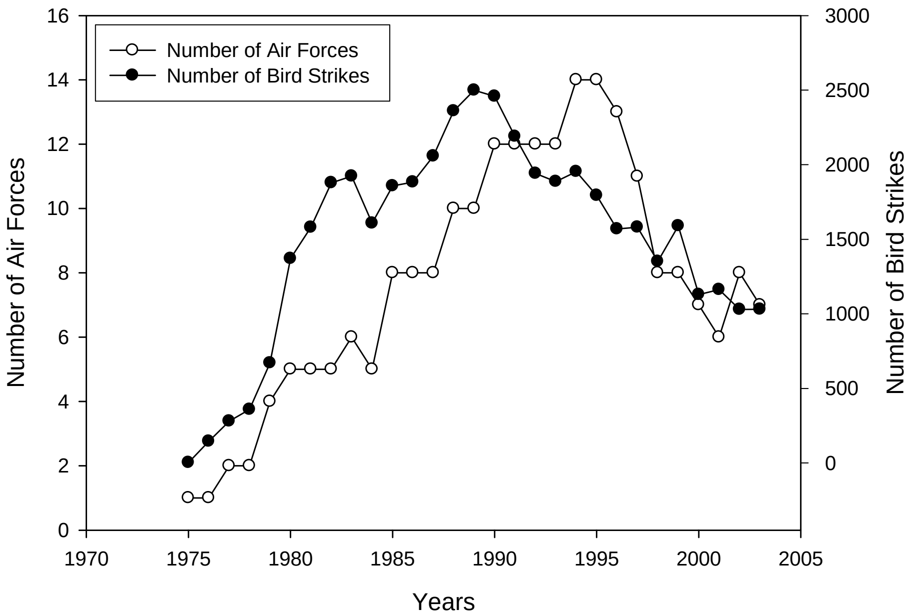
1.2. This report

In order to reach as many potential contributors to the database as possible, in May 2003, after the 26th IBSC meeting, a letter was sent to all 24 members of AFFSC(E). With this letter the flight safety departments were offered IBSC26/WP-ID2 and were requested to contribute missing data for their respective Air Force. Unfortunately hardly any reactions were received. In May 2004, via email, contact was sought with known bird strike experts from a number of these Air Forces. This resulted in data up to 2003 from a number of Air Forces that already contributed in previous years. This paper is first of all meant as feed-back to all the contributors of the database.
Comparing the contributed number of bird strikes from different Air Forces does in itself not reveal much about the real extent of the bird strike problem in Europe. We therefore used bird strike information in combination with flying hours to calculate a bird strike ratio for en-route fighter aircraft from a selection of Air Forces over the period 1991 – 2000. Due to differences in reporting standards these ratios were normalised on the basis of the proportion of bird strikes that resulted in damage. This learned that en-route bird strike ratios are varying considerably between the Air Forces. Using information on the location of the bird strikes we then constructed a “bird strike density map” of Europe.

2. Contributions as per the end of 2004

Despite several efforts (see para 1.2) the size of the database increased only little (plus 2.505 records) since the last report in May 2003 (Dekker et al., 2003). As is given in detail in annex 1 and shown in figure 1, both the number of contributed bird strikes as well as the number of contributing Air Forces per year is more or less stabilising. It is disappointing that despite the fact that all AFFSC(E) members were approached only a part of the Air Forces contribute to the database on a regular basis.

Figure 1: Number of contributors and contributions per year in Eurbase



3. The number of bird strikes in Europe

3.1. The number of bird strikes in Europe: Material and methods

Comparing the bird strikes per year and per Air Force given in annex 1 is a futile activity. Fleet size and composition, operational use (both quantitative and qualitative) and the geographical theatre that is predominantly flown in, are all factors influencing these figures. A far better way of looking at it is

using ratios (bird strikes per 10,000 flying hours). This rules out quantitative differences in fleet and operations between Air Forces. Fleet composition also has a great influence on the final numbers, there are considerable differences between carrier aircraft, helicopters and jet fighters. For this study we therefore selected jet fighters only. Narrowing the selection further down to non-local bird strikes (see annex 2) focuses the study to the situation en-route. We thus are comparing the "efficiency" of different Air Forces in sampling the sky for the presence of birds using jet fighters.
In annex 1 it is indicated from which Air Force and for which years flying hours were available. On the basis of the availability of both bird strike data and flying hours we selected the period of 1991 – 2000 and included 9 Air Forces (Belgium, France, Germany, Italy, United Kingdom, Denmark, Netherlands, Norway and Spain). In the few cases where flying hours were missing we calculated them by interpolation. Since operations in Europe have changed drastically since the end of the cold war we did not include the years before 1991.

3.2. The number of bird strikes in Europe: Non-local bird strike ratios for jet fighters 1991-2000

The calculated yearly average non-local bird strike ratios for jetfighters including the 95% confidence intervals are presented in figure 2. As is clear these ratios do vary considerable between Air Forces. The SAF scoring a ratio of only 2.6 (±1.3) while the GAF hitting 24.2 (±2.0) birds per 10,000 flying hours, nearly ten times as many. This surprising outcome made us look in more detail into the data. Since the data is of mixed origin we tried to determine whether there are consistent differences. We looked at the percentage damage for each Air Force as a clue for such phenomena (figure 3).

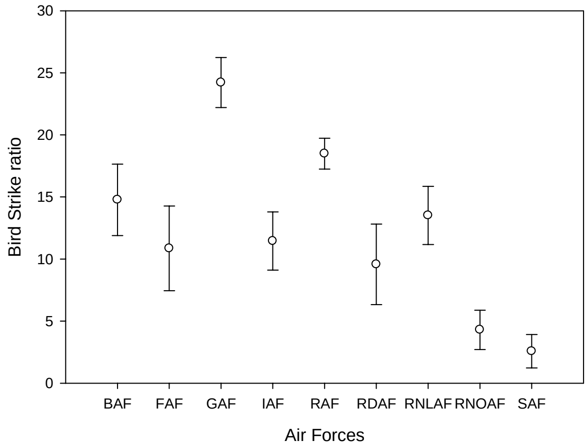


Figure 2: Mean and 95% confidence interval of the non-local Bird Strike Ratio (B S per 10,000 flying hours) per Air Force, Jets only, 1991-2000.

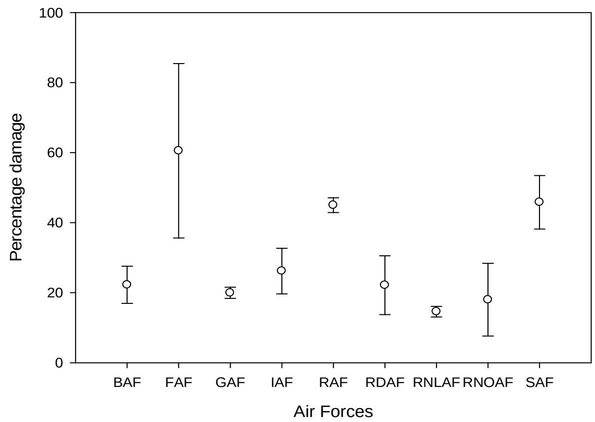


Figure 3: Mean and 95% confidence interval of the non-local percentage damage error Air Force, Jets only, 1991-2000

The comparatively low BS ratio for the FAF of 10.9 (±3.3) is accompanied by a very high percentage of damage of 60.5 (±25.3), the large confidence interval indicating that this high percentage of damage is inconsistent through the years. In fact, during a number of years, only bird strikes with damage were contributed. For the GAF on the contrary, the high BS ratio of 24.2 (±2.0) is accompanied by the consistent low percentage of damage of 20.0 (±1.6). The differences in damage pattern indicate that there is no common definition of a bird strike.
The differences in percentage damage between GAF and RAF were such that these Air Forces were looked at in more detail. The results are summarised in Annex 3. The overall conclusion is that both Air Forces have very complete and consistent reporting systems. The much higher proportion of BS of which the flight phase is unknown in the GAF means that in the GAF more bird strikes are reported that have not been noticed by the pilot. The high proportion of Passerines and Swallows in the GAF is also an indication for this. As a result the overall percentage of damage is much lower for the GAF.

For the purpose of this analysis we assumed that one in five en-route bird strikes with jet fighters does on average result in damage. We then recalculated the ratios from figure 2 for all Air Forces to this 20% damage standard. This resulted in figure 4 in which these normalised BS ratios are given, as well as the original ratios. We consider the normalised ratios to represent a realistic estimate of non-local bird strike ratios with jet fighters experienced in European Air Forces during the 1990´s.

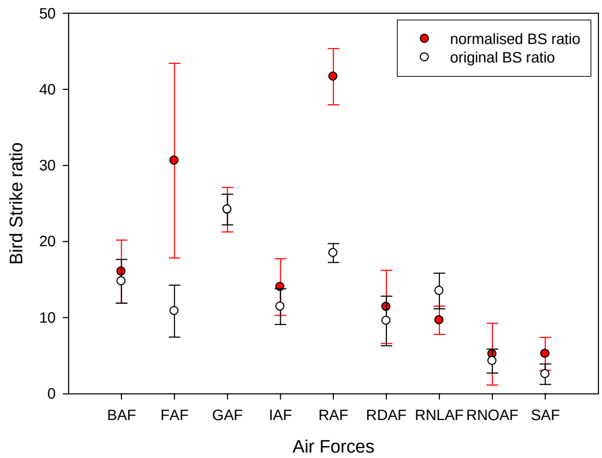


Figure 4: Mean and 95% confidence interval of the normalised and original non-local Bird Strike Ratio (number of Bird Strikes per 10,000 flying hours) per Air Force, Jets only, 1991-2000

Normalising the original data to a 20% damage level did not decrease the large variation in BS ratios. The SAF and RNOAF scored the lowest ratio (SAF 5.2 ±3.2 and RNOAF 5.2 ±6.4) and the RAF as much as 41.7 (±5.8) bird strikes per 10,000 flying hours. Another striking feature in figure 4 is the deviation of the normalised ratios from the original data for FAF and RAF. Compared with the other Air Forces the FAF and RAF had very high percentages of damage in the original data, this resulted in significantly increased normalised ratio´s for those two Air Forces

We do believe that the differences in ratio are related to the combined effect of differences in bird density in different European regions and differences between Air Forces in operational use of the airspace. One aspect of this operational use being the consequent inclusion of “bird migration warnings” in the planning process. The low ratio for RDAF and RNLAF compared to the neighbouring RAF and GAF is at least partly related to this. Another aspect is the flight altitude, with the RAF on average scoring a high proportion of BS at very low altitude.

Combining the normalised ratios from figure 4 with the flying hours, the yearly mean number of non-local bird strikes with jet fighters over Europe during the 1990´s is calculated for each Air Force and subsequently totalled for all Air Forces. This resulted in an estimated number of bird strikes over

Europe of 1,606 (±343) per year. Since the ratios from the different Air Forces do vary considerably these bird strikes are not evenly distributed over Europe.

4. Geographical distribution of the bird strikes over Europe.

4.1. Geographical distribution of the bird strikes over Europe: Material and methods

Simply plotting the bird strikes with known location on a map does give a description of what actually happened but is not the best way to present the results. Projecting a number of BS on more or less the same location results in "piles" of dots, one on top of the other and thus obstructing a good view. Furthermore, the flying intensity of the contributing Air Forces must be taken into account. We therefore used the normalised bird strike ratios from figure 4 as the basis for our calculations. By means of a bootstrap technique a density map was created assuming 10,000 flying hours for each contributing Air Force. The idea behind the bootstrap technique is that for each Air Force the number of bird strikes (N) is determined randomly within the range of the mean ± 95% confidence intervals. From the total number of bird strikes with known latitude-longitude co-ordinates N locations are selected and stored. This procedure is repeated 200 times for each Air Force. The result is a collection of co-ordinates of which those that are within the map boundary are plotted. This dot-map is then converted to a density map of which the densities are divided back by 200 resulting in a map representing differences in the bird strike risk for non-local jet fighters assuming all Air Forces realised 10,000 flying hours.

Unfortunately, of only 41.2 % of the 7,702 bird strikes in the selection the co-ordinates were given. It was, however, possible to add co-ordinates to another 1,022 bird strikes of which the location was given in the narrative, thus raising the overall percentage of bird strikes with co-ordinates to 53.1 varying from 37.8 for the FAF to
65.6 for the IAF. In table 1 details are given about the availability of bird strike data used for this geographical analysis.

	Total	BAF	FAF	GAF	IAF	RAF	RDAF	RNLAF	RNoAF	SAF
Total	7,702	396	1,512	1,965	698	2,494	112	372	58	95
Co-ordinates given	3,174	105	536	981	224	1,074	63	141	13	37
% co-ordinates given	41.2%	26.5%	35.4%	49.9%	32.1%	43.1%	56.3%	37.9%	22.4%	38.9%
Co-ordinates added	1,022	83	35	103	234	398	4	20	22	14
Co-ordinates known (total)	4,086	188	571	1,084	458	1,471	67	161	35	51
% co-ordinates used (total)	53.1%	47.5%	37.8%	55.2%	65.6%	59.0%	59.8%	43.3%	60.3%	53.7%

Table 1: Availability of data for the geographical analysis of non-local bird strikes with jet fighters.

4.2. Geographical distribution of the bird strikes over Europe: Results

Using the data as summarised in table 1 and the bootstrap procedure described in para 4.1. the map in figure 5 has been produced. The map shows the relative density of non-local bird strikes with jet fighters in the 1990´s, assuming that all Air Forces realised 10,000 flying hours with their jet fighters. The map is based on 30,633 selected locations of which 29,292 (95.6%) were situated within the map boundary.

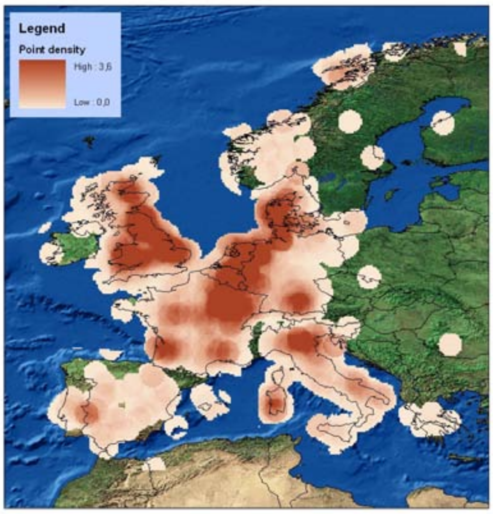


Figure 5: Bird strike density in Europe for non-loc Jets, 1991-2000. N=29,292 within map boundaries.

The map is smoothed to point-density with an output of 0.05 degree and a neighbourhood circle of 1 mapunit. The map does not discriminate whether high densities are the result of increased bird intensities or of a concentration of flying hours in a particular area at a given altitude. The number of flying hours may be standardised to 10,000 hours, we do not know the geographical nor the altitude distribution of these flying hours. So the map shows the combined effect of bird and aircraft density regardless of altitude effects

4.3. Geographical distribution of the bird strikes over Europe: discussion.

During the 1970´s a lot of effort was put into the composition of bird density maps for flight safety purposes by the "European Bird Movement Working Group" of the then Bird Strike Committee Europe. One of the first products of this Working Group was a set of maps of different European countries on which bird concentration areas as well as predominant migration routes were projected. This set of maps was published by the German Amt für Wehrgeophysik in 1973 as a result of the co-operation of experts from 12 countries led by Dr. Hild (Anonymous, 1973). Despite minimal co-operation in the following years (Hild 1977) in 1979 Dr. Hild succeeded in producing an integrated map of NW Europe indicating high and medium risk areas for different seasons (Anonymous, 1979). Figure 6 is a simplified reproduction of this map. Eurbase data from this study provides us the first opportunity to compare the 26 years old bird strike risk map of Dr. Hild with the actual bird strike density map of figure 5.

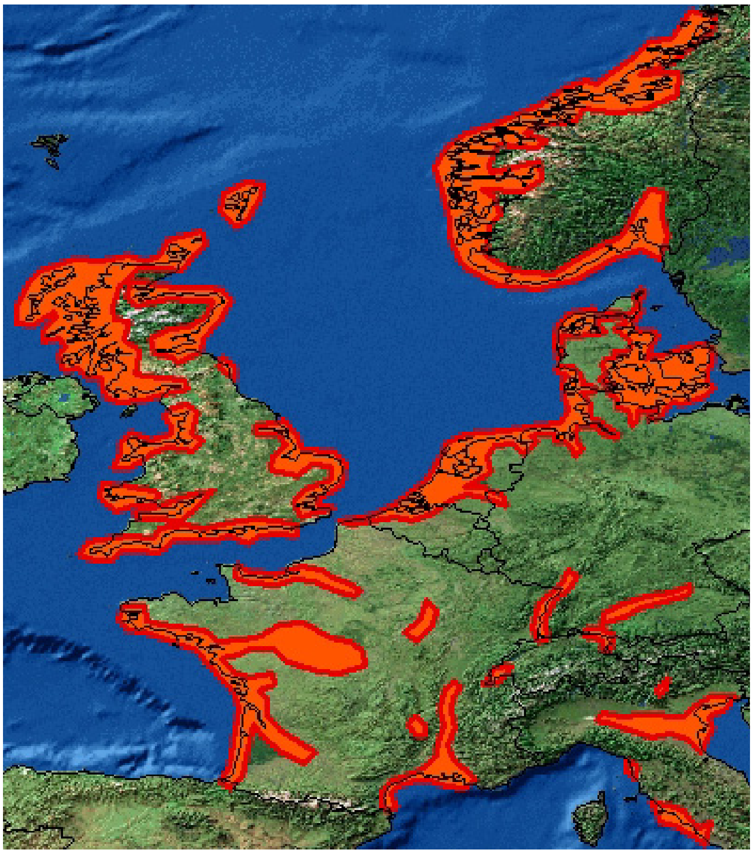


Figure 6: Bird strike danger areas in Europe according to Hild (Anonymous 1979).

Comparing Dr. Hilds map (figure 6) with the bird strike density map of figure 5 learns that there are striking differences. Most of the “bird strike danger areas” do indeed show high BS densities: Danish coast, inland parts of the Netherlands, along the river Donau, Po delta, along 3 major French rivers Loire, Garonne and Rhone. In the UK the same applies to the areas around the Firth of Forth, Moray Firth and the Solway Firth in Scotland, Lancaster and coastal area of North Wales, Severn estuary and the area around the Wash.
On the other hand, some of the “Bird strike danger areas” only show very low bird strike densities: coastal part of the Netherlands, Norwegian coast, West coast of Scotland, South coast of England, river Seine and the South coast of Normandy. The most striking outcome of the comparison of the two maps is that vast areas of Europe are not classified on the map of Dr. Hild as “Bird strike danger area” and nevertheless show high bird strike densities.
The above mentioned deviations are at least partly due to differences in aircraft density. That coastal parts of the Netherlands have only low BS density while being determined as a “Bird strike danger area” is easy to understand: the air space of the highly populated Western part of the Netherlands is more or less closed for yet fighters. Also the South coast of England is not regularly flown over with jet fighters (pers. comment Sqdr Ldr Mellings, RAF). The high BS ratios in large parts of Europe that are not recognised as “bird strike danger area” are probably due to high aircraft density at low level. Also broad front bird migration may be responsible for increased bird strike densities more or less diffusely distributed over large areas.

5. Conclusions

Bird strike ratios are varying considerably for different Air Forces. This variation in bird strike ratio is the result of geographical differences in the combined effect of bird density and aircraft density. Both are not evenly spread over Europe.
Bird concentration areas are known for a long time and static maps might be useful in avoiding known “Bird strike danger areas” but they are not the most efficient tool in the overall prevention of bird strikes. Apart from the operational draw back that static paper maps sooner or later are “forgotten”, the

information on such maps is too coarse, too general and based on birds on the ground, not on bird movement intensity. What is needed for en-route bird strike prevention are dynamic models in which bird mobility is predicted in time and three-dimensional space. The outcome of such models must be available for pilots in their operational planning systems. Only then peak bird densities (in time and 3D space) can successfully be avoided by jet fighters without loosing significant training opportunity.

6. Acknowledgements

Many people and organisations are to be credited for this paper. Needless to say that without the co-operation from the Air Forces there would be no EURBASE to work with. The contact persons in the contributing Air Forces were important in regularly providing the data in suitable formats. As custodian of EURBASE the Royal Netherlands Air Force (RNLAF) provided the time and facilities necessary for managing the database and analysing the data. Luit Buurma provided basic ideas and made valuable suggestions.

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Annex 1: **Contributions to EURBASE per december 2004 per year and per Air Force**

Included in the analysis — Flying hours available

Year	Air Forces	Bird strikes	BAF	CZAF	FAF	GAF	HAF	IAF	ISRAF	POAF	RAF	RDAF	RNLAF	RNOAF	SAF	SKAF	USAF
1975	1	3													3		
1976	1	145											145				
1977	2	281			93								188				
1978	2	359			179								180				
1979	4	670			155	378							136		1		
1980	5	1370			188	429					621		131		1		
1981	5	1580			206	503					693		175		3		
1982	5	1879			196	615					785		281		2		
1983	6	1924			170	655			104		768		224		3		
1984	5	1608			126	505			23		778		176				
1985	8	1858			70	474			112		743		151	25	1		282
1986	8	1884			70	415			125		710		154	14	22		374
1987	8	2058			180	580			138		679		181	13	9		278
1988	10	2360	112		189	604			167		746	38	196	38	6		264
1989	10	2499	115		180	623			262		638	45	243	37	20		336
1990	12	2458	95	41	122	602		66	238		638	66	183	36	10		361
1991	12	2189	75	25	221	497		101	247		589	51	92	26	11		254
1992	12	1941	64	38	183	443		84	218		613	40	107	29	7		115
1993	12	1887	70	23	211	489		184	170		533	46	93	36	13	19	
1994	14	1954	85	30	249	425	7	174	221	2	555	26	100	53	10	17	
1995	14	1794	67	33	156	367	15	186	194	9	506	32	108	33	65	23	
1996	13	1569	80	25	65	406	5	155	247	8	367	16	93	27	49	26	
1997	11	1581	88	12	289	383	50	153		10	434	28	77	20	23	14	
1998	8	1351	50	35	216	355		134			434	24	75	27			1
1999	8	1590	50	35	345	418		123			458	33	81	18	29		
2000	7	1129	40	28		371		118			435	30	74	18	15		
2001	6	1163	37	19		371		117			499	25	58	19	18		
2002	8	1030	33			354	43				493	29	50	16	12		
2003	7	1031	29			317	61				508	6	82	28			
Total		**43145**	**1090**	**344**	**4059**	**11579**	**181**	**1595**	**2466**	**29**	**14223**	**535**	**3834**	**513**	**333**	**99**	**2265**

Annex 2: Hierarchical system used to designate bird strikes as being "local" or "en-route".
In this scheme field names from EURBASE are printed italic, attributed field contents are printed upper-cast and the result is printed bold upper-cast . A key to the abbreviations is added at the end.
Non-local bird strikes are all bird strikes that are not designated as local

1. If LAN is among the *impact points* the bird strike is considered being **LOCAL**, else:

2. If *flight phase* is UNK the bird strike is considered **UNK**, else:

3. If *flight phase* is TAX, TOF or LAN the bird strike is considered **LOCAL**, else:

4. If *flight phase* is CRU or LLE the bird strike is considered **ENR**, else:

5. If *actype* unequals JET
    - 5a. and *flight phase* is HOL, TGO or FAP the bird strike is considered **LOCAL**, else:
    - 5b. and *flight phase* is CLI or DES:
        - 5b1. and *altitude* is 2000ft or less the bird strike is considered **LOCAL**, else:
        - 5b2. and *altitude* is over 2000ft the bird strike is considered **ENR**, else:

6. If *actype* is JET and *flight phase* is HOL or TGO or FAP or CLI or DES
    - 6a. and *speed* equals 300 kts or more the bird strike is considered **ENR**, else:
    - 6b. and *speed* is less than 300 kts the bird strike is considered **LOCAL**.

Abbreviations used:

UNK = Unknown
LAN = Landing gear (*impact point*) or Landing (*flight phase*)
TAX = Taxiing (*flight phase*)
TOF = Take-Off (*flight phase*)
CRU = Cruise (*flight phase*)
LLE = Low level, En-route (*flight phase*)
JET = Jet fighter aircraft (*actype*)
HOL = Holding (*flight phase*)
TGO = Touch and Go, Overshoot (*flight phase*)
CLI = Climb (*flight phase*)
DES = Descent (*flight phase*)
FAP = Final Approach (*flight phase*)

LOCAL bird strike occurred on an airfield or in the vicinity of it
EN-ROUTE bird strike occurred off airfield while aircraft was en-route
UNK unknown whether the bird strike was local or en-route

Annex 3. **Summay of details on bird strike data from GAF and RAF for non-local jetfighters 1991-2000**

	GAF		RAF		
Bird strike ratio	24.2 ±2.0		18.5 ±1.2		
% damage	20.0 ±1.6		45.0 ±2.1		
% damage Tornado only	22.8 ±2.8		48.0 ±5.4		(ANOVA, F=3,806, P=0,007)
Bird species unknown	83.5%		85.1%		
% damage of above	17.1		47.2		
Bird species known	16..%		14.9%		
of which:	proportion	% damage	proportion	% damage	
Anatidae	3.4	63.5	1.9	100.0	
Accipitriidae	10.5	76.5	3.5	100.0	
Lariidae	29.2	74.2	68.5	65.4	
Columbidae	4.9	68.8	4.9	77.8	
Corvidae	2.5	62.5	3.5	69.2	
Charadriidae	4.3	64.3	4.0	73.3	
Falconidae	3.4	45.5	1.6	83.3	
Sturnidae	1.2	50.0	3.8	57.1	
Apodidae	9.2	22.6	3.2	25.0	
Turdidae	3.4	18.2	0.5	100.0	
Passeriformes+Hirundidae	26.8	8.0	4.0	20.0	
Various	0.9	100.0	0,5	50.0	
% BS Flightphase unknown	51.6 ±4.7		29,3 ±3,2		
Average speed (kts)	407 (±2,5)		424 (±1,3)		(T test, F=14,16, P=0,001)