Birdweight and aircraftspeed in birdstrike statistics

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introduction

...'The pilot suddenly felt a severe blow on his head which almost incapacitated him. He could not move his right arm but managed to reach the ejection seat handle with his left hand and ejected'...

These were the first sentences of a telex-message which informed NATO colleagues about the first F-16 that crashed in Norway after striking a bird. The report mentions a Crane (Grus grus), weighting 11 lb, having penetrated the canopy. The telex continues:

...'He experienced the ejection as very pleasant, with no change in the airblast, the seat worked normally. However, when he managed to wipe the blood from his eyes, he discovered that he was hanging upside down in the harness, suspended only by the leg straps. The possibility of falling out of the harness altogether was imminent'...

Clearly, things might have been worse!
However, this accident as well as the first statistical data on bird encounteredby the F-16's of the RNLAF indicate that our newest generation of jetfighters and their pilots will meet a serious birdstrike risk! It remains to be seen wether our recent yearly average of 150-200 birdstrikes with some 40-50 damage cases and a frequency of aircraft once in every two or three years, will change in a positive or negative sense after the full introduction of the new aircraft.

When a 11 lb bird such as a Crane shows up in the flight path of a cruising jetfighter we may expect serious trouble. It is unrealistic to expect an airworthiness standard garanteeing aircraft to withstand amounts of impact energy to be possibly reached where a normal cruising speed of over 400 kts coincides with such a birdweight. But judging constructional measures infeasible or out proportion, taking into account the small chance of meeting such a heavy birdspecies, oncemore it appears to be a very important question which impactforces should then be considered as 'non-acceptable'. Such matters worried the RNLAF reflecting upon her own experiences. Since 1975 three jetfighters have been lost after striking a Kestrel (0.5 lb), a 'buzzardlike raptor' (2 lb) and an Eiderduck (4 lb) respectively. This raised the question whether these accidents due to collisions with birds of low or moderate weight should be considered as exceptional or indicative.

Consequently, high priority has been given to the study of the combinations of types of damage, aircraft speed and birdweight. However, both Dutch birdstrike statistics and foreign ones fail to mention the essential indicator for birdweight, namely the birdspecies involved in a majority of the reports, and especially in most damage-cases. This brought us to initiate a study on improvement of the only microscopic identification key of feather remains existing sofar (DAY 1966). In 1980 this work resulted in a far more extensive and fully modified key (BROM 1980). During BSCE 14 in The Hague we reported on that indentification method and its application to minuscule bird remains found on airframes and in engines (BROM & BUURMA 1979). Further the consequences of the results of the improved identification for RNLAF birdstrike statistics have been discussed preliminarily (BUURMA & BROM 1979).

Since then the data of three more years have been added to our files. In this report we present a further analysis of the data collected during the period of 1977 up to and including 1981. Next to concentrating upon the birdstrike risk we will discuss some types of bias affecting military birdstrike statistics which also, I guess, may throw some light on discrepancies between many civil statistical reports. The paper deals with jetfighters only.

identification results

As already reported in The Hague the quality as well as the quantity of correct identifications increased enormously on account of three reasons:
a. the introduction of the microscopic analysis of feather remains (often very minuscule and/or structurally deformed) as the first step in difficult identifications;
b. the improvement of the general reporting standard (bird control units pursuiting pilots and crewchiefs for data and remains); and
c. the skipping of all identifications by unauthorized persons because of the high percentage of obvious uncertain data.

The most important result was a substantial grow of data on birdspecies struck 'en route' and having caused damage. While in earlier years we only got three to five of such cases, now the yearly total of fully documented reports is fifteen up to twenty, which is approximately 66%. Also including birdstrikes at or around airbases and all cases without damage we can now make use of 332 birdstrikes for further analysis. All species or species groups concerned are listed in table I, in which also damage percentages and 'en route' percentages are given. 69 other cases in which bird remains were found after the flight, and in which data on aircraft speed remained unkwown, are also included.

The relative low percentage of strikes with gulls, already reported, continued to decrease. We arrived at 25%, which is the lowest figure of all European reports. This is a remarkable figure, taking into account the geographical location of the Netherlands, with coastal zones and many wet lowlands. Of course this result should not be interpreted as an indication that gulls only constitute a moderate problem. It only means that these large and white and therefore easily noticed and well known birds tend to become overrepresented. The opposite occurs with small and darker birdspecies, as is reflected by the order of the songbirds. Now this group constitues 40% in our list. Only the Danish military statistics (JOENSEN 1978) show some resemblance and this might have something to do with the fact that also in Denmark professional museum identifications have been promoted.

To aviation people it may look rather silly to discriminate between all sorts of small songbird species, but one example may weaken such an impression. In the summary of 'Birdstrikes to European registered civil aircraft' (THORPE & VAN WESSUM 1982, this meeting) the Swallow (Hirundo rustica) shows up with 119 strikes (14.4%) while the House martin (Delichon urbica) and the Swift (Apus apus) only have been recorded three times and ten times respectively. This does not at all reflect the occurence of these species. Of course it results from laymen identifications: 'Swallows' most probably were Swifts, not Swallows. The false high ranking of the Swallow might promote mass nest disturbing on airfields. Apart from a waste of energy this would also be a most regrettable step in the light of nature conservancy.

birdweight, aircraft speed and damage

Having found many birdspecies identities we now arrive at our main objective: the comparison of bird weights, aircraft speeds and types of damage. As reported earlier the most interesting and critical situations will be found among the 'en route' strikes. Cruising speeds of 390, 420 or 450 kts represent the prime prerequisit.for a dangerous bird encounter. But although we increased the number of fully documented reports considerably, the total number of available data on birdstrikes with damage seemed not yet large enough to permit quantitative discrimination of different types of damage. Therefore we restrict ourselves first to the simplest display of the 332 full documented reports, viz. damage: yes or no. Figure 1 shows the results.

Clearly, these data appear to belong to two distinct groups, viz. low and high speeds, representing 'local' and 'en route' birdstrikes. The gap between both groups is misleading in a certain sense. It results from the interaction between the flight envelopes of aircraft and birds and the different nature of'local' and 'en route' strikes. The low speed flight parts ('local') only constitute a minor part of the total flying time, but the high number of birds usually on the wing in the lowest airlayer nevertheless causes a substantial amount of incidents. The opposite situation occurs in the second group. While on the average birdnumbers on higher flight levels are relatively low, the time jetfighters spend cruising there at high speeds constitutes a major part of the flight duration. As a result a similar amount of birdstrikes is found in both groups.

'Local' and 'en route' birdstrikes differ to a large extent with respect to damage. This is illustrated by the distribution of solid and open symbols in figure 1. In order to facilitate a comparison of damage percentages we divided the graph in four speed and four weight catagories. The weight catagories roughly represent '0.25', '0.5', '1' and '2 lb-birds'. The result of this grouping of data is given in figure 2.
Two major conclusions can be drawn:

1. nearly 90% of the '2 lb-birds' caused damage when the aircraft flew at 450 kts or more;
2. also collisions with the smallest birds appear to result in a considerable proportion of damage cases (up to 31%).

In general we may conclude from figure 2a that practice confirms the theorethical expectation that speed is dominant over birdweight when determining the chance of damage. Only engine strikes constitute an exception in figure 1 because also the rotational speeds of compressor blades influence impact forces. The last category is responsible for most of the damage strikes at low speeds and with small birds.
The recent habit of discussing critical birdweights without mentioning a fixed standard aircraft speed in civil aviation might raise confusion. In military aviation, where the relevant aircraft speeds cover a much wider range, dealing with birdweights and aircraft speeds separately is flatly misleading.

A further remarkable feature of figure 1 is the <u>variation</u> in the occurence of damage. On the one hand a tiny little bird sometimes causes some tenthousend US $ repair costs, while on the other hand a 8 lb Gannet (Sula bassana) did not cause a single dent or crack to a F-104 Starfighter.

Obviously, not all parts of the aircraft show the same vulnerability! The physics of bird impact have been the object of experimental testing and of several theoretical calculations. Birdstructures were considered more semi-rigid than butter-soft, different 'givings' of aircraft skins and different impact angles were taken into account. However, the variable empirical results as well as the occasional danger of even very light birds seem to make it necessary to review those calculations and to improve the collection and comparison of many more fully documented birdstrikes with damage!

bias resulting from different reporting standards

Just as it is the case in civil statistics, the military birdstrike data show severe bias due to varying reporting standards. This became apparent twice during the recent history of RNLAF birdstrike statistics. Firstly, the introduction of bird control units raised the number of reports enormously (BUURMA 1977). Then, some years later, our emphasis on collecting even the smallest feather remains and the improved identification again appeared to increase the birdstrike rate. As a result the present yearly average of 148 reports is three times higher than it was during the years 1956 till 1965 (BLOKPOEL, 1966), while the amount of damage-cases remained roughly the same. Even when we neglect changes in flying hours, flight performances and aircraft types it is apparent that especially the amount of non-damage birdstrikes reflects the interest in the birdstrike problem rather than the actual safety situation.

This effect increasingly got attention within BSCE. It therefore does not seem necessary to put too much emphasis upon it. However, the reporting standard also affects the relative distributions of certain aspects of birdstrikes. Consequently we should be aware of certain types of bias not yet fully recognised, when pooling data from birdstrikes originated under different conditions and with different effects. Furthermore, even the chance of detecting serious birdstrikes as such may be influenced. An indication for the sources of bias can be found in the frequent use of the word 'unknown' in birdstrike reports. Our recent data provide a good possibility to illustrate some points.

In figure 2 we summarise not only the fully documented reports but also the incomplete sets of data. Three principally different types can be distinguished:

1. The most important group concerns birdstrikes that were documented with reference to aircraft speed but not birdspecies identity (figure 2b). Obviously the pilot noted the collision but no bird remains were found or collected. These omissions surely might be compensated for, though to a limited extent, by further propaganda. However, one remarkable effect will never be fully set right: the difference between 'local' and 'en route' reporting. While formerly virtually no data on birdspecies struck 'en route' were collected, now this is the case in about half of the incidents (figure 2c).

   'Local' birdstrikes appear to be documented satisfactorily. This is partly the result of the contribution of groundpersonnel finding birdcorpses on the runway. Therefore, the pooling of birdspecies data irrespective of speed ($\approx$ location) will lead to an overrepresentation of airfield birdspecies.

2. A second group of incomplete data consists of birdstrikes not noticed by the pilot, but diagnosed as such after the flight by finding bird remains. This was only the case in 9% of all the birdstrikes and might indicate that pilots usually are able to hear, feel or even smell bird collisions. They only have to report them. However, again not all birds have an equal chance of becoming detected. While heavy birds always draw sufficient attention to let the pilot remember location, speed and height, smaller birds tend to slip through. With large civil airliners this must be the case even far more often.

3. Finally, there is a remaining group of birdstrikes (also 9%) again showing that further reporting improvements are still possible. Here both speed and birdspecies have not been filled in. We assume that this group represents several cases of forgotten data or badly administrated ones and of birdstrikes revealed by inspection of engines. It is worth noticing that in spite of this one quarter concerned damage cases.

Our general feeling is that we will always be able to find more birdstrikes. In the first place this will concern non-damaging collisions but also several more costly air-accidents will appear to have been caused by birds. Even one or two of the three Dutch jetfighters written off after a birdstrike, given as the initial cause, could easily have been reported with the classification 'cause unknown'. The first case concerned an engine failure during take-off. The pilot was killed after the plane had crashed behind the end of the runway. It is uncertain whether the tiny bird remains, most of all hardly recognizable by the naked eye, should have been found if a specialist had not been sent along with the investigation committee because of the fact that the airfield was described in a manual as 'bird dangerous'. The second birdstrike occurred 'en route'. Here the pilot dearly saw, heard and felt a large 'buzzardlike raptor' entering the air intake. However, no remains were found in the totally destroyed wreckage which was recovered several weeks later. Only the third crash was an obvious case of birdstrike in all respects. The Eider, one out a flock of nine, was observed in advance but could not be avoided. The bird was found in a hole in the wing just between an air intake and fuselage of the F-104 Starfighter, where it damaged a fuel tank. The F-104 lost fuel inflight and caught fire while rolling out the runway (see art impression on cover).

improved statistics in the light of future developments

While it is evident that we should document all damage-birdstrikes according to the highest reporting standards and always should try to recover the birdspecies involved, it might be considered of little use to report also all non-damage cases. In the light of the bias discussed above indeed it can be questional whether such efforts will be rewarding enough. However, when all the conditions for a careful analysis are fullfilled an important increase in the understanding of the birdstrike risks can be reached. This is of particular importance with respect to the development of safer aircraft designs or, in case of the potential buyer, with respect to the formulation of certain specifications. It doesn't go to expect aircraft constructions to become safer and safer only. The demands of birdresistence may conflict with other design criteria and will always be met partially only.

Accepting such compromises might go hand in hand with a disregard of the chance of hitting a bird of a certain weight class. To illustrate this we compare in figure 3 the percentual weight distribution of all the eleven million Dutch breeding birds with that of birdspecies involved in the birdstrikes reported here. It appears that heavier birds have become over-represented in birdstrikes. This raises the question whether the smallest birds became underrepresented by a selective missing of actually occurred strikes or by a poorer ability of those birds to penetrate the compressed air in front of the aircraft. Further, birds heavier than the often discussed 4 lb level only form 0,1% of the total avian population. Considering the bird distribution it seems reasonable to ignore the chance of meeting such heavy birds. But one should realise that lowering the critical value with a factor 2 will enlarge the chance of meeting a species with 'above critical weight' by a factor 50 !
Further, once again it should be emphasized that flying at higher speeds than a certain critical value will coincide with a more than proportional lower critical bird weight. The find of 90% damage in case of collisions with 2 lb birds while flying normal cruising speeds gives the RNLAF great concern.

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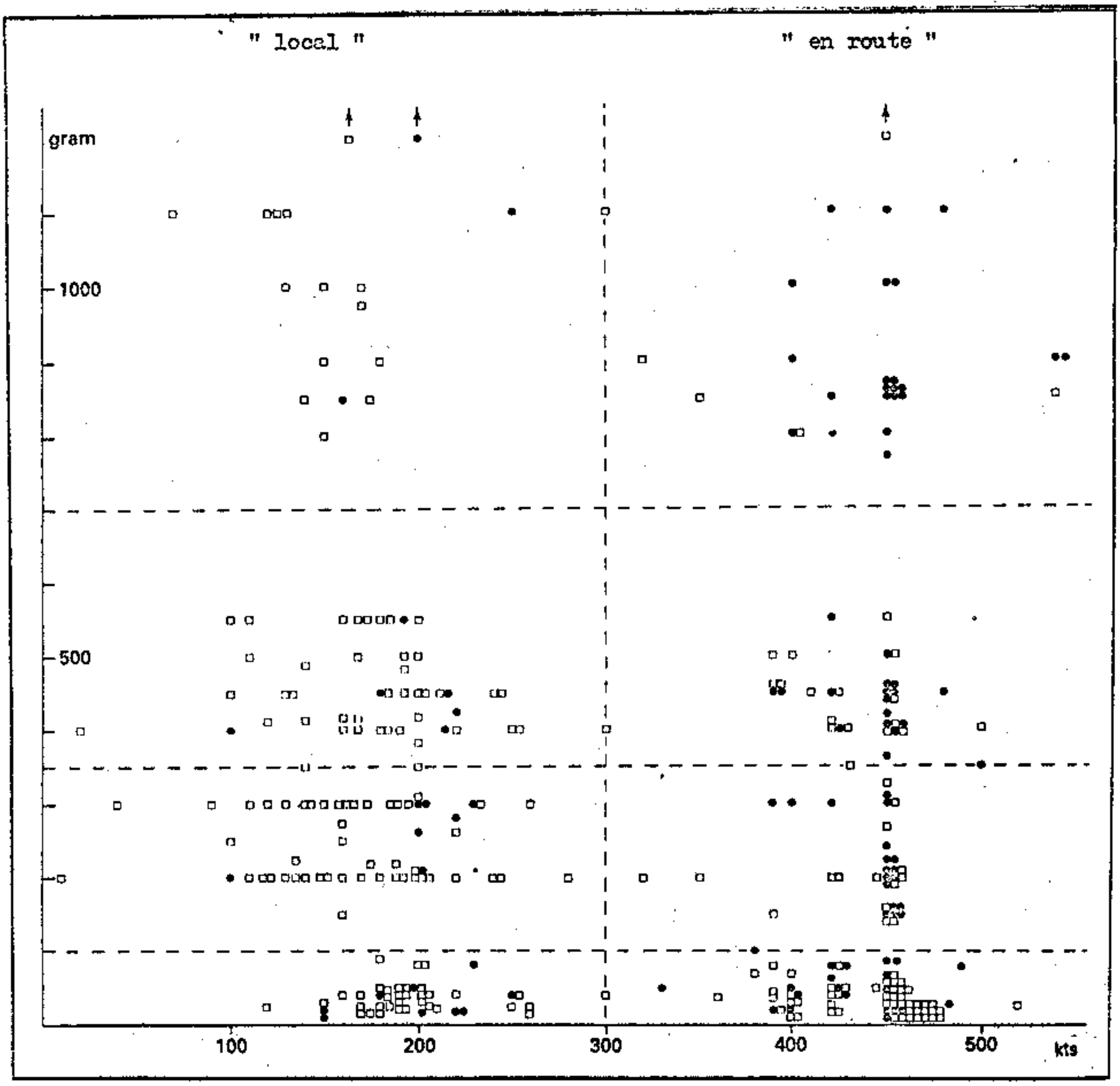
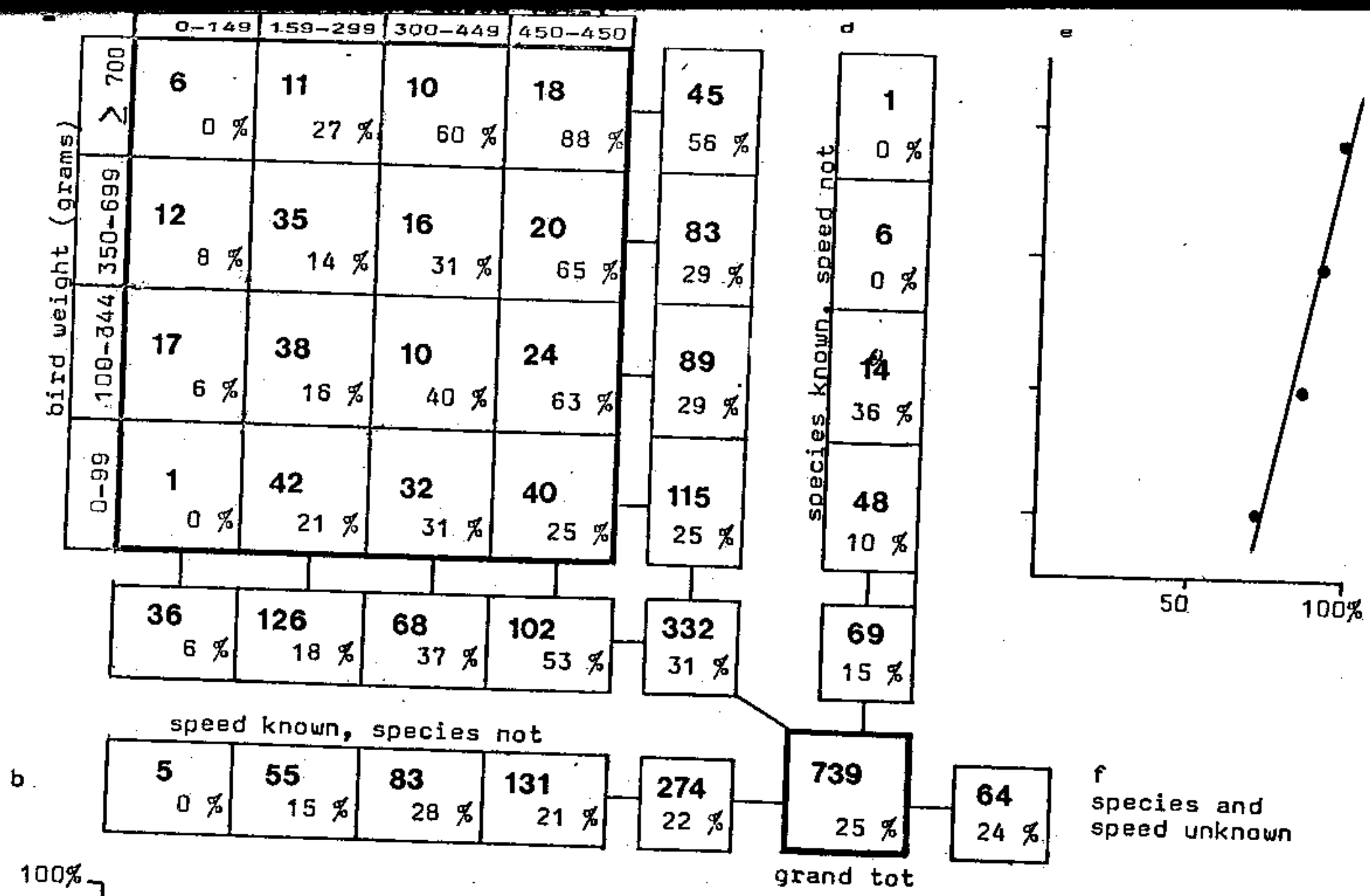


Figure 1

Bird strikes Royal Neteherlands Air Force 1977 up to and including 1981.
Speed of jet fighter versus weight of bird.
Solid symbols bird strikes with damage, open symbols bird strikes without damage. Incomplete bird strike reports not included.



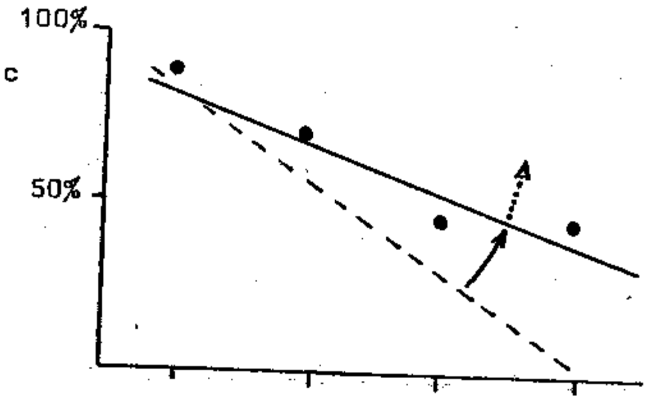


Figure 2

Numbers of bird strikes and percentages of damage cases within the combination of four aircraft speed classes and four bird weight classes plus class totals (a), and within three sets of incomplete reports viz. speed known but species not (b), species known but speed not (d) and speed and species unknown (f). The graphs c and e show the percentages of full documentation, viz. a/(a+b) x 100 and a/(a+d) x 100. In c the situation before the improved identification is also indicated (- - - -).

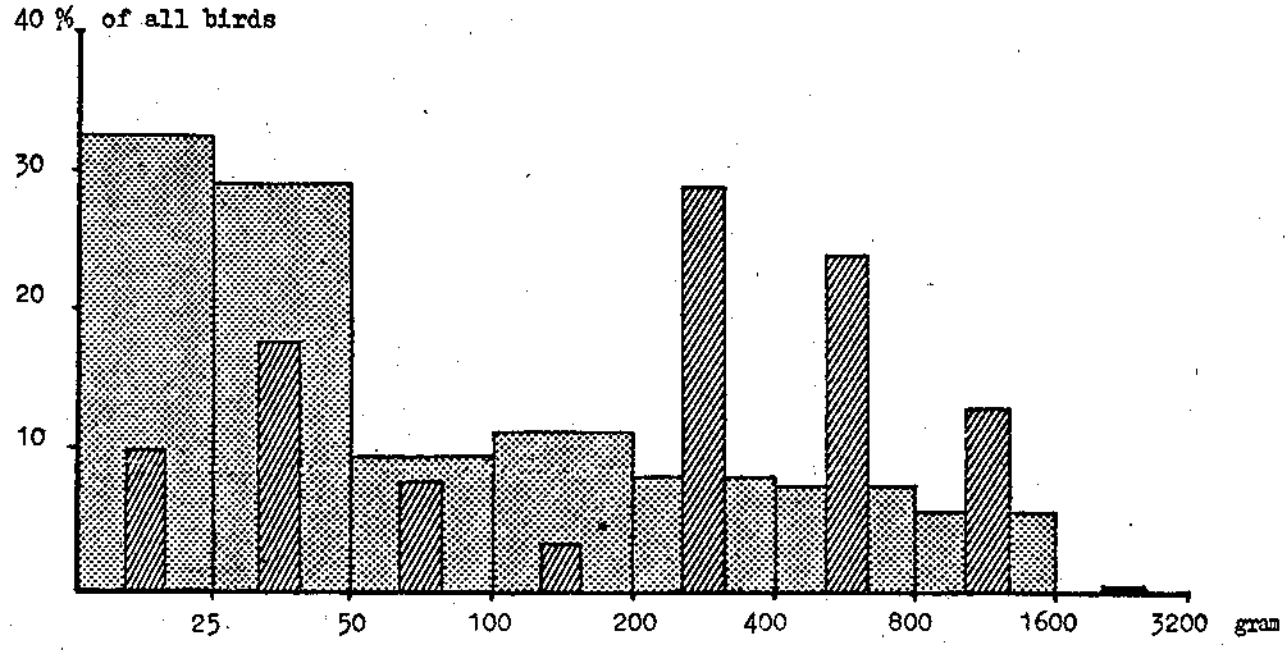


Figure 3

Percentual distribution of Dutch breeding birds (11 million)
and birds involved in collisions with Dutch jet fighters
in eight weight classes.
Breeding bird data taken from TEIXEIRA 1979.

Table 1 Bird species involved in birdstrikes of the Royal Netherlands Air Force during the years 1977 up to and including 1981

SPECIES	number	"en route"	damage
Swift - Apus apus	41	71 %	27 %
Lapwing - Vanellus vanellus	39	39 %	26 %
Black headed gull - Larus ridibundus	23	9 %	17 %
Buzzard - Buteo buteo	20	63 %	70 %
Common gull - Larus canus	17	6 %	6 %
Skylark - Alauda arvensis	14	27 %	7 %
Starling - Sturnus vulgaris	11	50 %	27 %
Wood pigeon - Columba palumbus	10	50 %	20 %
Oystercatcher - Haematopus ostralegus	9		
Kestrel - Falco tinnunculus	8		
Herring gull - Larus argentatus	8		
Racing pigeon - Columba livia var	6		
Swallow - Hirundo rustica	6		
Mallard - Anas platyrhynchos	5		
House martin - Delichon urbica	3		
Black-tailed godwit - Limosa limosa	3		
Pheasant - Phasianus colchicus	3		
Partridge - Perdix perdix	3		
Black grouse - Lyrurus tetrix	2		
Rook - Corvus frigilegus	2		
Redwing - Turdus iliacus	2		
Jackdaw - Corvus monedula	2		
Fieldfare - Turdus pilaris	2		
Stock dove - Columba oenas	2		
Song thrush - Turdus philomelos	2		
Bar-tailed godwit	1		
Greenfinch - Carduelis chloris	1		
Wheatear - Oenanthe oenanthe	1		
White wagtail - Motacilla alba	1		
Barnacle goose - Branta leucopsis	1		
Lesser black-backed gull - Larus fuscus	1		
Gannet - Sula bassana	1		
Knot - Calidris canutus	1		
Snipe - Gallinago gallinago	1		
Common tern - Sterna hirundo	1		
Carrion crow - Corvus corone	1		
Sand martin - Riparia riparia	1		
Magpie - Pica pica	1		
Woodcock - Scolopax rusticola	1		
Goosander - Mergus merganser	1		
Hobby - Falco subbuteo	1		
Golden plover - Pluvialis apricaria	1		
Sparrow - Passer domesticus	1		

SPECIES GROUPS	number	"en route"	damage
Songbirds	171	57 %	21 %
Gulls (including terns and Gannet)	108	39 %	32 %
Waders	58	40 %	24 %
Pigeons	40	53 %	38 %
Raptors	30	50 %	53 %
Ducks and Geese	10	70 %	70 %
Crows	7		
Game	8		

WEIGHT CLASSES	number	"en route"	damage
Below 100 gram	170	57 %	21 %
100 - 350 gram	103	34 %	28 %
350 - 700 gram	110	48 %	32 %
Over 700 gram	49	52 %	51 %