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HELSINKI MAY 21st-25th 1990

DOCUMENT IDENTIFICATION

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PORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1. AGENCY USE ONLY (Leave blank)

2. REPORT DATE
1990

3. REPORT TYPE AND DATES COVERED
Conference Proceeding
May 21st-25th 1990

4. TITLE AND SUBTITLE
Bird Strike Committee Europe (BSCE) , 20th Meeting, Helsinki, Finland
May 21st-25th, 1990. Working Papers.

5. FUNDING NUMBERS

6. AUTHOR(S)
Bird Strike Committee Europe

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Bird Strike Committee Europe
Civil Aviation Administration
Aviation House
Ellebjergvej 50
DK-2450 Copenhagen SV, Denmark

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Bird Strike Committee Europe

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES
Copyright waived per email from Willemijn Prast, Sent: Wednesday, September 01, 1999,
To: Short, Jeffrey, USAF IBSC Representative, Tyndall AFB, FL 32403.

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for Public Release; Distribution Unlimited

12b. DISTRIBUTION CODE
A

13. ABSTRACT (Maximum 200 words)

The Bird Strike Committee Europe consists of civil and military participants from Europe with a common interest in the bird strike problem. Attendence is open to participants from other parts of the world. Annual Meeting Proceedings include Chairman's Report, Working Group Reports and Papers Presented:

TABLE OF CONTENTS:

14. SUBJECT TERMS
Bird Strikes, Aviation Safety, Airports, Hazards, Survivability, BSCE, International Bird Strike Committee, IBSC

15. NUMBER OF PAGES

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT
UNCLASSIFIED

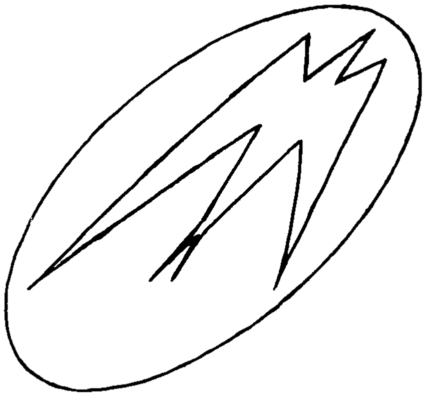
18. SECURITY CLASSIFICATION OF THIS PAGE
UNCLASSIFIED

19, SECURITY CLASSIFICATION OF ABSTRACT
UNCLASSIFIED

20. LIMITATION OF ABSTRACT
UL

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. 239-18
298-102



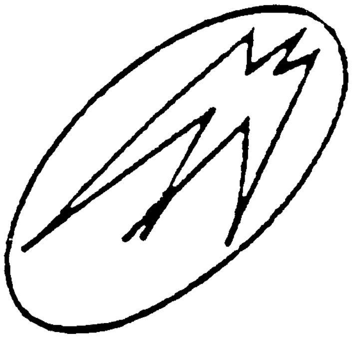
BSCE 20

HELSINKI

May 21st-25th, 1990

WORKING PAPERS

BIRD STRIKE COMMITTEE EUROPE
WORKING PAPERS
20th MEETING



BSCE 20

HELSINKI
May 21st-25th, 1990

HQ AFCESA/TIC
139 Barnes Drive
Tyndall AFB FL 32403-5319

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ADF 616400

AOP616453

BSCE 20 / WP 1
DECEMBER 1989

INVITATION LETTER

1. Bird Strike Committee Europe and the Civil Aviation Administration of Finland cordially invite you to attend the 20th meeting of BSCE, which will be held in Helsinki from 21 May 1990 and end on 25 May 1990.

2. Location of meeting:

Hotel Inter Continental Helsinki
Mannerheimintie 46
SF-00260 Helsinki

Tel.:	+ 358 0 4055 1
Telex:	122159 incon sf
Fascimilie:	+ 358 0 4055 255

3. Address of the organizing committee

Civil Aviation Administration of Finland
Att.: H. Helkamo
Helsinki Vanta Airport
Box 29
SF-01531 Vanta 53
Finland

Tel.:	+ 358 0 8293 897
Telex:	124437 EFHK SF
Facsimilie:	+ 358 0 8292 829

Mr. H. Dahl
Civil Aviation Administration
P.O. Box 744
Ellebjergvej 50
DK-2450 København SV
Denmark

Tel.:	45 36 44 48 48 / 275
Telex:	27096 caa dk
Fax:	45 1 44 03 03

4. Agenda

Registration of the participants will be held on 21 May 1990 between 0830 and 1000 local time

DATE	MORNING	
MON 21 MAY	0900	Steering Committee
	1000	Plenary
	1100-1230	Statistics Working Group
	AFTERNOON	
	1230-1400	Lunch
	1400-1700	Statistics Working Group and, if time permits, general videos

DATE	MORNING	
TUE 22 MAY	0900-1230	Radar Working Group
	0900-1230	Bird Remains Identification Working Group
	AFTERNOON	
	1230-1400	Lunch
	1400-1700	Bird Movements and Low-Level Working Group

DATE	MORNING	
WED 23 MAY	0900-1230	Aerodrome Working Group
	0900-1230	Testing of Airframes and Engines Working Group
	AFTERNOON	
	1230-1400	Lunch
	1400-1700	Aerodrome Working Group
	1700	Steering Committee

DATE	MORNING	
THU 24 MAY	0900	Plenary
	AFTERNOON	
	1400	Technical Visit

DATE	MORNING	
FRI 25 MAY	0900	Plenary

5. Terms of Reference of BSCE

Bird Strike Committee Europe consists of civil and military participants from Europe with a common interest in the bird strike problem. Attendance is open to participants from other parts of the world.

The Bird Strike Committee Europe shall:

a) collect, analyze, and circulate to all concerned data and information related to the bird strike problem in the European region;

NOTE:- This data and information should include the following:

1. Civil and/or military data collections and results of analyses on bird strikes to aircraft.
2. Results of any studies or examinations undertaken by states in the various fields related to the bird problem.
3. Any information available in the field of design and structural testing of airframes and engines related to their resistance to bird strikes.
4. Any other information having a bearing on the bird strike question and the adding to the various problems involved.

b) Establish liaison on further research programme in order to avoid duplication.

c) study and develop methods to control the presence of birds on and near aerodromes;

d) investigate electro-magnetic wave sensing methods, e.g. radar, invisible light, etc., for observing bird movements;

e) develop procedures for the timely warning of pilots concerned where the existence of a bird hazard has positively been established;

f) develop procedures, if appropriate, for the initiation by air traffic control of avoiding action where the existence of a bird hazard has positively been established;

g) develop procedures enabling a quick and reliable exchange of messages regarding bird hazard warnings;

h) develop any material, e.g. maps, background information, etc., intended for inclusion in Aeronautical Information Publications;

i) aim at a uniform application throughout the European region of the methods and procedures and the use of material developed in accordance with c) to h) above, provided suitable trials have proved their feasibility and monitor developments in this respect.

6. Terms of Reference of Working Groups

Aerodrome Working Group:

Exchange of information on methods used and results obtained from the work being done on aerodromes in order to minimize the bird problem at and around airports.

Statistics Working Group:

Collection, analysis, and circulation of data and information relating to birdstrikes.

Bird Movement and Low Level Flight Working Group:

Exchange of information on procedures used and results obtained from the study of bird concentration and movement, encompassing the drawing up of special bird hazard maps and preventive measures such as transmission of information taken to minimize the bird hazard to low-flying aircraft.

Radar Working Group:

Exchange of information on methods used and results obtained regarding the use of radar and other sensors in the surveillance and identification and the risk assessment of bird presence and movements.

Testing of Airframes and Engines Working Group:

1. Exchange of information on the results obtained from:
    (a) Bird impact reseach and development testing of materials, structural specimens, wind-screen, engines, etc.
    (b) Tests to show compliance with airworthiness requirements
2. Exchange of information on methods of prediction.
3. Assistance to national organizations in the production of design guidance material for bird impact resistent airframes and engines.

Bird Remains Identification Working Group:

Exchange of information on the methods used and the results obtained on identification of bird remains

7. Reception and Technical Visits

Will be announced at the beginning of the meeting.

8. Notification of participation

Participation in the meeting should be notified to the Chairman by filling out the attached paper, Appendix 1, and preferably before 1 April 1990.

9. Working Papers and Presentations

Working papers should contain references to proceedings of earlier meetings to avoid recapitulation of work done in the past and to further increase the continuity in the work.

Working papers should be sent to the Chairman of BSCE. **Working papers received before 1 April 1990** will be published in a bound set to be collected at the beginning of the meeting and papers arriving after 1 April 1990 will be published together with the report of the discussions and recommendations in the second part of the proceedings of the meeting.

The Chairman will send a summary of working papers to the Steering Committee members to decide whether a working paper or a film or a video should be presented in the Plenary or in a working group. The Chairman of BSCE will send a copy of the full working paper to the chairman of the working group in question.

As it is assumed that participants to the meeting have already studied the working paper, the oral presentation of a working paper should be reduced to a summary of the paper, and not take more time than 15 minutes in order to allow time for discussion. English shall be used.

In order to obtain consistency of presentation, the following shall be observed:

Type:

Papers must have a good quality black print on A4 208 mm x 295 mm (8 1/4" x 11 1/2") paper with 20 mm margins on all sides to allow for printing and binding.

It will be advantageous to draw a box 20 mm in from paper edge on all sides on a blank sheet of paper to use as a guide behind pages being typed or wordprocessed. Due to problems with reproduction and readability, low quality dot matrix printing is not acceptable. Use mechanical lettering devises or adhersive transfer letters. Typewriter or computer lettering is generally not acceptable. Choose a medium-weight, simple typeface (e.g. Futura Medium, Helvetica), one that is not bold, ornate or compressed. Lettering should be of such a size that it will be about as large as text type (7-10 point) when reduced. The size of the lettering is simple to plan with 50% reduction of the illustration. For patterned lines and areas, printed adhersive tapes and sheetss are preferable to handwork. For shading, use a pattern of lines or dots,not a solid tone. Make sure that lettering and patterns will not block up when reduced.

It is suggested to use a letter type comparable with Serif, and as closely as possible resembling Times.

Format

Text should be single spaced with double spacing between paragraphs with text including new paragraphs being left (or both) margin jusitified.

Front Sheet

Each paper submitted should start with a front sheet which at the top right hand has BSCE/20 then a space for the organisers to insert a WP number. Immediately below this should be typed Helsinki 1990. In the top third of the page should be typed the paper's title in capital letters and underlined and underneath it the author's name and affiliation in upper and lower case. Below this should be a brief summary of not more than 200 words.

The body of the paper should be started on a new sheet.

Heading and Paragraph Numbering

All headings shall be left-justified and underlined (or bold if available). Section heading shall be in upper case and each section numbered /to .. Sub-headings shall be in upper and lower case and numbered 1.1, 1.2, etc. Sub-paragraphs may be lettered if desired. The above will make it easier to refer to paragraphs during discussions, etc.

Figures and Tables

All figures and tables should be titled across the top with "FIGURE" or "TABLE" in capital letters followed by the number. The title should follow on the same line in upper and lower case letters.

Photographs

Photographs must be sharp and of good contrast, showing details in important areas. Prints should be made from monochrome ("black-and-white") film whenever possible. If a colour transparency myst be used, make the print from a custom-made monochrome internegative.

Page Numbers

Pages shall be numbered in light pencil at the bottom centre of each page. The organisers will renumber all pages when compiling the Proceedings.

10. Hotel Reservations

Reservations shall be made not later than 20 April 1990 to

Hotel Inter Continental Helsinki
Address: Mannerheimintie 46, SF-00260 Helsinki
Tel.: + 358 0 4055 1
Telex: 122159 incon sf
Facsimilie: + 358 0 4055 255
*)

If you choose not to stay at the Hotel Inter Continental, you are strongly advised to make hotel reservations as early as possible due to the fact that hotel accomodation in Helsinki at the time of the Conference might be difficult to obtain.

./. A list of Helsinki hotels and restaurants is enclosed.

Yours sincerely,

H. Dahl

H. Dahl
Chairman

*) In your order please mention B.S.C.E. Meeting for special prices.
- single room + breakfast 660 FIM
- twin bedded room + breakfast 780 FIM.

Appendix 1

BSCE ATTENDANCE

(to be sent to Mr. H. Dahl)
Statens Luftfartsvæsen
Box 744, Ellebjergvej 50
DK-2450 København SV - Denmark

Full name and full address: ....
....
....

Telephone number:
Fax number:
Telex number:

From organization:

will attend the 20th BSCE Meeting in Helsinki from .... to ....

I will attend the working group sessions

statistics	aerodrome	bird movement and low-level flight
radar	testing of airframes and engines	
bird remains identification		

I will present a working paper dealing with ....
....

and prefer to have the paper presented to (*) working group
plenary

(*): will the working paper be sent before 1 April 1990 Yes / No

ADF616401

BSCE 20 / WP 2

Helsinki, 21-25 May 1990

BIRD CONTROL AT GENEVA - AIRPORT

Mr. Jacques FRITZ

* * *

Geneva Airport Authority, Switzerland

INTRODUCTION

Geneva airport is located about 4 km away, as the crow flies, from Lake of Geneva. Numerous species of birds live in this area and watching them is always a wonder. But we must add that we very much prefer to see them as far as possible away from our 3900 meters concrete runway on which some 345 aircraft movements are everyday.

BIRDS

The most serious problems come from the black-headed gull and its kin the common gull. They usually appear in great numbers at the end of Fall and during the rainy days of Winter.
Looking for worms they fly around in flocks and alight on the grass or even on the runway.
Over a year, there are about 60 to 70 days of real trouble, during which we have to fight away these birds. We also have all year round visitors such as crows, ash-grey herons and buzzards.

AGRICULTURAL MEASURES

Since the seventies, the Airport Authority has developped various measures to set up an efficient control in order to prevent bird strikes.
As far as land under cultivation is cand intensity concerned, growing cereals is not allowed nor is the use of organic dung with straw and liquid manure.
Grass is cut twice or three times a year, down to 12-20 cm, according to the recommendation of the Swiss Federal Office for Civil Aviation (FOCA).
Regularly a specialist - what we call in French "taupier"(mole-catcher)- inspects the grass area of the airport and traps animals like moles, mice, etc,... the usual daily favorite menu of buzzards and herons.

ACTIVE CONTROL MEASURES

Constant bird watching and chasing are part of the duties devolved upon the Apron-Tower staff together with "follow-me" cars personnel.
In the past years, conventional equipments were used like loud- speakers installed on the roof of a "follow-me" car, transmitting with a portable tape recorder, gull distress calls as well as with pyrotechnics like birdscaring cartridges Shellcrackers, fired from barrelpistols.

Coming now to the unpleasant measures, we have to mention that exceptionally, from time to time, we are compelled to shoot gulls, but only in case of necessity. In those cases specialists from the Geneva Fauna and Forest Departement come to the airport and catch or shoot the undesirable birds.

RADIO-CONTROLLED BIRD DEFENSE SYSTEM

18 months ago, Geneva airport has been equipped with a controlled bird defence system developed by STEFFAN Gmbh in Dexheim, Germany.
It consists of a central transmitting station and, according to the airfield's size, of a variable number of sound generators which can be operated independently or in groups; each sound generator has four pipes producing a four-fold bang (quatro-bang). This device is operated by a ground traffic controller at the transmitter, situated

in our APRON TOWER. When birds are approaching or have already alighted on the airfield, the individual sound generator or the group of sound generators placed in such a way as to cover strategic positions on the airfield, is released by push button.
40 generators have been installed, 20 on each side of the concrete runway, at a distance of 75 meters from the center-line and each unit being 200 meters apart from the next.
The compact-units are equiped with special long-life accumulators energized by a solar panel, and each of the four fireing chambers are provided with acetylene gas bottles fitted in plastic containers in the ground.

The advantage: we can operate exactly where and when we want, as long as we want.
Efficiency is optimum as birds cannot get used to the device because of the flexible operating times and of the highly flexible sound intensities ranging from 25 cycles per second to 2,5 cycles per second; sound pressure level of a detonator at a distance of 10 meters, is 120 db.

FUTURE MEASURES

Together with other Swiss airport authorities - Zurich for example - we believe that the farmers in the immediate vicinity of the airport should be better informed so as to know what crops can sawn the bird strike problem in order to discourage our companions the birds.

We think that bird defence systems should not only be set up "on the ground" if I may say. Aircraft should also possibly be equipped with some system which would reinforce the actual measures.

For that reason we are fully supporting studies and tests done by Swissair DC-10 Captain R. STEFFEN, in order to build up a new equipment using an optical signal to catch the birds attention and giving information on direction and speed/distance of the aircraft.

This system called ABC-Light (Anti-Bird Collision Light) consists of two strobe lights mounted approximately 5-25 meters apart on the wings to give direction information. Both lights begin to flash with increasing frequency during the taxiing for take-off, whereby an acceleration is simulated and attention increased up to 200 times; it is also used for the approach and landing, the frequency of the flash is reduced, showing a speed reduction.
Swissair is interested in this system and ten of their DC-9 will be equipped in the near future, in order to see in practice what hundreds of take-offs and landings have shown during test flights.

CONCLUSION

I would not like to conclude without thanking all the organizers of this 20th BIRD STRIKE COMMITTEE EUROPE for their efforts in preparing this meeting and allowing us to exchange our experiences. Let me once again underline how important it is to cooperate in harmony with Nature and our dear friends the Birds.

J. Fritz

ADF616402

BSCE 20 / WP 3
Helsinki 1990

EXTERNAL SURFACE STRUCTURES OF RACHIS, RAMI AND RACHIDIAL BARBULES OF FEATHERS AND THEIR POTENTIAL FOR DETERMINATION PURPOSES.

Karin Perremans
Section of Systematics and Ecology,
Zoological Institute, Naamsestraat 59,
B-3000 Leuven, Belgium

SUMMARY

Microstructures were discovered by SEM analysis of the surface of the rachis, rami and rachidial barbules of bird feathers. These appear to be intraspecifically stable. Up to now 108 bird species belonging to 54 families and 17 orders were studied. Many structures were found, appearing in numerous combinations. These data will be used for determination purposes and will eventually elucidate some classification problems in the class of Aves.

INTRODUCTION

It is generally accepted that one of the first actions to be taken to solve the birdstrike problem is the proper identification of the bird(s) involved (Brom 1984, 1988, Brom & Buurma 1981, Buurma 1982, Buurma & Brom 1980, Buurma, Dekker & Brom 1984). Birdstrikes of the Belgian Air Force are reported by the pilot and/or maintenance personnel. A "Bird Identification Form" is send to the laboratory together with the bird remains. The identification is carried out at the macroscopical, microscopical and scanning electron microscopical (SEM) level. This procedure results in a positive identification in 90% of the cases.

Up to now none of the morphological methods available gives an identification up to species level. Examination of the shape and presence or absence of the tegmen (Gladstone 1918, Lucas & Stettenheim 1972), studies of the internal structure of feather parts (rachis, barbs and barbules) (Auber 1957, 1964, Swales 1970, Dyck 1977) and of the structure of the downy barbules (Brom 1980, 1986, Chandler 1916, Day 1966) provide insufficient resolution.

Therefore I examined to which extent external surface structures on the rachis, rami and rachidial barbules are useful to identify bird remains up to the species level. I looked whether these features were intraspecifically stable. If so, they will be used as diagnostic character and eventually to solve some problems in the classification of birds.

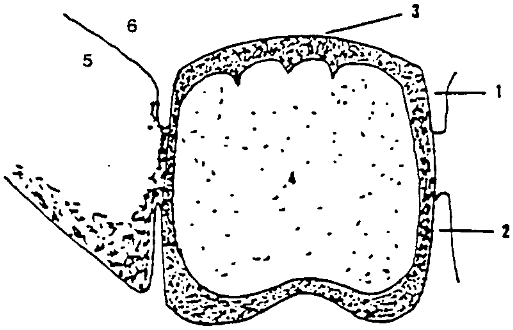
MATERIAL AND METHODS

Small pieces of rachis (± 1 cm) with cut-off barbs were used for SEM examination. A review of the different feather parts is given in Fig. 1 and 2.

"FIGURE 1: Cross section through a feather with dorsal lateral surface of the rachis (1), ventral lateral surface of the rachis (2), dorsal surface of the rachis (3), rachis (4), proximal surface of the ramus (5), distal surface of the ramus(6)."

"FIGURE 2: Position of the rachidial barbules with rachis (1), barb (2), barbules (3), rachidial barbules (4)."

1.



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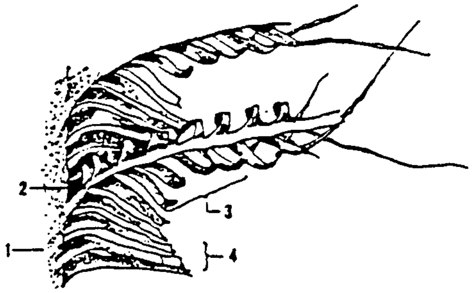


For the intraspecific study the following feathers were subjected to an extensive morphological study: feathers of the tail, an upper and under tail-covert, a feather of the rump, of the back, of the nape, of the crown, of the throat, of the breast, of the belly, of the flank and a primary and an upper and under wing-covert.
Only the ninth primary was used in the interspecific study.
Nine sites on the feather (I to IX) together with the type of cell boundary (X) were examined.

RESULTS

1. Intraspecific study

The dorsal surface of the rachis, the dorsal and ventral lateral surface of the rachis, the proximal and distal surface of the rami and the ventral surface of the rachidial barbules all exhibit externally the same structures along the entire length of the rachis, with the exception of the lower 0.75 to 1.50 mm. This observation is true as well for the primaries and tail feathers as for the body contour feathers. These structures are absent on the calamus.

I also examined whether the site of feather implantation has an influence on the appearance of these microstructures. For this study a Woodpigeon (*Columba palumbus*) and a Collared Dove (*Streptopelia decaocto*) were taken. The results are presented in Table 1.
All feathers investigated of the Woodpigeon nearly show the same features. Three of these categories of features are however not fully constant and consist of the presence or absence of villi on the ventral lateral surface of the rachis ventral to the rami (feature I), the structure on the dorsal surface of the rachis (feature IX) and the type of cell boundary (feature X). For determination purposes these three categories have to be treated with care.
Similar results were obtained with the Collared Dove.

We compared feathers of 23 species (2 to 16 individuals per species) to determine to which extent there are individual differences for these structures within one species. No differences between individuals of the same species were found.

Feathers of both sexes of nine species were compared. In none of the examined species, not even in species with a strong sex-linked colour dimorphism such as the Mallard (*Anas platyrhynchos*) and the Ring-necked Pheasant (*Phasianus colchicus*), were differences between the sexes for the described structures found.

The rachis of one juvenile and one adult specimen of 18 different species were compared to study the age differences. They proved to be identical to each other.

Feathers of seven fresh specimens of the Mallard and eight museum specimens (preserved for over 40 years) were compared (Table 2). No differences in external surface features were found between both groups.

"TABLE 1: Woodpigeon (*Columba palumbus*). External surface structures of rachis, rami and rachidial barbules at different implantation sites."

	I	II	III	IV	V	VI	VII	VIII	IX	X
tail feather	Vi(b)	Vi(b)	Vi(b)	Vi(b)	o	Vi(e)	Vi(e)	RF	F	4
upper tail-covert	Vi(a)	Vi(a)	Vi(a)	Vi(a)	o	Vi(d)	Vi(d)	RF	VSP	4
rump feather	Vi(c)	Vi(c)	Vi(c)	Vi(c)	o	Vi(c)	Vi(d)	Vi(e)	VSP	-
back feather	-	Vi(c)	Vi(c)	Vi(c)	Vi	Vi(e)	Vi(e)	Vi(<e)	RS	-
nape feather	-	Vi(c)	Vi(c)	Vi(c)	Vi	Vi(d)	Vi(d)	Vi(e)	RS	-
crown feather	-	Vi(c)	Vi(c)	Vi(c)	Vi	Vi(c)	Vi(d)	Vi(e)	F	-
throat feather	-	Vi(b)	Vi(b)	Vi(b)	Vi	Vi(d)	Vi(d)	Vi(e)	VSP	-
breast feather	-	Vi(b)	Vi(b)	Vi(b)	Vi	Vi(c)	Vi(c)	Vi(c)	VSP	-
belly feather	-	Vi(c)	Vi(c)	Vi(c)	Vi	Vi(e)	Vi(e)	Vi(e)	VSP	-
flank feather	Vi(c)	Vi(c)	Vi(c)	Vi(c)	Vi	Vi(e)	Vi(e)	RF	F	-
under tail-covert	Vi(b)	Vi(b)	Vi(b)	Vi(b)	Vi	Vi(e)	Vi(e)	Vi(<e)	RS	4
primary	Vi(b)	Vi(b)	Vi(b)	Vi(b)	Vi	Vi(<e)	Vi(e)	Vi(<e)	F	4
under wing-covert	Vi(b)	Vi(b)	Vi(b)	Vi(b)	o	FF	Vi(e)	Vi(<e)	VSP	o
upper wing-covert	Vi(b)	Vi(b)	Vi(b)	Vi(b)	Vi	Vi(e)	o	o	RS	4

"TABLE 2: Mallard (*Anas platyrhynchos*). External surface structures of rachis, rami and rachidial barbules of fresh and museum specimens."

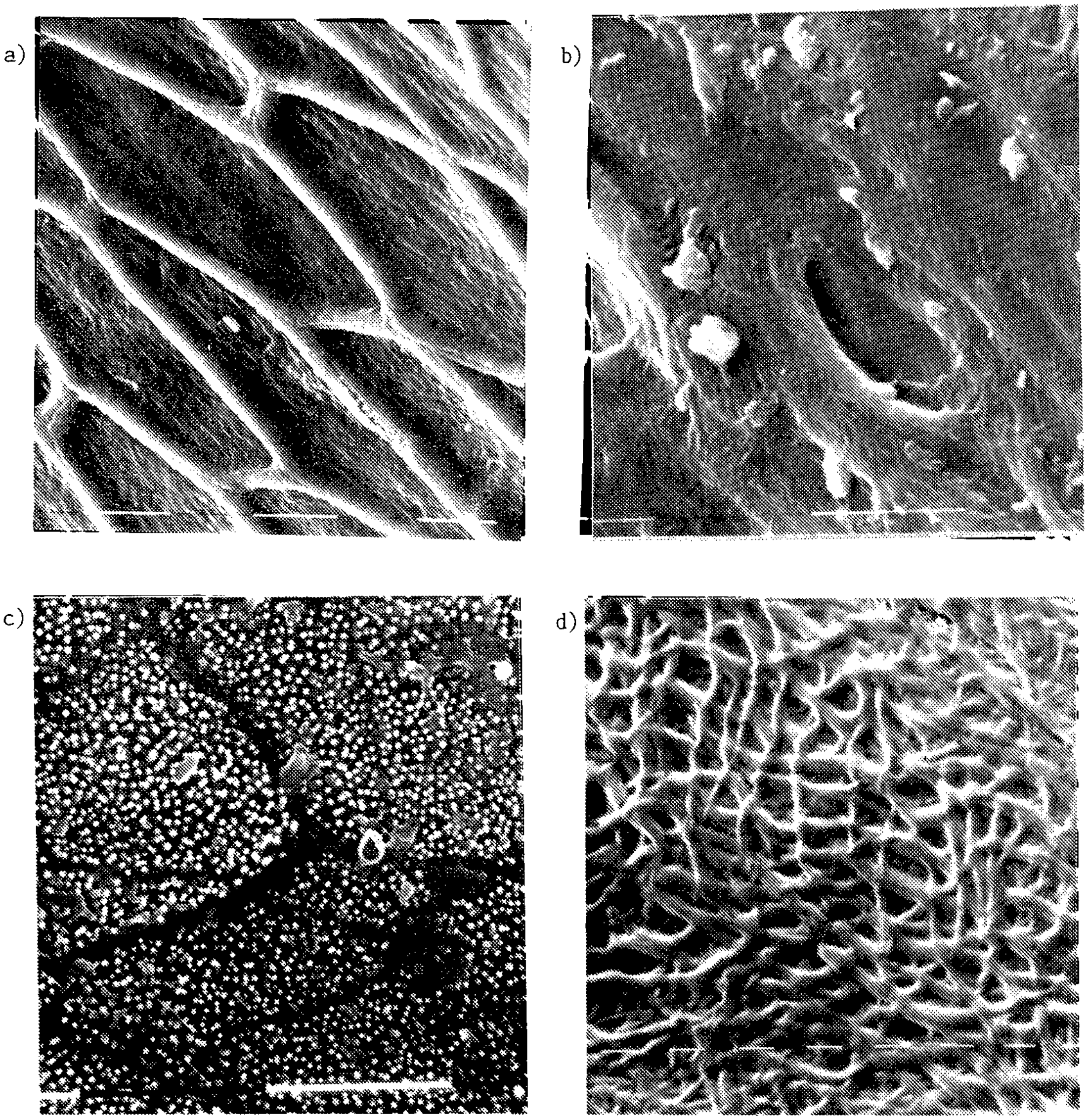
	I	II	III	IV	V	VI	VII	VIII	IX	X
fresh specimens Mallard 1 --> 7	R(FF)	R(FF)	R(FF)	R(FF)	F	R(FF)	R(FF)	RF	VSP	5
museum specimens Mallard 1 --> 8	R(FF)	R(FF)	R(FF)	R(FF)	F	R(FF)	R(FF)	RF	VSP	5

Legend Table 1 and 2
I= structure on the ventral lateral surface of the rachis ventral to the rami, II= structure on the ventral lateral surface of the rachis between the rami, III= structure on the proximal surface of the ramus at the ventral lateral part of the rachis , IV= structure on the distal surface of the ramus at the ventral lateral part of the rachis , V= structure on the ventral surface of the rachidial barbules , VI= structure on the dorsal lateral surface of the rachis between the rami, VII= structure on the proximal surface of the ramus at the dorsal lateral part of the rachis , VIII= structure on the distal surface of the ramus at the dorsal lateral part of the rachis , IX= structure on the dorsal surface of the rachis, X= type of cell boundary.
With: -= absent; o= unknown; R(FF)= rachidial ribs containing a finely frayed surface; Vi (a to e)= rachidial villi with densities ranging from abundant, common, frequent, ordinary to rare; RF= roughly frayed; FF= finely frayed; RS= relatively smooth; F= frayed; VSP= very small pits; 4= cell boundary type 4= incomplete cell boundaries; 5= cell boundary type 5= very thick lines.

2. Interspecific study

An interspecific study was carried out since there were no intraspecific differences in the features examined. Special attention was given to their possible use as determination characteristics and to their possible use in solving some of the problems in bird classification.
A lot of different structures (e.g.: Fig.3a to d) were discoverd in the examination of the surface of the feather rachis, rami and rachidial barbules.

"FIGURE 3a to d: Structure on the lateral ventral surface of the rachis: a) between the rami: R(FF): Mallard (*Anas platyrhynchos*), b) ventral to the rami: GDP: Green Woodpecker (*Picus viridis*), c) between the rami: Vi with cell boundaries type 1: Northern Gannet (*Morus bassanus*), d) between the rami: R(VRF): Common Gallinule (*Gallinula chloropus*)." One graduation equals 10 µm.



2.1. Structures on the lateral surface of the rachis (dorsal and ventral) and on the proximal and distal surface of the rami

Up to now, five main different structures were found on the dorsal and ventral lateral surface of the rachis and on the proximal and distal surface of the rami: 1) rachidial ribs containing either a granular (R(FF)), a roughly frayed (R(RF)) or a very roughly frayed (R(VRF)) surface; 2) rachidial villi (Vi) in various shapes and densities; 3) roughly frayed (RF); 4) finely frayed (FF) and 5) great deep pits (GDP) only found, when present, on the ventral lateral surface of the rachis ventral to the rami.

The structures described above are more pronounced on the ventral part of the feather in most cases. In some species these structures appeared with the same intensity on the dorsal part of the feather. At the proximal and distal surface of the ramus, close to the attachment of the ramus with the rachis, mostly the same structure was found as on the corresponding lateral surface. Away from the attachment, these structures become more and more indistinct although there are certain species for which the rami show no fading of the present structures along the cut-off piece. In still other species the structure on the rami surface differs from that on the lateral surface of the rachis.

2.2. Structures on the ventral surface of the rachidial barbules

In the species so far examined this part of the rachidial barbules may be frayed or may carry rachidial villi.

2.3. Structures on the dorsal surface of the rachis

The ventral surface of the rachis is simply frayed, while its dorsal surface may carry different structures. The dorsal rachis surface may be relatively smooth, frayed, pitted (small or deep pits, whether containing a kind of a core or not), may carry villi or show the structure of a honeycomb.

2.4. Different types of cell boundaries

The cell boundaries are supposed to correspond with the cell borders of the surface cells. Five types are distinguished:
Type 1: fine, deep laying lines
Type 2: fine, rising lines
Type 3: thick rising lines
Type 4: incomplete cell boundaries
Type 5: very thick lines.

All features described above are found in numerous combinations.

3. Conclusions

Although I am aware that statistical analysis and quantification of certain features will provide more precise conclusions, I can, at the moment, draw your attention to a few striking observations.

An advantage of using external surface structures of the rachis, rami and rachidial barbules as determination features is that all the feathers of a bird show the same structures along the whole length of the rachis. At the same time no intraindividual, sex linked or age differences are found. I agree with Brom (1986) and Frank (1939) that there are no differences in micromorphology between fresh feathers and feathers from bird skins that have been preserved for many years.

Concerning the interspecific study, a lot of external surface structures appear in numerous combinations.

No differences are found among the species studied in the order Anseriformes, family Anatidae. The only difference that the Common Pochard (*Aythya ferina*), Black Scoter (*Melanitta nigra*) and Common Goldeneye (*Bucephala clangula*) show with the other anseriform species is that the dorsal surface of the rachis exhibits a regular cell pattern with an elevation between the cell borders.

In the order Passeriformes differences between species are minute. Only the nature of cell boundary and the dorsal surface of the rachis show slight differences.

In other orders (e.g. O. Pelecaniiformes, Ciconiiformes, Gruiformes, Charadriiformes, Coraciiformes) large differences between families have been observed.

Before drawing any further conclusions, I will quantify certain parameters and perform a detailed statistical analysis of my observations. Further study will give more information on the exact value of this set of characters for determination purposes and for avian taxonomy.

ACKNOWLEDGEMENTS

I wish to express my thanks to Prof. Dr. F. Ollevier and Prof. em. Dr. A.F. de Bont for enabling me to carry out this study on the surface structures of bird feathers.
I would like to thank Dr. M. Louette from the Museum of Tervuren, Drs. Steven Vansteenkiste, Werner Vonckx and the Wielewaal Turnhout for providing the feathers and the Royal Belgian Institute of Natural Sciences for the use of the scanning electron microscope.
This research was supported by the General Staff of the Belgian Air Force.

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ADF616403

BSCE 20 / WP 4

Helsinki 1990

INFLUENCE OF BIRD-SHOOTING ON THE RELATION:
NUMBERS PRESENT/INCIDENTS

Ing. A. Klaver

Manager Operations

AMSTERDAM AIRPORT SCHIPHOL

INFLUENCE OF BIRD-SHOOTING ON THE RELATION: NUMBERS PRESENT/INCIDENTS

Recent B.S.C.E. meetings have always underlined or left open the possibility of shooting birds in bird control operations as an aid in the range of making the airport area unattractive to birds or dispersing birds from the airport. This is also reflected by the action with respect to the European bird directives whereby the shooting of (protected) birds in relation to air traffic safety remains allowed.

In the Green Booklet of the Aerodromes Working Group are listed the countries that have taken the measure of shooting birds. It may be argued once more that it is clear that the shooting of birds is a last resort to get rid of stubborn individuals as a final underlining of the dispersal technics.

It is also clear that the non-elimination of populations comes first (filling up the biotope), but elimination of individuals to such an extent that no or hardly any supplement from outside will take place. Seen in this light I would like to introduce the term "maximum/minumum population" in the control of bird species at an airport.

For this category are eligible those bird species brooding on an airfield or in the immediate vicinity and staying there either the whole year and/or showing dangerous behaviour or do so during their breeding season.

For Schiphol Airport they include pheasants, herons, partridges, sea pies, pigeons (various species) and wild ducks.

The enclosed graphs show, on a long-year basis, the relation between registered birds (17 counts per year) incidents/birds found dead and birds shot.

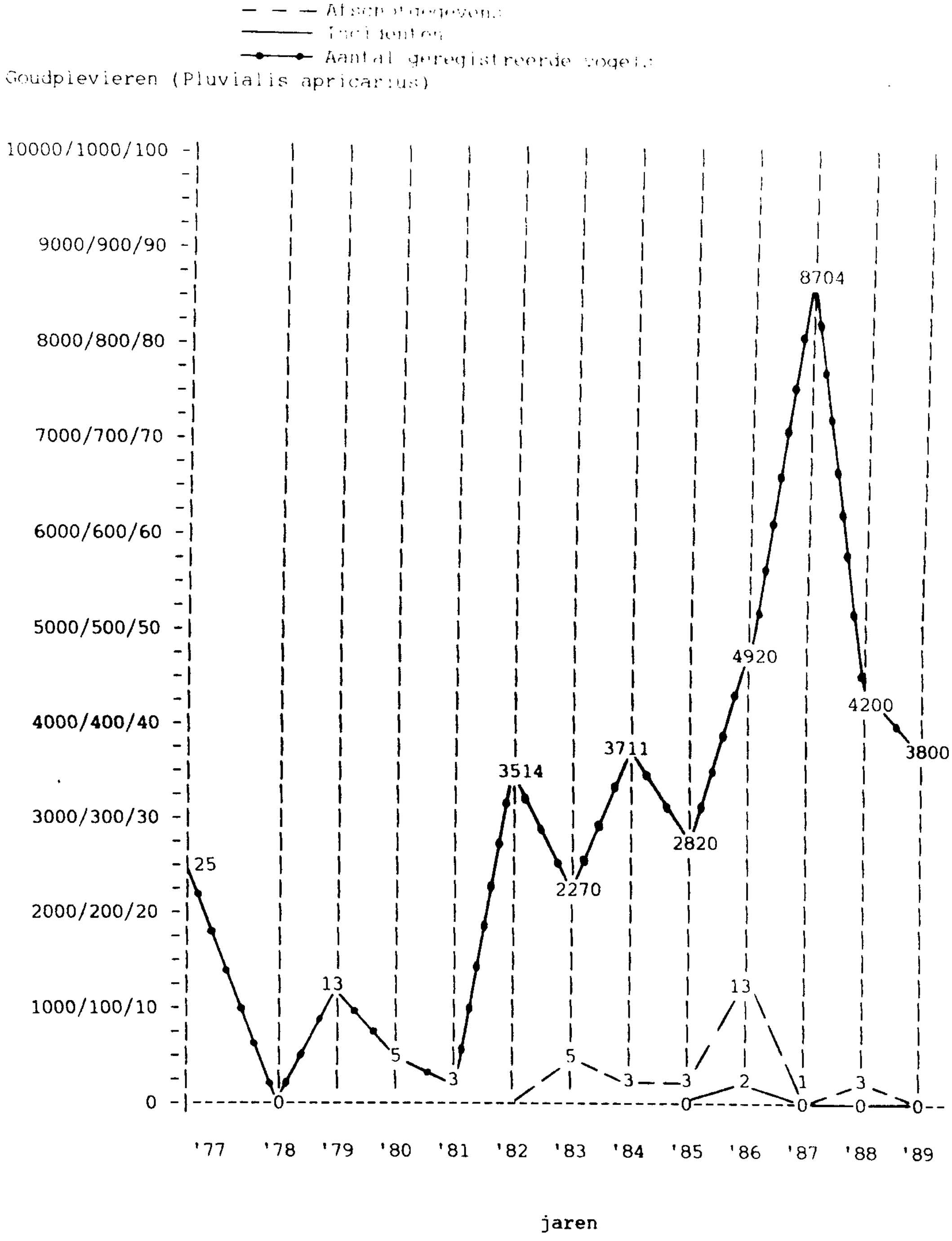
For sea pies, herons, pheasants and partridges it is evident that the aim of reaching a maximum/minumum population by means of shooting has some success in the reduction of bird strike incidents. Of bird species such as lapwings and gull species, there is hardly question of an effect of shooting other that the underlining of the dispersal methods applied.

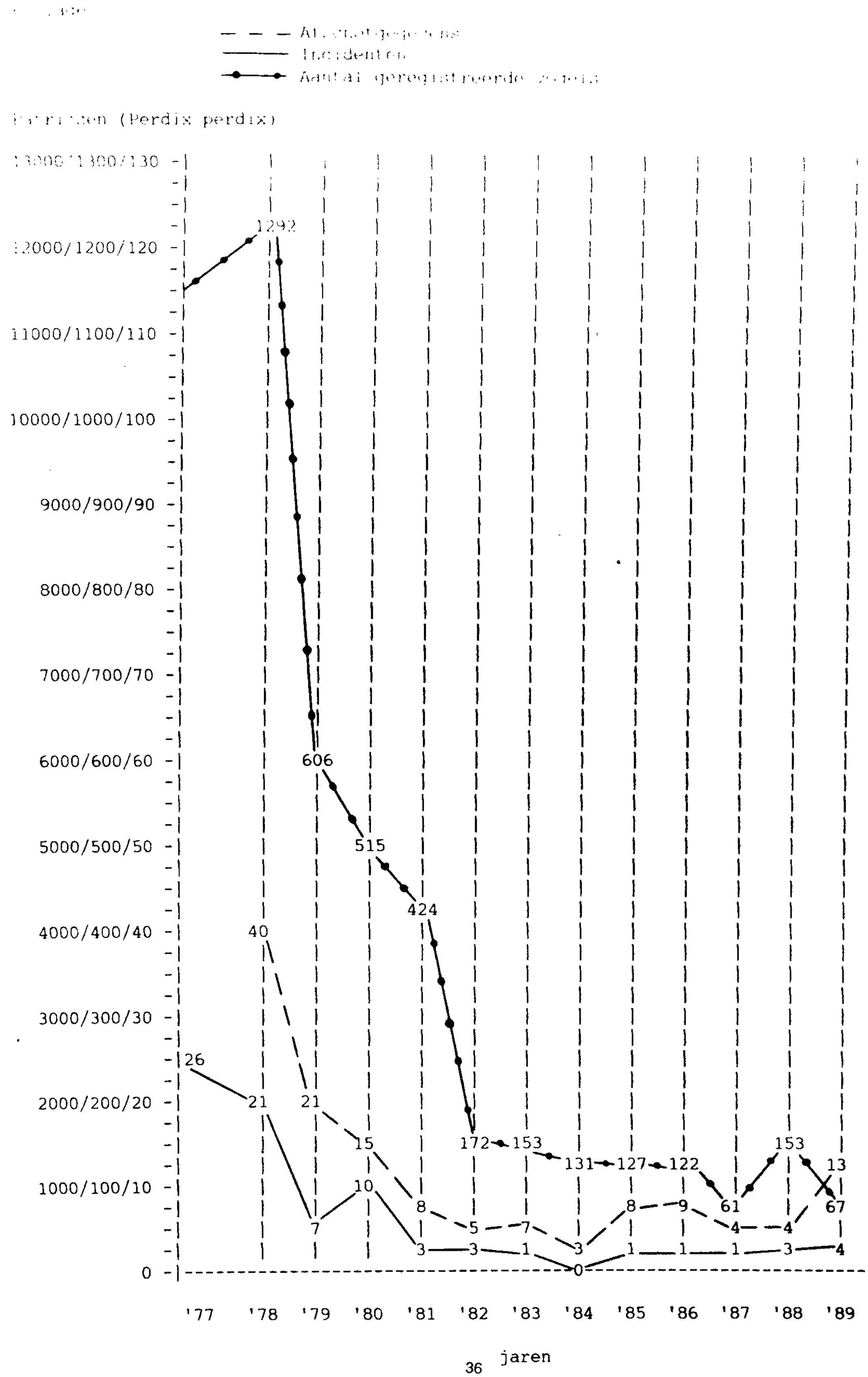
I suggest that the influence of shooting/hunting birds within the framework of bird control/prevention be elaborated further in the Aerodromes Working Group, whether or not in a sub-working group.

Amsterdam Airport Schiphol
Ing. A. Klaver
Manager Operations

Bijlage [illegible]

Goudplevieren (Pluvialis apricarius)

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Aantal geregistreerde
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12000/1200/120
11000/1100/110
10000/1000/100
9000/900/90
8000/800/80
7000/700/70
6000/600/60
5000/500/50
4000/400/40
3000/300/30
2000/200/20
1000/100/10
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1292
606
515
424
172
153
131
127
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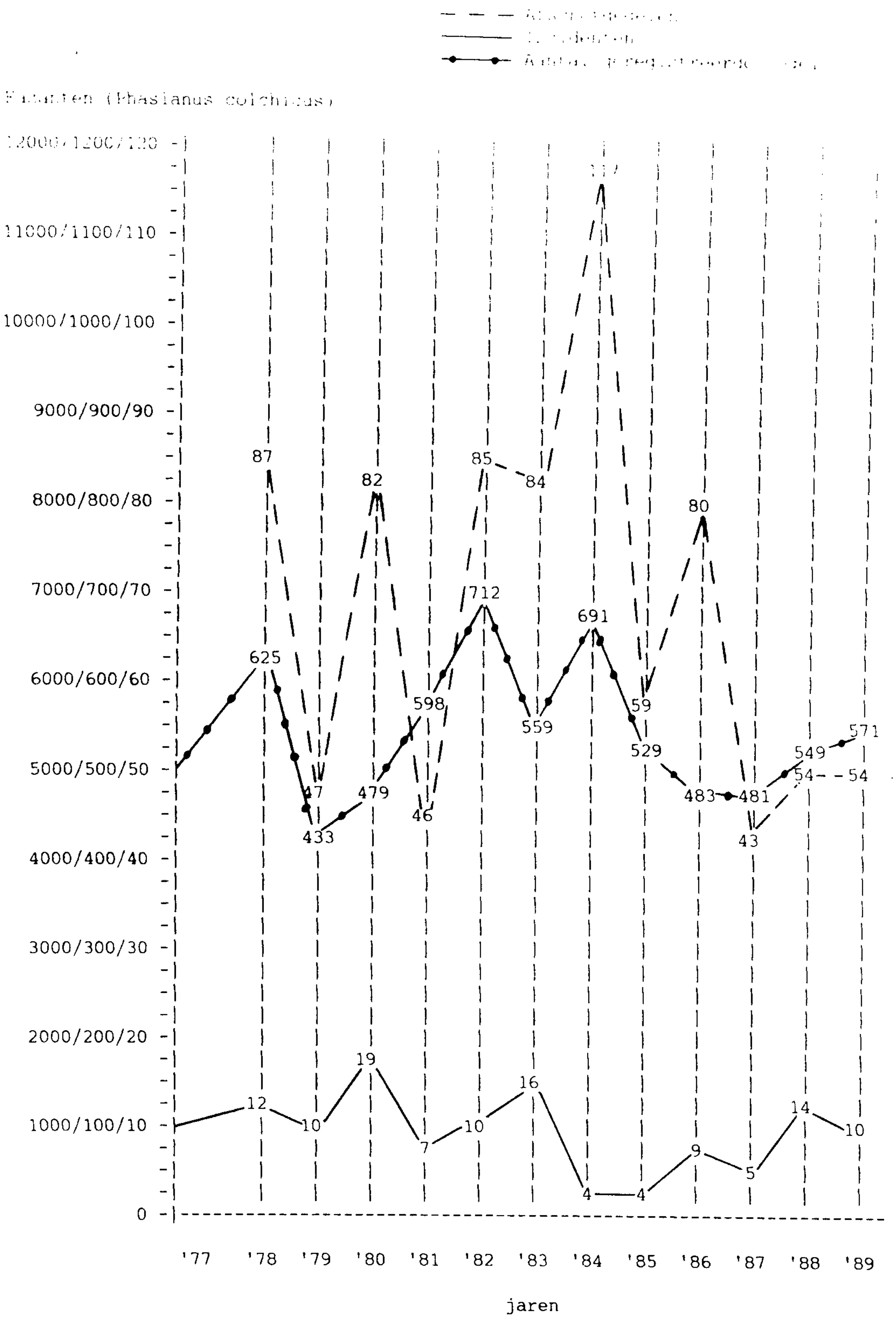
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10000/1000/100
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8000/800/80
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6000/600/60
5000/500/50
4000/400/40
3000/300/30
2000/200/20
1000/100/10
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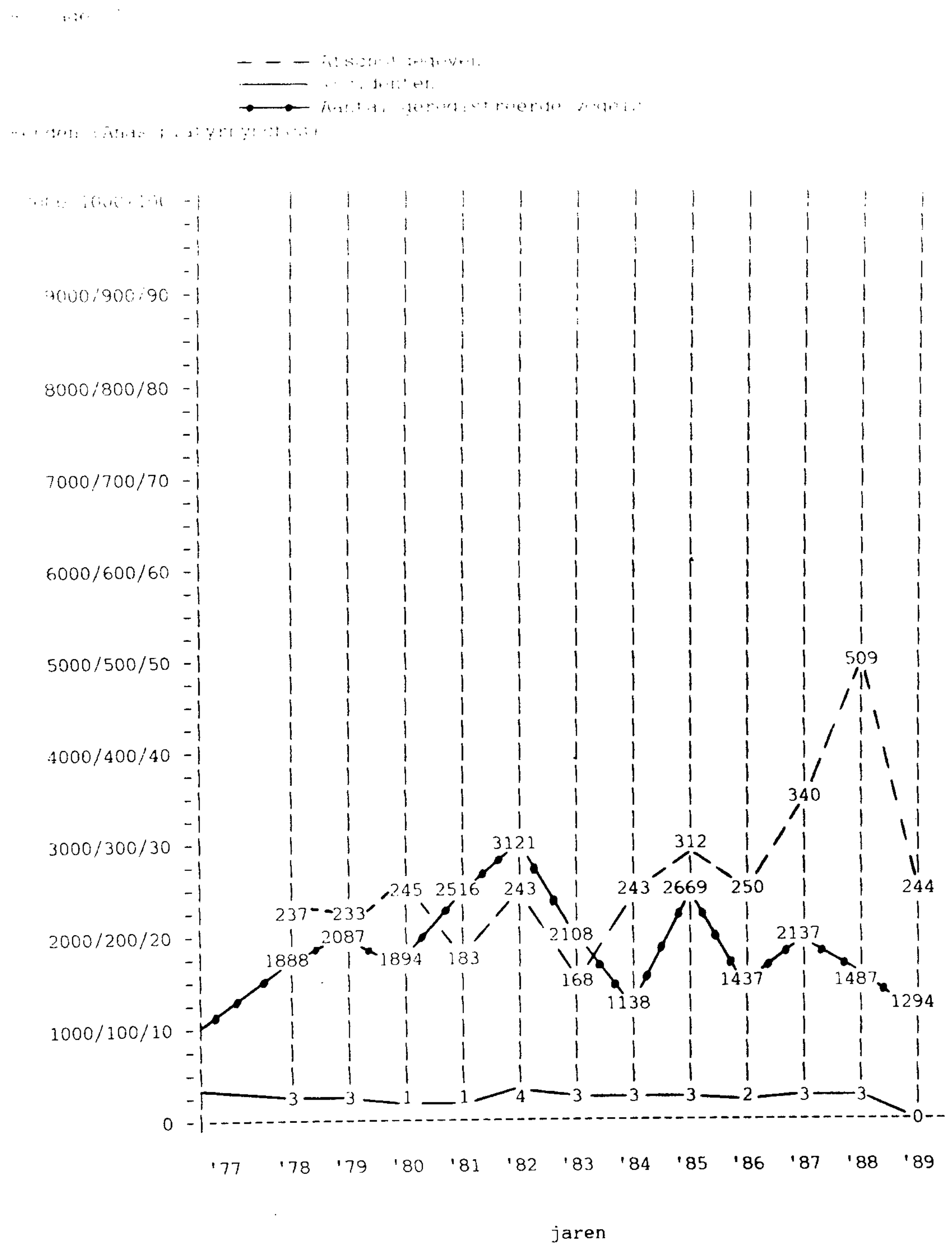
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3000/300/30
2000/200/20
1000/100/10
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245
2516
3121
243
183
243
312
2669
250
340
509
244
1888
2087
1894
2108
168
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2137
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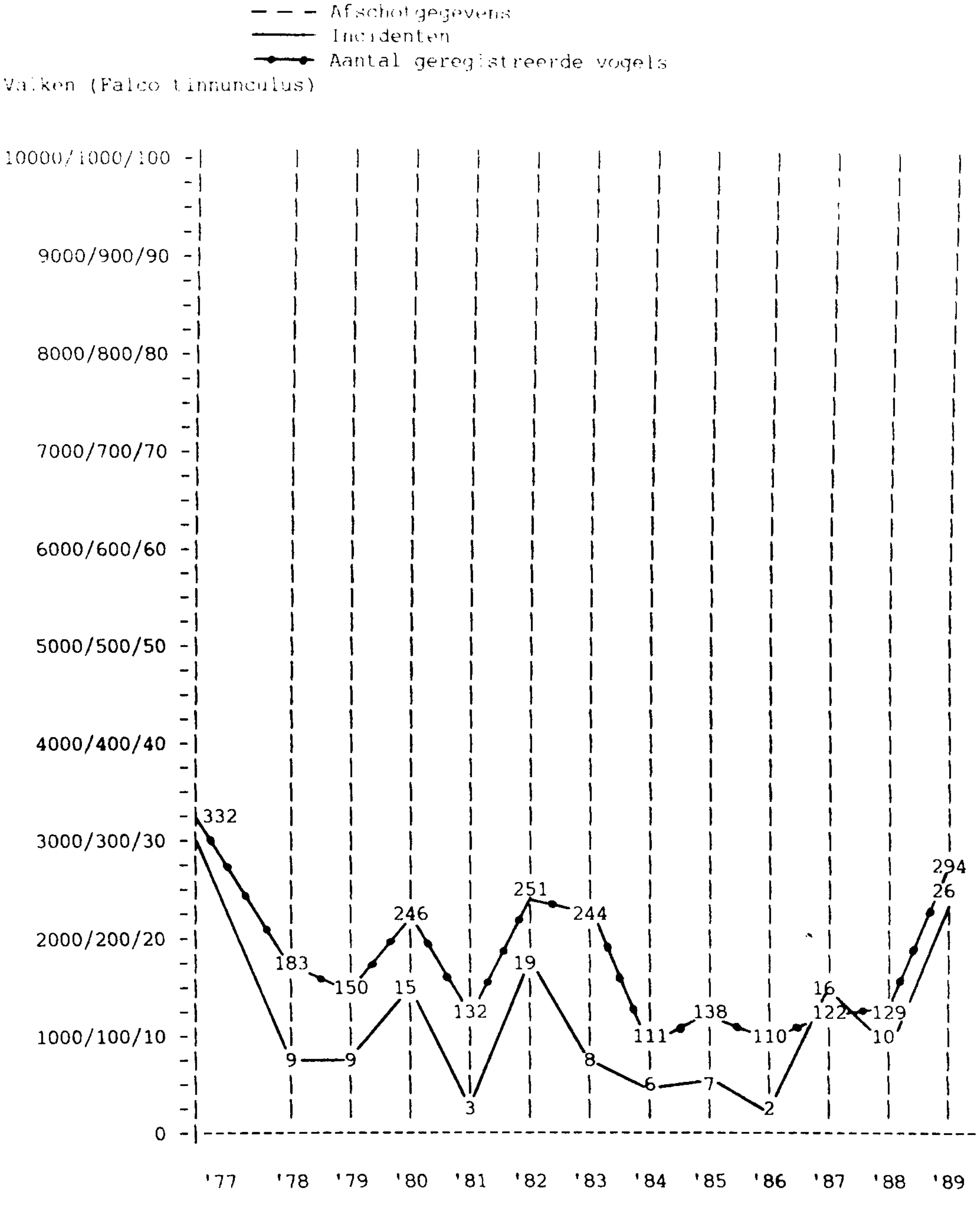
Bijlage II



Afschotgegevens
Incidenten
Aantal geregistreerde vogels
Valken (Falco tinnunculus)
10000/1000/100
9000/900/90
8000/800/80
7000/700/70
6000/600/60
5000/500/50
4000/400/40
3000/300/30
2000/200/20
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0
332
183
150
246
132
251
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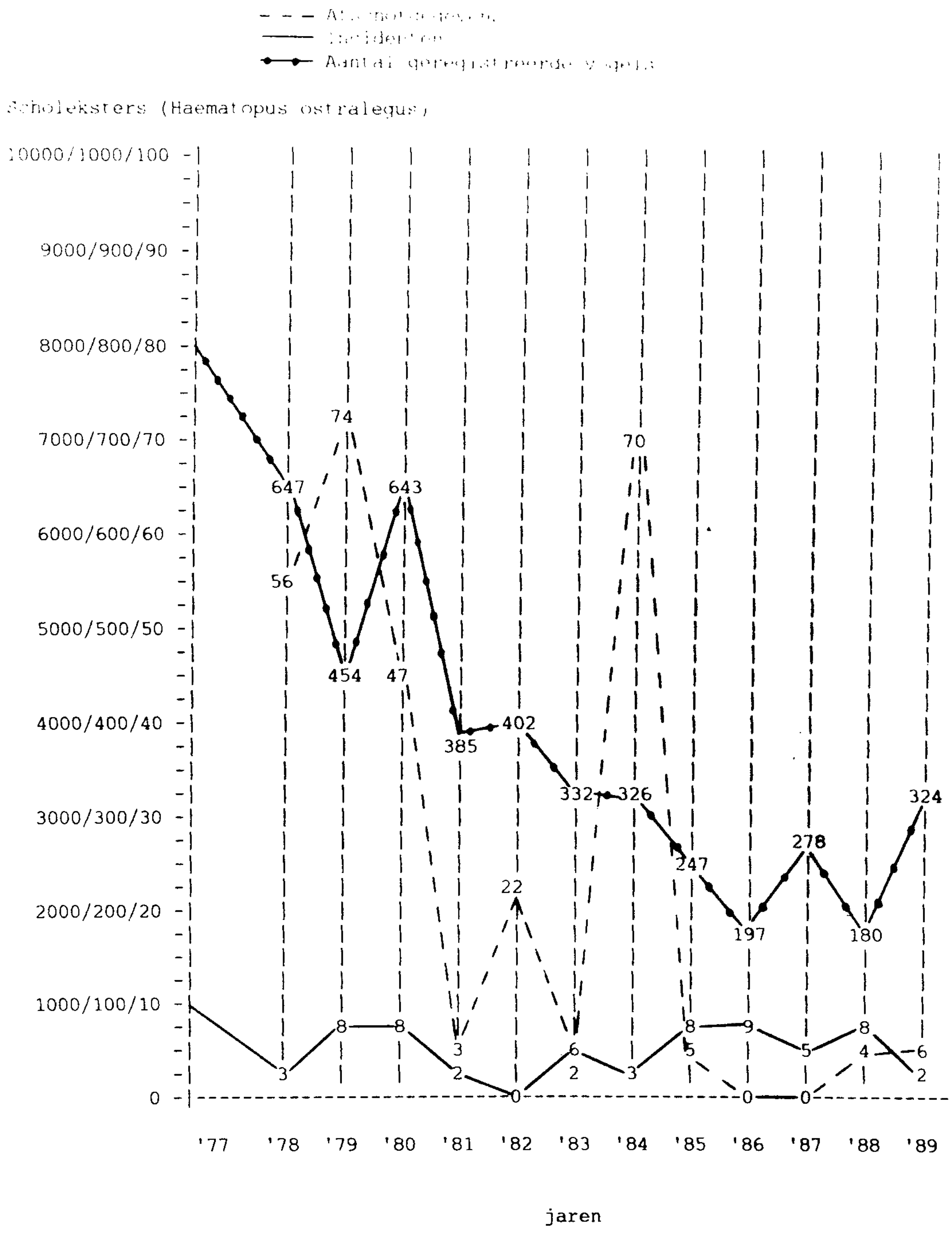
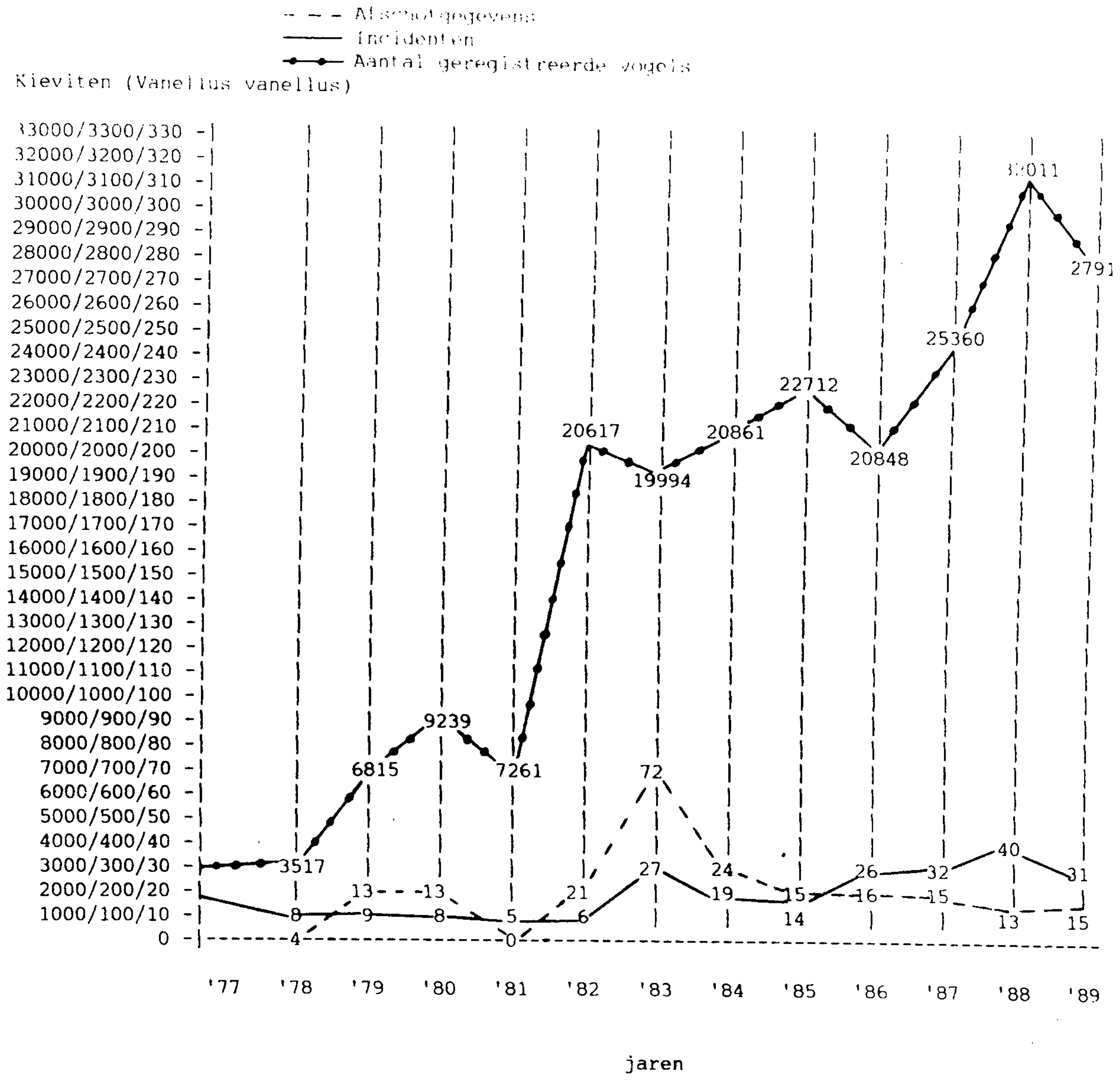
Bijlage 11



Scholeksters (Haematopus ostralegus)

Bijlage 11



Afschotgegevens
Incidenten
Aantal geregistreerde vogels
Kieviten (Vanellus vanellus)
33000/3300/330
32000/3200/320
31000/3100/310
30000/3000/300
29000/2900/290
28000/2800/280
27000/2700/270
26000/2600/260
25000/2500/250
24000/2400/240
23000/2300/230
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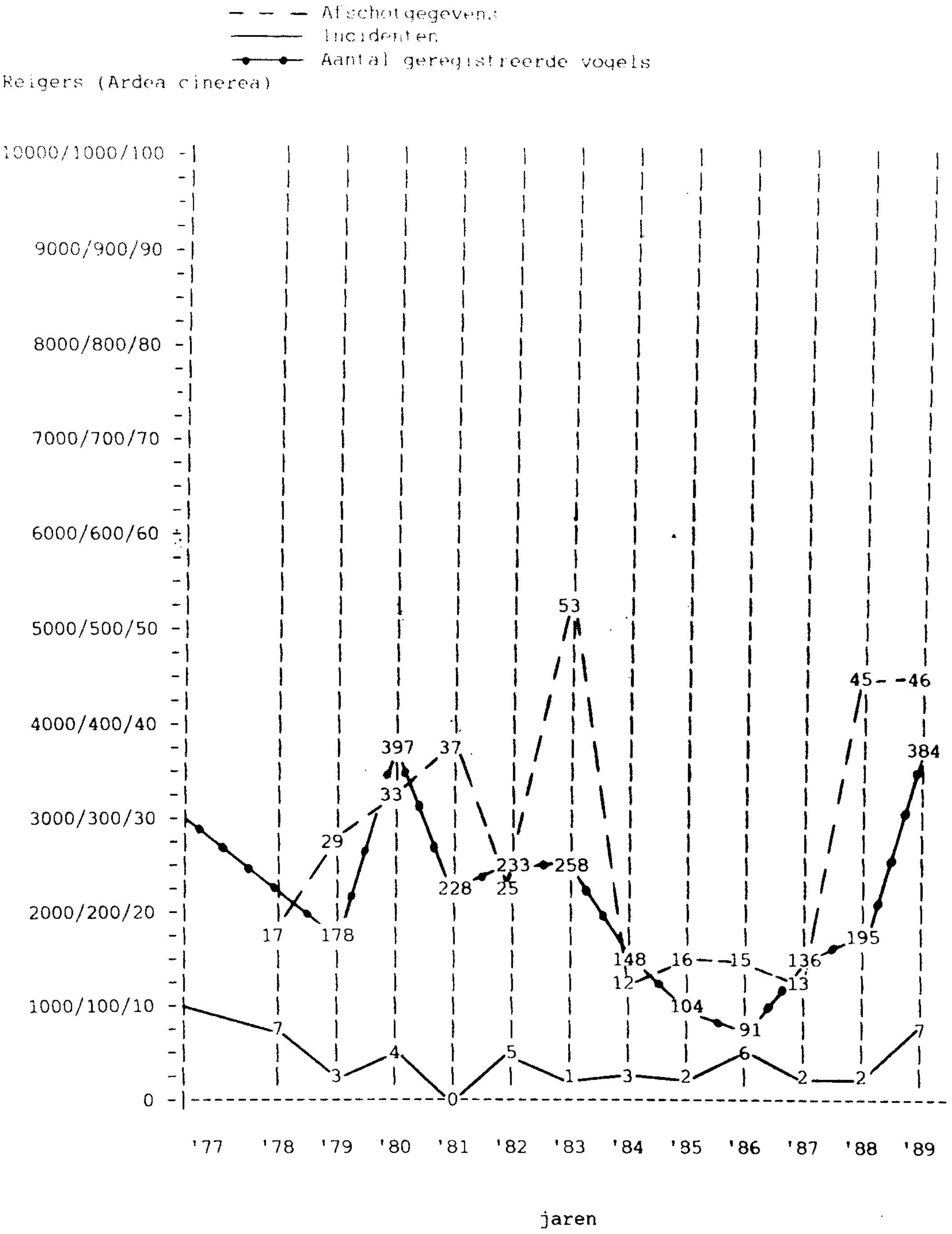
- - - Afschotgegevens
——— Incidenten
—•—•— Aantal geregistreerde vogels
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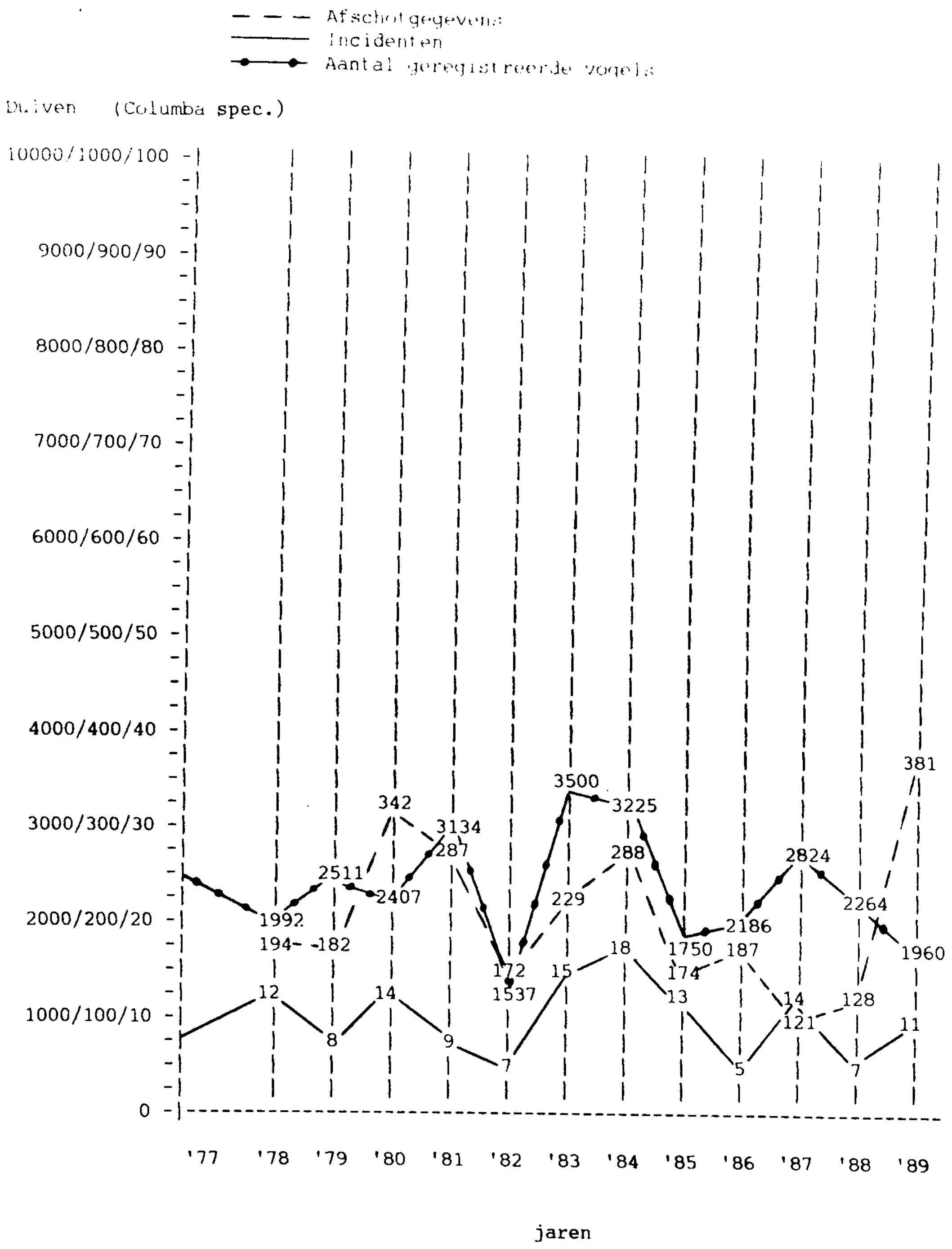
Bijlage 11



Afschotgegevens
Incidenten
Aantal geregistreerde vogels
Duiven (Columba spec.)
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6000/600/60
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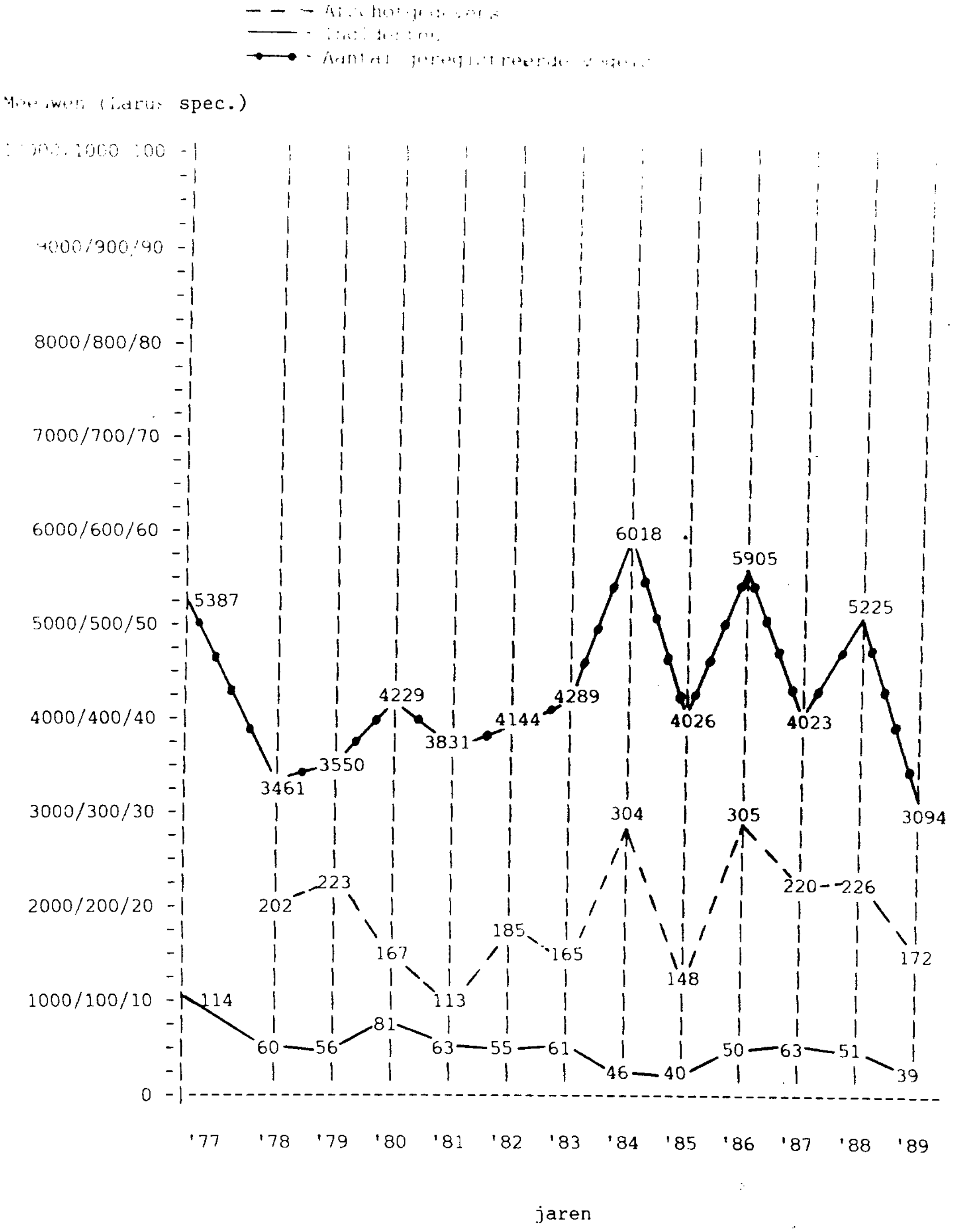
Aantal geregistreerde [illegible]
Meeuwen (Larus spec.)
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ADF616404 BSCE 20 / WP 5

RACHIDIAL STRUCTURES OF FEATHERS AND THEIR POTENTIAL USE FOR DETERMINATION PURPOSES.

Karin Perremans
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A first approach in solving the problem of collisions between birds and aircrafts is the identification of the bird species involved.

Birdstrikes of the Belgian Air Force are reported by the pilot and/or maintenance personnel. A "Bird Identification Form" is send to our lab together with the bird remains. The identification of those remains is carried out as following:

1. macroscopical analysis;
2. microscopical analysis;
3. scanning electron microscopical analysis.

This procedure gives a positive identification in 90% of the cases.

Because none of the published methods gave satisfactory results, I developed a new method. I searched the feather from base to tip by means of the S.E.M.. In doing so I discovered microstructures on the rachis.

In an intraspecific study I found that these external rachidial structures are present along the total length of the rachis. I also discovered that neither the site of feather implantation nor the duration of preservation influenced the observed structures. Even the feathers of different individuals of the same species show the same external rachidial structures: they are neither influenced by sex or age.

Since there are no intraspecific differences I progressed to an interspecific study. A lot of different rachidial structures were found on the rachis. Five types of cell boundaries seem to be present, while the dorsal surface of the rachis shows at least six different structures.

All these features, discovered in an interspecific comparison, appear in numerous combinations.

I will focus further research on the Charadriiformes (gulls and waders). I intend to use these data for determination purposes and eventually to elucidate a few classification problems in the class of Aves.

ADF616 405

BSCE 20 / WP 6

IMPROVING BIRDSTRIKE RESISTANCE OF AIRCRAFT WINDSHIELDS

R.J. Speelman
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Flight Dynamics Laboratory
Wright Research & Development Ctr
Wright-Patterson AFB OH 45433

R.C. McCarty
Aircrew Protection Branch
Flight Dynamics Laboratory
Wright Research & Development Ctr
Wright-Patterson AFB OH 45433

ABSTRACT

USAF aircraft repeatedly prove that birds and aircraft cannot occupy the same airspace at the same time; over 3000 birdstrikes per year cause millions of dollars in damage to USAF aircraft. During the past 20 years sixteen aircrew members have been killed and 23 aircraft have been destroyed due to bird impact. More of these losses are due to birdstrikes on the windshield subsystem than to any other subsystem. Windshield systems on several different aircraft are being redesigned to improve tolerance of the birdstrike event. These efforts to improve windshield system birdstrike resistance and other efforts to improve cost-of-ownership characteristics of these windshields will be discussed. Some technical voids in designing for, and integration of, birdstrike resistance will be discussed.

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*Status report/working paper to be presented inn fulfillment of responsibilities as member of Structural Testing Working Group at the Birdstrike Committee Europe Meeting, 21-25 May 1990, in Helsinke Finland.

BSCE 20
HELSINKI
May 21st-25th, 1990

ADF616406

BSCE 20/WP 7
Helsinki, 21-25 May 1990

Contact Persons Regarding Bird Strike Work

(Presented by BSCE Chairman)
(revised August 1990)

1. Introduction

At the end of the 19th BSCE meeting in Madrid 1988, the Plenary decided that there is a need for a revised list of persons to be contacted in connection with bird strike work in each country.

2. On the basis of replies received from persons appearing in former lists, the below persons may be considered as persons to be contacted in each country for bird strike subjects:

Mr. Peter Davidson
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Tel.: +32-2/2121211
Fax: +32-2/2176284
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Tel.: +1 (613) 990-1401
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Telex: 053-3130

Mr. Jiri Dobísek
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Czechoslovakia

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Rob de [illegible]

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[illegible]

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Fax: +358 0 8292 829
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Fax: +30-1-8947101 GR
Telex: 214444 GR

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Bombay Natural History Society
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Shahid Bhagat Singh Road
IND-Bombay 400 023
India

Tel.:
Fax:
Telex:

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3. The meeting is asked to note the working paper and inform the Chairman of any changes or errors.

ADF616402

BSCE 20 / WP 8
Helsinki 1990

FEATHER IDENTIFICATION BY MEANS OF KERATIN PROTEIN ELECTROPHORESIS

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SUMMARY

Identification of feathers by visual means leaves a percentage of unidentifiable samples, particularly at the lower taxonomic levels. Optical or scanning electron microcopy can improve results but about 25% of the samples cannot be identified below the family level. Electrophoresis of proteins extracted from feather keratin, used previously in taxonomic research, can provide reliability and repeatability in identifying feather remnants from any source. Protein extraction has been refined and standardized, as well as the methodology for electrophorizing feather protein concentrates. Current results indicate that identifications to the species level provided the sample is at least 10 mg can be obtained in most cases. There is little individual variation and differences between species are significant and can often be assessed visually. When gels are scanned with a laser densitometer, the differences between each keratin profile are more obvious and can be measured. The values of the curve can be used for separating closely related species. Our results indicate a high success rate and precision in identifications exceeding the results obtained by other means for the samples that cannot be identified visually.

1. INTRODUCTION.

The identification of bird remains resulting from collisions with aircraft can be a difficult task particularly when remnants are very small or have been seriously fragmented on impact. When the samples are sufficiently large, direct comparison with specimens in research and reference collections coupled with the use of macroscopic visual clues is the usual procedure to insure identifications. In this manner no less than 50% of the samples can be identified by an experienced ornithologist. It is necessary to employ different techniques to identify the remaining 50% of the samples with various levels of success. Although a number of feather identification techniques have been described elsewhere (Robertson et al. 1986), the procedure in use at the Canadian Museum of Nature for bird strike remains identification is outlined briefly before detailing the methodology and procedure for feather identification using protein electrophoresis of keratin.

2. IDENTIFICATION BY VISUAL MEANS.

2.1 Basic Visual Means.

A project was initiated to improve upon the identification performance of undetermined samples by straight visual comparisons or with the use of low optical magnification and to obtain identifications at the Species level in higher proportions. One of the first objectives was to devise identification keys for two families of North American birds based on the extensive visual analyses of certain feathers selected on body parts. These feathers were selected because they display homogeneity in form, colour, or coloration pattern. Only thoroughly cleaned feathers, free of any dirt, oil or other deposits were used for comparison purposes with reference specimens in the research collection. Two Families, the Anatidae (ducks, geese, and swans) and the Charadriidae (waders and plovers), were selected because of their regular occurrence in bird strikes in Canada. Feathers were obtained from the upper and lower parts of the body [crown, neck, upper and lower dorsum, throat, breast, flanks, and abdomen] for all the Canadian species of Anatidae (12 feathers) and Charadriidae (11 feathers). Each species is represented by adult males and females, and immatures of both sexes when sexual dimorphism occurs. Each feather was meticulously examined and described using various criteria such as colour, coloration patterns, the presence of characteristic markings, or other distinctive features. Comparisons of these characters were then made for all the feathers from each area and for each species. This long and tedious process was followed for each feather represented in the sample.

The results permitted to isolate individual feathers or groups of feathers with common characteristics, thus allowing for the identification of a single species or a group of species sharing similar characters. Identification keys were then constructed manually based on a dichotomous choice of characters. The keys were later verified on a computer programme. It was then estimated that approximately 70% of the unidentified samples taken in these two families could be identified to the species level. The remaining 30% which comprises feathers without characteristic markings such as colour, bars, stripes, etc., could not be identified to the Species or even the Genus level. Feathers with a uniform coloration such as sandy beige, drab, buff, or white, form the bulk of this category. For example, nearly all the species of plovers have white feathers on the under parts. Similarly nearly all waterfowl species have white in their plumage. Having been unable to isolate specific differences in the structure of those feathers we found it impossible to provide identification beyond the Family level. The problem appears to be similar for other families of birds found in Canada although it has not been studied extensively. For such groups as the Laridae (gulls) and many species of songbirds in which several species share large numbers of common characters in a very large number of feathers, the specific determinations are usually impossible to make when using only visual clues.

2.2 Optical Microscopy.

The microscopic structure of feathers (Chandler, 1916; Sick, 1937; Voitkevich, 1966) provides as well important clues and is very useful in the identification of a significant number of samples that cannot be identified readily upon basic visual examinations but seldom provides the essential clues for identifications to the Species level. Using the structure of downy barbules, Brom (1986) stated that

97% of the feather samples can be identified at the Order or Family levels. Our results concur but our success rate for any identification below the Family level (Genus and Species) using this technique is very low and does not improve significantly the overall identification performance.

2.3 Scanning Electron Microscopy.

Another phase of the study consisted in trying to detect differences and identify at a more precise taxonomic level the samples of the Anatidae and Charadriidae which could not be identified by other means. Feathers of all the species studied earlier by other techniques were examined by means of a scanning electron microscope. With this powerful tool it was possible to study accurately (Davies 1970) the microscopic structure of feathers. Magnification was either at 500 or 1000 times, which permits a detailed examination of the barbs, barbules, nodes, and internodes. Precise measurements of the various components of the feathers were recorded for comparative purposes and analysis. Within each family, only insignificant differences were found between the various species but these differences are not sufficient to allow identification, even at the Genus level.

The distance between the various components of the feather structure (nodes, internodes, etc.) or the shape of these elements (nodes, barbs, hooks, etc.) are so overlapping in size or form, even on the same feather that it is impossible to obtain an identification on that basis. However, the differences recorded in the structure of the feathers in the Laridae and Charadriidae can be used to identify feathers at the Family level.

These results are in agreement with Brom (1987) and Chandler (1916) who used standard microscopic techniques in their studies. It can be concluded that satisfactory results can be obtained using Brom's (1986) technique for identification at the Order and Family levels and that the utilisation of the scanning electron microscope is an expensive and labour intensive technique which, although it reveals more information than standard light microscopy in the study of feather structures, is not satisfactory for the identification of feathers.

2.4 Summary.

A critical evaluation of these results, including series of tests to verify the accuracy of identification keys, techniques of macroscopic visual examination, conventional dissection microscopy, and light transmission microscopy, indicates that the detailed and precise identifications of nondescript feathers, which constitute approximately 25% of the samples submitted for determination, can only be achieved through other techniques.

3. ELECTROPHORESIS OF FEATHER KERATIN.

Electrophoresis of proteins obtained from the keratin of feathers has been used in a limited way in taxonomic work and indicate that the proteins of keratin have similarities among themselves, have small molecular weights, and vary from species to species (Brush 1976; Brush and Witt 1983; Busch and Brush 1979; Knox 1980a, 1980b). These results suggested that the technique could have a useful potential in the identification of feather samples that could not be identified by any of the other means as outlined earlier.

3.1 Protein Extraction.

Whole feathers are cleaned in batches by washing in hot detergent and rinsing in hot tap water. When dry, they are rinsed in two changes of naphtha (hexanes, Fisher), once in distilled water, and in two changes of denatured alcohol. After final drying they are packaged and stored for future use (Knox 1980a).

Keratin is extracted from 10 mg of finely cut feather samples. To each of these samples 1.0 ml of extracting solution consisting of 0.05M THAM (Fisher T-370), 8M urea (Fisher 4204-1), and, at the last minute, 0.05M dithiothreitol [DTT] (Pharmacia) is added (Marshall et al. 1986). The samples are stirred overnight under an atmosphere of nitrogen at room temperature. Each reaction mixture is centrifuged [12,000 rpm, 10 min; Eppendorf 5415 Microfuge] to sediment the residual feather fragments. The supernatant is removed and stored at -20° C.

To 25μL of each extracted sample 5μL of 0.1M DTT is added at least 10 min before typing (Carracedo et al. 1986). The samples are added to Pharmacia polyacrylamide Phastgel IEF 3-9 presoaked for 15 min in 1.0μl Pharmacia Pharmalyte 3-10, 250μl 20% NP-40, 12% sucrose, and 5.0ml distilled H_2O.

3.2 Protein Electrophoresis.

Isoelectric focusing proceeds at 2000V, 25mA, 4W, 20° C for 400Vh with a prefocusing phase at 2000V, 25mA, 2W, 20° C for 50Vh using the Pharmacia Phast System Separation and Control Unit. The gels are stained in the Pharmacia Phast System Development Unit using the protocol for Phast Gel IEF silver staining techniques (Phast System Owner's Manual) except that an extra step using 0.0125% DTT (Pharmacia) for 10 min at 40° C is added between steps Nos. 8 and 9 of the protocol.

4. GEL ANALYSIS.

After drying the gels are examined visually and differences between the bands of the tracks are compared. Then each track (8 on each gel) is processed on a laser densitometer (LKB Ultro Scan XL) in order to obtain quantitative values for each of the bands shown on the tracks as well as a curve of these values. Some of the bands may be undetected visually but can be separated by the beam of the densitometer. In this manner, it is possible to obtain distribution curves of the values recorded for each sample and compare these with curves of unknown samples. We designate these curves as "KERATIN PROFILES". The comparison of unknown keratin profiles against profiles obtained from known samples permits the identification of unknown feathers. An exact match can be obtained in most cases although a slight variation has been observed and is interpreted as individual variation.

5. RESULTS.

5.1 Protein Variation in Body Regions.

It was originally suspected that some variation could occur in keratin profiles corresponding to the nature of the feathers and their region of origin on the body. This possibility was tested twice. Feathers from different parts of the body of a single bird were selected and subjected to the entire electrophoresis process and the results indicate that there is no significant variation in the protein bands of the gels nor in the keratin profiles of the feathers obtained from the same individual, regardless of the parts of its body. However, when dealing with feathers longer than 15 to 20 mm or with a thick shaft, only the vanes are used.

5.2 Intersexual Variation.

Similarly, no intersexual differences in keratin profiles were noted between individuals of the same species upon extensive comparisons of keratin profiles of over 300 species.

5.3 Individual Variation.

Our results indicate that there is little individual variation in a given species. As an example, eight different individuals of the Ring-billed Gulls (Larus delawarensis) representing different sexes and ages are compared to each other and later verified by comparing large samples of keratin profiles from several species. The tracks of the gels show a great uniformity in the location of the various bands and the keratin profiles are very similar.

5.4 Interspecific Differences.

Interspecific differences between closely related congeners can be important in some cases and can often be estimated visually as indicated in Figure 1. In this case the gel shows the protein electrophoretic patterns of seven species of gulls (Larus delawarensis, L. argentatus, L. glaucoides [kumlieni], L. hyperboreus, L. marinus, L. heermanni, L. californicus, L. glaucescens). It can be evaluated visually, without the aid of any equipment, that a number of bands on each track have a common position and that the others are situated in a different place on the track. Bands that occupy a similar position in a series of tracks can be interpreted as characteristics common to species in a same taxonomic category such as the Genus, Family, or even the Order. The other bands, located in different places on the track, are considered to be Species characteristics. These differences are more obvious on the keratin profiles obtained through densitometric scanning than from the examination of the gels as shown for the eight species of gulls of Figures 2 to 9. In addition, the differences between each curve can be measured as well as any point on the curve. The values obtained can then be used for separating closely related Species or Species that have small differences such as is the case with the eight Species of gulls. Certain differences between species are small but are sufficient to distinguish between species, particularly when the values are computed and averaged for the peaks or highest values of the curves.

6. CONCLUSIONS.

The methodology described above provides a technique that allows the accurate identification of feather samples even of small size. The amount of feathers available for analysis should be in excess of 10 mg and the feathers should not have been altered by excessive heat or degenerated by chemical products. For any feather meeting these basic requirements and unsuitable for identification by visual methods, our results indicate that a high success rate, combined with a high degree of precision, exceeding by far the results secured by any other identification techniques can be attained through keratin electrophoresis and subsequent analysis of the gel patterns with a scanning densitometer. It is hoped that protein profiles for the bird species known to occur in Canada will be available during the next few months and that the results can be computerized to eventually generate rapid and accurate comparisons of unidentified samples against the known protein profiles of a data bank.

7. ACKNOWLEDGMENTS.

We wish to extend our thanks to Transport Canada for the sustained support given to this project particularly to Paul McDonald of the Environmental Review Services. We also thank Dr. Jean Vaillancourt of Université d'Ottawa for having so graciously made

available the results of his work on identification using optical microscopy and scanning electron microscopy.

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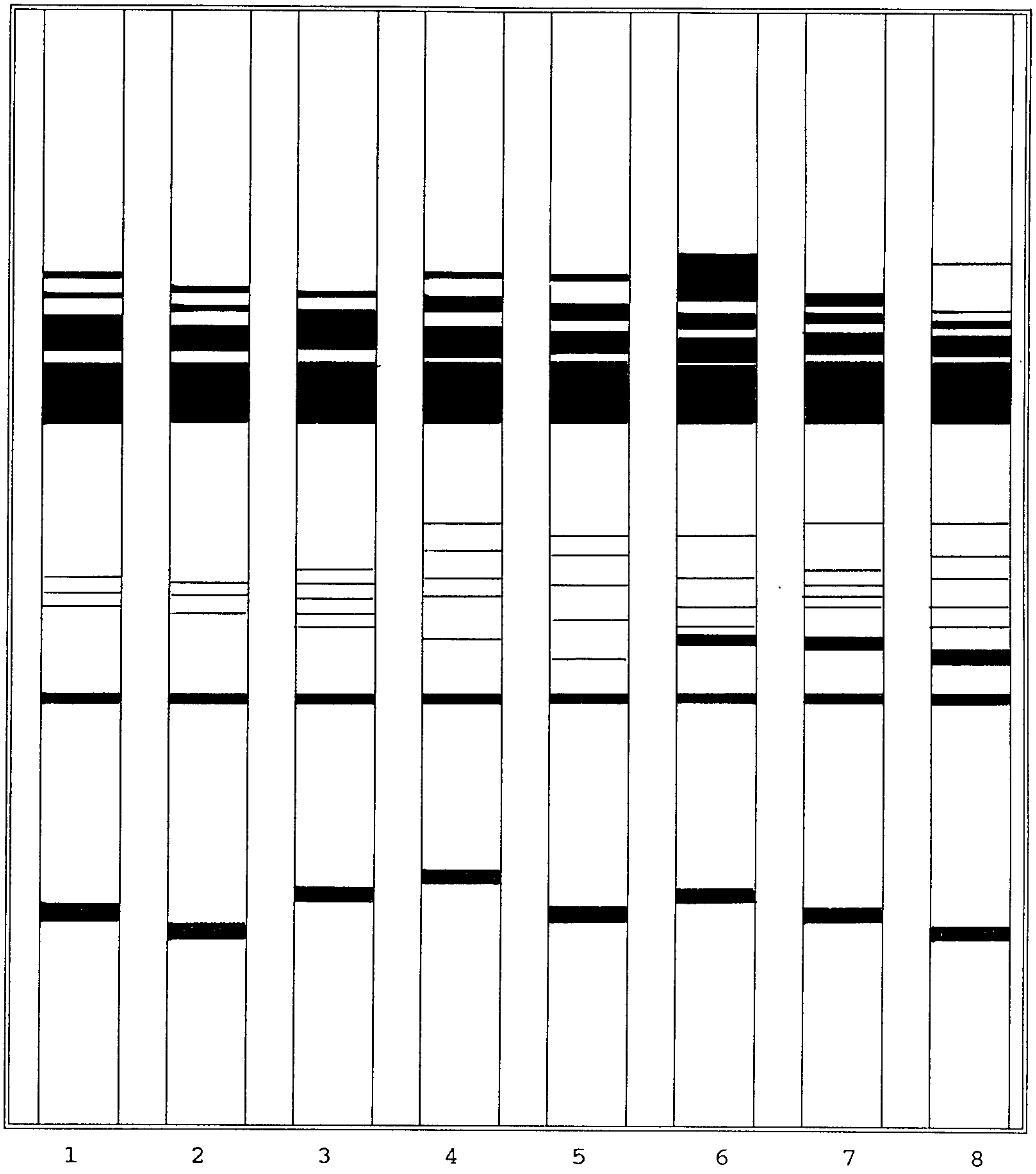
Figure 1. Schematized gel of eight species of gulls (Laridae) showing the position of the bands on the tracks in relation to each other.



1. Larus delawarensis
2. Larus argentatus
3. Larus glaucoides [kumlieni]
4. Larus hyperboreus
5. Larus marinus
6. Larus heermanni
7. Larus californicus
8. Larus glaucescens

Figure 2. Keratin profile of the Ring-billed Gull (*Larus delawarensis*).

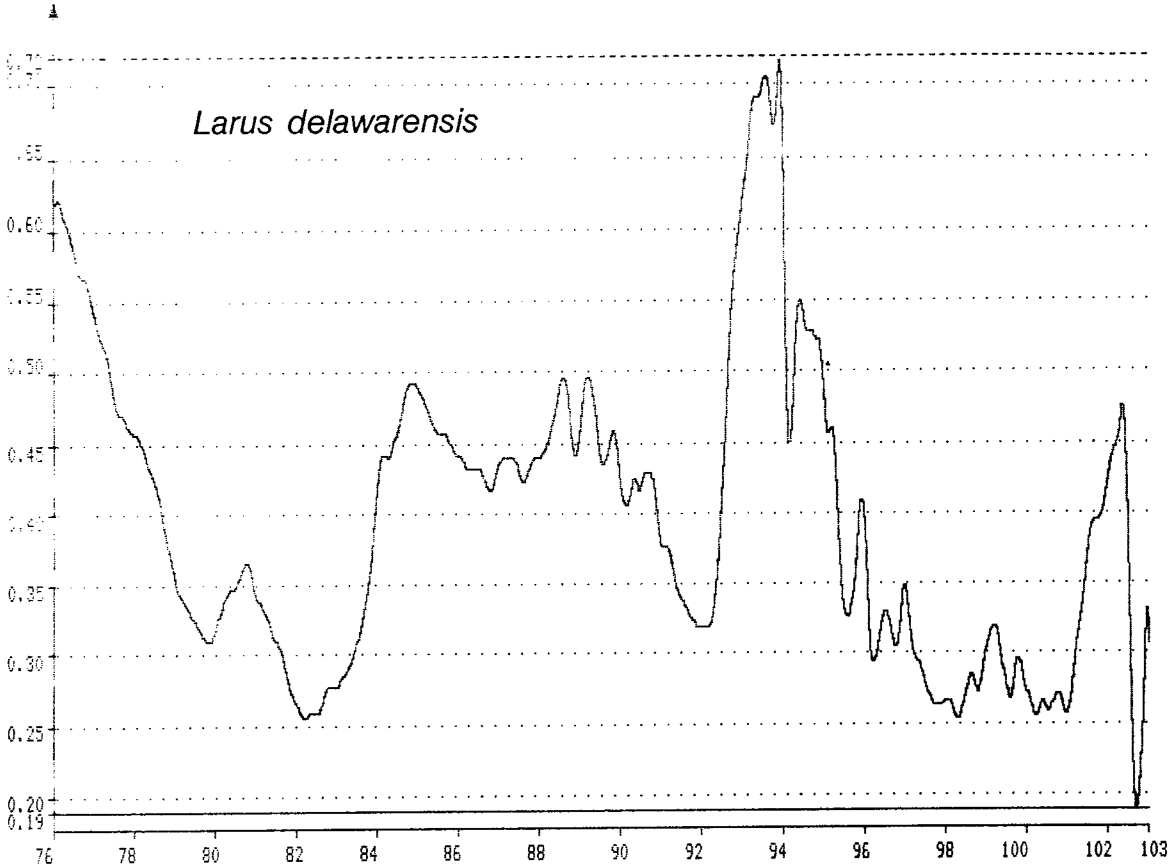


Figure 3. Keratin profile of the Herring Gull (*Larus argentatus*).

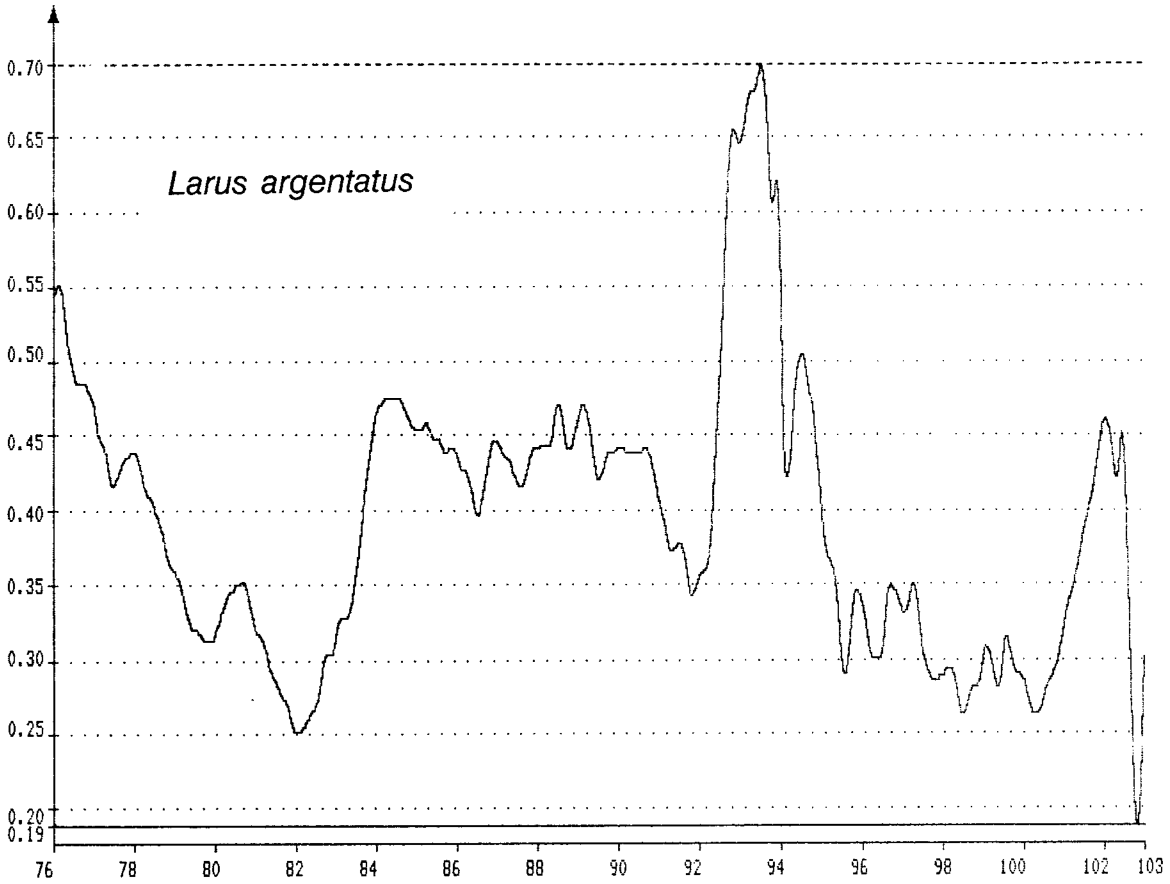


Figure 4. Keratin profile of the Iceland Gull (*Larus glaucoides [kumlieni]*).

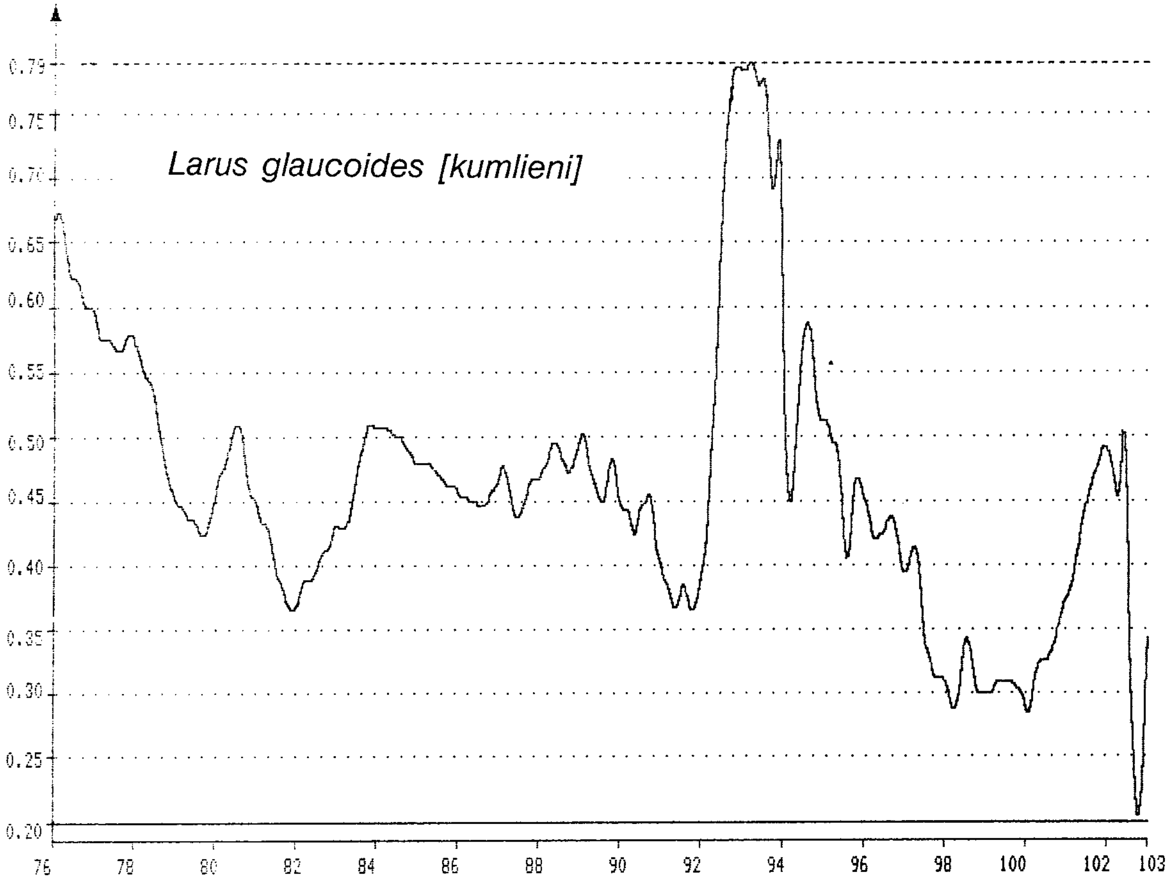


Figure 5. Keratin profile of the Glaucous Gull (*Larus hyperboreus*).

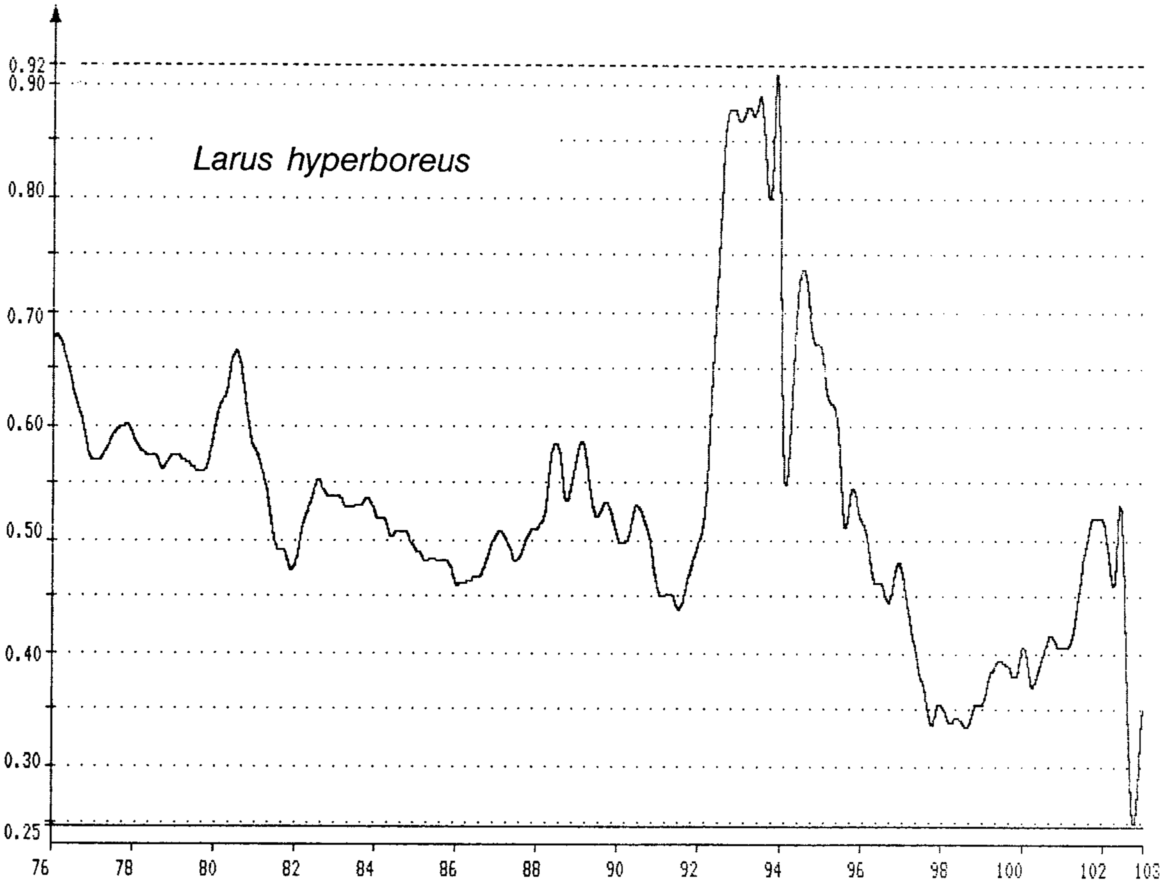


Figure 6. Keratin profile of the Great Black-backed Gull (*Larus marinus*).

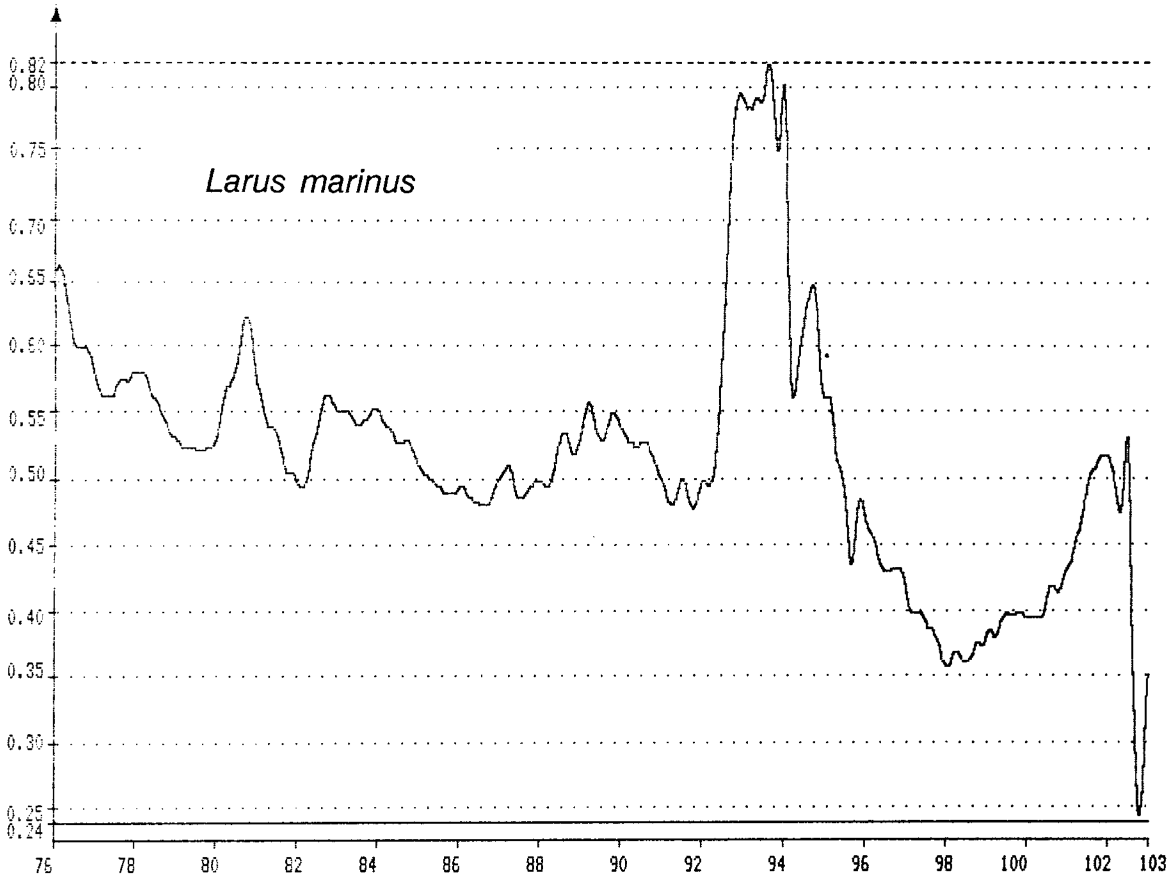


Figure 7. Keratin profile of Heermann's Gull (*Larus heermanni*).

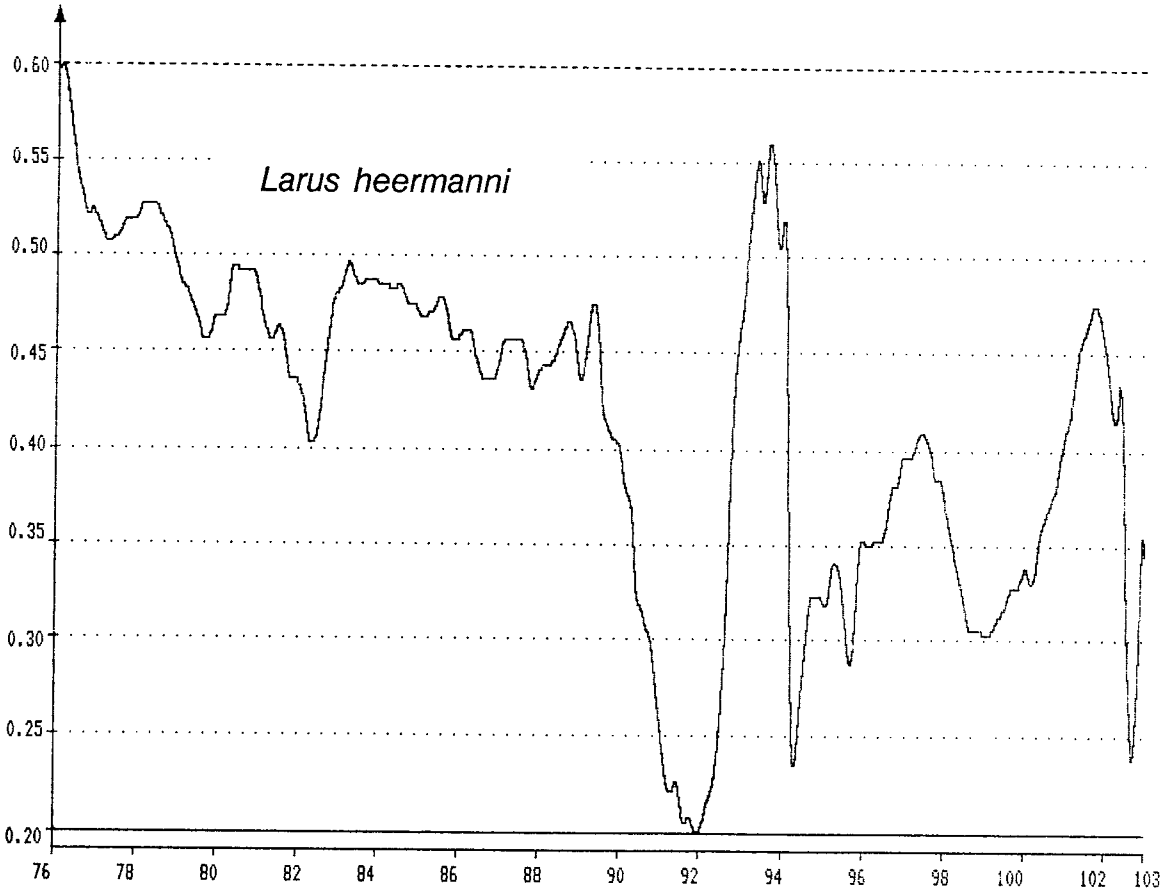


Figure 8. Keratin profile of the California Gull (*Larus californicus*).

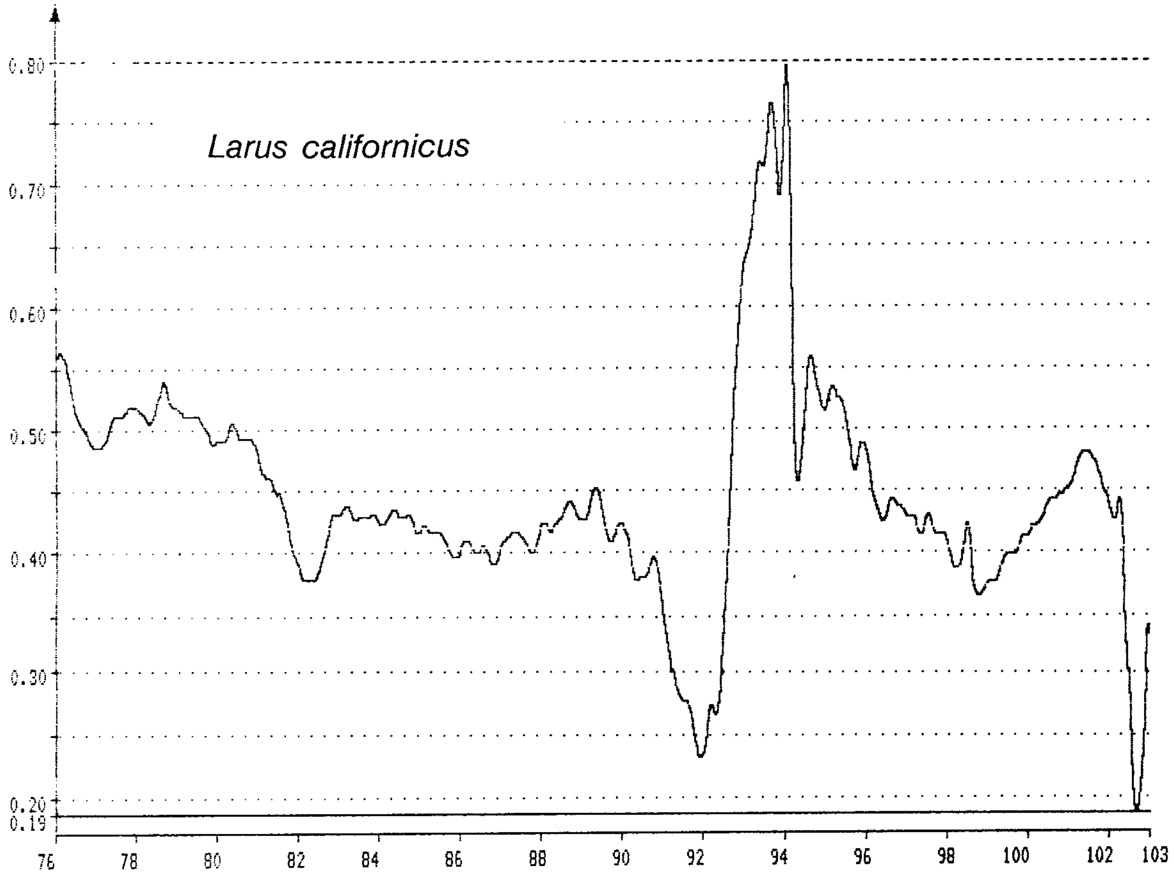
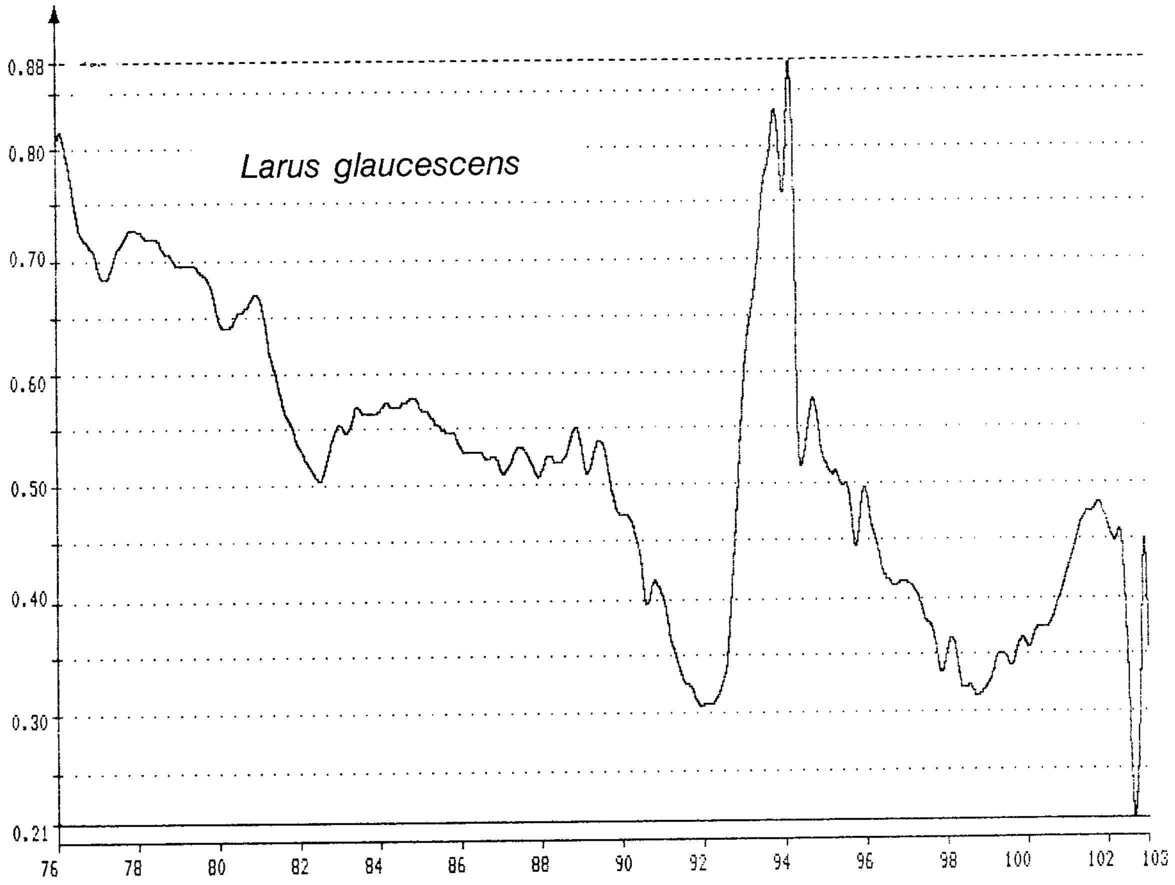


Figure 9. Keratin profile of the Glaucous-winged Gull (*Larus glaucescens*).



ADF616408

BSCE 20 / WP 9
Helsinki 1990

BIOACOUSTIC SCARING OF BIRDS IN AIRPORTS

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First results are presented of broad implementation of bioacoustic bird scaring device "Berkut" in civil airports. A list of scaring signals used in the airports is given. The prospects of new scaring signals obtaining are also described.

In 1989 229 strikes of aircraft with birds were registered in the USSR civil aviation which is 37 per cent less than in 1988. One of the reasons for such drastic reduction in the number of strikes may be broad implementation in Soviet civil airports of bioacoustic bird scaring device "Berkut" (its performances were given in the materials of the 19th BSCE Meeting, Madrid, 1988, WP No. 41).

In the meantime more than 30 airports are equipped with "Berkut", and in 1990 it will be installed in about 100 airports. According to the airport authorities having operated the device for a long time (Pulkovo, Borispo, etc.) it demonstrated high efficiency, birds' getting used to transmitted signals being insignificant. First of all it may be explained by the fact that the airports used several signals for each bird species which were changed periodically to impede birds' getting used to them.

To this end rather a large "library" of scaring signals was collected by scientific specialists consisting mainly of distress cries birds produce being in a man's hands and including the following: common black-headed gull (Larus Ridibundus), common gull (Larus Canus), hepping gull (Larus Argentatus), Polar terns (Sterna Paradisaea), rook (Corvus Frigilegus), common jackdaw (Corvus Monedula), crows (Corvus Corone), common starling (Sturnus Vulgaris), b.billed magpie (Pica Pica), common jay (Garulus Glandarius), house sparrow (Passer Domesticus), suy lark (Alauda Arvensis), com. song thrush (Turdus Philohelos), North long-eared owl (Asio Otus), com. lapwings (Vanellus Vanellus), mallard (Anas Platyrhynchos) and others. The library is constantly replenished, the recording being made with high quality equipment eliminating distortions in acoustic band of 20-18000 Hz. Afterwards all the signals are analysed at a sonograph to identify and compare them with standard specimens.

In 1990 we started experiments to obtain distress cries of gulls used to warn of danger (from men or predators). The conditions necessary are simulated both in laboratories and in nature. Stimulation of distress cries of various birds caught beforehand and put near the recording equipment is achieved easily by way of utilizing specially taught birds, mostly Northern goshawk (Accipiter Gentilis). The program is developing actively.

ADF616409

BSCE 20 / WP 10
Helsinki,1990

ANALYSIS OF BIRD COLLISION WITH PLANES AND POSSIBILITY OF UTILIZATION OF THE BIRD STRIKE PREVENTION MEASURES.

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ABSTRACT

Usually after serious bird strikes is undertake the measures of prevention similar case in future. Careful analysis of the bird strike, including bird behaviour and various factors of environment show reveal the reasons of appearance of birds on the plane way and consider the possibilities of various measures against repetition such cases. On examples of collision of landing plane with starling flock,flying up from land,and collision of plane at high altitude 3000 m with swift show impossibility bird strike prevention without timely revelation of birds. It is discussed some approachs for solution of this problems.

If one turn to BSCE history and to beginning of problem of bird strike danger in the world - then the mighty impuls for the works on bird strike prevention on airdromes has become the crush of Viscount plane at Boston(USA) in 1960 as a result of collision with flock of starlings. The crush of DC-3 in 1962 in the area of the American bird ringing centre in Lowrel as a result of collision with the flock of american swans migrating by night,was an impetus to develop investigations of bird migrations- not only swanes but also other species dangerous for planes(geeses, ducks). This may be related to military aviation, too.For example a series of accidents with F-104 fighter because of collisions with migrating snow geeses lead to development of investigation of their migrations with the aim to prognose their mass flight on the planes way(Blokpoel, 1973). Such an approach, when after dangerous bird strike measures are taken to prevent repetition of such cases in future, increases effectiveness of taken measures because in each case there is knowm the bird species and the situation which led to collision and it is possible to prognose such situation and to undertake concrete measures.The considerable increase of the effectiveness of measures to be undertaken is connected with discovered by us the general regularities of bird behaviour in interaction with various technical devices,including a plane. Victims of bird strikes becomes first of all bird who saw for the first time a plane on short distance and who could not deviate from its way in due time. There are first of all migrating birds and birds coming for winter stay as well as young birds local mesting on airdromes.This determines general strategy to carry out measures to prevent bird strikes(time to carry out measures during season of migration and of young birds appearance and general principles of bird behaviour control on airdromes: active frightening off or creation of ecologically unattractive places for birds on airdrome,or prognosing of appearance of mass bird accumulation on planes way.at airdromes and out of them,as well as concrete tactics to carry out such measures on individual airdromes.It is connected here with concrete species and groups of birds inhabiting individual airdromes with periods of their migrational activity,with time of young birds activity,with concrete features of attractiveness of ornithological situation on airdrom.The task of aviational experts and ornithologists is to select the most effective tactics of "fight" against birds on each airdrome.And only concretization of bird species against which one are fighting and of terms of conducting measures increases considerably their effectiveness. If one points concrete terms of flight of migrating birds, dangerous for a plane or time of appearance of young local nesting bird species- the effectiveness of preventive measures increases sharply.Just during these periods and in other time(for example in a winter) there will not be any nessesity to carry out such measures on northern airdroms. However,being prompted by results of analysis of bird strikes at given airdrome- it will be possible to propose concrete tactics of preventive measures application in concrete terms. These means are proposed from a fact that formerly they were applied succesfully under similar circumstances.And in the same time-when considering circumstances of a bird strike and possibilities to prevent them- there appear situations when tested bird frightening means because of series of reasons can't be used to prevent bird strike. Furtherly, proceeding from an example of one bird strike analysis, I would like to consider- whether it could be possible to prevent this bird strikee and what can be recommended to prevent similar bird strikes in the future. 17.04.1985 at 14.57 at airdrome Vilnius(Lithuania) transport four engine turboprop plane AN-12 collided during a landing with flock of starlings at altitude 20 m. and a 300 m distance from the end of runway.According to pilot's evidence the starlings flock composed by 100 individuals at the sight of quickly approaching plane took of from a land against a wind and than turned to wind and started to turn aside when it was overtaken by the plane.The remains of 29 starlings were found on a land under place of collision at 20 m radius. At the plane there were noticed bird hits at pilot cabin glass,at oil radiator,chassis,wing.

;one bird hit in airintake of the first engine and three birds hit in airintake of the second engine.This last one was removed from the plane and replaced.The plane has been landing with switched landing lights. At 14.30 that is 27 min. before AN-12 landing,another passenger two-engine turboprop plane AN-24 had been landing by the same course consequently the starling flock sat on land within period 14.30-14.57. Circumwhich determined the flock's flying off were following:

1.A bird attention was distracted by food searching on humid ground between a turf of last year grass. 2.The birds were turned by "face" toward wind and by back to landing plane and did not see it and its landing lights. 3.The birds took off formerly toward a wind and not aside of the plane. 4.The contrary wind has decrease the speed of sound from planes engines to birds. 5.The flock was migrating one and bird did not know the plane's danger here in this place.Can airdrome dispatcher do anything to prevent such collision?

The first what comes into mind is to use more frequent and more succesfully applied active repellents: shoot from a rocket pistol,bioacoustic installation(stational or moving-at an car).To use these means it is necessary first of all to discower birds.But in examined case the landing of starling flock and its taking off when the plane approached were not discovered neither by starting point dispatcher nor by radar dispatcher.It was not discovered neither visually from 0,5 km distance,nor at radar of landing from 1 km distance. Therefore it is not possible here to use active bird frightening means,mentioned above.The more this relates to rocket shoot or to bioacoustic repellent signal translation from an car- insofar as apart of birds discovery it is necessary to come to them by a car. And such an approach by an automobile may become more difficult if birds are sitting not on runway concrete but-for example-on relatively large distance from the end.In this aspect is more useful to apply the stational plant: bioacoustic or pyrotechnical which switches on by telemetric way.In order to discover birds and to have to approach them it is necessary to use such frightening means as hawks,falcons,radiocontrolled models.

It is not necessary to discover birds and to have time to approach them- when creating ecologically unattractive conditions-first of all for bird's feeding,nesting,and rest at places of their possible landing in the area of an airdrome or creation of some obstacles for such a landing. However inspite of great variety of these means- they are not universal. The obstacles for feeding of grainivorous birds don't prevent feeding of insectivorous birds and conditions unfavourable for nesting of one birds are favourable for other bird species. And there is no such chemical means utilization of which could fright off all bird species.

Because the change of attractiveness of some or other places for birds can prevent bird's landing on these places but not a flight over them(Jacoby,1982). Processing by chemical means-repellents don't prevent(in my opinion) the flight over these places and according to some experiments they did not confirmed as bird repellents because majority of birds have weak sense of smell.

Chemicals against insects will not act as defoliants and so on. Birds will fly over a land or water surface covered by a net. In such a way even passive means to prevent bird landing on the ways of plane's flight toward an airdrome don't give any full effect.In the same time there are not any good proposals to prevent bird landing on warm concrete of a runway under cold weather,or to prevent catching of insects by swifts or swallows over a runway. The only thing what can be done to repel birds feeding on a runway is to remove from runway's concrete rain worms,birds,insects and mammals killed by a plane or plant seeds brought by a wind. Therefore we don't see means to prevent swallow flight over a runway for catching of insects in warm air over a concrete. And we know several cases when swallows hit jet-plane engines during take-off or landing run along the runway.And it was neccesary as a result to change orcremove damaged engines. Bioacoustic,pyrotechic and other active repelling means practically do not act against swallows. In such a way in some cases-the exploitational shortcomings of repelling means (the necessity to discover birds and approachto them) and in other cases bioacoustic shortcoming of relling action against birds are determining impossibility to prevent bird strike(Jacoby,1986).

Out of an airdrome one can undertake measures to prevent plane's collision with the accumulations,mainly migrating birds as a result of their discoverage(visual or radar)or prognosis of mass bird's appearance on plane's way.However it is practically impossible to discover in due time visually or by radar(surveillance,precision approach,jacoby,1984 a and aircraft)the birds flying one by one or by scattered groups and to prognose their appearance on plane's way.

For example 26.07.1970 at 19.30 four engines turbo prop plane IL-18 which took off from Sochi airdrome(Black sea cost) having speed 480 km/hour collided at 3000 m altitude with swift(Apus apus).The bird make a hole in plastic cover of radome and damaged aircraft radar aerial.In result arised difficulties during plane landing in Erevan.In this case neither a pilot nor dispatcher of airdrome surveyllance radar have seen a bird(may be flock of birds)before a collision. This is concerned with relatively numerous cases of collisions with soaring birds-eagles,buzzards,black kite,single flying pigeons,gull and series of sparrowlike species.

As typical example of this kind it may serve the collision of four engine turbojet plane with vulture(Aegypius monachus)at 12 km altitude over a mountain in Africa.It is unreally to see slowly soaring even large bird on screen of surveyllance airdrome or plane's radar.I don't know cases when a pilot after noticing soaring bird could turn away from it in order to prevent bird strike.In the same time according to information airdrome surveyllance radar dispatcher at Odessa he noticed echo-signal of relatively great size on the way of IL-18 plane approaching Odessa at altitude 3000 m.The Pilot being warned by disputscher,saw in front of plane tremendous geese flock and had time to turn away from them.

As an optimal solution of problem of bird strike danger on airdrome and out of it(including cases considered above) it would be bird frightening away of a plane by means installed on a plane.Unfortunately the attempts to use for this sake the light impulses,switching of landing lamps,radar and lazer radiation,colouring of nose part of a plane by "eyes" do not give,in my opinion,any biologically explicable repellent effect(Jacoby,1978).

In such a way one can speak about exploitational,biological and technical shortcomings of utilization of means to direct and to prognose bird behaviour with aim to prevent bird strikes.Therefore when working out recommendations to use some and other means to prevent bird strikes on concrete airdromes it is necessary to prognose its effectiveness with taking into consideration the shortcomings of its application. And it is necessary here to foresee measures to eliminate for example the shortcomings of bird discoverage in due time or bird landing on ground or on airdromes runway.This can be done by means of instruction to pilots of starting plane to inform about birds discovered on a runway or to modernize airdrome radar in order to discover the birds sitting on the ground taking up of which can bring a bird strike. It would be ideal to work out authomatic disclosure of birds in flight by plane's radar and presenting of command to plane's steering gear in order to escape appearing in front bird accumulation.I don't know-whether such device exist practically. Apparently it can be used only under horizontal flight when a plane flies out of an airdrome.

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BSCE 20 / WP 11
Helsinki, 1990

NOCTURNAL MIGRATION OF BIRDS OVER ISRAEL - CHANGES IN DIRECTION AND RATE OF MIGRATION ACCORDING TO THE TIME OF NIGHT

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BSCE/20
Helsinki, 1990

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Israel is a land bridge between three continents and a major crossroads for birds migrating from Europe and Asia to Africa and back twice yearly, during spring and autumn. Most birds migrating over Israel (280 species) do so mainly at night.

Night migration over Israel was first examined in 1989, with an ASR-8 scanning radar. Migration rates and directions through the night, in spring and autumn, were studied. The rate of nocturnal migration in autumn was found to be double that in spring.

Direction of migration was found to be closely related to the time of night. Overland north-south migration characteristically occurs throughout the night, and stops almost completely in the morning. Migration from northwest of the Mediterranean Sea to the Israeli coast, however, commences only at midnight, and continues until 09:00 in the morning.

There is a distinct correlation between nocturnal migration and bird-aircraft collisions in the Israel Air Force (IAF). At the present time it should already be possible to set up a real-time warning system for night flights of IAF aircraft. The system would be based on the relation between migration rates during the first three evening hours and rates throughout the night.

1. INTRODUCTION

Israel is a land bridge between three continents and a main migration junction for birds migrating between Europe, Asia and Africa in spring and autumn.

About 280 species migrate over Israel, mainly at night. Diurnal migration of soaring birds over Israel -- raptors, storks and pelicans -- has been thoroughly studied with radar, ground observers and motorized glider (Leshem, 1988,1984). Most of the damage done to Israel Air Force aircraft is attributed to these birds. This is due mainly to their large size and their flight altitude, which may reach 5000 ft. above sea level.

Nocturnal migration, on the other hand, occurs at altitudes up to 5000 ft. and is far greater, by at least one order of magnitude, than diurnal migration. As a result, the probability of collisions with these birds is far higher. Civilian flights are damaged by nocturnal migrating birds mainly during take-off and landing, since they fly at greater altitudes than the migrating birds. Air force aircraft all over the world, however, fly at lower altitudes and therefore suffer much more damage from night-flying birds.

Due to objective difficulties in tracking nocturnal bird migration the subject has remained in the "dark" in many parts of the world. Passerine migration, for example, occurs mainly at night, when visual means of observation are not applicable, so radar remains the best source of information on nocturnal bird migration.

Despite the importance of this area as the junction of three continents and a region on the coast of a broad sea barrier which separates Europe from Africa, nocturnal bird migration has never been studied in Israel. In spring 1989 nocturnal migration tracking by radar was first initiated and its magnitude and distribution in time and space studied.

As reported in works done up to now in Europe (Bruderer,1981, Buurma, 1988 and Buurma and Bruderer, 1989), here too, nocturnal migration appears on the radar screen as a broad front of individuals or small groups migrating independently. Continuous tracking during all hours of the night and throughout the migration season showed that the distribution pattern of nocturnal migration direction changes with the time of night. Significant differences in the magnitude of migration were found as well, between spring and autumn (Hunt, 1975).

The migration seasons coincide with the rise in the rate of night collisions in the IAF. The establishment of a real-time warning system, based on the significant correlation between the rate of migration during the early night hours to the rest of the night can allow night flights and bring about a significant reduction in the number of collisions with migrating birds.

2. METHODS

The radar used in the study was the ASR-8 surveillance radar, beam width 35°/4.8°, 10(cm), used as the air traffic control radar at the Ben Gurion Airport, Tel-Aviv. Nocturnal migration for a radius of 20 miles can be seen on the radar screen.

The radar screen was photographed with a Nikon reflex camera, diaphragm opening 4.5, continuous exposure of 10 minutes for each still photograph. Photographs were taken once every 1/2 hour during the night in spring and autumn. Control photographs were taken during the day, at 0900, 1200 and 1500 hours, using the same method.

Degrees of migration were determined by the rate of flashes received from migrating birds on the radar screen photographs. A scale of 5 migration levels was established and according to it the rate of migration was determined during each hour of the night during the season. The direction of migration was determined by the flight route appearing on the radar screen photographs, which was possible due to the long exposure (10 minutes) time.

Nocturnal migration velocity was measured directly from the radar screen by tracking several flocks each hour and recording them concurrently with the photographs.

3. RESULTS AND DISCUSSION

A large amount of information on times, routes and rates of nocturnal migration has accumulated from the radar data. The data, however, did not provide information on migration altitude or on the species migrating. Nevertheless, on the basis of direct moonlight observations and listening to birds migrating at night, it seems that passerines and water birds overfly Israel at night. Different species of swifts, Sylvia warblers, pipits, waders and ducks have been definitely identified.

As opposed to diurnal migration which is seen on the radar screen along definite, clear routes, nocturnal migration is characterized by movement along a broad front, which covers a large part of the radar screen (plate 1). This is probably a result of scattered migration of individuals or small groups of birds.

Times of migration at night - nocturnal migration commences at sundown and continues to 0900. At sunrise there is a significant reduction in the migration rate and overland migration stops almost completely (figure 1). Most of the migration during these morning hours is of birds arriving at the Israeli coast from the Mediterranean.

These differences in the rate of migration may be the result of the fact that a large number of juveniles leave Europe in the fall but do not return in spring; or possibly some of the birds which migrate south in the fall return in the spring via a different route. It should, however, be borne in mind that the data are from 1989 only.

Rates of migration at night - relative migration rates were calculated as the average migration rate during all hours of a given night (figure 2). Migration rates in spring are about 50% lower than migration rates in autumn. In spring nocturnal migration starts in March and ends in May, in autumn it starts during the last ten days of August and ends in mid-November (Fig. 2).

PLATE 1: Nocturnal migration on a broad front from the north, autumn 1989.
At the center -- Ben Gurion International Airport; the solid line on the left side of the screen is the Israel coastline. Migration on a broad front can be seen from 16 miles north of the Ben-Gurion Airport to 14 miles south of it. Radius lines are at a distance of 2 miles from each other. On the circumference are compass directions relative to Ben-Gurion.

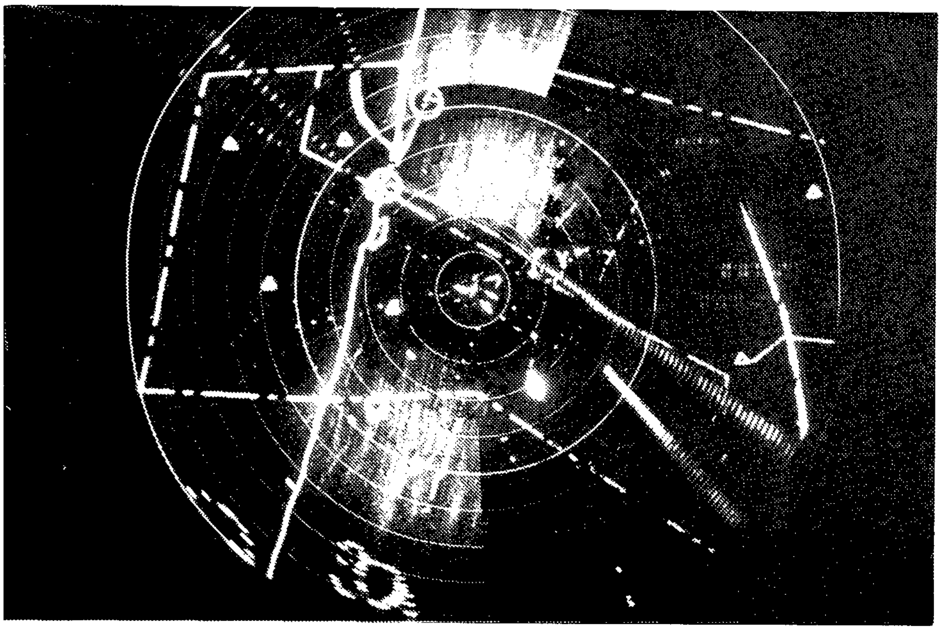


FIGURE 1 - Distribution of nocturnal migration direction in relation to the time of night. The change in frequency of migration appearance from the direction of the sea or from over land throughout the night in August 1989. Until midnight all migration is overland and from midnight there is a significant amount of migration from the sea.

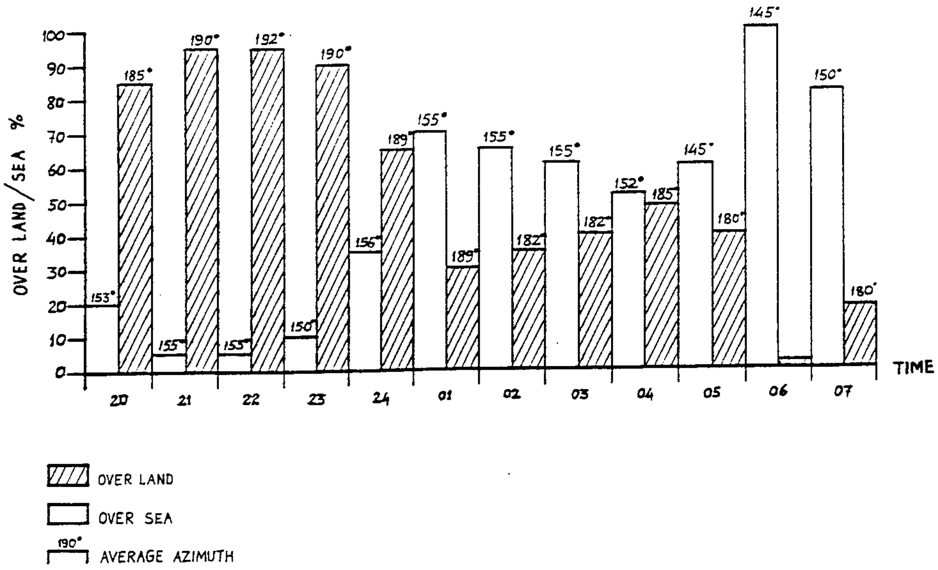
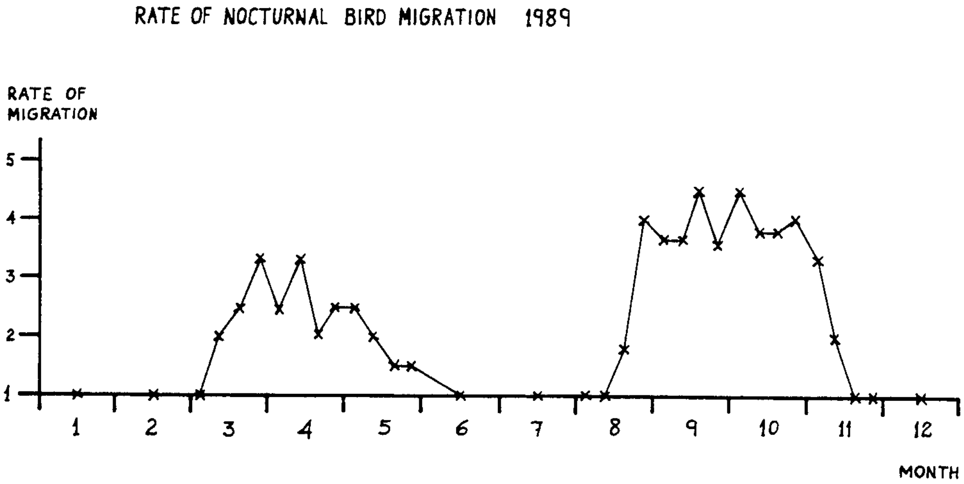


FIGURE 2 - Average monthly migration rates in spring and autumn.
Each point on the graph represents the average migration rate checked during that time.



3.1 Distribution of nocturnal migration directions

During the fall of 1989, 2 main directions of migration were observed - one from north to south over land; the other from northwest to southeast, from the Mediterranean to the shores of Israel. Some of the birds which leave Europe for Africa in the fall migrate in a straight line, across the Mediterranean, traversing a distance of 500 km or more without stopping. Others cross over land, taking a longer route, circumventing the Mediterranean. Some of these shorten their route by flying over the northeastern part of the Mediterranean, landing on Israel's shores, and later continuing southward. By doing this they reduce the time spent over the Mediterranean and make their first stop as close as 250 km from their departure point.

Radar data provide evidence that both the latter routes in fact occur. In August 1989, when the frequency of migration directions during the various hours of the evening or night was examined, a clear connection was seen between the time of night and the frequency of each of the two above-mentioned directions of migration.

Until midnight, the radar shows migration from north to south over land only. From midnight on, migration from the sea begins to appear on the screen. This trend continues until 0500 hours. At sunrise, migration from north to south ceases almost completely. Traces of migration from the direction of the Mediterranean continue into the morning hours, sometimes until 0900 hours.

Examination of the direction from which nocturnal migrants arrived from the Mediterranean (azimuth 320, 330 degrees) may indicate the estimated location from which they began their migration -- Cyprus and the coasts of southern Turkey.

If we assume average flight speed of 50-60 k.m.h., the first birds to arrive in Israel at midnight would have left the Cyprus coast (azimuth 330 degrees) 6 hours previously.

There seems to be a clear connection between the rate of night bird strike and the seasons when nocturnal migration takes place. During the migration months -- spring and fall -- the number of such collisions doubles, a significant increase compared to the rest of the year ($\alpha = 0.009$, F=10.3, Tdf=11 -- ONE-WAY ANOVA). 70 % of night collisions take place up to an altitude of 2000 f. At this point no quantification of radar data has been made, but there is no doubt that millions of birds are involved. In the light of these facts, the grave danger to night flights below this altitude is clear.

In an attempt to establish a real-time warning system for the Israel Air Force on the rates of nocturnal migration, the correlation coefficient between the rate of migration during the first three hours of night and the rate of migration during the remaining night hours was calculated. A significant correlation was found between the two (regression coefficient $r=0.85$, $\alpha<0.001$, Tdf=44). This connection will make it possible to predict the expected degree of nocturnal migration from the first three hours after sunset with a very high degree of accuracy, thus enabling night flights and ensuring flight safety at the same time.

ACKNOWLEDGEMENTS

Thanks are due to senior officers D., Z., H., A., G., O., B., and R. of the IAF for their close cooperation at all stages of the project;

A. Gilead, E. Satat, and Z. Frank of the Israel Airport Authority; P. Magor, A> Firedman and the women operators of IAF radar equipment, for professional work; I. Agat, for assistance at Ben-Gurion International Airport;

Special thanks to Buurma, L.S. to Y. Yom-Tov, Scientific Supervisor, the Israel Ministry of Science and Development, and the Ecology Foundation for providing funds for the study.

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ADF616411

BSCE 20 / WP 12
Helsinki 1990

THE DEVELOPMENT OF A BIRD MIGRATION REAL-TIME WARNING SYSTEM FOR THE ISRAELI AIR FORCE UTILIZING GROUND OBSERVERS, RADAR, MOTORIZED GLIDER AND DRONES; AND A PRELIMINARY REPORT ON THE USE OF TRANSMITTERS RECEIVED BY SATELLITE AS A NEW WARNING METHOD

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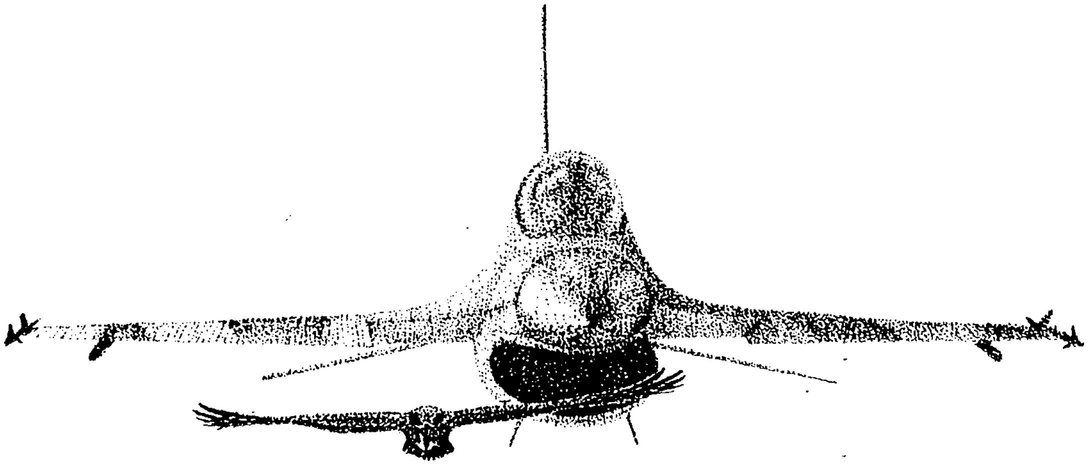

BSCE/20
Helsinki, 1990

THE DEVELOPMENT OF A BIRD MIGRATION REAL-TIME WARNING SYSTEM FOR THE ISRAELI AIR FORCE BY GROUND OBSERVERS, RADAR, MOTORIZED GLIDER AND DRONES; AND A PRELIMINARY REPORT ON THE USE OF SATELLITE TRANSMISSIONS AS A NEW WARNING METHOD

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ABSTRACT

In 1985-88 a joint research project was carried out by the Israel Air Force (IAF), the the Israel Raptor Information Center (IRIC), Tel Aviv University and the Ministry of Science and Technology, with the purpose of precisely identifying the central migration routes of birds soaring over Israel, their flight elevation, dates of their arrival, and the effect of climatic changes on the character of the migrations.

The study was conducted in the wake of very severe damage to the IAF, mainly during the migration seasons; preliminary results were published in the Proceedings of the Madrid BSCE Conference (1988). This article contains a detailed presentation of the applicable methods developed in the course of our research. During the spring (March 1-May 30) and fall (August 1-November 20) migrations, for a total of about seven months per year, the IAF activates a real-time warning system based on the data we collected. A procedure regulating flights in Bird-Plagued Zones (BPZ) was developed. Detailed maps were prepared and are now distributed to all aerial units, obligatorily limiting the elevation, location and time of flights.

A "Birdwatching Center" was established at the approach radar of Ben-Gurion International Airport. All information about birds throughout Israel is channeled to the Center -- from flights towers in IAF bases and from control units in the IAF. Manned 24 hours daily, the Center produces real-time warnings based on all the information amssed from IAF radar units, from a network of birdwatchers across the country, and from drones and a glider. With the data collected, IAF flights are able to fly at low altitudes when bird migration is low.

Following the study and the development of the real-time warn- ing system, damage to IAF aircraft was significantly reduced, compared to the ten years preceding the study. In 1990, the civil aviation system began to utilize the military system.

A preliminary report explains how satellites may receive trans- missions from storks fitted with transmitters, eventually provi-ding a real-time warning system for the approach of flocks.

INTRODUCTION

The location of Israel at the junction of three continents has made it part of a migration route of international importance in spring and autumn. Because of the large concentration of birds in the extremely limited air space of Israel, the Israeli Air Force (IAF) sustained severe damage resulting from collisions with birds, mainly migrating soaring birds (Leshem, 1988a).

From 1985-1988, a joint research project was carried out by the IAF, the Israel Raptor Information Center (IRIC), Tel Aviv University and the Ministry of Science and technology. Our research addressed several questions:

1. Do migration routes on the horizontal plane conform to specific patterns?

2. Do migration altitudes (the vertical plane) conform to specific patterns?

3. Do the birds' dates of passage conform to specific migratory patterns?

4. How do climatic factors influence the variables in the migratory system?

5. Is is possible to predict changes in the characteristic migratory patterns and appply them to the IAF's activities?

Our research methods and findings are described in the proceed- ings of the BSCE's meeting in Madrid (1988a), as well as in the cited literature (1,2,4,5,6,7). As we were carrying out the above research, we simultaneously activated five parallel sources of information. Each of these sources complemented the other, providing information which was lacking in the others and thus making it possible to verify the authenticity of the data collected via these sources: 230 motorized glider flights, on which we accompanied migrating flocks of storks, pelicans, and birds of prey; 29 flight days with drones; 19 flight days with a Cessna; thousands of Polaroid photos of the radar screens at Ben-Gurion Airport, of IAF radars, and of meteorological radars; and ten years' data collected by ground crews of birdwatchers.

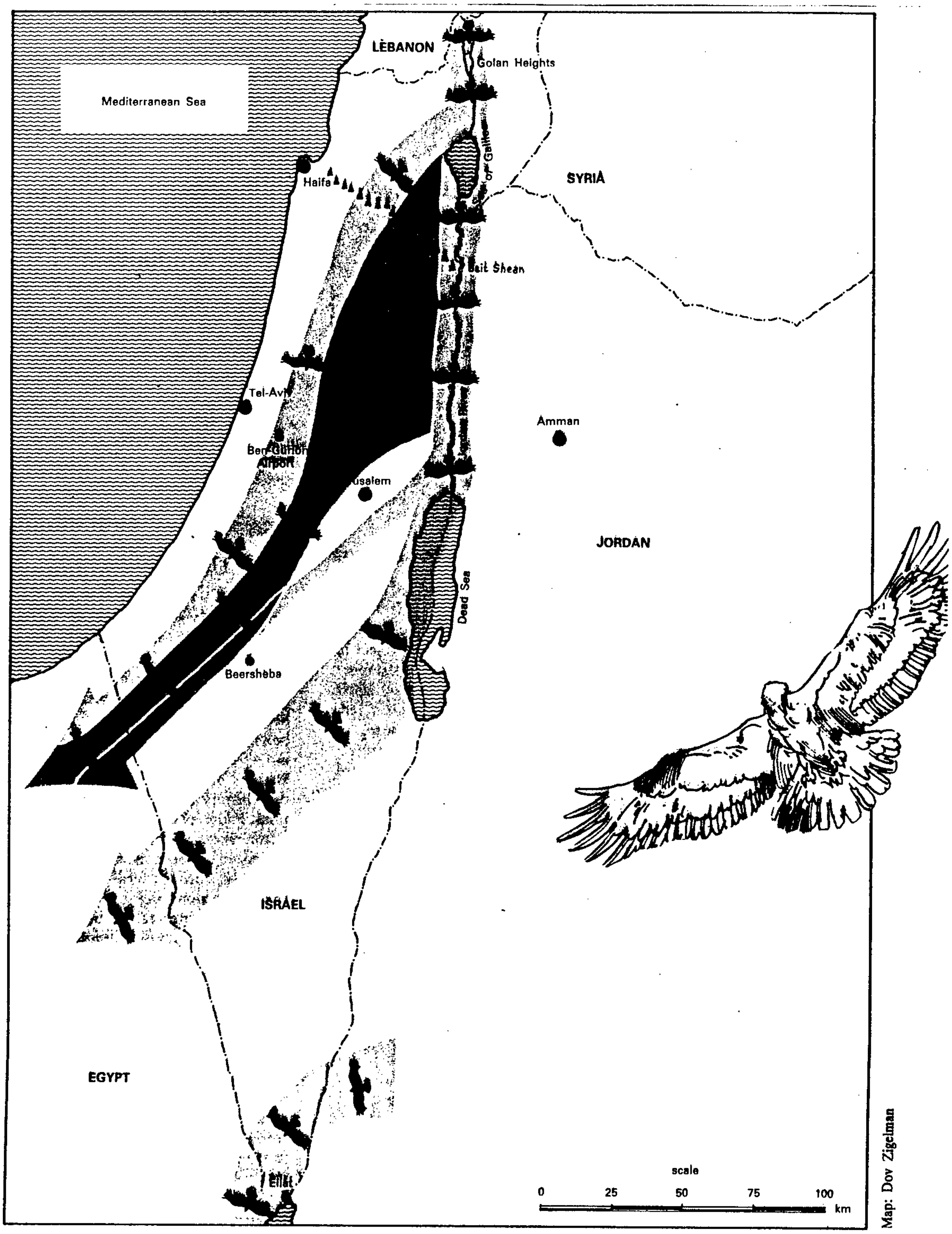
RESULTS

1. PRODUCING A MAP OF THE BIRD-PLAGUED ZONES.

From the reservoir of data which were collected and analyzed, we were able to draw a map of the Bird-Plagued Zones (BPZ) delineating the routes taken by the major concentrations of birds. Fighter planes have been forbidden to use these routes at low altitudes, except for take-offs and landings (see Map #1). Research data revealed that the masses of soaring birds are concentrated, on most days, at altitudes up to 3000 ft. AGL, and the permitted altitude for fighter planes was regulated accordingly. It was recommended that carrier planes fly at lower speeds within the limited areas.

Predicted times for the start and end of the migratory season are printed on the map. Various colors are used to show the areas where different varieties of birds appear on different dates, for instance: Large masses of storks migrate south along the Afro-Syrian Rift as early as the middle of August, while the great wave of birds of prey arrives only at the start of September, flying primarily along the parallel route to the west. The map also carries detailed instructions for planning flights during the migration season and for dealing with any sort of collision with the birds.

Schematic drawing of the Bird-Plagued Zones (BPZ), produced by the Israel Air Force, depicts areas where flights are forbidden during migration seasons. Also noted is the Autumn Real-Time Warning System, comprised of a network of 17 observation points. ▲



Map: Dov Zigelman

Two separate maps were published, one for the spring migration season and one for the autumn; and the written procedures, known as the BPZ Regulations, became part of the IAF's official codes. The maps are distinguished by high-quality color printing meant to stand out and attract the eye of every pilot when they are hung, according to orders, in the briefing rooms of every air squadron.

2. "MARKETING" THE BIRD ISSUE AND THE BPZ, AND "SELLING" THEM TO THE IAF.

During the course of our research, an elaborate program was introduced into the IAF to raise pilot' consciousness about birds and the IAF's conflicts with them. A course of lectures accompanied by films and slides was delivered to all air squadrons and other IAF personnel, such as radar units, who are involved in flight systems. The IAF also produced, in cooperation with IRIC, a series of color posters on the subject along with calendars, stickers, explanatory pamphlets, and a video-cassette series which was distributed to all flight squadrons during every migratory season. Thanks to this "marketing" program and the new army regulations, the bird issue had a significant impact on the largest part of the Air Force, becoming part of the IAF's consciousness within an unexpectedly short time.

3. DEVELOPING THE REAL-TIME WARNING SYSTEM.

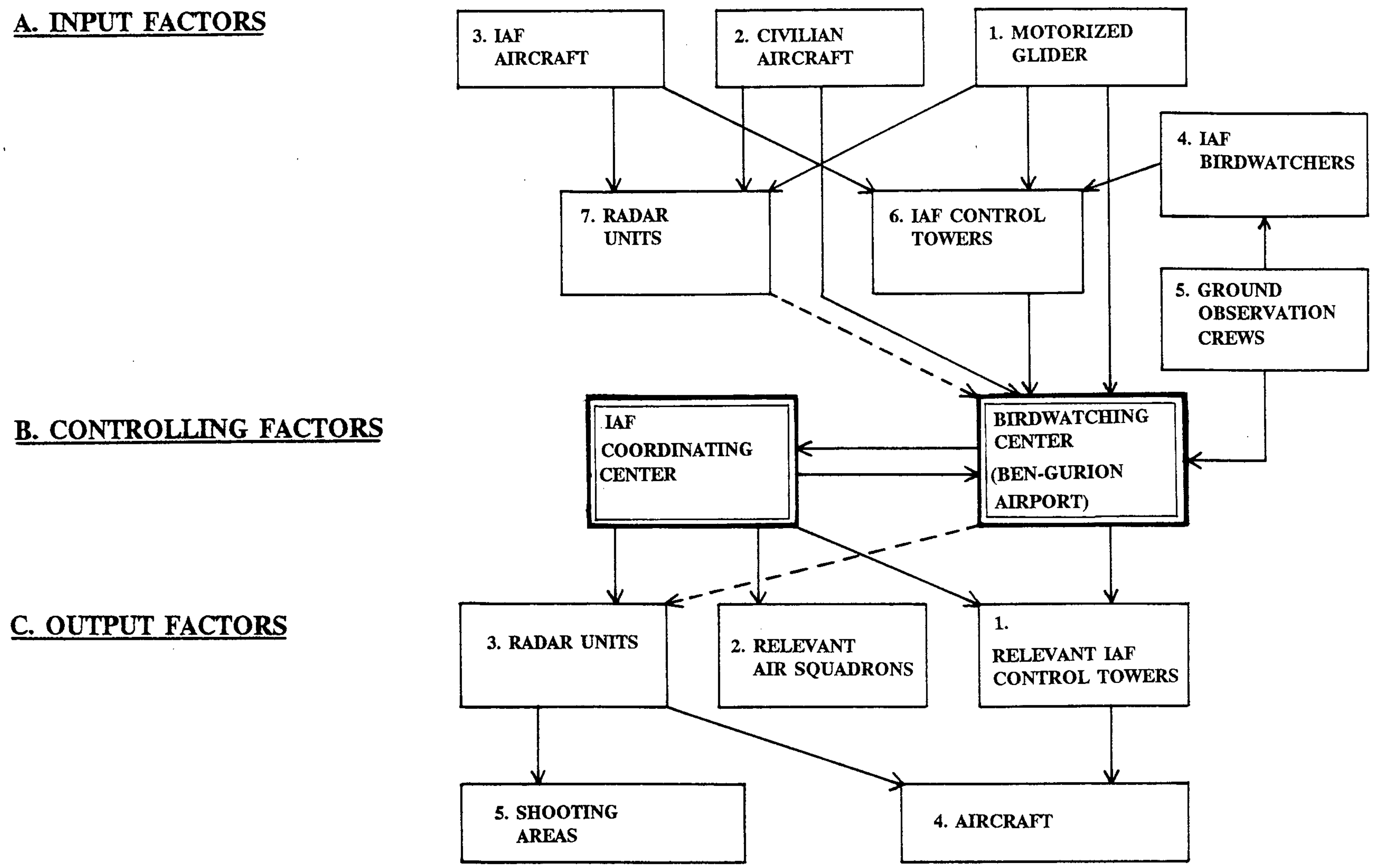
During the first phase of the research, when the first BPZ map was produced, it became clear to the IAF that due to Israel's special location, 50% of the country's air space would have to be closed to low-altitude flights for half the year (see Map #1). This could seriously damage the level of the Air Force's training program. Hence the Real-Time Warning System was developed, based on several sources of data:

Ground crew observers. During the autumn migration season, a network of ground crews was spread across the entire country, from Haifa to Beit She'an (located 20 km. south of the Sea of Galilee - Lake Kinneret). These 17 ground observation posts were manned by a total of some 60 volunteers (see Map #1). Three vehicles which served as mobile observation posts were at the head of the system. The volunteers, who largely came from abroad, were lodged free of charge in local kibbutzim, systematically followed the migration. The Air Force provided radio transmitters for their communications, one mobile transmitter for each post. Thus the observers were able to obtain information within "real time" on the shifting movement of the migration throughout the country.

The network of ground observers made it possible to obtain a relatively accurate picture (which was later completed by radar reports from Ben-Gurion Airport) of the large flocks of birds. The IAF was then able to begin adjusting and correcting the regulations according to real-time information regarding the birds' actual appearance. In years when the migrating birds arrived later than usual, the Air Force could sometimes add a few more flight days to its schedule.

The research made it clear that, during about 30% of the migratory season, the strength of the migrating flocks dwindles to almost nothing, and on such days low-altitude flights can be allowed even in the middle of the migration season. The observer network provided early warning on days with poor migration. When few birds were seen at dusk, and radar confirmed the report, we developed a procedure for informing the IAF. The following morning aircraft would be permitted to make low-altitude flights; however, if large flocks were sighted in the morning -- either by birdwatcher crews or on radar -- permission was withdrawn immediately.

FLOW CHART OF THE BIRDWATCHING CENTER



3. ESTABLISHING THE BIRDWATCHING CENTER AT BEN-GURION AIRPORT. In order to establish a single center which could collect all relevant data regarding movement of birds from all the sources of information, and to distribute this information in real time to all parties in the IAF who might need it, we established the Birdwatching Center in the control tower of Ben-Gurion Airport. It is currently run 24 hours a day by a retired radar officer of the IAF and by four female IAF radar specialists. A direct, private telephone line near the radar screen ensures that the information is relayed smoothly and quickly. Input comes from the network of ground observers, aircraft (motorized glider and civilian and military planes), control towers of IAF bases, and radar control units.

The Birdwatching Center provided ongoing information about flocks of birds located by radar which were flying in close proximity to IAF air bases or the approaches to them. In

Cooperation with the NRA, a woman soldier trained in birdwatching was positioned in each IAF control tower to help locate particular flocks which had been sighted on radar.

We also developed a procedure to calculate the speed of the migrating flocks so that it was possible to deliver real-time warnings even to those Air Force bases which are out the range of Ben-Gurion's radar system.

When huge flocks flew over shooting training areas, a real-time warning was given to the IAF control center to close the area in real time until the birds had completely passed by.

On days of heavy migration, warnings were also delivered to IAF radar control units to call off flights even outside the BPZ. Since some of the Air Force's largest bases are located in the center of the BPZ, with a high number of landings and take-offs, this real-time information was highly effective. Officers in the control towers thus had the opportunity to change the direction of landings and take-offs according to information about the birds' routes which was provided by the Birdwatching Center. On days with low migration, we permitted low-altitude flights in the BPZ, depending on the high reliability of radar to immediately signal any new flocks approaching.

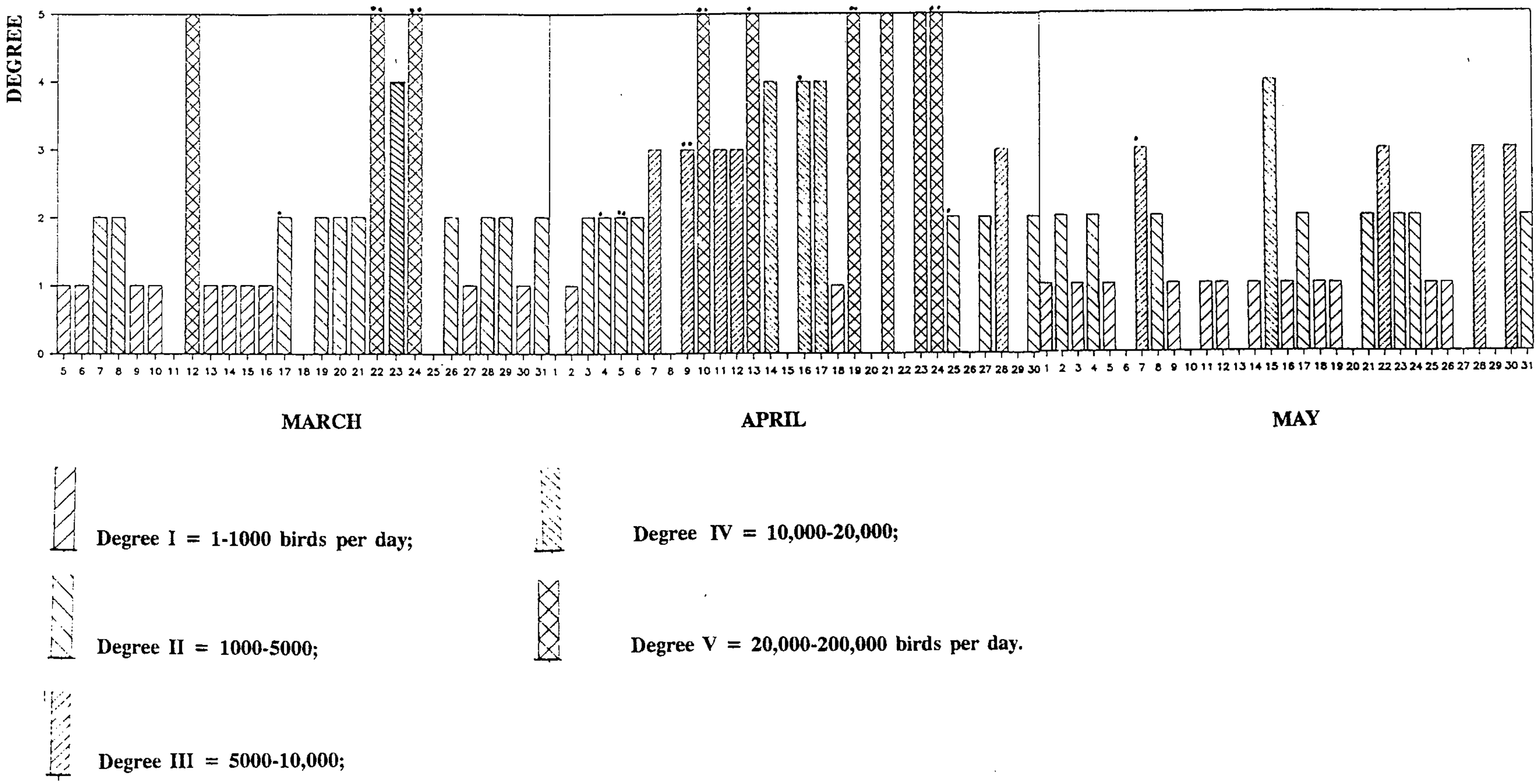
The following graph shows the movement of flocks from March 5 - May 31, 1989, according to data from Ben-Gurion Airport's approaching radar. Data was collected on a total of 73 days (the IAF is not in training on Saturdays and holidays, and therefore the radar is not manned at these times).

Degree of Migration	**Birds per Day**	**Total days**
Degree I	1-1000	24
Degree II	1000-5000	25
Degree III	5000-10,000	9
Degree IV	10,000-20,000	5
Degree V	20,000-200,000	9
		Total: 73

As shown on the graph, there is a low migration rate on 32.8% of the days.

Operation of the Birdwatching Center is critical because, during each season, there are a few days with dramatic changes in wind direction and speed. These changes, such as NW winds becoming southerly or SE, push the flocks out of the BPZ. In such cases the Center provides immediate reports to warn the whole system of the changes in real time.

Total of 1989 spring migration as tracked by Ben-Gurion approach radar (ASR-8), March 5 - May 31, 1989. Data is based on photos of radar screen.



The Birdwatching Center begins its Real-Time Warning System activity on August 1 for the autumn migration and on March 1 for the spring season (in each case, two weeks before heavy migration is expected to begin). The activity ends on November 30 and May 30, two weeks after the heavy migrations cease.

This procedure allows us to follow the migration from the moment it starts to build up in significant numbers, and to provide warnings about the presence of smaller flocks flying through which do not necessitate putting the BPZ regulations into effect. The final two weeks of the Center's season give the IAF the opportunity to fly at low altitudes, with no limitations in the BPZ, with the understanding that the Center will provide real-time warnings about small flocks which are still present and might cause problems.

Motorized glider and drones. Neither Ben-Gurion's approaching radar nor the network of ground observers can provide accurate information about the altitudes of migrating flocks. The motorized glider, flying along the migration route, is the perfect tool to provide real-time warnings of the birds' altitudes, and is crucial to the success of the Birdwatching Center. In addition to its radio, the glider is equipped with a cellular phone, and from the air it can locate the main flocks and their flying heights and report back to the Center instantaneously.

Due to a shortage of funds, we were not able to fly the glider daily. Nevertheless, the net work of the Birdwatching Center, as described above, made it possible to significantly shorten the BPZ limitations (primarily during the heaviest migration season), closing and re-opening it as needed in response to real-time warnings. During the fall, the BPZ was closed about October 10, but every other day through the end of November, one-four large flocks of pelicans flew across the whole country, potentially causing severe problems. We thus developed another procedure for cancelling even the PBZ regulations. The glider accompanied the flock from the moment they took off in the north of the country till they flew over the Egyptian border. A two-mile zone around the glider and the pelicans was declared a "moving BPZ" and closed to all flights.

Instead of the glider, on some days we used drones for the same purpose, escorting the birds for four-five hours, from the time they took off in the morning. The drones were also an ideal tool, mapping out the migration routes for our research. Flying some 4000-5000 feet above them, the drones filmed the birds along the whole length of their flight with a sophisticated video camera; as far as we know, this is the first time drones have been used for this purpose anywhere in the world.

Real-Time Warning System for Civilian Flights. We spent two years developing the IAF's Real-Time Warning System, and seeing it through till it was accepted and integrated into the Air Force's operations systems, with data flowing smoothly between the Birdwatching Center and all IAF units. Although the warning system was developed for the IAF, we began providing data regularly to civilian systems as well in 1989. They too had well absorbed the significance of the BPZs, and we received a great deal of information from them.

FINAL RESULTS

Since the BPZ regulations and Real-Time Warning System were put into effect, the number of air collisions with migrating birds has fallen dramatically. In the six years since we began the operation, the IAF lost no aircraft due to accidents with migrating birds, and there was not a single instance of its sustaining severe damage in such a collision. Considering that, from 1972-1983 the IAF suffered from tens of serious collisions with birds, this is clearly our greatest achievement.

REAL-TIME WARNING SYSTEM VIA SATELLITE

Professor U. Renner and A. Ginati, of the Technical University of Berlin, West Germany, are developing the TUSBAT project -- following the migration of 12 white storks fitted with radio transmitters which will be tracked by satellites in 1991.

In April 1990, Renner, Ginati, and Leshem equipped three white storks in Israel with transmitters and followed them with the motorized glider to check the operation of the system and whether or not the storks can fly freely carrying the transmitters. The results were promising (see cited literature, 8), and it is planned to launch the satellite in 1991. We believe that, in the coming decade, we will be able to attach tens or even hundreds of transmitters to migrating pelicans, storks and raptors, and these will provide a superb new real-time warning system for the IAF when flocks approach Israel from abroad.

ACKNOWLEDGEMENTS

Thanks are due to senior officers D., Z., H., A., G., O., B., and R. of the IAF for their close cooperation at all stages of the project; to E. Peretz, M. Pinkus, and the other glider pilots for many magnificent hours and days with the birds; to
A. Gilead, E. Satat, and Z. Frank of the Israel AIrport Authority; P. Magor, A> Firedman and the women operators of IAF radar equipment, for professional work; I. Agat, for assistance at Ben-Gurion International Airport; E. Dovrat, D. Alon, S. Blitzblau and R. Yosef, and all the 300 birdwatching volunteers from 27 countries, who helped collect the data in the field; to SPNI and NRA staff who also helped in the field.

Special thanks to Y. Yom-Tov, Scientific Supervisor of my PhD. thesis, the Israel Ministry of Science and Development, and the Ecology Foundation for providing funds for the study. And finally, to Prof. U. Renner and A. Ginati for launching the exciting new satellite project.

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BSCE 20/WP 13

EEC Regulations Regarding Reforesting of Former Farm Lands

(presented by Denmark)

1. In the Green Booklet, 3rd edition, May 1988, para. 2.2.1, you will find rules regarding the existence of trees and bushes in the vicinity of airports.

2. In accordance with EEC Council Directive 797/85, farmers under certain conditions are entitled to a grant to change arable land into forests.

3. The objective of this EEC Council Directive might be opposed to the work performed by the airport to minimize the risk of bird strikes as indicated under para. 1 where certain restrictions as to the presence of trees and bushes in the neighbourhood of airports are found.

4. Consequently, the participants to the meeting are urged to ask the appropriate authorities to take into account when approving regulations for turning arable land into forests that a working forestry programme on or near airport should play a secondary role to the airport priorities in the interest of flight safety.

ADF616413

BSCE 20/ WP 14
Helsinki, 21-25 May 1990

AFFSCE, London, sept. 1990
(slightly revised)

TOWARDS A EUROPEAN DATABASE OF MILITARY BIRD STRIKES

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ABSTRACT

The analysis of bird strike reports will only be a rewarding task when a multifold of biases can be avoided. In statistical terms this means that proper selections should be made. Depending on the questions to be answered the number of data available often is too small to achieve significant results. Therefore there is a strong tendency to lump data as much as possible. But as a result summary reports, such as those used in BSCE military statistics up to now, often cannot serve as comparison between countries. Even worse, they are not suitable for repeated analyses according to different criteria. The only way out is sharing the original bird strike forms while improving and standardizing the format. This report discusses a pilot study on the basis of 1988 data of six European Air Forces and gives some preliminary results.

TOWARDS AN EUROPEAN DATABASE OF MILITARY BIRD STRIKES.

1. INTRODUCTION

1.1. General Introduction

Bird strike statistics are a main source of information on which the prevention of bird strike hazards should be based. Improvement of airworthiness, bird avoidance measurements, and on-airfield bird strike prevention strategies all are served by a sound knowledge about the circumstances under which bird strikes happen and the consequences of certain types of bird strikes. We emphasize three crucial aspects. Firstly, there is the calculation of impact forces. For the development of proper and realistic design criteria, for each part of the aircraft good and detailed information on the relation between bird weight, aircraft speed and damage are of utmost importance (Ref.1,2).
Secondly, adapting flying operations to bird movements should be verifyable with respect to cost effectiveness. En-route bird strikes do make up the greater part of all military strikes. Any system that does warn pilots for high densities of birds has to take into account that with a minimum of operational loss a maximum degree of safety is to be obtained. In other words how many bird strikes are to be prevented at what reduction in flying. Again, good statistics are of vital importance (Ref.3).
Thirdly, bird strike statistics and biological knowledge can only be linked through proper assesment of the bird species involved. Once the problem species are identified one can disclose the true nature of the danger. This was illustrated by Lapwing data from the RNLAF (Ref. 4,5).

However, bird strike statistics traditionally are confined to summary tables which contain different break downs of the number of strikes over bird species, parts struck, type of aircraft etc. etc. (Ref.6,7). Due to shortcomings in the collection of data as well as in the presentation, these summaries do contain only limited information (Ref.8). Furthermore, military BCSE-statistics are very incomplete. It is therefore not surprising that the usefulness of these rudimentary military statistics is questioned (Ref.6).

Once it is acknowledged that bird strike statistics should be collected, it also becomes clear that the collection of such data only makes sense when it is done in a correct and detailed manner. This paper explores the methodological pitfalls on the basis of 1988 data.

1.2. Historic Perspective

Within the Air Forces Flight Safety Committe (Europe) (AFFSC(E)) the USAF(E) has stated that -since BSCE also produces joined statistics- the "bird strikes summaries" as reported by all members to AFFSC(E), should be given up. But the argument that military bird strike statistics already are taken care of by the BSCE is only true to a very limited extend. RNLAF repeatedly draw AFFSC(E)'s attention to the fact that the way in which their own "bird strike summaries" were compiled do result in so much loss of information that they become virtually useless. Mixing up data from fighters, transport aircraft and helicopters obscures all comparability. Loss of information is also caused by the fact that no clear-cut discrimination is made between strikes with and without damage. In general it is the lack of definitions and of discrimination between different types of bird strikes that reduces the value of these "bird strike summaries". Furthermore there is hardly any knowledge as to what extend the collected data is reliable. These shortcomings in the present way of compiling bird strike summaries were acknowledged by the committee. But also the potential importance of good statistics and their exchange between members was emphasized. Rightly so, good statistics were reckognised as a main tool in the effective understanding of the bird strike problem. It was therefore agreed that member states no longer contribute summaries but instead dump their individual bird strike reports in a joined database. This database then could be used as a commonly owned source of information.

Analysis of a very detailed and complete but relatively small database, as the one of the RNLAF, did show that it is possible to obtain information about airworthiness (Ref.2); altitudinal distribution (Ref.3); temporal distribution (Ref.4) and bird species involved (Ref.9). Since the RNLAF is only a small Air Force, the main problem in any use of the database is the relatively small amount of records. To do sound and proper statements, databases for a large number of years have to be combined to overcome this problem. However,not for all analyses it is possible to lump data from a number of years. For instance, to get some idea about the clustering of bird strikes by day RNLAF data simply are not sufficient in numbers. Another bias resulting from the use of data from only one country is the unballanced use of the airspace. The German plain is the main operational area for the RNLAF. Since all air bases are located within the Netherlands the flying hours are not evenly distributed over the entire operational area. Missions normally begin from, and end at a dutch airbase. Thus, on average the geographical distribution of the flight intensity will be skewed towards more flying time spent near the bases than in perifery of the operational area. Geographical information should therefore be corrected for this phenomenon.

Most of the above raised objections against the use of the database of only one country could be undone by compiling a joined database.
The RNLAF was engaged to compile this joined bird strike database from data provided by the AFFSC(E) forces for the year 1988. Experience gained could then be used to evaluate the reporting requirements and give some idea about the effectiveness of such a database.

1.3. Outline of this Paper

We have chosen a step-by-step approach. Fistly, the data are summarised in the "classical" way , taking several recent BSCE papers as an example (Ref. 6,7,10,11). Then, limitations of the material are illustrated by making very specific selections needed to answer questions concerning the geografical distribution of bird strikes. Thirdly, distributions of bird strikes are made over altitude and time.

It is emphasised that the results only are presented to show what information potentially could be available in the raw material and that on the basis of these preliminary results only a few firm conclusions can be drawn.

2.METHODS AND MATERIAL

2.1. Methods

As a consequence of the decission of AFFSC(E), individual records of 1988 bird strikes were obtained from RDAF, GAF, RAF, USAF(E) and RNLAF. Only USAF(E) and RNLAF records were available on floppy disk, other forces either sent copies of their original forms/telexes or computer output on paper.
From all individual bird strike records the key items were put in a database. By modifying the structue of the RNLAF database it was possible to use standard ways of describing all different aspects of a bird strike. Nevertheless, it took some effort to line up the data to one standard. Very often, usefull information was extracted from the pilots description of the incidentin his own words. While compiling this database, notes were made on problems encountered. These problems mostly concerned the standards used in denotating the different aspects of a bird strike.
All handling of the data was done using the DBase-III database handling package. The total number of records added up to 1.766 bird strikes during 1988 for the five forces concerned. Apart from all the obvious standard information on each bird strike some extra characteristics were denoted to each strike. These items are:

REGION
Giving some broad idea of geographical location. The main regions used were:
German Plain
>49.00 deg. N and <56.00 deg. N
>02.00 deg. E and <11.00 deg. E
United Kingdom
Rest of Europe
Other regions like parts of the american continents and Africa were used infrequent and were left out from the present analysis.

TYPE OF AIRCRAFT
In order to make proper use of the database, distinction is needed between (at least) three types of aircraft:
JETS.......All types of fighter/trainer jet aircraft
HELI......All types of helicopters
OTHER.All cargo aircraft, wether it be prop or jet
engined. Also smal prop or turboprop aircraft.
In fact all a/c not denoted as JET or HELI.

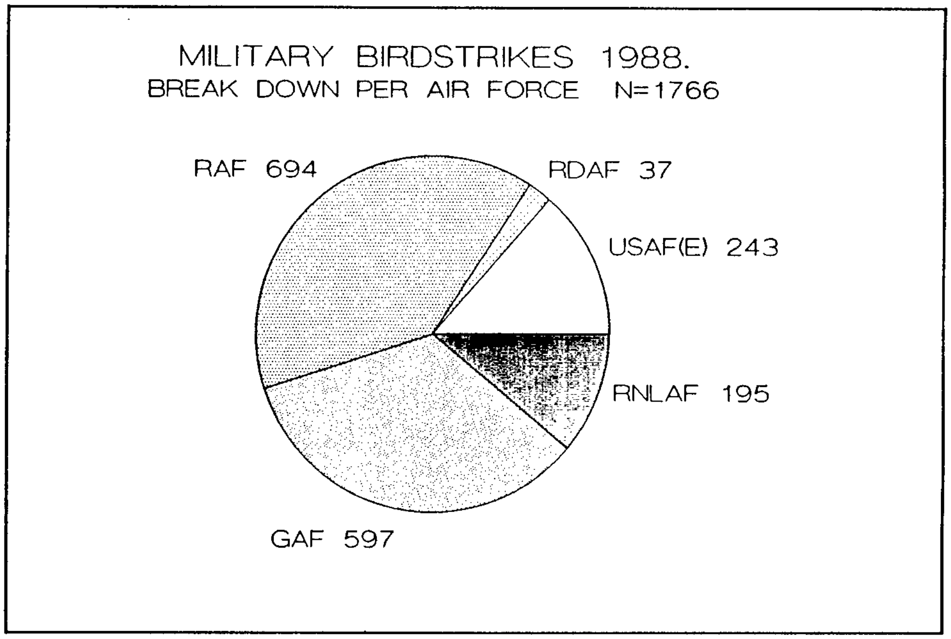
STAGE OF FLIGHT
For the right selections to be made, it is neccesary to know wether the bird strike occurred en-route or during the presence of the aircraft on or near an airbase. Using a number of criteria every record was attributed as en-route, local or unknown. The most useful criterium is aircraft speed (Ref.3). Other information used to attribute birdstrikes to these selections sometimes were:
-altitude
-parts struck (landing gear)
-phase of flight
-remarks like "dead bird found on runway"

2.2. General Information on the Available Material

2.2.1. Available Bird Strikes from the Different Air Forces

The number of strikes for each contributing air force is given in figure 1. The fact that the RAF clearly is top scorer does by no means imply that this air force is really running a greater risk of bird strikes than for instance the GAF or RNLAF.

FIGURE 1.



Apart from the obvious differences in fleet size, differences between the forces concerning the following factors may have contributed to the final results presented in figure 1.

- Reporting standards. Reporting of bird strikes can be organised in a number of different ways. It will be clear that differences in reporting system may result in different standards of reporting. For instance, the inclusion of crew chiefs in the reporting system means that far more strikes without damage will be reported then when only pilot reports are included (Ref.2). In addition, the attitude of pilots towards bird strikes and their consequences will irrevocably have influence on the willingness to report all bird strikes.

- Composition and activity of the air fleet. Apart from the obvious distinction between slow moving helicopters and propeller aircraft on the one hand and fast flying turbo-prop and jet aircraft on the other hand, it is clear that -if only because they cover a larger distance- (high speed) jet fighters do have per flying hour a greater chance to encounter birds than any other kind of aircraft. Another important fact is the relation between aircraft size (frontal area) and the number of bird strikes. Thus, the distribution of flying hours over the different aircraft is a major factor determining the total number of bird strikes an air force will suffer.

- Type of operations. Since the distribution of bird movements is extremely skewed towards lower altitudes (Ref.12), operational tasks which include low level missions of long duration and/or extreme low altitude will have a relatively high score of bird strikes (Ref.1). The importance of altitude is clearly demonstrated by the fact that a special subgroup within the BSCE was formed, called "Bird Hazard to Military Aircraft at Low Level" (Ref.13)

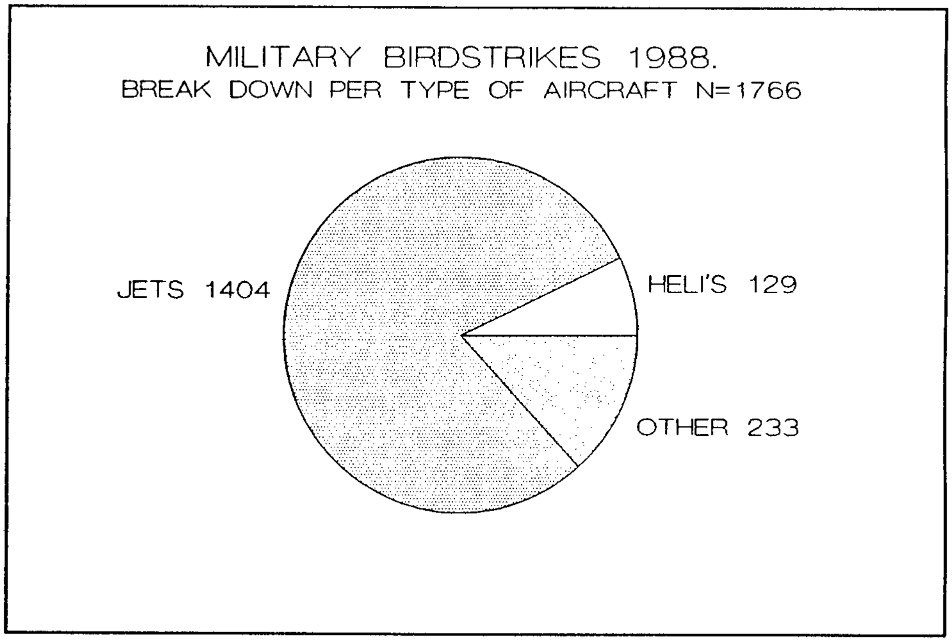
- Geographical location of the arena. Birds are not evenly distributed over a region. It is well known that for instance arid areas do only hold a fraction of the number of birds that are frequently present in wet, fertile and lush areas. The bird movement working group of BSCE has therefore been active in drawing up maps of bird concentrations. The cooperation in this working group even resulted in a NW European map of bird concentrations (Ref.14). It is clear that air forces in whose arena vast bird concentration areas are located do run a more than average risk to encounter birds during missions.

2.2.2. Distribution of the Bird Strikes over Aircraft Type

Only three categories of aircraft were reckognised, JETS, HELI and OTHER. The number of strikes for each category is given in figure 2. Detailed information about the break down per air force is given in appendix A. As is apparent from figure 2, the majority of bird strikes are encountered by jet aircraft. Since no information was available on the number of flying hours these results have to be looked at with some reserve. From RNLAF statistics it is known that the difference in ratio (number of bird strikes corrected for the number of flying hours) between jet aircraft and both other categories roughly amounts to a factor 10. If this is also valid for the other forces it means that a realistic comparison between the aircraft types based on ratios will reveal that the susceptibility for bird strikes of jets is far more overwhelming than is shown in figure 2.

Since the number of bird strikes with non-jet aircraft is quite low and very unevenly distributed among the forces, for reasons of comparibility only jet aircraft are considered in the majority of the following presentations.

FIGURE 2



2.2.3. Bird Species Involved in Bird Strikes

As is clear from figure 3, in relatively few cases information is available on the bird species involved (25.9%). In only 56 cases it was explicitely stated that no bird remains were found. The break down over the Air Forces of the strikes of which the bird species is known is rather surprising. The different Forces are not represented in the proportion one would expect on the bases of their total number of strikes (see figure 1). Most striking is the underrepresentation of GAF and USAF(E) while RNLAF is extremely overrepresented.
The different types of birds that are encountered by the different forces are given in figure 4. Two phenomena in this figure are rather prominent. As was already indicated in figure 3, the proportion of bird strikes on which no information is available on
bird species does vary dramatically between 90.2% for the FAF and 20.0% for the RNLAF. Furthermore, as the proportion of "unknowns" decreases the greater part of the known cases is made up by songbirds, swallows and swifts; virtually all birds of less than 100 grams. To detract this fact with the argument that these small birds are insignificant since they will hardly cause any damage does not hold. On average the RNLAF scored 10% damage for strikes with these relatively light birds in 1988. In earlier analysis of the RNLAF database it became clear that in the case of jet aircraft flying at speeds of more than 300 knots, strikes with these light birds did result in damage in about 20 percent of the cases (Ref.2).

From figures 3 and 4 it will be clear that firm and solid conclusion as to the bird species involved in bird strikes cannot be made. The discrepancy between the forces in the amount of information on bird species simply still is to large.

FIGURE 3

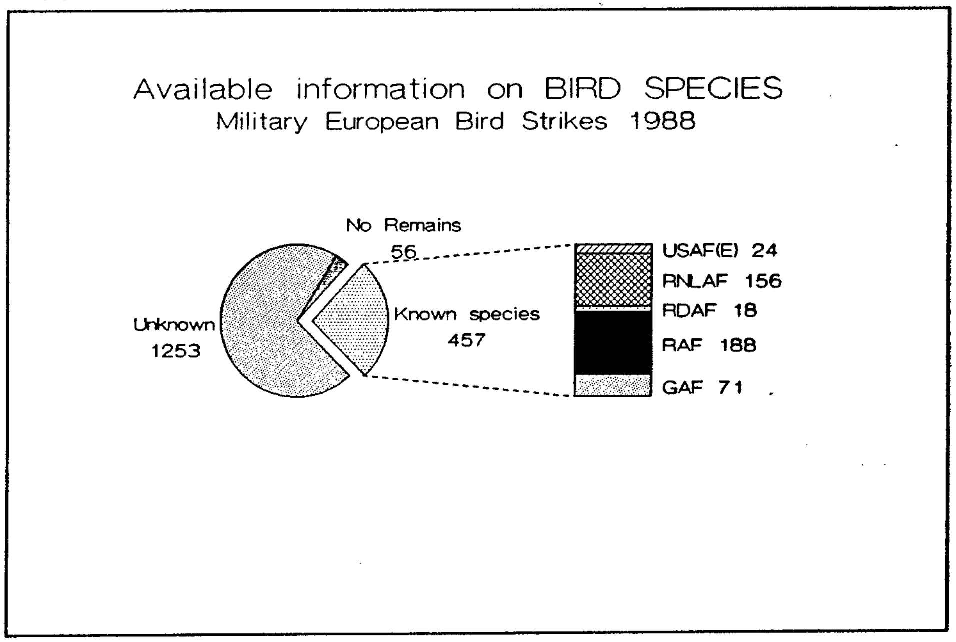
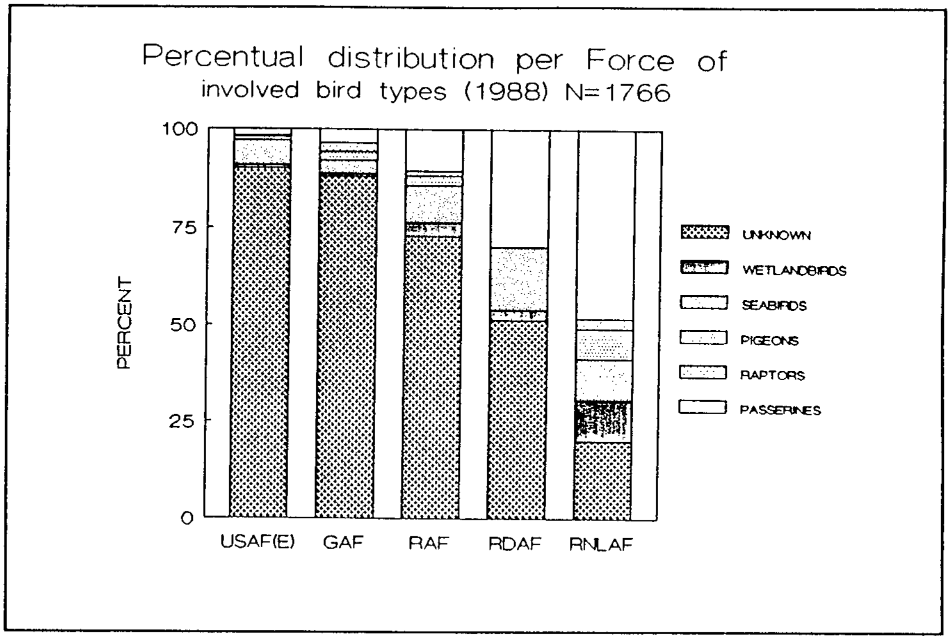


FIGURE 4



2.2.4. The Distribution of Bird Strikes over the Stages of Flight

As is mentioned under section 2.1. each bird strike was earmarked as being of local, en-route or of unknown stage of flight. The distribution of all strikes with jet fighters/trainers over these three categories is given in figure 5. Clearly the majority of bird strikes do occur en-route. From over a quarter of all strikes it is not known at what stage of flight they happened.

Detailed information per Air Force about this topic is given in figure 6. There is a marked difference to be noticed in the proportion of en-route strikes between GAF and RNLAF on one hand and RAF and USAF(E) on the other hand. This could well mean that the reporting discipline of RNLAF and GAF is higher. Detailed analysis of RNLAF data in the past (Ref. 2) has revealed that in both the typical en-route bird strikes as well as the "unknowns" more or less the same bird species are involved. These strikes with mainly small passerines and Swifts are often unnoticed by the pilot and, for a greater part, are reported thanks to the attentiveness of the crew chief.

FIGURE 5

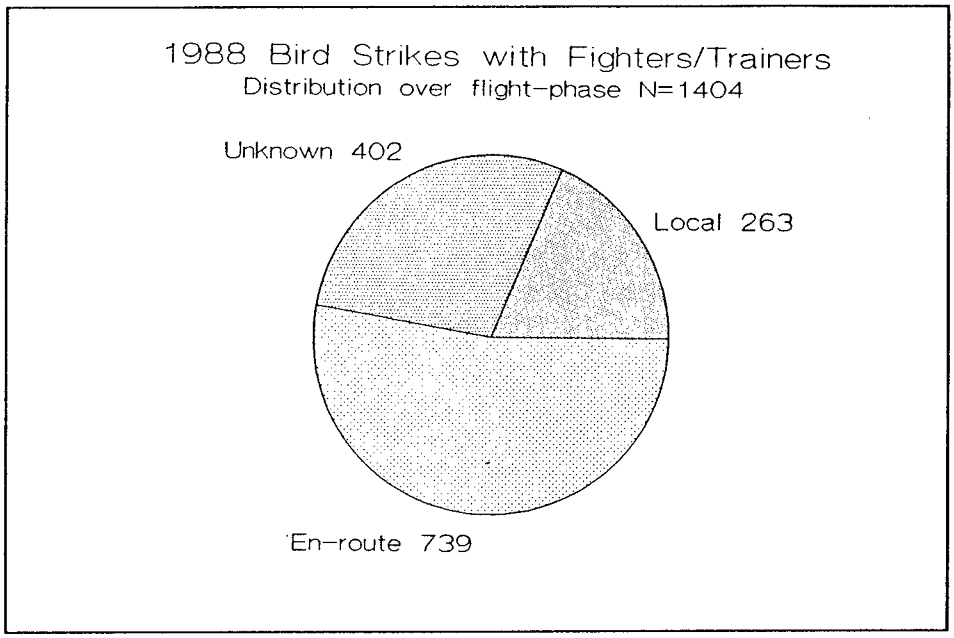
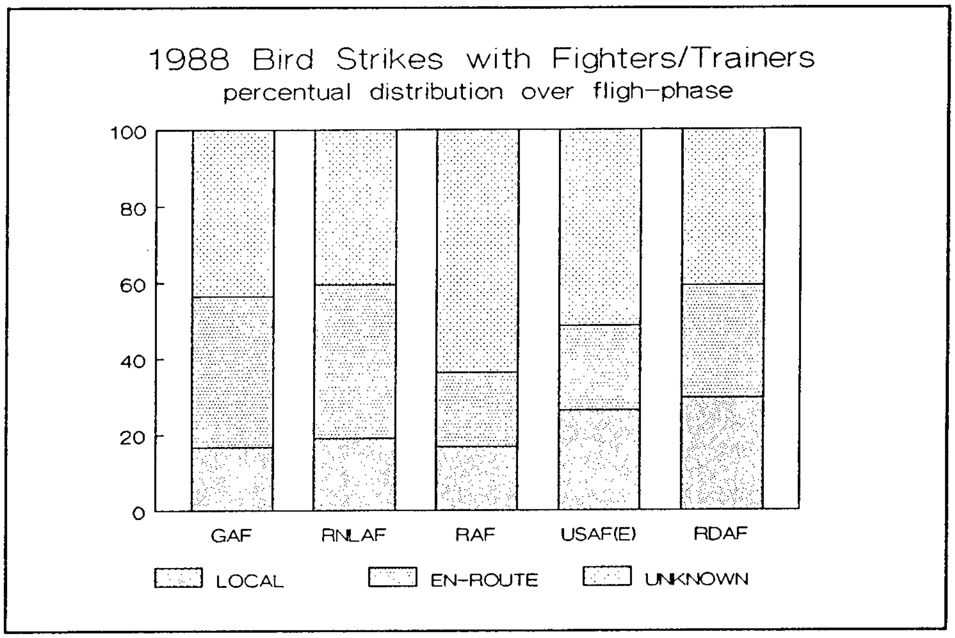


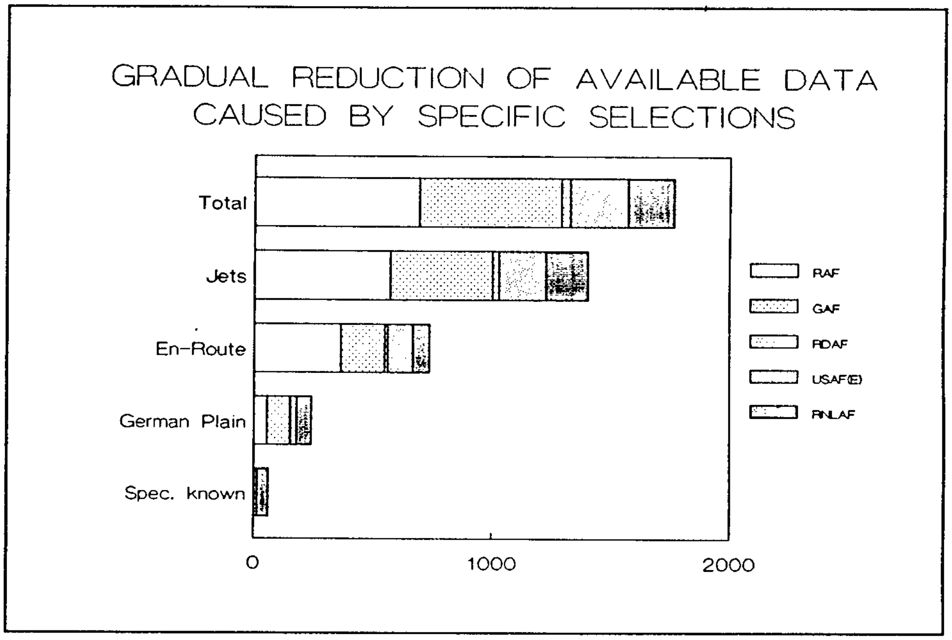
FIGURE 6



2.3. Suitability of the Material for Detailed Analysis

The data presented so far raised more questions than that they provided answers. In order to understand this, one has to realise that for specific questions to be dealt with, different selections of the database need to be consulted. Quite often, within these selections different break downs are needed as well. This does mean that the original available number of bird strikes drastically diminishes once detailed and specific analysis are to be made. This effect is shown in figure 7 (based upon data from appendix A). If the geographical distribution of bird strikes with en-route jet aircraft over the German Plain is to be analysed from the original available 1766 strikes only 61 strikes remain from which the bird species involved is known. To look for differences between the geographical distribution of the species involved therefore is rather an unpromising job. Numbers of bird strikes with sufficiently detailed information within the 1988 joined database still are to low to make sound statements. Hence, analysis of the geographical distribution of the strikes within the German Plain are limited to the overall distribution, regardless of the bird species.

FIGURE 7



However, even interpretation of these maps showing locations of bird strikes is very difficult. A number of factors certainly will have influenced the final result. To mention only the main reasons:

a. As emphasized in 1.2, flying activity is not evenly distributed. To make balanced maps which are corrected for this fact one needs geographical information on the overall average flying activity per geographical unit.

b. Bird strike warnings have been issued in certain regions. This will mean that -as a consequence- accents are shifted.

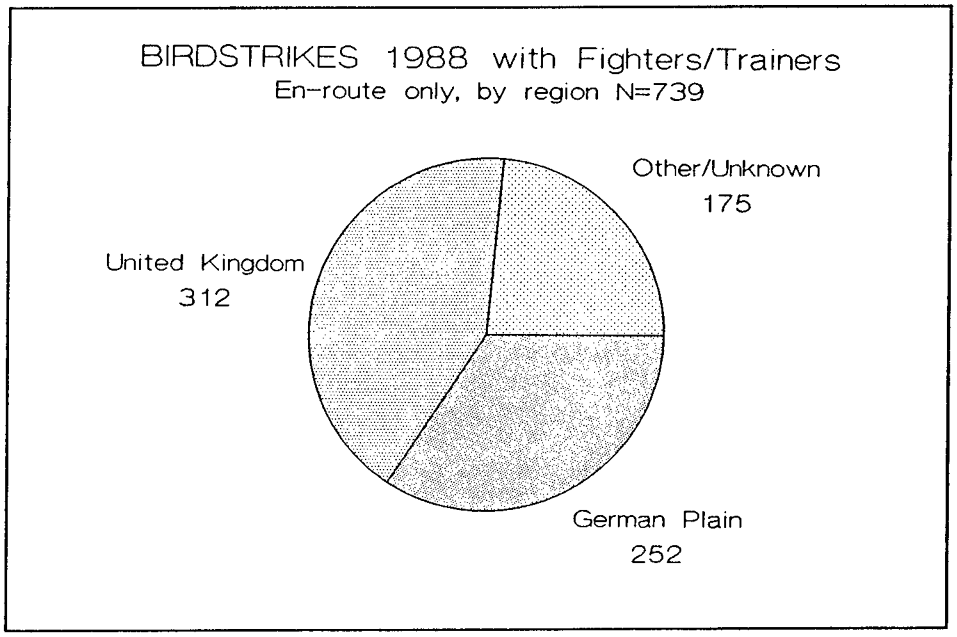
c. In reporting, pilots tend to remember the location as it is related to generally used landmarks. Some heavy dots on the map may in fact mean that the exact location was in the broad surroundings of that specific location.

d. The time aircraft spend at different altitude levels also is of great importance. Bird densities generally are concentrated in the lower airlayers. Knowledge as to the altitude layers in which the majority of bird activities are concentrated and the circumstances (wheather, landscape,season) with which these vary are only scarcely known (Ref.12).

About the role each factor plays, little is knowledge is available. The total effect of all influences is that for different areas different correction factors are needed. About the range of these corrections no information is available. It has to be stressed that for a realistic and proper interpretation of the geographical distribution of bird strikes much more additional, detailed information is needed.

If the en-route strikes with jets are grouped according to the region in which they occured, the United Kingdom and the German Plain roughly score the same number of strikes (figure 8). This enabled us to make comparisons between both geographical regions for the variation in time and altitude. Both aspects are not susceptible to differences in reporting. For the variation in time all weekends were excluded and distributions were made of the number of strikes per day. For the variation in altitude, a distinction could be made between en-route strikes and local ones as well as between strikes in the separate regions.

FIGURE 8



3. RESULTS

Since in fact nothing news was added to the existing (BSCE) literature, the data presented so far were ranked as "material" and not as "results". We only used the 1988 joined miltary data set to expose the unbalanced and confusing picture one gets when looking at bird strike statistics sorted out only superficially. In this chapter we try to make one step further. The results are still preliminary.

3.1. Geographical Distribution of Bird Strikes

All contributing Air Forces do operate to a lesser or greater extend within the German Plain; each Air Force therefore only has limited knowledge about the total geographical distribution of bird strikes within this region. In the United Kingdom as a contrast, hardly any non-RAF operations do occur apart from those from USAF(E). Figure 9 pictures the distribution of all en-route bird strikes with known location in the Geman Plain; low flying areas are also indicated. No distinct concentrations of bird strikes within these low flying areas is apparent.

Realising the difficulties in interpretation as mentioned in section 2.3, from figure 9 still some conclusions can be drawn.
First of all a concentration of bird strikes is to be noticed in the north west part of Germany and in Schleswig-Holstein. The heavily populated Ruhr area stands out as an area completely devoid from bird strikes. Both facts clearly are related to flying activity of aircraft. The relative shortage of strikes in Belgium of course is mainly due to the missing of BAF data.
If looked upon in detail, concentrations of bird strikes can be reckognised at the shooting ranges. Vlieland range stands out markedly, as do Siegenburg range and Nordhorn range. Helchteren range is not as prominently represented as one would expect; the fact that no data from BAF is included might well be responsible for this. No bird strikes were reported from Terschelling range. At first sight this may be surprising since Vlieland range nearby stands out so markedly and the resemblance in use of both ranges. The difference in bird strikes between these two ranges probably can be explained by marked differences in the immediate surroundings. Vlieland range is located near a very densely populated (year-round) bird sanctuary which also acts as a high tide roost and twice a day accumulates numerous birds from vast areas of the Waddensea. Terschelling range on the other hand is located at a bare sandbank and no mudflats are situated near the range; in fact the immediate surroundings of Terschelling range are rather poor in birds.

The results justify the conclusion that for all species considered together, no clear geographical clusters of bird strikes do emerge from the material.

3.2. The Distribution of Bird Strikes over Time

Generally the distribution of bird strikes over time is given as a monthly frequency of all strikes. In this way day-to-day variations are obscured and all flight phases are lumped. In the latter case distinctly different seasonal patterns for local and en-route bird strikes are mixed up (Ref.4). Here, the analysis is restricted to the en-route data from jet fighters/trainers. On a day-to-day basis a comparison is made between the bird strike frequency in the German Plain and in the United Kingdom.

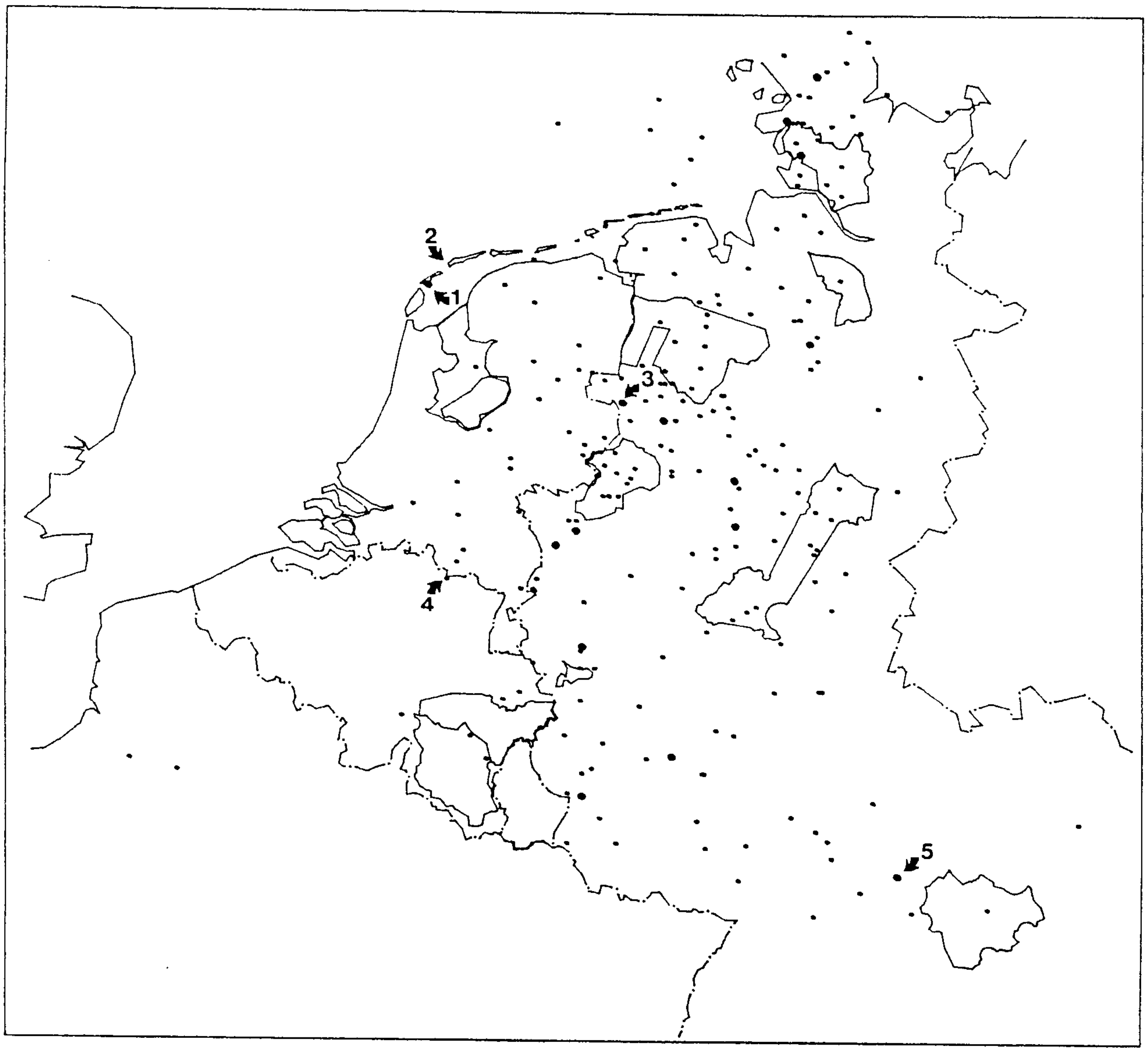


Figure 9.

BIRDSTRIKES 1988, JETS
EN-ROUTE, GERMAN PLAIN

Air Forces included:
RAF, RAF(G), USAF(E), RDAF,
GAF and RNLAF.

German Plain defined as:
49.00N < X < 56.00N
02.00E < X < 11.00E

SHOOTING RANGES:

1 VLIELAND
2 TERSCHELLING
3 NORDHORN
4 HELCHTEREN
5 SIEGENBURG

NUMBER OF STRIKES

Location on-page	:	238
Location off-page	:	4
Location unknown	:	10
Total	:	252

·:	1 strike
•:	2-5 strikes
●:	6-10 strikes
⬤:	>10 strikes

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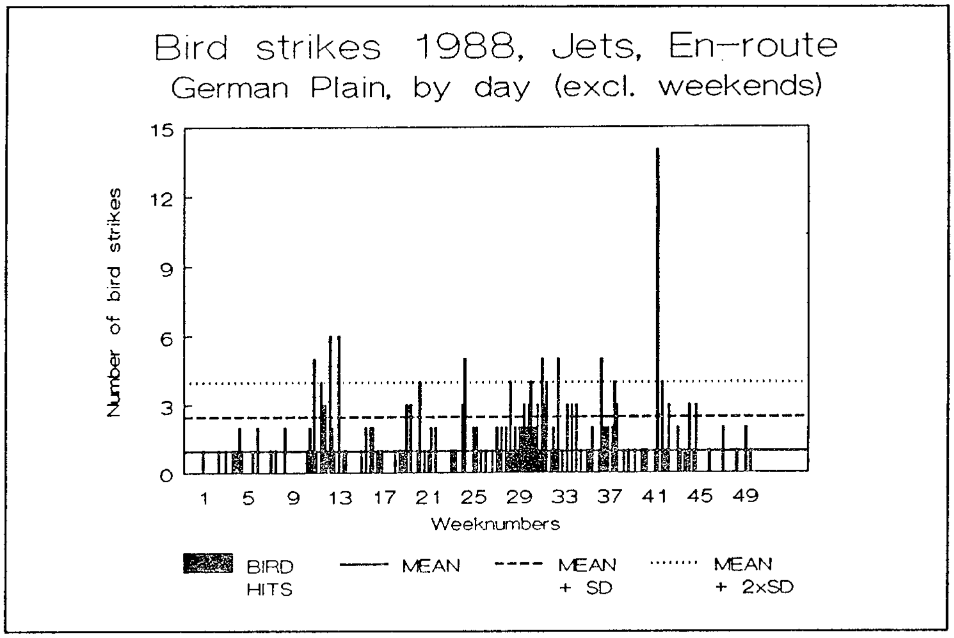
To get a better and more detailed idea about the amount of clustering in time, for each day (excluding weekends) the number of bird strikes per region is given in figure 10a and 10b. In order to indicate the real deflections in these figures also the mean number of strikes per day and the single as well as the double Standard Deviation is shown. If only the real deviating days (with a number of strikes that exceeds the two times SD line) are taken into account, the two regions differ in a very distinct way. The extreme days in the United Kingdom are more or less evenly distributed over the year with only a slight concentration in late summer. In the German Plain a concentration of strikes did occur in spring and during autumn migration, when there was one day with an extreem high score. While reading figure 10A (German Plain) one should keep in mind that bird strike warnings are issued in this area and consequently this will have lowered the potential number of strikes during both spring and autumn migration (Ref.15). Therefore, figure 10A,(German Plain) does not reflect the amount of bird activity, as is the case in figure 10B (United Kingdom).

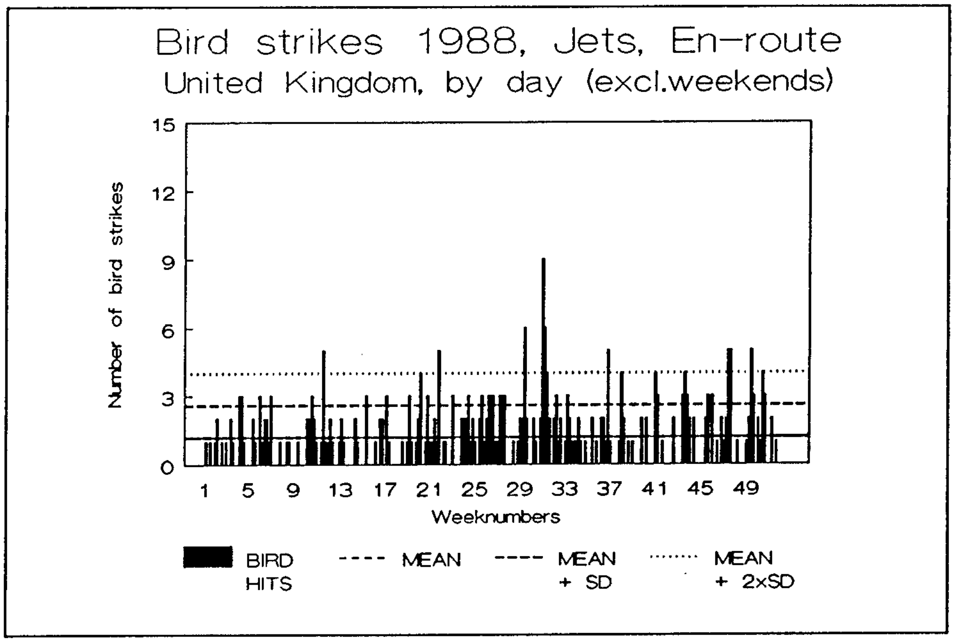
Thus, despite the fact that birdtams are issued for the German Plain, in both regions concentrations of bird strikes in time evidently are existing. This does mean that by avoiding only days with more than average bird strike risk, a substantial gain in flight safety can be achieved without reducing the flying program correspondingly.

FIGURE 10A



Bird strikes 1988, Jets, En-route
German Plain, by day (excl. weekends)

FIGURE 10B



Bird strikes 1988, Jets, En-route
United Kingdom, by day (excl.weekends)

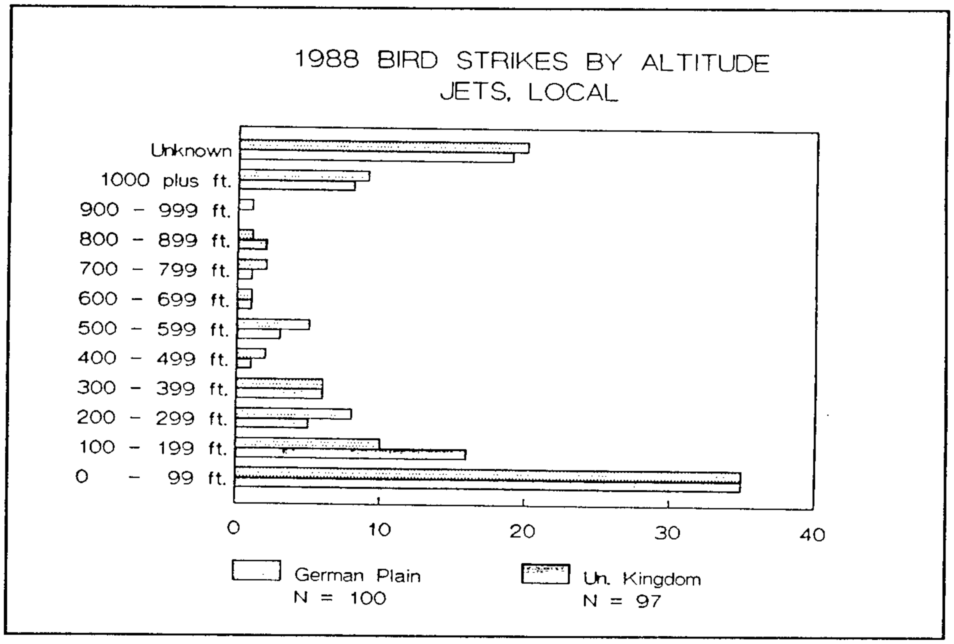
3.3. The Distribution of Bird Strikes over Altitude

Since there are distinct differences in the characteristics of local bird strikes and strikes en-route (Ref.2) the analysis of the distribution of birdstrikes over altitude was done for both situations seperately.

3.3.1 Altitude Distribution of Local Bird Strikes

The distribution over altitude from local bird strikes with jet fighters/trainers is given in figure 11. As is known from detailed studies using small scale radars combined with visual observations from highly skilled bird watchers, the majority of bird movements in Western Europe does take place in the lowest air layers (Ref.12). Aircraft taking off or landing normally cover all altitudes below 1000ft. under fixed angles with the earth and therefore have an equal chance of hitting birds in each 100 ft. layer. The risk of encountering a local bird strike therefore is to a great extend dependent on the number of birds in each air layer. This means that the altitude distribution of local bird strikes does reflect the distribution of birds over altitude (Ref.2,3). As is clear from figure 11 there are no distinct differences in the distribution of local bird strikes over altitude for the different regions. In both cases the majority of strikes occured below 200 ft. This result may surprise those who think that, since the United Kingdom is situated at the end of migratory flyways, the altitudinal distribution of birds in the United Kingdom will differ from that in the German Plain.

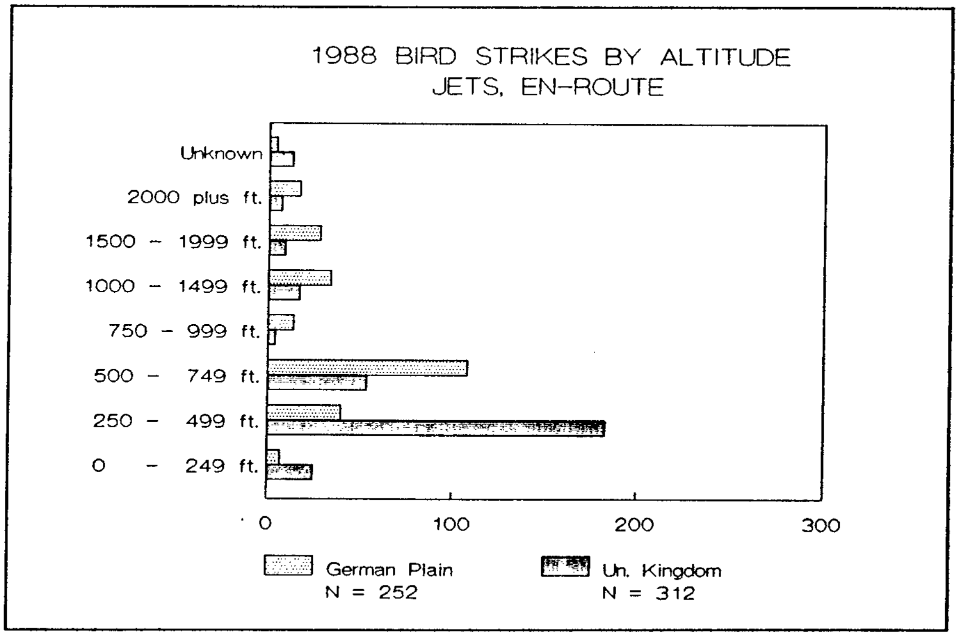
FIGURE 11



3.3.2. Altitude Distribution of En-Route Bird Strikes

In contrast to the local situation the distribution of en-route bird strikes does not represent the altitude distribution of birds but rather resembles the time spent by aircraft at different altitudes (Ref.2,3). For the German Plain as well as the United Kingdom the altitude distribution of en-route bird strikes of jet fighters/trainers is given in figure 12. Knowing that the majority of aircraft movements do take place at low levels it is not surprising that in both regions more than half of all strikes occured below 750 ft. Nevertheless there is a difference between both regions. The distribution of bird strikes is more skewed towards lower altitudes in the United Kingdom than in the German Plain. Flying at lower altitudes in the United Kingdom than in the German Plain by birds, aircraft or both may be the reason for this. We suggest that RAF operations in the United Kingdom do involve more hours of extreem low flying than all forces together do over the German Plain operations in the German Plain.

FIGURE 12



4. CONCLUSIONS AND DISCUSION

The feasability of a joined European Military Database is the main topic of this paper; the presented arrangements of data only serve as examples as to what kind of analysis and monitoring is possible, using such a database . Therefore, this section only deals with methodological aspects, putting emphasis on the weak points.

4.1. General Conclusions

4.1.1. Implementation of a joined database

The first preliminary results of this analysis do offer such good prospects that it is more than worthwile to pursuit a joined European Military Bird Strike Database. Already now , with still limited material, it proved very well possible to do the kind of analysis that provides new information and offers better insight into the bird strike problem. For instance, the temporal distibution of bird strikes both in the United Kingdom and in the German Plain holds clues to an improvement in the prevention of en-route bird strikes.
Standardisation, added to just a slight improvement in the reporting standards of the plainer items should not be considered impossible and would substantially improve the results. This implies that with all contributing Air Forces reporting a limited number of items in a consequent and complete way, a reliable set of data can be achieved which is very well suited for analyses in broad terms.

A number of items are not easily put in a general joined database. These items for instance concern information that is difficult to acquire since expert knowledge is needed (i.e. identification of feather remains). Information on effects from bird strikes on operations is another item that needs very consistent and solicitous reporting. Not all Air Forces might be willing or able to go in such detail in reporting bird strikes. This does not need to be considered an insuperable barrier for the set up of a common European military database. Having available very detailed information on some items from only a limited number of Air Forces could well mean that the value of the whole database can be upgraded. Provided that all Forces do contribute to the database their basic information in a standardised an consistent way it is very well possible to extrapolate in-depth analyses done on the detailed material of just part of the contributors. But first of all, emphasis should be put on the improvement of the contributed basic information.

4.1.2. Problems Encountered

The difficilties that arose in this first attempt to set up a joined European bird strike database can be classified as belonging to three main categories which will be dealt with below:

<u>Absence of standardisation in the reports.</u>
For a number of questions less detailed information is sufficient and only a broad idea about specifics items is needed. Such rough indications could serve as a basis for selection. To illustrate this point we consider the break down of the material over the regions as it is presented in figure 7. The majority of the strikes that had to be attributed to the "unknowns" certainly could be avoided. Bird strikes that are not

noticed by the pilot during the mission and are reported on the basis of evidence of a strike during post flight inspection can in almost all cases be said to have happened during the last mission. Since it is known where this mission took place the rough geographical region can be registered.
The same can be said about the time of the bird strike, the least that is known is the time the mission begin and ended. Records in which the time of the event is marked as "unknown" can in most cases be avoided.

Reliability of the material.

For a number of items it is neccesary to have information on the extend to which the information is reliable. This is best illustrated using the "bird species involved". For only a minor part of the bird strikes it is known with what species the aircraft collided. And even from these relatively few records it is often not clear how the given bird species was identified. It is obvious that identification of feather remains by an expert will be of better quality than information from pilots who saw a glimps of the bird prior to the impact. In the last case there will be a tendency to call light coloured birds "gull" and darker ones "crow"; likewise small birds will be called "sparrow" or swallow", if they are seen at all. To what extend these abberations are present in the material is not clear. That they are present is nicely illustrated by the pilot that claimed that the bird strike he encountered during a mission in the Falklands involved a Robin. Wether this has to be judged as a joke or as an indication that a small bird was involved it not clear. Certainly Robins do not live in the Falkland area.

The distinction between "definite no" and "not reported".

A major source of concern is the fact that from the bird strike reports, for a number of items the discrimination between "definite no" and "not reported" cannot always be made. This kind of uncertainties do for instance emerge when insight is to be acquired on all the consequences of bird strikes. Apart from financial losses also the loss of operations has to be included. Information on aborted missions then becomes vital. Quite often it is not mentioned on bird strike forms, wether or not the mission was aborted and a precautionary landing was made. In evaluating the bird strike form one then has to assume that no such actions were taken, but onbe cannot be completely positive about the decision. These kind of problems mostly arose for items that were not treated separately on the forms and where the information had to be extracted from the pilots description. It is clear that these uncertainties only can be avoided if very clear bird strikes forms are used on which each seperate item has to be dealt with. Even more important, it should be the possibility for each item to tick at as being really "unknown".

Handling the above mentioned imperfections might at first sight seem a considerable task. However, the use of a not to extensive but standardised bird strike form in a disciplined way wil surmount most of the problems. In this way it is possible to score a considerable increase in extractable information and improve the quality of this information without much effort.

4.2. Discussion

In setting up a joined database, in which the records consist of information on the individual bird strikes, an important extra dimension is given to the traditional joined summaries in BSCE as well as in AFFSC(E). Not only more detailed analyses now are possible, the same data will be available for future analyses as well. Of course all individual Air Forces had (and will have) their own databases. But, as in all statistics, the reliability of the analyses is strongly dependent on the numbers included in these databases; for detailed analyses numbers of national databases will often be to small to do draw sound conclusions. It is therefore surprising that former initiatives to set up a joined database of European military bird strikes did not succeed. As to the reasons why it took so long before the importance of such a joined database was reckognised one can only guess. Certainly confidentiallity, differences between Air Forces, tradition, but also disbelief in the potention of such a database may have played a role. Taken into account the promising results described in this paper all of these objections seem superficial. A slight effort of each contributing Air Force will be sufficient to create the optimal circumstances for the succesfull set-up of a European military bird strike database.

Despite the optimistic views displayed above, some legitimate problems remain to be solved. First of all it is very important to convince pilots of the benefit to be drawn from good basic information on bird strikes. Acording to experiences in the RNLAF this almost certainly will improve the willingness to make proper reports of bird strikes and improve the reliability. Realising that in order to collect the data one needs the cooperation of the pilot the introduction of straight forward and simple bird strike forms, that are easily filled in, seems a sensible and obvious thing to do. In order to develop such a form it has to be decided which items are to be considered as the minimal basic aspects of a bird strike and which items have to be considered as being of more importance in relation to very specific and country dependent aspects. Once these decisions are made, the adoption of a (partly) standardised bird strike report form (cq. data base structure) becomes feasable. Such a form could well consist of one part containing aspects that will be fed in the joined database and another part containing country specific information that may differentiate with respect of criteria and degree of detail.

Once agreement is reached on the above mentioned matters a decision can be made as to the final database structure. It then seems fair to share the burden of feeding data in computer files. This could best be realised if a standard and straight forward program is available to accomplish this in an efficient way. RNLAF is willing and able to develop such a program and make this available to contributing Forces.

Another substantial problem is illustrated in figure 3. For most Air Forces, in only very few cases, information is available on the bird species involved in bird strikes. Even when species are mentioned it is often not clear how reliable this information is (see allso section 4.1.2.). It has to be stressed that collecting and professional identification of feather remains considerably increases the value of reported bird strikes, especially those strikes that resulted in damage of the aircraft.

5. ACKNOWLEDGEMENTS

The realisation of this first attempt to set up a joined bird strike database was only possible thanks to the cooperation of the contributing AFFSC(E) members. Flight safety departments of the air forces of Denmark, Germany, United Kingdom, France, United States of America (Europe) and the Netherlands made available their individual bird strike records. Secretarial facilities were provided by the RNLAF. The time consuming job of feeding data, that only were available on paper, into computerfiles could only be done thanks to the help of Mrs. W.A.C. Wakker. The computerised mapping of bird strikes in the German Plain was done with a custom-made program developed by Mr. M.A. Strobbe who spent part of his conscription on this project. Other people who, each in their own way, made contributions to this paper are: Lt.Col. W.H.J. Christiaans, Mr. G.H. Kamphuis, Mr. J.R. van Gasteren and the student pilots J. Post, E. Murer and M. Bakker.

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APPENDIX A

	GAF	RAF	RDAF	USAFE	RNLAF	TOTAL
Total number of bird strikes	597	694	37	243	195	1.766
Of which were with JETS	429	573	27	197	178	1.404
From JETS:						
Local	72	97	8	52	34	263
Unknown	170	112	8	40	72	402
En-route	187	364	11	105	72	739
From the en-route:						
location elsewhere/unknown	93	20	6	50	6	175
location in the United Kingdom	0	285	0	26	1	312
location in the German Plain	94	59	5	29	65	252
From the German Plain: coordinates known	94	55	5	24	64	242
Of which bird species known	11	1	0	1	48	61

……

Bird Species:						
Unknown	479	460	19	217	34	1.209
No bird remains	36	15	0	0	5	56
Remains sent for ID, yet unknown	11	31	0	2	0	44
Known bird species	71	188	18	24	156	457

……

Type of Aircraft:						
Carriers, props etc.	56	120	8	45	4	233
Heli's	112	1	2	1	13	129
Jet fighters/trainers	429	573	27	197	178	1.404

ADF616414

BSCE 20 / WP 15
Helsinki, 21-25 May 1990

STARLING ABATEMENT AT PIRINCLIK AIR STATION IN EASTERN TURKEY

L.S. Buurma & R. McKenna

ABSTRACT

Massive starling roosts near runways may pose a threat to aviation, especially when the birds perform their aerial display flights shortly before sunset. But also the droppings of hundreds of thousand birds may cause unacceptable hindrance, while the extra weight put on wires and installations may result in serious damage. This report illustrates the problems and possibilities encoutered at the US air station Pirinclik in Eastern Turkey where Asiatic starling populations traditionally roost in extreme numbers. Earlier measures taken to dislocate the birds failed. However, the abatement described here has proven to be succesful. Emphasis is put on the need to understand the behavioural aspects of communal roosting in the starling.

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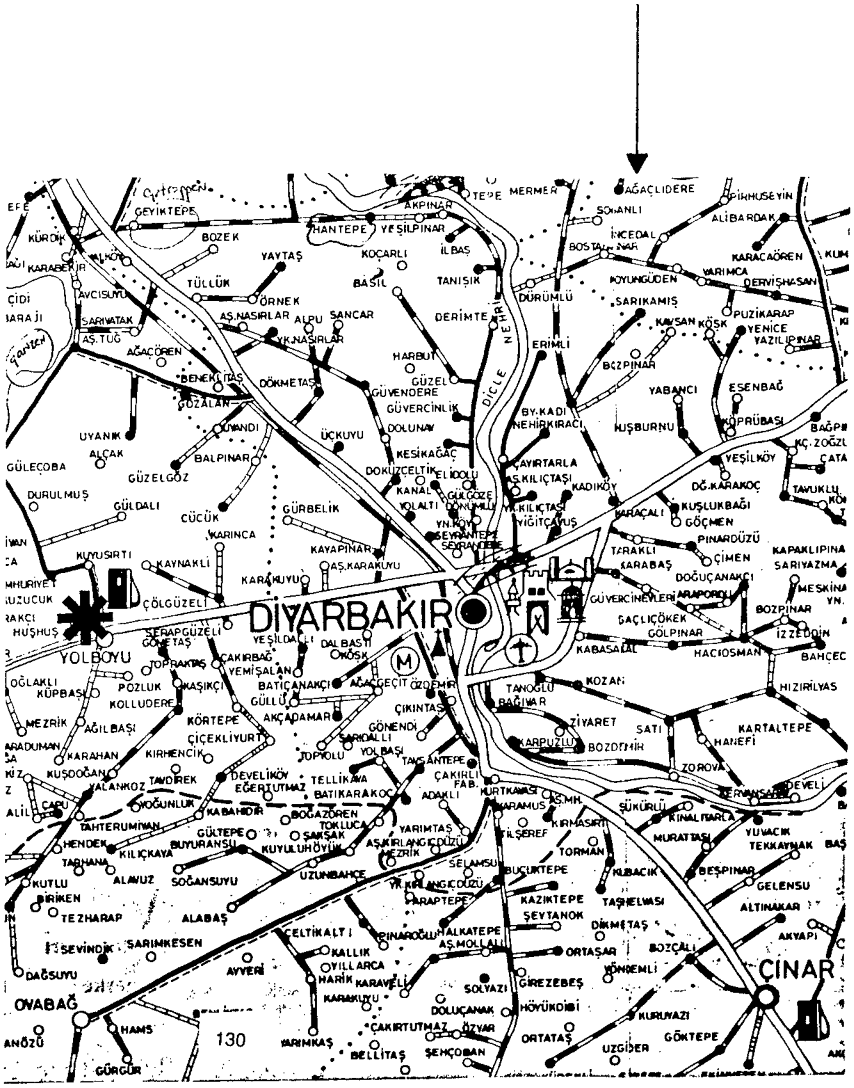
Figure 1: Maps of Turkey and the area around Dyarbakir
The asterix indicates Pirinclik Air Station



Contents

1. Introduction

Since the early fifties starlings (Sturnus vulgaris) have caused problems at the US Air Station of Pirinclik in Eastern Turkey (figure 1). Pirinclik AS is located approximately 5 miles west of Dyarbakir, a city of about half a million inhabitants. The communications and radar installation (89 acres with 157 buildings) is located in an open area at 2805 feet MSL. It is close to the small village of Yolboyu. Starlings arrive at this remote place in late autumn coming from their Russian breeding grounds. Wintering numbers of birds seem to have increased, perhaps because of recent increased agriculture in the local area. At Pirinclik the Starlings have chosen the huge radar antennae as roosting sites. The maximum number spending the night there has been estimated to be as high as 3 million individuals! Noise, smell and droppings are the most frequent reasons for complaints. However, technical problems with the equipment, and even power failures have been directly attributed to the large roosts of these birds. Despite all the problems, many menbers of the station community still enjoyed the flocks during their aerial displays around sunset.

In the spring of 1987, the RNLAF was asked to consider the feasibility of sending a Dutch team of bird controllers to abate the starling roost. To determine the magnitude of the effort and to answer the question whether the Starlings have alternative roosting sites, a study visit was conducted by the authors during the last week of October 1987. The positive results from this visit led to the follow-on campaign by an eight member team from 5 till 25 November 1988.

The year in between appeared to be essential for the formal arrangement between US, Dutch and Turkish authorities for the purchasing of equipment and for the transportation of all materials to Pirinclik. A real bottleneck was the import of scaring cartridges ("ammunition") and flare pistols ("weapons") by an US transport aircraft crossing Greek airspace.

This report summarizes the history of the bird problem at Pirinclik, some aspects of starling biology and the observations of distribution of roosts and flight lines around Dyarbakir and Pirinclik, and finally the set-up and results of our campaign. As starling roosts can pose serious hazards to aircraft and therefore cannot be allowed near airfields, the abatement set-up described here may serve as an example.

2. Acknowledgements

The authors wish to thank HQ USAFE in Ramstein (Germany) and US Space Command for their trust in the RNLAF "Starling Abatement Team", and all team members (A.M. Adema, J. Bergman, H. de Groot, T.E. van Klaveren, F.T.W.M. Lelieveld, H.G.V. Linckens) and in particular A. Dekker for their professional work. At the Air Station both commanders (Col Wyraz, USAF and Col Hayreter, TAF) and the civilian chiefs (mr Cherry, Scheidemann, Askoy and Thomas) were most cooperative. Special thanks go to Mr Lew Ryan (dep chief operations) and Capt All Trivette (civil base engineer) for their full involvement in the campaign.

3. History of the Starling problem at Pirinclik

Several trip reports of USAF biologists indicate that the starling problem has existed since the construction of the super structures in the early fifties. The general impression is that the birds arrive late October and that they reach peak numbers at the end of November. If the winter is not severe the birds may continue to roost at Pirinclik Air Station till February or March. However, when the ground is fully covered with snow or when the winter is particularly cold, they leave earlier. Therefore, some years have experienced worse infestations than others.

The long tenure employees at Pirinclik reported that many different methods including shooting with shotguns, broadcasting loud noise, ultra sounds and distress calls and using trained falcons had been tried without success. During the fall and winter of 1978-1979 over 100 trees were removed and others were heavily pruned. This did not stimulate the starlings to look for another sleeping place. During the winter of 1979-1980 the birds were unsuccessfully scared by spotlights at night and sprayed with water during cold nights. In 1985 a further pruning of trees followed, causing a further destroying of the ambiance of the station and loss of shade during the hot summer. In November 1985 a valiant attempt to use AFFF foam (a detergent in water) by the fire department to distress a few birds and have them disturb the main flock underscored the impracticality of this method.

Further discussions with the long tenure employees revealed that while many different techniques had been tried, none had been done persistently. Furthermore, past efforts were too general and too oriented towards chemical pest control measures. This might have been caused by the fact that the size of the problem was judged in a ambivalent way. Not only did the maximum number of starlings vary from winter to winter, but also did the willingness of the successive military commanders to enjoy and/or to hate the birds. The quick changes of personnel in the base staff also hindered a long term recognition of the problem.

4. General remarks on the Starling

Figure 2 gives am impression of the different subspecies of the starling in the old world and a rough indication of their flyways during the seasonal migration. The map indicates that starlings passing through Eastern Turkey belong to the subspecies Sturnus vulgaris poltaratskyi, S. v. caucasicus and/or S. v. purpurascens. So far nobody has tried to find banded birds in order to check their recruitement areas. Judging from the numbers of dead birds that are usually found in and below the antennae (see photo) this could be a rewarding task!

The starlings are not breeding in the region. Among the local Kurdish people the starlings are known as "snowbirds" (kar kucu) because large populations arrive when the first snow falls. Part of the migrating population spends the winter around Dyarbakir, but many birds leave the area when it becomes really cold. Their final destination is the east Mediterranean region. Large midwinter roosts occur in Jerusalem and large numbers are eaten along the north african coast (Egypt, Lybia).

The reason that large populations of starlings stop to winter in the Dyarbakir region is the local agricultural developement. The areas very rich soil has been exploited by many old cultures for more than 4000 years. After a poor period, the land around the Euphrates and Tigris rivers is again undergoing rapid developement. Many natural areas are threatened but the starlings appear to have profitted from the increased human activity. Most probably they also stay here for longer periods than in the past. The roosting behaviour facilitates food finding (see chapter 5.1.) and the growing number of birds spending the night at Pirinclik Air Station can be seen as an indication of their increased presence around Dyarbakir.

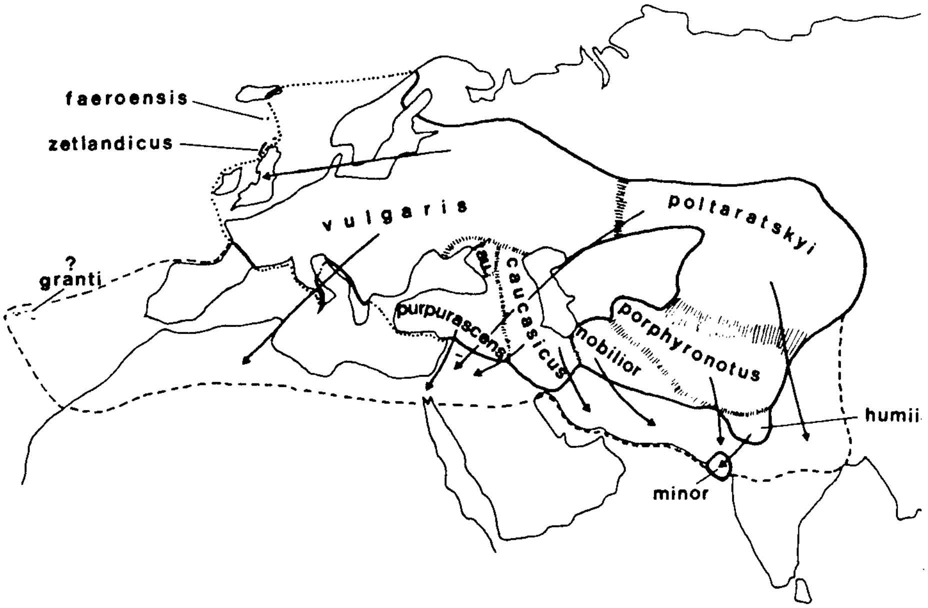


Figure 2: The breeding ranges of the subspecies of Sturnus vulgaris and their approximate directions of autumn migration. Hatched area's indicate zone of hybridization between subspecies (from Feare 1984).

5. Survey of the roosting behaviour

In this chapter we describe some recent literature on the roosting behaviour of the starling as well as report on our own first hand field oberservations. We refer to the book by Feare (1984), "The starling", published by Oxford University Press, UK for further reading and other literature references. Also Monograph No 23 of the British Crop Protection Council "Bird problems in Agriculture" (E.N. Wright ed. 1980) gives very valuable information.

5.1. Roosting behaviour in general

Bird are thought to roost communally for three reasons: conservation of energy, defense against predators, and transfer of information. Starlings try to protect themselves against wind and thereby reduce metabolic losses but whether they derive any benefit from the heat output of neighbours is moot. The energy saving that might be derived from roosting together certainly seems unlikely to be sufficient to offset the expenditure involved in commuting to and from distant feeding areas. Reduction of metabolic losses at night is not believed to be the ultimate factor responsible for the evolution of communal roosting behaviour (Feare 1984).

It also seems unlikely that social gatherings are always effective as defense against predators. In fact a traditional roost attracts predators and some birds of prey are real specialists in feeding upon the starling. Kestrels are very numerous at Pirinclik.

The modern hypothesis is that roosts primarily serve as information centers. Newcombers profit from the knowledge of birds that are already some time in the area by following them in the early morning. This however, is not yet explaning in detail the whole social affair. Furthermore, experienced birds have other interests and should try to avoid competition: why do they continue to visit the roost? Part of the answer may be the fact that the food itself has a highly unpredictable distribution. It appears in patches within the landscape, mainly due to agricultural activities. A permanent information exchange probably is an insurance for all the birds.

5.2. Starling Roosts in the Region

A very crucial question with respect of the chances of success for an abatement attempt is whether the birds have alternative places to sleep communally. In other words, to what extent are the starlings confined to the air station? Is it really the only suitable roosting site in the area? If it is not, what is the special attraction of these US super structures?

The first answers came already after three trips up to 30 miles from Pirinclik (towards NE, SE and WSW - see figure 1). Firstly, several suitable roosting sites were found i.e. small groups of reasonable high trees, tree plantations, small bushes etc. They were fairly scattered over a wide area, and partly invisible from the roads because many of them are situated in the lower areas (undeep valleys) below the plateau. Most potential roosts were found along the Tigris and close to and in Dyarbakir. A long talk with a farmer family in Hantepe made clear that the starling is very well known and, more important, that it is caught and eaten on a large scale. One of the catching technics is to blind the birds at night with a flash light and take them by hand or with a small net. Another possibility is the use of catapults, as we found out our selves when we discovered young boys shooting many starlings in the centre of the city at night in 1988.
From several talks with local (Kurdish) people we conclude that the starling is in fact a welcome extra source of protein. One "kar kucu" is worth about 10 Turkish Lira on the market. This in turn leads to our assumption that starling roosts have not much chance to settle at one particular place. Traditional (huge) roosts as they do occur in W. Europe would

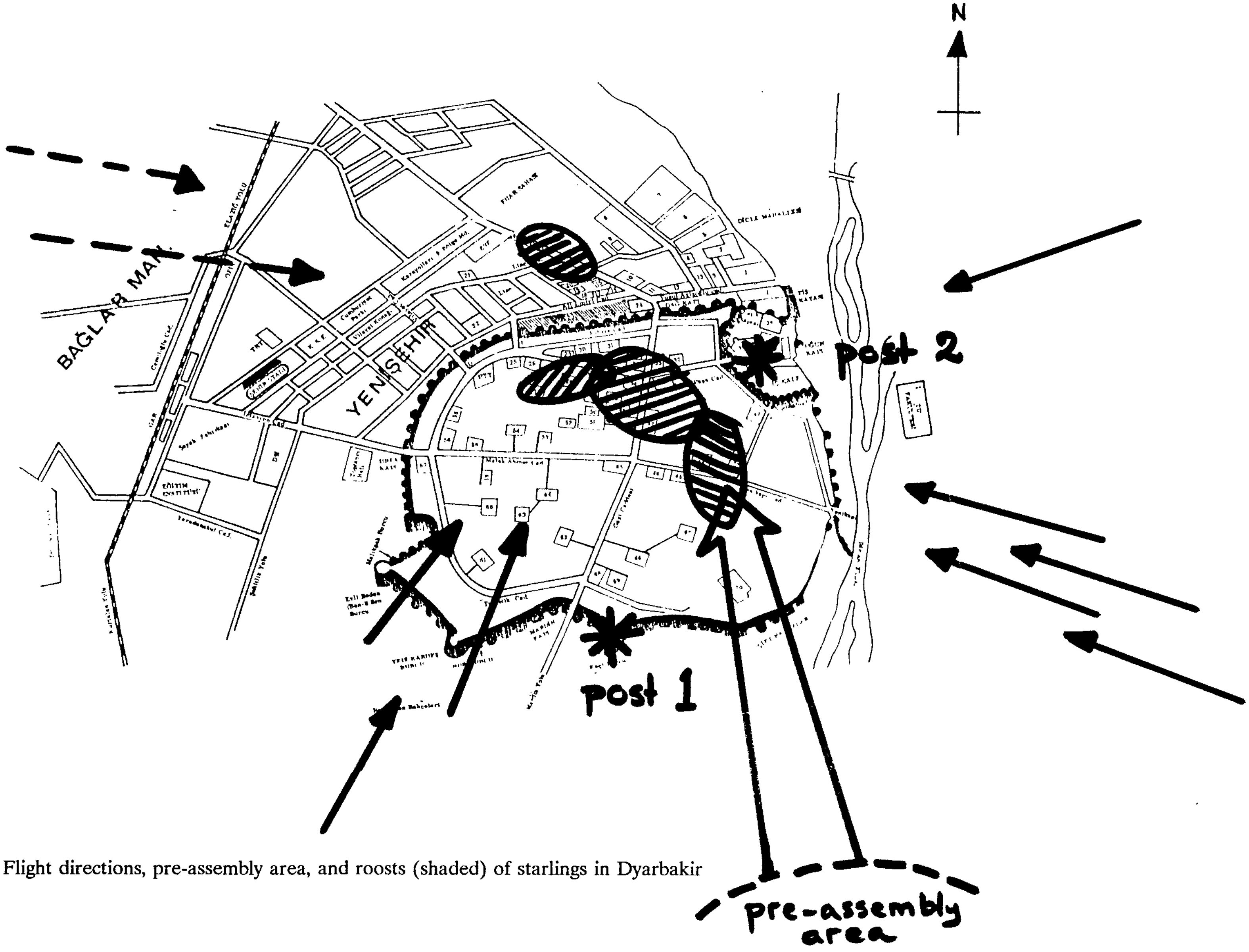


Figure 3: Flight directions, pre-assembly area, and roosts (shaded) of starlings in Dyarbakir

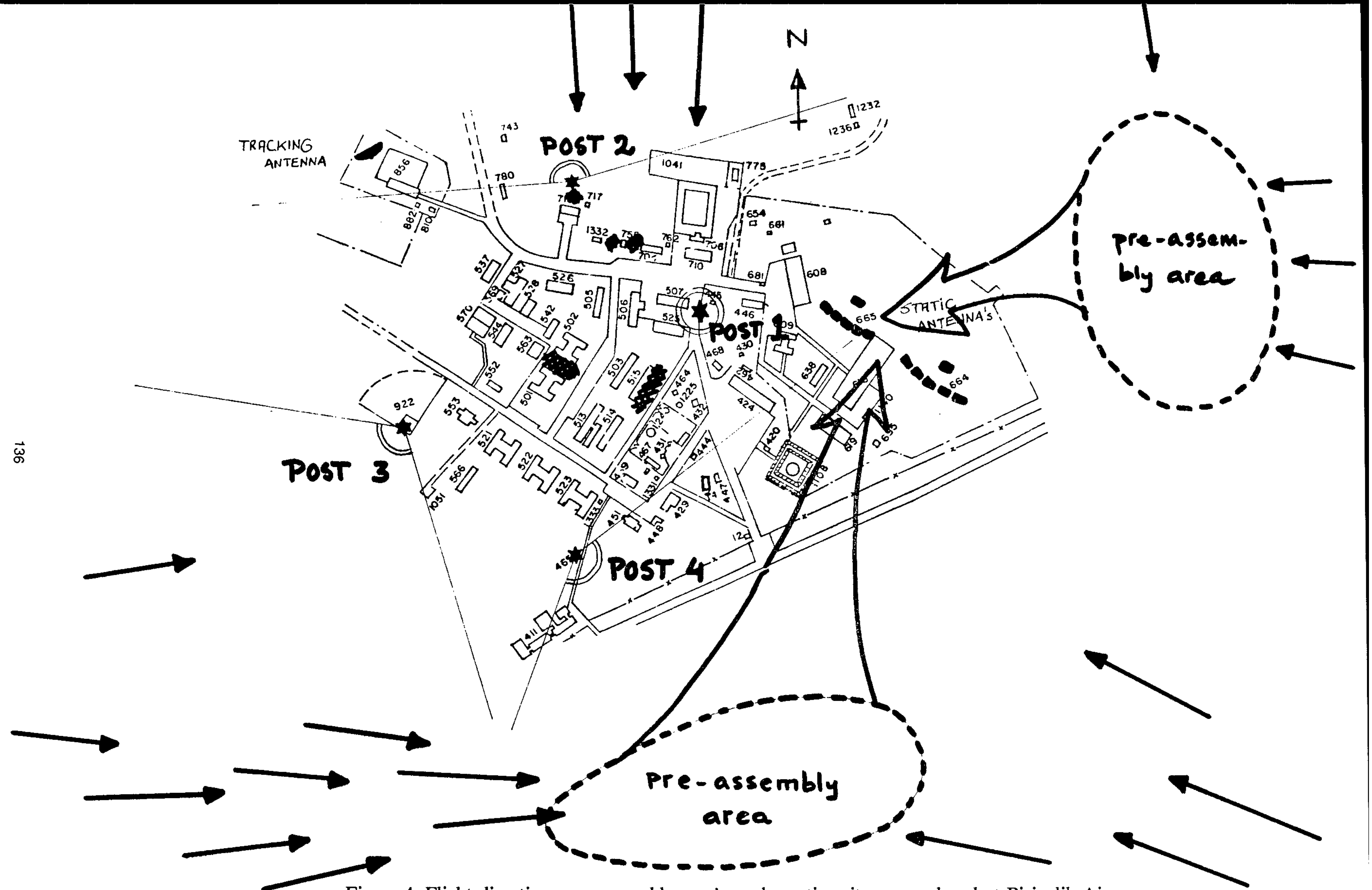


Figure 4: Flight directions, pre-assembly area's, and roosting sites around and at Pirinclik Air Station.

attract many (young) hunters in Turkey and therefore would disband easily. Because this permanent threat doesn't occur at Pirinclik, the radar site is a relatively safe place.
In 1987 we did not found other starling roosts for the simple reason that we were too early in the season. Probably the starlings were also fairly late that year. We did not get much chance to detect overflying individuals in order to calculate on the map their roost by taking bearings. For the same reason we also got no good impression of the feeding habitats.

The next year we were later in the season and were much more succesful. All the assumptions of 1987 proved to be true. Pirinclik appeared not to be the most important roost. During our first days we had sufficient manpower to observe the flight lines and aerial display flight above the city of Dyarbakir. In figure 3 some of the most important flyways and four roosting sites (one could better speak about roosting areas - the birds seemed to chance places a lot) are indicated. The best points of observation were at the big wall around the city, especially the two spots indicated on the city map. After four days of observations, in the evening as well as in the early morning, we estimated the number of roosting starlings in Dyarbakir as at least one million. The best way to avoid double counts is to scan the whole area during the peak aerial displays. However, just before this moment the visibility was quickly reduced by the smoke of wood fires in all the house of Dyarbakir.

5.3. Numbers and Flight Lines to and from Pirinclik

During the second half of the afternoon we tried to detect the first starling movements in the direction of Pirinclik. This was done from the station as well as by quick drives by car to the W and the E (see figure 1). Once the influx started we counted all birds from four fixed positions and within certain angular sectors making notes on times, numbers per flock, flight directions and behaviour.

Figure 4 is a summary of the flight line pattern, the pre- assembly areas and the roosting sites. The total number of birds spending the night at the station increased from 120,000 to over 200,000 during the first five days of our stay. Many birds came in from the West more or less following the main road. We could not find out from how far they originated, but presummably it was more the 10 miles. Thanks to the many drives between Pirinclik and Dyarbakir we are sure that the most remote birds came from half way both locations. Further eastward all birds move E. Walks around the station revealed big starling flocks at the wheat fields. The heavy clay with many stones but only very few pathes did not permit extensive observation trips. Furthermore, the wandering flocks close to Pirinclik obscured the pattern of movements of birds coming from further away. Apart from the very obvious arrivals from the W there was also an important stream from the SE and less bird coming from due N.

5.4. Arrival, Departure and Aerial Display Timing

The starlings followed a more or less fixed daily pattern of arrival. The birds started to enter the station in small numbers from 14:.30 onward. But sometimes they might also leave the station again. We discovered an important pre-assembly area south of the site in the open fields. Tens of thousands of starlings took off repeatedly for a few meters and than landed again. Around 16:00 the birds left the pre-assembly areas usually in a few huge flocks, but sometimes in one long stream. The birds that had arrived earlier and were settled would now usually join the big flocks when they started to perform their magnificent aerial display flights. By 16:.30 most flying activity is over. Smaller numbers were still trying to get a place in the few trees at the station. Large numbers remain on the big antenna's.

In the early morning the first sign for departure was the periodically intensifying noise production. The birds climb to the top of the trees as far as there is space left for them. Once and a while a flock takes off but soon lands again. Then, roughly one quarter to half

an hour after sunrise, an massive exodus takes place after a sharp increase of calling activity. Different from the situation in Western Europe most of the birds leave in a big stream into one direction, soon followed by another big exodus. Simultaneous departures in all directions (producing nice ringlike echo's on radar screens, see the book "radar ornithology" by Eastwood 1967) could be observed only to a limited extent.

6. The Abatement of the Starling Roost

6.1. Principles

We have used the technics and followed the procedures which are practized when we dislocate starling roosts in Holland. The proper use of a combination of loud bangs plus light flashes (bird scaring cartridges) and broadcasting of amplified distress calls usually leads to a complete displacement of the bird population within a few days. When planning the campaign three aspects were kept in mind.

a. Disturbance of information transfer: As was explained in chapter 5.1. recent theories on roosting behaviour emphasize the importance for inexperienced birds (newcomers, young ones) of finding the good feedings places by joining the flocks when leaving the roost in the early morning. Furthermore, there is a clear but by far not yet fully understood social process going on when the birds arrive (aerial displays) as well as when they depart (wave like exoduses). Probably it serves not only the information transfer but also helps to regulate the competition for food during the day. We believe that the scaring actions should disturb these social processes, and that it therefore is essential to extend the actions to the early morning, just before the departures.

b. Stress optimalization: Birds, as all living creatures, are highly adaptive, and soon become habituated to phenomena that do not pose a real threat. Even the physically intense scaring signals that we used act only as "superstimuli" when they cannot be mentally handled. Therefore, they should happen in logic sequences and time intervals but also should be as shocking and unpredictable as possible. Thus, silence intervals can be considered as important as the stimuli itself. Never should the scaring get a "automatic nature", become predictable by means of preceeding signals and originate from fixed locations.

c. Reinforcement of the feeling that the location is unsuitable: This takes time. Once the birds have been discouraged to settle, they will nevertheless remember the place and will inspect the situation again and again the first evening and time by time on consecutive days. Remember that the birds have no alternative during the first night. It is already too late to find and/or to fly to another roost. Overacting makes no sense during this first night of the campaign. It may even be wrong because the birds have to be in a reasonable condition to understand that something is really bad with the place. Overstressed individuals may learn nothing (and even kill themselves by flying against obstacles etc). One should keep in mind that we need knowledgeable (highranking) birds that teach new immigrants not to use the place. Especially in the gregarious starling most decisions are flock decisions. Flock behaviour enforces the learning process and enforced habituation is crippling the power of our scaring signals. However, socially enforced habituation can also be reversed. Once the flocks know the danger a few alarm cries will do the job and only need to be affirmed by loud bangs (or a very few real killings by shot-cartidges).

6.2. Equipment and Methods

The most fruitful method of "communicating" with the birds is the alarm cry or distress call. Although these terms are often used interchangeable (also in this report) they indicate in fact two levels of communication. Distress calls are weaker and more species specific signals, more apt to warn other birds than alarm cries which just express panic and pain. We have

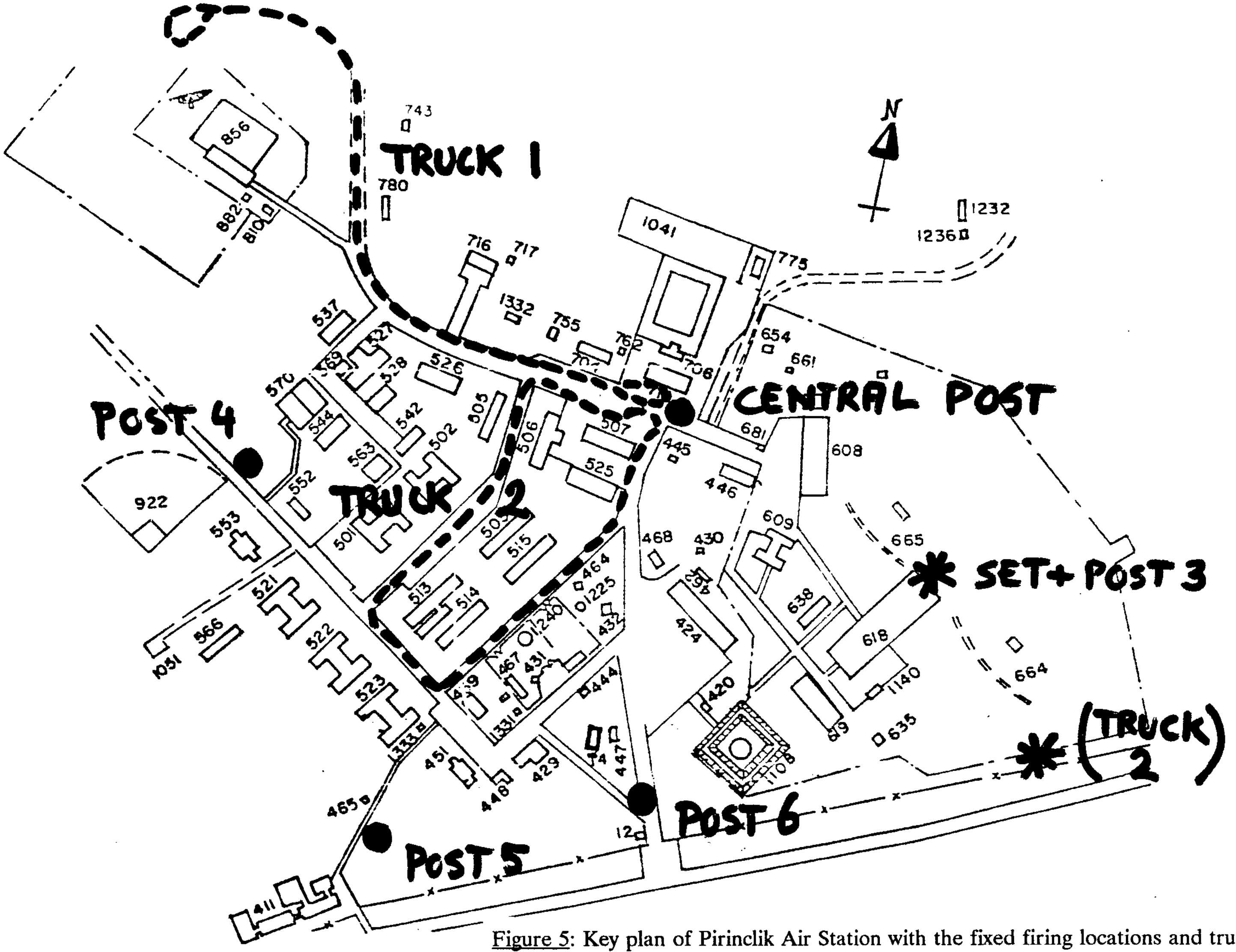


Figure 5: Key plan of Pirinclik Air Station with the fixed firing locations and truck loops used during the canpaign

not attempted to separate cries expressing different levels of emotion. During the 1987 survey some starlings were caught by means of mistnets between trees at the station. Cries were taken from the birds by pinching them in the legs. A long series of cries from 3 individuals was selected and put into a loop before it was copied on 10 tape cartridges.

Broadcasting was done by means of "bird scaring units" developed by the Dutch firm Redstar for the RNLAF (see photo's). The three units delivered to Pirinclik AS were used from cars. They also can be applied as stand alone systems, but this type of use should be avoided during the initial abatement of a starling roost. Although the broadcasting can be performed at random and in at random varying boutlength (both of course within certain limits) a fixed location was judged to be too risky with respect of habituation.

To enforce the frightening of the birds two types of bird scaring cartridges, also called shell crackers (see photo), were shipped in. The most heavy one is a 1.5 inch cartridge producing two loud bangs and an intense white flash. The interval time between the bangs is approx. 4.5 seconds. It is a type especially produced for use at airfields and has proven very effective. The only disadvantage is that it is really loud and may scare humans as well. Therefore we also used a smaller and cheaper cartridge (caliber 12) with a delay time of 3 seconds. Finally a few green and red flares (1.5 inch) were used, not only to further increase the frightening of the birds but also as warning signals for the team members firing from different locations.

The bird scaring cartridges were all fired by means of Verey flare pistols (photo). In order to shoot the smaller caliber 12 cartridges inserts were placed in the Verey pistols.
As a supplementary tool all team members used strong flashlights. Communication was possible by means of Motorola walkie talkies.

6.3. Time Schedule and Locations

The scaring actions were executed synchronically from four firing points and along two routes (figure 5). Three firing points were manned by one or two team members, using only a Verey pistol and flash light. One fixed firing point was between the two big radar antennaes where also one bird scaring unit was located. Two vehicles were driven slowly over the two fixed routes. Both had sound equipement onboard as well as one Verey pistol. If necessary one of the trucks spent some time at the SE corner of the station, between the fence near road to Dyarbakir and the most remote fixed antenna.

In order to synchronize the burst of action, even in case of malfunction of the radio's, a tight time schedule was agreed upon and all watches were time-checked. This daily schedule was briefed to US and Turkish commanders who than notified the human population of the base. Of particular importance was the notification of the defense patrols who might misunderstand the sudden "war time" conditions.

On the basis of the census of the influx of starlings during the first days of our presence we pinpointed the bursts of action at 16:15, 16:45, 17:15, 19:15 and 21:00. The early morning burst was fixed at 05:30. This early morning abatement remained fixed but the starting times of the evening actions during the following days were adapted a little bit depending on the behaviour of the birds. All actions lasted five to fifteen minutes.

6.4. The Campaign and Reactions of the Birds by Day

Due to the delay in arrival of the equipement we could not start the campaign until 19 November. Fortunately, it was also the first day with rain after several days with perfect weather for field observations. The wetness gave us a safe feeling with respect of the risk of fire (shell crackers), and made it easier to offer the starlings a really bad first night. Exactly at 16:15 the first flare was launched from between the two big antennae. The birds had already settled there and took off for a massive and impressive flight around and around the tall structures. They clearly attempted to reorder the movement by showing the typical aerial

display maneuvering as they usually do before entering the roost at dusk. The following five minutes the birds were kept in the air by a few shell crackers from the different locations combined with intense broadcasting of distress calls from the driving trucks. As predicted, most of the birds landed somewhere within the station fence after the first burst ended, and many birds were reassembling at the antennae. A part of the birds may have escaped to the surrounding fields where we could not see them.
The second burst started at 16:45 when the starlings were barely visible due to the rain and dusk. This time, as well as during the subsequent actions, the anti-collision on top off the super structures were switched off, causing even more unsafe conditions for the birds. The starlings again performed a massive panic flight but the majority settled again on the antennae.

During the third burst at 17:15 it was clear that the birds that day had no possibilities to leave the place for another roost. Many birds flew criss-cross over the station while uttering short alarm cries.

During the following interval many birds were scared from the trees in the center of the station by handclapping of the team members to concentrate as many birds as possible on the big antennae. The fourth and fifth bursts were directed toward the antennae and again caused big panic among the starlings. Probably the majority of the birds entered the antennae again but many were dispersed all over Pirinclik and nearby Yolboyu. Many solitary birds were fluttering around while crying frequently. For a long time we heard birds up in the air. During the night the sky cleared and the temperature went rapidly down. The birds must have suffered a lot...

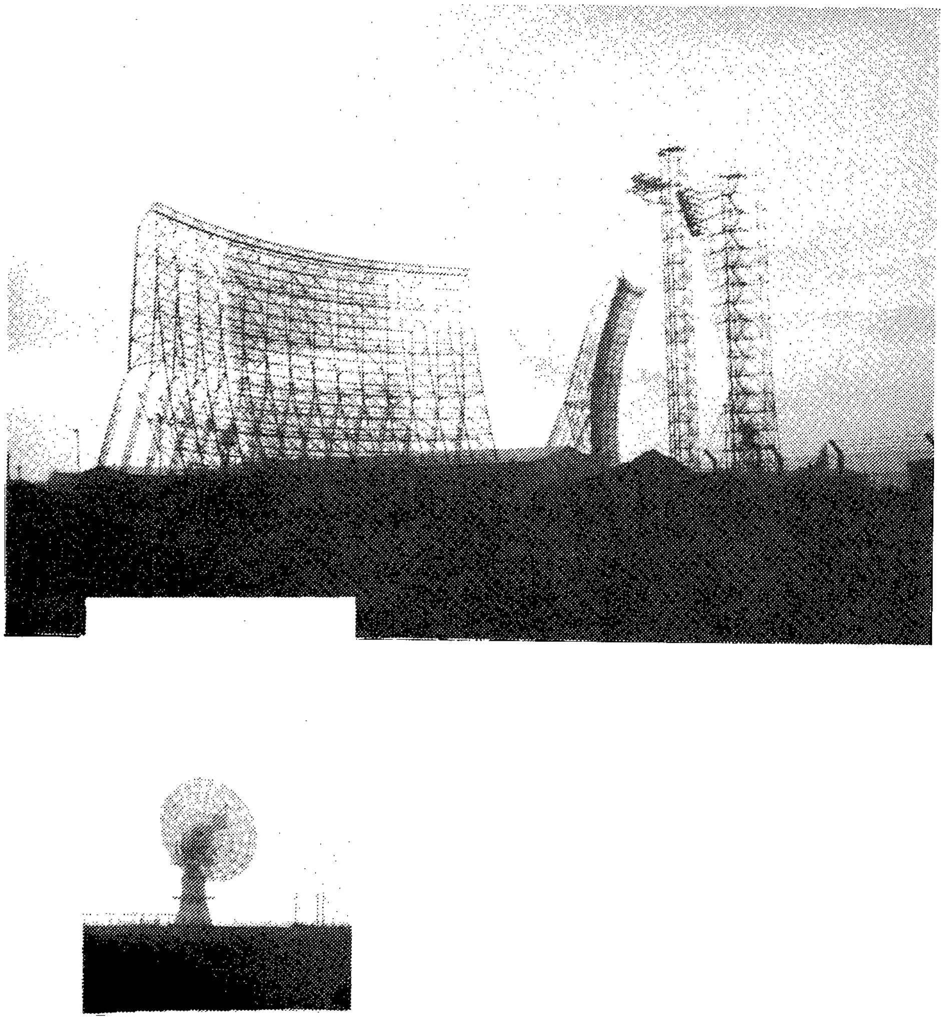
The following morning the birds were "kicked out their beds" at 05:30. Remarkably, the last flocks weren't very quick in leaving the place. Did they suffer too much or did the loss of a normal morning exodus derorientate them?

During late afternoon it became very clear that the first night of the campaign really had affected the birds. Their arrival behaviour indicated that they did not trust the site anymore. Several big flocks were seen simply passing Pirinclik, flying more or less parallel to the west-east road. Small flocks sailed above the station much higher and longer than normal. At 15:55 a first flock of over 1000 birds landed at the wave tube tower, but quickly flew up again. At 16:05 and 16:10 two big flocks came in from the preassembly area's south of the station and settled at the big antannae. Directly after the first shell cracker burst at 16:15 the birds flew up and splitted into much smaller flocks than during the evening before. These small but very dense flocks moved in remarkedly long and straight flights again and again over the station at high speed. The speeds were clearly higher than normal and the performances significantly deviated from the undisturbed aerial display flights. Nevertheless the birds flew with highly synchronized wingbeats. This suggests that new birds, not knowing about the disaster of the night before, are "told" that something is wrong by being socially pressed to flap their wings abnormally.

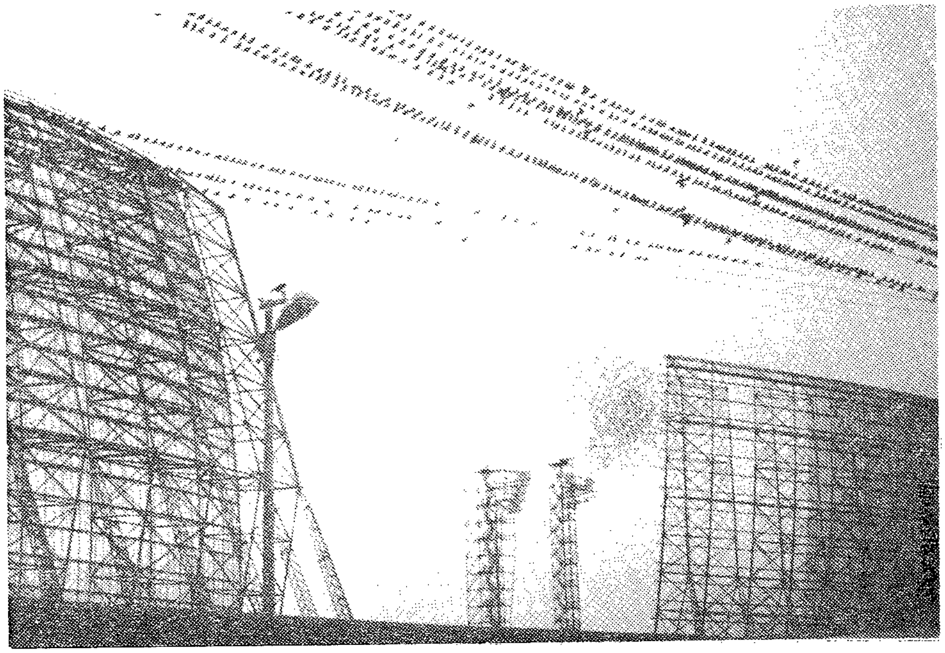
Only a very small number of starlings choose to land again at the antennae. The second burst of scaring activity instantaneously prompted the last birds to leave the station in one dense flock towards the Southwest.

The third action period was mainly directed at the big tracking antenna in the NW corner of the station. Here a few hundred starlings had hidden themselves in a clump against the backside of the aerial.

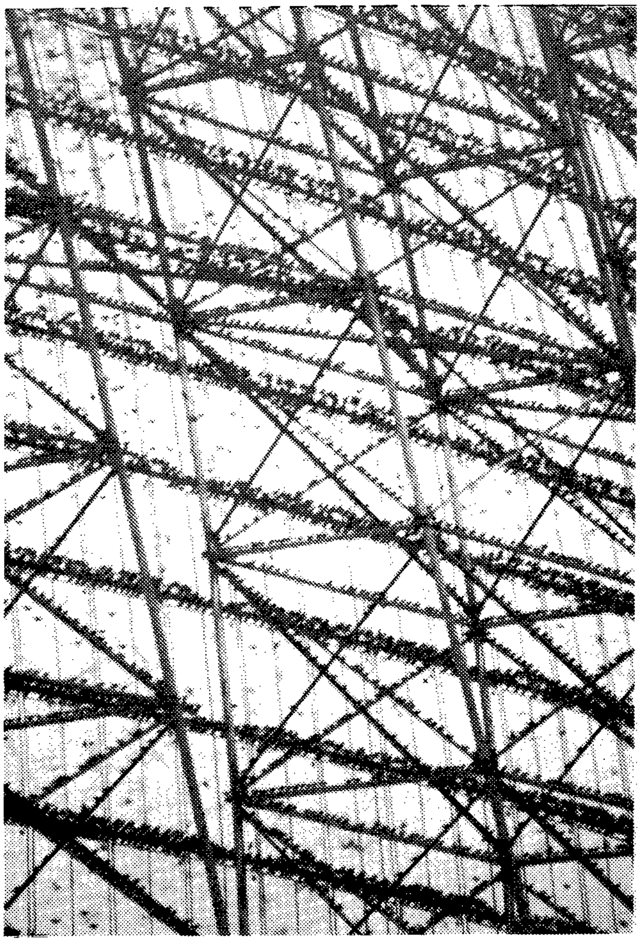
The following morning, November 21, we counted about 500 starlings closely packed at the same spot. At the wide static antenna only 200 birds were found. We were surprised by the relatively strong effect of the alarm cries compared to the flares this morning.



Two huge antennaes at Pirinclik, attracting over a million starlings in winter. Insert: the big tracking antenna, sometimes nearly underpowered due to the extra weight of tens of thousands starlings.



Starlings on the wires and in aerial display flight. A kestrel on top of a lamp post is watching them.



Starlings on the high antenna alive and dead. The bird bodies in the meshes were victims of a mass collision during a storm with rain.

From 15:00 onward we started the evening actions according to a different strategy. In case a passing flock happened to land, it was directly chased again. This was primarily done by means of alarm cries. The bursts of heavy bangs were kept at the regular times but were kept limited in number of flares. More than 75 % of the passing birds came from the West and most of them flew high over without any hesitation. Some birds in the tail ends of the bigger flocks passing against sun set started to glide. This slightly slowed down birds in front of them. Usually one flare was enough to stop this process and speed up the continuation of the flight. Driving one truck around the whole station helped to scare birds passing the near vicinity. The total number of birds passing Pirinclik was again lower than the evening before. The next morning revealed only 150 birds at the tracking radar. They could easily be chased away and left the station eastward. Further, 6 starlings hid in a few solitary trees near the petrol station. They could not be chased.

During the evening there was again passage of some flocks of thousand birds or more but only very limited hesitating behaviour was observed. One shell cracker was necessary to remove a flock off the tracker. Mostly a short bout of distress calls was enough to end hesitation. Aerial display flights were virtually absent now.

On November 23 the early morning action was cancelled because of the succesful progress of the campaign. During the evening period a very limited amount of distress calls were sufficient.

Thanksgiving day, November 24, was celebrated with the whole station community and had an extra dimension for us. A short check of the starlings in the evening by four of us implied not much more than a "say hello" to some overflying flocks.

6.5. Final Results

A very few birds, possibly the local starling population living at the air station or in nearby Yolboyu, persisted to settle at the back site of the big tracking antenna. This was also the only place that (for security reasons) we could not reach with the flares. These birds which numbered about one hundred did not attract other starlings overflying the station during our last day.

Because of the remaining few birds (deviating in behaviour) and because of the starling roost population was not at full strength, we emphasized during our debriefing the need of further actions (see chapter 7).

From a letter from the Base Civil Engineer we learned that only few extra birds entered the station later on. Following our technic these starlings could be removed easily, leaving the station for the first time in 30 years free of starlings during the winter! Recently we heared that also winter '89/'90 has given no starling problems.

7. Proposed Future Countermeasures

As long as no new big roost has settled the responsible people should keep an eye open during the appropiate hour, between 16:00 and 17:00 in November, and, if necessary, scare away the
first arriving birds which will act as the nucleus for a new roost. It is most cost-effective to do this job when the starling population has not yet started to trust the roosting site again. Moreover, it saves expensive flares.

This is not meant to say that each incoming bird should be unwelcomed directly by bangs and cries. Let them explore the site in flight. The first arriving birds will take time for that.

This exploring behaviour costs energy and the more they have spent, the bigger the frustration that they finally not are allowed to settle.

The amount of alarm cry production should always be minimized. Don't broadcast continuously (bouts of a few seconds should do the job) and change position as much as possible. When the birds seem to become habituated to the alarm cries, then the time for heavier means has come. But use the bird scaring cartridges in a planned manner. Before using the first flare (which always will work) there is enough time to let a big flock settle. A good moment for the first flare is waiting until a new big flock is coming in. The flock that already settled will help you to discourage the newcombers. When they fly up after the first bang they give an extra signal to the newcomers. Don't use flares for scaring the last few birds in the darkness. The efficiency of the same flares will be much bigger the next morning and /or following evenings.

Reduce the use of 1.5 inch flares as long as the small cartridges do the job satisfactorily. However, once in a while beginning with one heavy bang enforces the surprise effect and enlarges the effectiviness of the small flares thereafter.

In case the roost has builded up big numbers, a real campaign as the one performed by us should be prepared. The following remarks should be kept in mind:

a. Don't worry too much about birds that settle during the first evening and keep the schedule of burts and silence intervals as planned;
b. Always repeat the action during the early morning (before the birds depart naturally);
c. Bad weather (drizzle) is excellent for the start of the campaign because it helps to let the night be very nasty for the starlings and it is also safe with respect of the risk of fire caused by the flares;
d. Have the equipment in perfect state (batteries fully charged), and check your watches in case of more patrols working simultaneously according to a time schedule;
e. Never panic and decide upon one or more stop signals (emergency);
f. Always notify people in the station and neighbourhood.

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BSCE 20 / WP 16

Helsinki, 21-25 May 1990

ON PREDICTING ACCIDENTS AND SERIOUS INCIDENTS TO CIVIL AIRCRAFT DUE TO BIRD STRIKES IN A FUTURE TIME PERIOD FROM KNOWN OBSERVATIONS

Presented by Nikolai A. Nechval

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ON PREDICTING ACCIDENTS AND SERIOUS INCIDENTS TO CIVIL AIRCRAFT DUE TO BIRD STRIKES IN A FUTURE TIME PERIOD FROM KNOWN OBSERVATIONS

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SUMMARY

The problem of predicting the number of accidents and serious incidents to civil aircraft due to bird strikes during a future time period with the specified number of aircraft movements, knowing accidents and serious incidents during time intervals (with the known numbers of aircraft movements, respectively) in the past, is considered. It is known that in many familiar situations, the predictive estimators based on the principles of maximum likelihood and of minimum variance unbiased estimation are uniformly worst among all predictive estimators which one would consider using. In this paper, we suggest (as a particular possibility) the use of uniformly undominated predictive estimators and give the conditions that a predictive estimator must satisfy in order that it be uniformly undominated. It is assumed that accidents and serious incidents to civil aircraft due to bird strikes follow a binomial distribution. An illustrative example is presented.

1. INTRODUCTION

The binomial model can be widely used to describe the distribution of the number of accidents and serious incidents to civil aircraft due to bird strikes in a future time period with the specified number of aircraft movements. Here "serious" has been defined as: (a) loss of life, (b) injury to occupants, (c) destruction of aircraft, (d) damage/loss/shutdown of more than one engine, (e) uncontained engine failure, (f) fire, (g) significant sized hole eg shattered radome, holed windscreen, holed wing, (h) major structural damage, (i) particularly unusual or dangerous features eg complete obscuring of vision, multiple loss of system, damage to helicopter blades or transmissions. The paper of J. Thorpe (1982) contains brief details of accidents and serious incidents due to bird strikes world wide up to and including 1980.

Whatever may be the reasons for adopting a binomial model, having decided to accept such a model, results derived in this paper will be found appropriate. In practice, the true parameter of the binomial distribution is not known, and the inference must be based on the observed bird strike data during certain time periods with the known numbers of aircraft movements, respectively.

One of the problems considered here is to predict the number of accidents and serious incidents to civil aircraft due to bird strikes during a future time period with the specified number of aircraft movements, knowing accidents and serious incidents during time intervals (with the known numbers of aircraft movements, respectively) in the past.

2. PROBLEM STATEMENT

Frequently one is interested in estimating the value of a random variable rather than that of a parameter. A customary method for this is to estimate the expectation of the random variable (a parameter) and then to "identify" the variable and its expectation; i.e., to use the estimate of the expectation as a prediction for the variable. As we shall see below one is led to this procedure if one adopts the point of view of unbiased estimation, so that from this point of view prediction poses no new problem. This however is no longer true when one employs the principle of uniform undomination (see, in this connection, Nechval (1988)).

Consider a pair X,Y of random variables having a joint distribution P_θ (with $\theta \in \Theta^\circ$(parameter space)) belonging to a parametric family P° of distributions. It is desired to use the observed X to predict, say, g(Y) where g is a some function of Y. If the value x of X is observed one makes an predictive estimate, say d(x), and thereby incurs a loss of $W[g(y),d(x)]$. We shall assume that the loss function is nonnegative. It then follows that the expectation of the loss will always exist (although it may be infinite).

The risk associated with the predictive estimator (decision rule) d(X) is defined to be the expected loss, as given by

$$R_\theta(d) = E_\theta(W[g(Y),d(X)]) \quad . \tag{1}$$

The choice of predictive estimator, d(X), should then be made according to the risk function (1). As a particular possibility we suggest the use of uniformly undominated predictive estimators.

A predictive decision rule d_1 is said to be uniformly better than a predictive decision rule d_2 if $R_\theta(d_1) < R_\theta(d_2)$ for all $\theta \in \Theta^\circ$. A predictive decision rule d is said to be uniformly undominated if there exists no predictive decision rule uniformly better than d. Otherwise, it is uniformly dominated. The examples described in Nechval (1988) may be of interest in that there the maximum likelihood and unbiased decision rules are uniformly worst among all decision rules which one would consider using.

The conditions that a predictive decision rule must satisfy in order that it be uniformly undominated are given by the following theorem.

Theorem 2.1. Characterization of the uniformly undominated decision rules. Let $(q_s; s=1,2, \dots)$ be a sequence of the prior distributions on the parameter space Θ°. Suppose that $(d_s; s=1,2, \dots)$ and $(Q(q_s,d_s); s=1,2, \dots)$ are the sequences of Bayes predictive decision rules and prior risks respectively. If there exists a predictive decision rule d^* such that its risk function $R_\theta(d^*)$, $\theta \in \Theta^\circ$, satisfies the relationship

$$\lim_{s \to \infty} [Q(q_s,d^*) - Q(q_s,d_s)] = 0, \tag{2}$$

where

$$Q(q_s,d) = \int_\Theta R_\theta(d)\, q_s(d\theta), \tag{3}$$

then d^* is an uniformly undominated predictive decision rule.

Proof. Suppose d^* is uniformly dominated. Then there exists a predictive decision rule d'' such that $R_\theta(d'') < R_\theta(d^*)$ for all $\theta \in \Theta^\circ$. Let

$$e = \inf_{\theta \in \Theta^\circ} [R_\theta(d^*) - R_\theta(d'')] > 0. \tag{4}$$

Then

$$Q(q_s,d^*) - Q(q_s,d'') \geq e. \tag{5}$$

Simultaneously,

$$Q(q_s,d'') - Q(q_s,d_s) \geq 0, \tag{6}$$

$s=1,2, \dots$, and

$$\lim_{s \to \infty} [Q(q_s,d'') - Q(q_s,d_s)] \geq 0. \tag{7}$$

On the other hand,

$$Q(q_s,d'') - Q(q_s,d_s) = [Q(q_s,d^*) - Q(q_s,d_s)] - [Q(q_s,d^*) - Q(q_s,d'')] \leq [Q(q_s,d^*) - Q(q_s,d_s)] - e \tag{8}$$

and

$$\lim_{s \to \infty} [Q(q_s,d'') - Q(q_s,d_s)] < 0. \tag{9}$$

This contradiction proves that d* is an uniformly undominated predictive decision rule.

Corollary 2.1.1. A Bayes predictive decision rule,whose risk function is constant, is an uniformly undominated predictive decision rule.

Suppose now that X and Y are independent and that

$$W[g(y),d(x)] = [g(y) - d(x)]^2. \tag{10}$$

Consider the problem first from the point of view of unbiasedness. A prediction could reasonably be called unbiased if

$$E_\Theta(d(X)) = E_\Theta(g(Y)). \tag{11}$$

Subject to unbiasedness, the risk is given by

$$E_\Theta([g(Y) - d(X)]^2) = \mathrm{Var}_\Theta(g(Y)) + \mathrm{Var}_\Theta(d(X)). \tag{12}$$

But $\mathrm{Var}_\Theta(g(Y))$ is a known function of Θ, and hence the problem of minimizing (for a particular Θ) the expected squared error reduces to that of finding an unbiased estimate of $E_\Theta(g(Y))$ with minimum variance at Θ. In a similar way one sees, without any restriction to unbiased predictions, that the Bayes prediction for g(Y) is the same as the Bayes estimation for $E_\Theta(g(Y))$. One might expect that as in the unbiased theory the predictive estimate will coincide with the unbiased estimate. This however is not the case since the prior distributions that give constant risk in the two cases will usually be distinct. In fact the two problems are rather different in that the "least favourable" prior distribution for the prediction problem must not only take into account the difficulty of finding the correct value of Θ for various prior distributions but also the difficulty of predicting g(Y) when Θ is known.

The main purpose of the present paper is to obtain uniformly undominated predictive estimators for a number of specific problems.

3. PREDICTION OF THE NUMBER OF ACCIDENTS AND SERIOUS INCIDENTS TO CIVIL AIRCRAFT DUE TO BIRD STRIKES

Consider an ornithological situation in which accidents and serious incidents to civil aircraft due to bird strikes follow a binomial distribution with parameter p. The situation is under observation for time interval with the known number m_1 of aircraft movements, where $X(m_1)$ of accidents and serious incidents is recorded. In some future time interval with the specified number of aircraft movements m_2, the number of accidents and serious incidents is denoted by $Y(m_2)$. The specific problem is to predict the value of a random variable $Y(m_2)$ observing a random variable $X(m_1)$, where $X(m_1)$ and $Y(m_2)$ have the probability distributions

$$f(X(m_1)=x;p) = \binom{m_1}{x} p^x(1-p)^{m_1-x}, \quad x=0,1,2, \dots ,m_1, \tag{13}$$

and

$$f(Y(m_2)=y;p) = \binom{m_2}{y} p^y(1-p)^{m_2-y}, \quad y=0,1,2, \dots ,m_2, \tag{14}$$

respectively, which are dependent on the same (unknown) parameter p, $0\leq p\leq 1$. Here we consider the situation when a statistician predicts systematically the value of Y observing $X_1(m_1)$, $X_2(m_2)$, ... ,$X_n(m_n)$ at the stages 1,2, ... ,n, respectively, and when the loss function is the sum of losses at the particular stages. There are many problems of this type which can be stated and solved (and some of them have been actually solved). We restrict ourselves to one of them.

Let $X_1(m_1)$, ... ,$X_{n+1}(m_{n+1})$ be independent random variables with the distributions

$$f(X_i(m_i)=x_i) = \binom{m_i}{x_i} p^{x_i}(1-p)^{m_i-x_i}, \quad x_i=0,1,2, \dots ,m_i; \quad i=1(1)n+1. \tag{15}$$

Let

$$\underline{X}_k = \sum_{i=1}^{k} X_i(m_i). \tag{16}$$

We want to predict the random variable $\underline{Y}_n$ on the basis of observations of $\underline{X}_1,\underline{X}_2, \dots ,\underline{X}_n$. Since at the kth stage we know the values of random variables $X_1(m_1)$, ... ,$X_k(m_k)$ and $\underline{X}_k$ is sufficient for p, it is sufficient to predict the values of

$$\underline{Y}_k = \sum_{i=k+1}^{n+1} X_i(m_i), \quad k=1(1)n, \tag{17}$$

on the basis of $\underline{X}_k$. Let $d_k=d_k(\underline{X}_k)$ be a kth predictive estimator (decision rule) for $\underline{Y}_k$ and let the loss function be

$$W[\underline{Y}^n,d^n] = \sum_{k=1}^{n} c_k(\underline{Y}_k-d_k)^2, \tag{18}$$

where

$$\underline{Y}^n = (\underline{Y}_1, \dots ,\underline{Y}_n), \tag{19}$$

$$d^n = (d_1, \dots ,d_n), \tag{20}$$

and $c_k\geq 0$ for $k=1, \dots ,n$, $c_k>0$ for at least one k.

Let

$$d_k = \underline{M}_k\left(a_k \frac{\underline{X}_k}{\underline{m}_k} + b_k\right), \quad k=1(1)n, \tag{21}$$

where

$$\underline{m}_k = \sum_{i=1}^{k} m_i \tag{22}$$

and

$$\underline{M}_k = \sum_{i=k+1}^{n+1} m_i . \tag{23}$$

Then the risk function takes the form

$$R_p(d^n) = E_p(W[\underline{Y}^n, d^n])$$

$$= \sum_{k=1}^{n} c_k E_p([\underline{Y}_k - \underline{M}_k(a_k \frac{\underline{X}_k}{\underline{m}_k} + b_k)]^2) = \check{a}p^2 + \check{b}p + \check{c}, \tag{24}$$

where

$$\check{a} = \sum_{k=1}^{n} c_k \underline{M}_k \left[\underline{M}_k \frac{\underline{m}_k - 1}{\underline{m}_k} a_k^2 - 2\underline{M}_k a_k + \underline{M}_k - 1 \right] , \tag{25}$$

$$\check{b} = \sum_{k=1}^{n} c_k \underline{M}_k \left[\frac{\underline{M}_k}{\underline{m}_k} a_k^2 + 2\underline{M}_k b_k (a_k - 1) + 1 \right] , \tag{26}$$

and

$$\check{c} = \sum_{k=1}^{n} c_k \underline{M}_k^2 b_k^2 . \tag{27}$$

(24) is constantly equal to $\check{c}$ (i.e., (24) is independent on p) whenever

$$\check{a} = \check{b} = 0. \tag{28}$$

It can be shown that (21) is the Bayes solution corresponding to the prior distribution of p,

$$q(p;a,b) = \frac{\Gamma(a+b)}{\Gamma(a)\Gamma(b)} p^{a-1}(1-p)^{b-1}, \quad 0 \leq p \leq 1 \quad (a,b > 0), \tag{29}$$

with

$$a_k = \frac{\underline{m}_k}{a+b+\underline{m}_k} , \quad b_k = \frac{a}{a+b+\underline{m}_k} , \quad k=1(1)n. \tag{30}$$

Suppose that (a^*,b^*) is a solution of equation (28). It follows from Corollary 2.1.1 that (21) with

$$a_k = \frac{\underline{m}_k}{a^*+b^*+\underline{m}_k} , \quad b_k = \frac{a^*}{a^*+b^*+\underline{m}_k} , \quad k=1(1)n, \tag{31}$$

is the uniformly undominated decision rule for $\underline{Y}^n$.

For example, in the case n=1, the uniformly undominated predictive estimator of $Y=X_2(m_2)$ based on $X=X_1(m_1)$ with respect to the loss function

$$W[Y,d_1] = c_1[Y - d_1]^2 \tag{32}$$

is

$$d_1 = m_2(a_1 \frac{X}{m_1} + b_1), \tag{33}$$

where

$$a_1 = \frac{m_1}{m_1-1}\left[1 - (1/m_1 + 1/m_2 - 1/(m_1m_2))^{1/2}\right] \tag{34}$$

and

$$b_1 = (1 - a_1)/2. \tag{35}$$

Note that (33) is the Bayes solution corresponding to the prior distribution of p (29) with

$$a^* = b^* = (m_1/2)((1-a_1)/a_1) \tag{36}$$

and hence uniformly undominated.

It is interesting to compare the risk of the above uniformly undominated predictive estimator (33) with that of the standard unbiased estimator

$$d_0 = m_2 \frac{X}{m_1} . \tag{37}$$

We have

$$R_p(d_1) = E_p(W[Y,d_1]) = E_p(c_1[Y - d_1]^2)$$

$$= c_1 \frac{m_2^2}{4}\left[1 - \frac{m_1}{m_1-1}(1 - (1/m_1 + 1/m_2 - 1/(m_1m_2))^{1/2})\right]^2 \tag{38}$$

and

$$R_p(d_0) = E_p(W[Y,d_0]) = E_p(c_1[Y - d_0]^2)$$

$$= c_1 \frac{m_2}{m_1}(m_1 + m_2)p(1 - p). \tag{39}$$

As is easily seen,

$$R_p(d_0) \leq R_p(d_1) \tag{40}$$

if and only if

$$\left|p - \frac{1}{2}\right| \geq \left[1 - \frac{m_1m_2}{m_1+m_2}(1 - \frac{m_1}{m_1-1}(1 - (\frac{1}{m_1} + \frac{1}{m_2} - \frac{1}{m_1m_2})^{1/2}))^2\right]^{1/2}/2. \tag{41}$$

If, say, $m_1=70{,}000$ and $m_2=156{,}463$ of aircraft movements, then

$$\left[1 - \frac{m_1 m_2}{m_1+m_2}\left(1 - \frac{m_1}{m_1-1}\left(1 - \left(\frac{1}{m_1} + \frac{1}{m_2} - \frac{1}{m_1 m_2}\right)^{1/2}\right)\right)^2\right]^{1/2} /2 = 0.0396188. \tag{42}$$

Thus the standard unbiased estimator d_0 (37) is better than the uniformly undominated predictive estimator d_1 (33) if and only if

$$\left| p - \frac{1}{2} \right| \geqslant 0.0396188. \tag{43}$$

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ADF616416

BSCE 20 / WP 17

Helsinki, 21-25 May 1990

HOMOGENEITY TESTING PROBLEMS IN BIRD STRIKE DATA PROCESSING WHEN SAMPLE SIZES ARE SMALL

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SUMMARY

This paper deals with testing the homogeneity of bird strike data when sample sizes are small. The traditional statistical approaches developed for large sample data processing will usually not be applicable in the above case. Using a method of conditioning on a sufficient statistic of the likelihood function of bird strike data, we develop some new homogeneity tests. The present paper undertakes a statistical analysis with respect to homogeneity testing problems in the Poisson and two-parameter exponential distributions. Tests are recommended on the basis of certain optimal power properties. The illustrative examples are given.

1. INTRODUCTION

Bird strike reporting systems have been in operation in many countries for a number of years and it is generally accepted that the statistics arising from these reports provide a valuable insight into the aviation bird hazard. However, bird strikes are comparatively rare events with the result that the data set available for statistical analysis is reasonably small. Consequently the traditional statistical approaches developed for large sample data processing will usually not be applicable in the above case.

The motivation for this paper is to focus attention on an exact statistical method which can be applied for bird strike data processing when sample sizes are small. This method is based on that certain conditional distributions, obtained by conditioning on a sufficient statistic, can be used to transform a data sample into a set of random variables whose distribution does not depend on the unknown (nuisance) parameters. The given distribution can be utilized in the solution which is strictly applicable when the parameters are completely specified.

2. A METHOD OF CONDITIONING ON A SUFFICIENT STATISTIC

This method consists in the following. Let $X^n=(X_1, \dots ,X_n)$ be a set of independent random variables that represent observations on a random variable X and are identically distributed with probability density function $f(x;\theta)$ indexed by an unknown (nuisance) parameter θ (in general, vector), $\theta\in\Theta^{\circ}$ (parameter space). Suppose that $T_n=t_n(X^n)$ is a sufficient statistic for θ with the probability density function $g(t_n;\theta)$. Let $v_{r+1}(x^n), \dots ,v_n(x^n)$ be new functions of x^n such that the transformation $x^n=(x_1, \dots ,x_n) \longrightarrow t_n=(t_{n1}, \dots ,t_{nr})$, $v=(v_{r+1}, \dots ,v_n)$ is one-to-one and smooth enough for the Jacobian to exist. Then the likelihood function of x^n can be transformed as

$$L(x^n;\theta) = f(t_n,v;\theta)\left|\frac{\partial(t_n,v)}{\partial x^n}\right| = g(t_n;\theta)f(v;t_n)\left|\frac{\partial(t_n,v)}{\partial x^n}\right|, \qquad (1)$$

where $f(t_n,v;\theta)$ is the joint probability density function of T_n and V,

$$f(v;t_n) = \frac{f(t_n,v;\theta)}{g(t_n;\theta)} = \frac{L(x^n(t_n,v);\theta)\left|\dfrac{\partial x^n}{\partial(t_n,v)}\right|}{g(t_n;\theta)} \qquad (2)$$

is the conditional probability density function of V given $T_n=t_n$ which does not depend on the unknown parameter θ (in virtue of the property of a sufficient statistic).

By relying upon the multivariate probability integral transformation of Rosenblatt (1952), an absolutely continuous density function $f(v;t_n)$ can be used to transform a set of random variables $X_1, \dots ,X_n$ into a smaller set of random variables that are identically and independently distributed with uniform distributions on the interval from zero to one.

To obtain a simple procedure for transforming a set of random variables $X_1, \dots, X_n$ we need the following theorem.

Theorem 2.1. Let $X_1, \dots, X_n$ be a sample of independent random variables that are identically distributed with probability density function $f(x;\theta)$ indexed by an unknown (nuisance) parameter θ (in general, vector), $\theta \in \Theta^\circ$ where Θ° is a given parametric set. Let $T_i = t_i(X_1, \dots, X_i)$, $i=r(1)n$, be the sufficient statistics for θ such that $T_i = \underline{t}_i(T_{i+1}, X_{i+1})$, $i=r(1)n-1$, and

$$g(\underline{t}_i(t_{i+1},x_{i+1});\theta)f(x_{i+1};\theta)\left|\frac{\partial \underline{t}_i}{\partial t_{i+1}}\right| = f(t_{i+1},x_{i+1};\theta)$$

$$= g(t_{i+1};\theta)f(x_{i+1};t_{i+1}), \tag{3}$$

where

$$f(x_{i+1};t_{i+1}) = \frac{g(\underline{t}_i(t_{i+1},x_{i+1});\theta)f(x_{i+1};\theta)\left|\frac{\partial \underline{t}_i}{\partial t_{i+1}}\right|}{g(t_{i+1};\theta)} \tag{4}$$

is the conditional probability density function of X_{i+1} given $T_{i+1}=t_{i+1}$. Then

$$\prod_{i=1}^{n} f(x_i;\theta)\left|\frac{\partial x^r}{\partial t_r}\right|\prod_{i=r}^{n-1}\left|\frac{\partial \underline{t}_i}{\partial t_{i+1}}\right| = \prod_{i=r+1}^{n} f(x_i;t_i)g(t_n;\theta). \tag{5}$$

Proof.

$$\prod_{i=1}^{n} f(x_i;\theta)\left|\frac{\partial x^r}{\partial t_r}\right|\prod_{i=r}^{n-1}\left|\frac{\partial \underline{t}_i}{\partial t_{i+1}}\right| = L(x^r;\theta)\prod_{i=r+1}^{n} f(x_i;\theta)\left|\frac{\partial x^r}{\partial t_r}\right|\prod_{i=r}^{n-1}\left|\frac{\partial \underline{t}_i}{\partial t_{i+1}}\right|$$

$$= \frac{L(x^r(t_r);\theta)\left|\frac{\partial x^r}{\partial t_r}\right|}{g(t_r;\theta)}\prod_{i=r}^{n-1}\frac{g(\underline{t}_i(t_{i+1},x_{i+1});\theta)f(x_{i+1};\theta)\left|\frac{\partial \underline{t}_i}{\partial t_{i+1}}\right|}{g(t_{i+1};\theta)}$$

$$\cdot\, g(t_n;\theta) = \prod_{i=r+1}^{n} f(x_i;t_i)g(t_n;\theta), \tag{6}$$

where r is the minimum size of sample required for constructing a sufficient statistic T_r for θ.

Corollary 2.1.1. The procedure of transforming $X^n=(X_1, \dots, X_n)$ is defined by

$$\prod_{i=1}^{n} f(x_i;\theta) \longrightarrow \prod_{i=r+1}^{n} f(x_i;t_i). \tag{7}$$

3. AN ITERATED PROCEDURE FOR TESTING THE HOMOGENEITY

Let $X_1, \ldots, X_n$ be a random sample of n observations on a random variable X with cumulative distribution function F(x) and probability density function f(x). The general problem of testing the homogeneity of n observations consists in testing the null hypothesis H_0 that $F(x)=F(x;\theta_1, \ldots, \theta_s)$ for every x_i, $i=1(1)n$, against unspecified alternatives. Here the θ_q's denote the parameters of the hypothesized cumulative distribution function F_0. In the sequel $f_0(x;\theta_1, \ldots, \theta_s)$ will denote the hypothesized probability density function. Two cases of this problem are of interest.

Case 1. The hypothesis H_0 is simple, that is the cumulative distribution function F_0 under H_0 is completely specified as to its functional form, such as normality, exponentiality, etc., as well as to the values of the parameters θ_q involved.

Case 2. The hypothesis H_0 is composite. This is when only the functional form of F_0 is given, and some or all of the parametric values are left unspecified.

The given paper deals with Case 2, that is we assume that under H_0 only the functional form of F_0 is given to us but one or more of the parameters θ_q $(q=1, \ldots, s)$ are left unspecified. This case is in fact of more relevance since situations are very rare in practice where the cumulative distribution function to be tested is completely specified. It is well known that the classical Pearson chi-squared test of goodness-of-fit (χ^2) can be modified to fit this case by properly estimating the unspecified parameters. But it possesses an element of arbitrariness in the choice of group boundaries and one of the objections to this procedure is that its validity is questionable when the sample size n is small, i.e., it does not have the desirable property of being an exact test in the sense of giving exact probabilities of rejection when the null hypothesis is true.

In this paper we propose an iterated procedure (free from the above objections) for testing the null hypothesis H_0 that n independent observations $X_1, \ldots, X_n$ come from a common specified distribution with a common but unspecified parameter, i.e., in other words, for testing the homogeneity of n observations.

The proposed procedure is based on the above method of conditioning on a sufficient statistic and consists in that we consider the test of the null hypothesis H_0 of the homogeneity of $n \geq 2$ independent observations. We resolve this hypothesis into the following sequence of nested hypotheses: $H_0(2)$, the homogeneity of the first two observations; $H_0(3)$, the homogeneity of the first three observations; ... ; $H_0(n)$, the homogeneity of all n observations. Here, the test of $H_0(j)$ is not made unless $H_0(j-1)$ is accepted, $j=3,4, \ldots, n$. Then the homogeneity of the n observations is accepted if and only if all of $H_0(2), H_0(3), \ldots, H_0(n)$ are accepted. Let $W_2, W_3, \ldots, W_n$ denote, respectively, the n-1 test statistics. These test statistics are so selected that they are not only mutually stochastically independent but each W_j is a function of the first j observations alone, $j=2,3, \ldots, n$. This last condition is extremely important to our procedure because if $H_0(j)$ is rejected, using W_j, $j<n$, we stop the testing at that point; thus there is no need to perform the test for the last n-j

observations. For example, suppose $H_O(2)$, and thus $H_O(n) \equiv H_O$, is rejected; we then are not required to go to the trouble and expense of performing the test for the third through n observations since we do not need to compute the statistics $W_3, \ldots, W_n$.

Let a_j be the significance level of the test of $H_O(j)$, $j=2,3, \ldots, n$. The mutual independence of $W_2, W_3, \ldots, W_n$ implies that the significance level of the test of the homogeneity of the n observations by this iterated scheme is

$$a = 1 - \prod_{j=2}^{n}(1-a_j). \tag{8}$$

It is important to emphasize at this point that this probability is the significance level of this overall test even though the sequence of tests is truncated with the test of $H_O(j)$, $j<n$. For example, if $H_O(2)$ is rejected, we have that H_O is rejected at significance level

$$a = 1 - \prod_{j=2}^{n}(1-a_j), \tag{9}$$

not simply a_2. Moreover, we have some reason as to why all n observations are not homogeneous; namely, it seems that the first two observations are not homogeneous. Now at this point, it is quite possible that the experimenter would desire to formulate a new hypothesis, such as the homogeneity of the last n-1 observations. This can then be tested in the manner outlined above with n replaced by n-1.

We illustrate this procedure with two important applications.

4. HOMOGENEITY TESTING FOR THE POISSON PROCESS

Let $X(u)$, $u \geq 0$, be the Poisson process with probability mass function

$$f(X(u)=x;b) = \frac{(bu)^x}{x!} e^{-bu} \quad (b>0,\ x\geq 0), \tag{10}$$

where $X(u)$ represents the number of events occurring in the interval $(0,u)$, $X(0)=0$ with probability 1, b is the rate parameter.

To introduce the Poisson homogeneity testing problem, we suppose that we observe n independent random variables $X_1(u_1), \ldots, X_n(u_n)$. Under the null hypothesis of homogeneity, each $X_i(u_i)$ follows a distribution (10) governed by the same parameter b, i.e.,

$$f_O(X_i(u_i)=x_i;b) = \frac{(bu_i)^{x_i}}{x_i!} e^{-bu_i}, \ \forall i. \tag{11}$$

In some problems b may be known, in others unknown. The u_i's, however, denote constants which are always given rather than unknown. For example, if $X_i(u_i)$ is the number of bird strike incidents incurred during ith of n intervals then u_i could be the number of aircraft movements (in terms of 10,000 movements)(or flying hours) and b the average bird strike incident rate per 10,000 aircraft movements (or flying hours).

We wish to test the null hypothesis (11) against an alternative hypothesis of non-homogeneity. By non-homogeneity we mean that, roughly speaking, the $X_i(u_i)$'s are more "spread out" than under the null hypothesis, either as a result of b being different for different i or else as a result of some kind of non-independence of events.

An iterated procedure for testing the homogeneity of n observations from the Poisson process (for the case of unknown b) is based on the transformation

$$\prod_{i=1}^{n} f_0(X_i(u_i)=x_i;b) \longrightarrow \prod_{i=2}^{n} f(x_i;t_i,p_i), \tag{12}$$

where

$$f(x_i;t_i,p_i) = \begin{pmatrix} t_i \\ x_i \end{pmatrix} p_i^{x_i}(1-p_i)^{t_i-x_i}, \quad 0 \leq x_i \leq t_i, \tag{13}$$

$$t_i = \sum_{q=1}^{i} x_q , \tag{14}$$

$$p_i = u_i / \sum_{q=1}^{i} u_q . \tag{15}$$

Here, at ith stage, the hypothesis $H_0(i)$, $i \in \{2, \ldots, n\}$, is accepted if

$$x_i \in [x_L, x_U], \tag{16}$$

where x_L and x_U satisfy the relations

$$\begin{cases} \displaystyle\sum_{x_i=0}^{x_L-1} f(x_i;t_i,p_i) \leq a_i/2 \\ \displaystyle\sum_{x_i=0}^{x_L} f(x_i;t_i,p_i) > a_i/2, \end{cases} \tag{17}$$

and

$$\begin{cases} \displaystyle\sum_{x_i=x_U+1}^{t_i} f(x_i;t_i,p_i) \leq a_i/2 \\ \displaystyle\sum_{x_i=x_U}^{t_i} f(x_i;t_i,p_i) > a_i/2, \end{cases} \tag{18}$$

respectively.

Note that the sample range (when the sample size n is small) is also useful in testing the homogeneity of n observations from a common Poisson process (10), since it is known that the conditional distribution of n observations x_i from (10) subject to

$$t_n = \sum_{i=1}^{n} x_i = \text{constant}$$

is the multinomial,

$$f(x_1, \dots, x_n; t_n, p_1, \dots, p_n) = \frac{t_n!}{x_1! \dots x_n!} p_1^{x_1} \dots p_n^{x_n}, \quad (19)$$

where

$$p_i = u_i / \sum_{q=1}^{n} u_q, \quad i=1(1)n. \quad (20)$$

The exact distribution of the range $\underline{r}$ conditional upon t_n=constant can be computed from (19) for a variety of n and nominal levels of significance a, giving values $\underline{r}_a$ such that

$$\Pr(\underline{r} \geq \underline{r}_a) = \sum_{\underline{r} \geq \underline{r}_a} f(x_1, \dots, x_n; t_n, p_1, \dots, p_n) \leq a. \quad (21)$$

For the sake of illustration, let us suppose that we observe two independent random variables $X_1(u_1)=6$ and $X_2(u_2)=0$, where $u_1=u_2=3$, with the range $\underline{r}=6$. It follows from (19) that, for n=2 and $t_2=6$, $\underline{r}=6$ is significant at the probability level equal to 0.03125. If the nominal level of significance a=0.05, there is evidence against the assumption of a common Poisson process. Note that the same result, in this case, can be obtained by the iterated procedure.

The test based on the Poisson range supplements the usual index of dispersion of equation

$$X^2_{n-1} = \sum_{i=1}^{n} \frac{[X_i(u_i) - u_i\hat{\theta}]^2}{u_i\hat{\theta}}, \quad (22)$$

where

$$\hat{\theta} = T_n / \sum_{i=1}^{n} u_i \quad (23)$$

and

$$T_n = \sum_{i=1}^{n} X_i(u_i), \quad (24)$$

which is approximately distributed as χ^2 with n-1 degrees of freedom (see, e.g. Rao, 1952, pp. 205-6).

Table 1 (see below) includes the bird strike data taken from Thorpe and Wessum (1982). Using the statistic (22) for testing the homogeneity of 4 observations from Table 1 for the Poisson process (10) we obtain $X^2_3=4.975$. From tabulations of the statistic χ^2_3 we get $\Pr(\chi^2_3 \geq 7.81)=0.05$. Since our computed X^2_3 is smaller than 7.81 (at the nominal level of significance a= 0.05) we conclude that there is no evidence against the assumption of a common Poisson process with the common parameter b, i.e.,

$$X_i(u_i) \sim \frac{(bu_i)^{x_i}}{x_i!} e^{-bu_i}, \quad i=1(1)4, \qquad (25)$$

where $\hat{b}=3.2656931$ represents the maximum likelihood estimate of b.

TABLE 1. National Reporting - 1980

Country	Number of bird strike incidents	Number of aircraft movements (in terms of 10,000 movements)
i	x_i	u_i
1. Austria	21	7.0000
2. Denmark	51	15.6463
3. France	134	47.7637
4. United Kingdom	356	101.6821

5. HOMOGENEITY TESTING FOR THE EXPONENTIAL DISTRIBUTION

Considerable attention has been given in the literature to the problem of testing a composite null hypothesis H_0 that a set of variables $Y_1, \ldots, Y_n$ represents a set of independent identically distributed exponential random variables with probability density function

$$f(y;\theta) = (1/\theta)\exp(-y/\theta), \quad y \geq 0, \qquad (26)$$

for some unspecified common parameter $\theta > 0$. Some authors discuss the hypothesis that the variables have a common two-parameter exponential distribution with probability density function

$$f(y;\grave{a},\theta) = (1/\theta)\exp(-(y-\grave{a})/\theta), \quad y \geq \grave{a}, \qquad (27)$$

for unspecified $\grave{a} \in (-\infty, \infty)$ and $\theta > 0$.

For testing the homogeneity of n observations from a common exponential distribution, a procedure is used that involves transformation of the data resulting in (n-2) new variables, which under the null hypothesis of homogeneity are distributed as independent observations from the uniform distribution on [0,1]. Thus, the many known tests of this completely specified distribution can be used.

Let $Y_1, \ldots, Y_n$ be a random sample of size n from a two-parameter exponential distribution (27). It will be convenient throughout the paper to denote the order statistics of $Y_1, \ldots, Y_n$ by $Y_{(1)} \leq Y_{(2)} \leq \cdots \leq Y_{(n)}$. Then

$$f(y_{(1)}, \ldots, y_{(n)};\grave{a},\theta) = n! \prod_{i=1}^{n} f(y_{(i)};\grave{a},\theta) \longrightarrow \prod_{i=2}^{n} f(z_i;\theta), \qquad (28)$$

where

$$f(z_i;\theta) = (1/\theta)\exp(-z_i/\theta), \quad z_i \geqslant 0, \tag{29}$$

$$z_i = (n-i+1)(y_{(i)}-y_{(i-1)}), \ i=2(1)n. \tag{30}$$

Using the method of conditioning on a sufficient statistic, we have

$$\prod_{i=2}^{n} f(z_i;\theta) \longrightarrow \prod_{i=3}^{n} f(z_i;t_i), \tag{31}$$

where

$$f(z_i;t_i) = \frac{i-2}{t_i}\left[1 - z_i/t_i\right]^{i-3}, \quad 0 \leqslant z_i \leqslant t_i, \tag{32}$$

$$t_i = \sum_{q=2}^{i} z_q, \ i=3(1)n. \tag{33}$$

Now if the probability integral transformation defined by

$$w_i = F\,(z_i;t_i) = \int_0^{z_i} f(\check{z}_i;t_i)\,d\check{z}_i = 1 - (1 - z_i/t_i)^{i-2}, \quad i=3(1)n, \tag{34}$$

is used, we obtain

$$\Pr(W_i \leqslant w_i; i=3(1)n) = \int_{\{\check{z}_i : F(\check{z}_i;t_i) \leqslant w_i;\, i=3(1)n\}} \cdots \int \prod_{i=3}^{n} dF(\check{z}_i;t_i)$$

$$= \int_0^{w_n} \cdots \int_0^{w_3} \prod_{i=3}^{n} dw_i = \prod_{i=3}^{n} w_i, \tag{35}$$

where $0 \leqslant w_i \leqslant 1$, $i=3(1)n$. Hence $W_3, \ldots, W_n$ are uniformly and independently distributed on $[0,1]$ random variables.

To test the null hypothesis H_0 we can use, for example, K. Pearson's probability product test

$$P_{n-2} = -\ln \prod_{i=3}^{n} W_i, \tag{36}$$

a $\Gamma(n-2,0,1)$ random variable, or, equivalently,

$$2P_{n-2} = -2\ln \prod_{i=3}^{n} W_i, \tag{37}$$

a $\chi^2_{2(n-2)}$ random variable.

To illustrate the above procedure for executing a test of the homogeneity for the exponentiality, the following data were taken from the paper of H. Dahl (1982) (see Table 2).

TABLE 2. National Reporting - 1982

Country	Airports	Costs per average yearly bird strike ($)
	i	y_i
Austria	1. Vienna	2,400
Belgium	2. Brussels	1,800
Denmark	3. 12 airports	3,200
Federal Republic of Germany	4. Civil airports	8,000
Finland	5. Helsinki-Vantaa	1,700
France	6. Lyon	2,350
	7. Charles de Gaulle	7,400
	8. Orly	2,500
	9. Marseille	9,000
	10. Nice	2,000
United Kingdom	11. Military airfields	7,000

Applying (37) we have

$$2P_9 = -2\ln\prod_{i=3}^{11} W_i = 15.12. \qquad (38)$$

$2P_9$ is a χ^2_{18} random variable iff the Y_i are drawn from a common two-parameter exponential distribution. At the 5% level of significance, we get from χ^2-tables that $\Pr(\chi^2_{18} < 28.87) = 0.95$. Since the observed value 15.12 of our χ^2_{18} random variable is much smaller than 28.87, the conclusion about the homogeneity for the exponentiality with common parameters à and θ can be made with sufficient certainty.

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ADP616417

BSCE 20 / WP 18
Helsinki, 21-25 May 1990

A GENERAL STATISTICAL APPROACH TO IDENTIFICATION OF BIRD REMAINS AFTER COLLISION BETWEEN AIRCRAFT AND BIRDS

Presented by

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A GENERAL STATISTICAL APPROACH TO IDENTIFICATION OF BIRD REMAINS AFTER COLLISION BETWEEN AIRCRAFT AND BIRDS

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SUMMARY

The aim of this paper is to present a general statistical approach to identification of bird remains after collision between aircraft and birds, which is based on bird strike statistics and can be applied in combination with some methods currently used and described by Brom (1988). The proposed approach is, therefore, trying to improve the situation by applying to the bird strike databases more sophisticated analytical techniques generally used to analyse rather variable biological data. The sample sizes of the data set of bird strike reports are small and in some cases, multivariate analysis is not possible. The data are, therefore, statistically weak. However, in order to illustrate a suggested statistical approach to identification of bird remains after collision between aircraft and birds, these weaknesses have been ignored. The approach is based on the results of Nechval (1988, 1989) and is immediately applicable when the alternative distributions have given functional forms but with unspecified parameters. The nonparametric cases can be treated in a similar manner, but no attempt has been made in this paper to offer explicit solutions. The main feature of the approach to identification of bird remains is the population elimination rule. When certain conditions are met, the decision is taken to eliminate specific populations from further consideration, and the identification process is continued with a reduced number of populations. An example is given.

1. INTRODUCTION

Identification of bird remains after collision between aircraft and birds is the subject of growing interest and has the many areas of application. For example, civil engine airworthiness regulations relating to bird hazards have required the development of complex and extremely expensive test routines. The way in which a bird of a particular species passes through an engine can result in some cases in no damage and in others to catastrophic failure to the engine. Because of the high costs of testing engines, it is never possible to repeat tests in sufficient quantity to take into account the many variables involved in a bird ingestion, even with the advent of modern computer simulation. A valuable source of information is, therefore, obtained from in-service incidents. This is an area where the complete collection and accurate identification of bird remains is essential.

The traditionally used and most simple way of feather identification is that of comparing unknown feathers with a reference collection. In order to be able to determine whether younger (and therefore less experienced) birds are more accident-prone than adults, a distinction between age classes is needed in bird strike statistics. Since no diagnostic characters are found in the micromorphology of feathers by which juvenile and adult birds can be distinguished, all information on the age of the bird depends on macroscopical criteria, and hence on the size and condition of the bird remains available for examination. 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.

Bird strike reports arise from one of three sources: 1) from pilots of aircraft which have experienced a strike, 2) from ground staff who find a corpse on the manoeuvring area, 3) from engineers who find evidence of a bird strike during a routine inspection of an aircraft. Pilots will often have details about the aircraft, the effect on the flight, the time of day etc. when a strike occurred, but not the species of bird involved. Ground staff, on the other hand, may know the bird, but not the aircraft or the time of the incident. Engineers often know the effect upon the aircraft, have the bird remains but may have no details about when or where the strike occurred. A high proportion of bird strike reports will, therefore, be incomplete. It is self evident that complete and accurate reporting of bird strikes is an essential prerequisite to the development of a meaningful and useful data base from which to carry out analysis. The coordination required to ensure complete and accurate reporting again relies upon education of the parties involved and also often, the goodwill and cooperation of the air traffic controllers at the airport.

The aim of this paper is to present a general statistical approach to identification of bird remains (after collision between aircraft and birds), which is based on bird strike statistics and can be applied in combination with some methods currently used and described by Brom (1988). The proposed approach is, therefore, trying to improve the situation by applying to the bird strike databases more sophisticated analytical techniques generally used to analyse rather variable biological data.

The sample sizes of the data set of bird strike reports are small and in some cases, multivariate analysis is not possible. The data are, therefore, statistically weak. However, in order to illustrate a suggested statistical approach to identification of bird remains after collision between aircraft and birds, these weaknesses have been ignored.

2. FORMULATION OF THE PROBLEM

Let us suppose we are considering the remains of bird that suffered the collision with aircraft. It is known that this bird belongs to one of m species of birds, but to which of them it belongs is unknown. Our problem is to identify the bird remains with the proper species, on the basis of the values of measurements of p characteristics of these remains available from bird strike.

The problem of identification, that is of assigning the observed remains of bird to the appropriate group, admits a simple solution when the probability distributions of measurements in the alternative groups (populations) of measurements of p characteristics of bird remains are completely specified. The decision rule consists in setting up a correspondence between observed values of measurements of p characteristics of bird remains and one of m distributions of measurements of p characteristics of bird remains, where each distribution corresponds to one of m alternative populations of measurements of p characteristics of bird remains associated with certain species of birds. In practice it is rarely possible to specify completely the distributions of these characteristics, but they may be estimable on the basis of independent samples from each of the alternative distributions.

Let X(1), ... ,X(m) be independent samples of observed values of measurements of p characteristics of bird remains from m alternative populations of measurements of p characteristics of bird remains, which may be partially specified, as when the functional forms of the probability densities are given but with unspecified parameters, or completely unspecified. In this paper we consider the identification problem when the alternative distributions have given functional forms but with unspecified parameters. After a p-dimensional vector X (measurement of p characteristics of bird remains) is drawn from a population known a priori to be one of the above set of m populations of measurements of p characteristics of bird remains, the problem is to infer from which population the vector X has been drawn. The decision rule should be in the form of associating X with one of the samples X(1), ... ,X(m), and declaring that X has come from the same population as the sample with which it is associated.

In this paper a general statistical approach to identification of bird remains after collision between aircraft and birds has been developed with help of which the identification problem can be solved, utilizing only the sample information. This approach is based on the results of Nechval (1988, 1989) and is immediately applicable when the alternative distributions have given functional forms but with unspecified parameters. The nonparametric cases can be treated in a similar manner, but no attempt has been made in this paper to offer explicit solutions.

3. AN APPROACH TO IDENTIFICATION OF BIRD REMAINS

The main feature of the proposed approach to identification of bird remains is the population elimination rule. When certain conditions are met, the decision is taken to eliminate specific populations from further consideration, and the identification process is continued with a reduced number of populations. The elimination rule is based on some exact tests for discriminant analysis in the presence of unknown parameters and small samples of the data. These tests are based (in the main) on the parameter-free or distribution-free statistics which are obtained by means of suitable transformations on the original observations and possess certain known distributions with known parameters (see Nechval, 1988, 1989).

If all the populations except one are eliminated, we decide that the vector of observations, X, belongs to the remaining population. If however the set of populations not yet eliminated contains more than one element, in this exceptional situation the object (bird remains) is treated as belonging to the population for which the value of the likelihood function of the test statistic is greatest. When there is the possibility that the object does not belong to any of the m populations and all the populations are eliminated from further consideration, we decide that the measurement X does not belong to any of the m populations, i.e., it belongs to the (m+1)th population whose distribution is unspecified.

To illustrate the application of the proposed approach to constructing the procedure of identification of bird remains, when sample sizes of the statistical data are small, an example is given below.

4. AN EXAMPLE

Consider X, a (p x 1) vector of observations on an object (bird remains etc.), which is to be classified as belonging to one of two given populations or to a third population whose distribution is unspecified. Assume that if X is an observation vector from population i then

$$X \sim N_p(b_i, Q), \ i \in \{1,2\}, \tag{1}$$

where $N_p(b_i, Q)$ denotes p-variate normal distribution with the parameters b_i and Q. Suppose that the means b_1, b_2 and a common variance-covariance matrix Q are unknown and estimated by $\overline{X}_1$, $\overline{X}_2$ and S, respectively. Here S is the pooled estimate of Q from two independent random samples of sizes n_1 and n_2 from populations 1 and 2, respectively, and $\overline{X}_1$ and $\overline{X}_2$ are the corresponding sample means,

$$S = \sum_{i=1}^{2} \sum_{j=1}^{n_i} (X_{ij} - \overline{X}_i)(X_{ij} - \overline{X}_i)' / (n_1 + n_2 - 2), \tag{2}$$

$$\overline{X}_i = \sum_{j=1}^{n_i} X_{ij} / n_i, \ i=1,2. \tag{3}$$

If $X \sim N_p(b_i,Q)$, $i \in \{1,2\}$, and is distributed independently of the two samples then

$$(X-\overline{X}_i) \sim N_p(0,[(n_i+1)/n_i]Q) \tag{4}$$

and is independent of

$$(n_1+n_2-2)S \sim W_p(n_1+n_2-2,Q), \tag{5}$$

where $W_p(r,Q)$ denotes the central Wishart distribution with r degrees of freedom (d.f.). Thus the statistic

$$T_i^2 = [n_i/(n_i+1)](X-\overline{X}_i)'S^{-1}(X-\overline{X}_i) \tag{6}$$

has Hotelling's T^2 distribution and

$$kT_i^2 \sim F(p,n_1+n_2-p-1), \tag{7}$$

where

$$k = (n_1+n_2-p-1)/[p(n_1+n_2-2)] \tag{8}$$

and $F(p,n_1+n_2-p-1)$ denotes the central F distribution with p and n_1+n_2-p-1 d.f.

Let

$$C_i = \left\{X\colon (X-\overline{X}_i)'S^{-1}(X-\overline{X}_i) \leq [(n_i+1)/(n_i k)]F_{a;p,n_1+n_2-p-1}\right\}, \qquad \text{for } i \in \{1,2\}, \tag{9}$$

where $F_{a;...}$ is the upper (100)a percentage point of the central F distribution with the indicated degrees of freedom. Considering the distribution of kT_i it is noted that

$$\Pr(X \in C_i) = 1-a \quad \text{for } i \in \{1,2\}. \tag{10}$$

Thus C_1 and C_2 are ellipsoids of concentration of size 1-a for the two given populations. For a fixed value of i,

$$\overline{C}_i = \left\{X\colon X \in \text{Complement of } C_i\right\} \tag{11}$$

may be taken as the critical region with exact size a for the sub-hypothesis

$$H_{0i}\colon X \in \text{Population } i, \tag{12}$$

i.e., reject H_{0i} iff

$$(X-\overline{X}_i)'S^{-1}(X-\overline{X}_i) > [(n_i+1)/(n_i k)]F_{a;p,n_1+n_2-p-1}\,. \tag{13}$$

If one of the two populations is eliminated, we decide that the vector of observations, X, belongs to the remaining population. If however the set of populations not yet eliminated contains the two populations, in this exceptional situation X is treated as belonging to the ith population for which

$$f_i((x-\bar{x}_i)'S^{-1}(x-\bar{x}_i)) > f_j((x-\bar{x}_j)'S^{-1}(x-\bar{x}_j)),$$
$$i,j \in \{1,2\},\ i \neq j, \qquad (14)$$

where $f_i(\cdot)$ is the probability density function of the test statistic $(X-\bar{X}_i)'S^{-1}(X-\bar{X}_i)$.

If the two populations are eliminated from further consideration, we decide that X belongs to the third (unknown) population whose distribution is unspecified. Note that the probability of accepting the hypothesis H_{03}: X does not belong to either population 1 or population 2, when H_{03} is not true, is defined by

$$\Pr(X \in \text{Complement of } C_1 \bigcup C_2) = \Pr(X \in \overline{C_1 \bigcup C_2}) = \Pr(X \in \bar{C}_1 \bigcap \bar{C}_2). \qquad (15)$$

From a geometric argument presented in the theorem given below, it is guaranteed that this probability is between a and a/2. This should be sufficient for most practical applications.

Theorem 4.1. The probability of accepting the hypothesis H_{03}: X does not belong to either population 1 or population 2, when H_{03} is not true, satisfies the inequality

$$a/2 \leq \Pr(X \in \bar{C}_1 \bigcap \bar{C}_2) \leq a. \qquad (16)$$

Proof. Assume that H_{03} is not true, and without loss of generality, that $X \in$ population 1 (a parallel argument interchanging 1 and 2 holds for the other case). It follows from (11) that

$$\Pr(X \in \bar{C}_1) = a \qquad (17)$$

and hence

$$\Pr(X \in \bar{C}_1 \bigcap \bar{C}_2) \leq a. \qquad (18)$$

The lower bound on $\Pr(X \in \bar{C}_1 \bigcap \bar{C}_2)$ is more difficult to establish. Let

$$N_a = [(n_1+1)/(n_1k)]F_{a;p,n_1+n_2-p-1} \qquad (19)$$

and $X \in \bar{C}_1$. We have

$$N_a < (X-\bar{X}_1)'S^{-1}(X-\bar{X}_1) = [(X-\bar{X}_2)-(\bar{X}_1-\bar{X}_2)]'S^{-1}[(X-\bar{X}_2)-(\bar{X}_1-\bar{X}_2)]$$
$$= (X-\bar{X}_2)'S^{-1}(X-\bar{X}_2) - (2X-\bar{X}_1-\bar{X}_2)'S^{-1}(\bar{X}_1-\bar{X}_2). \qquad (20)$$

Thus, if

$$(2X-\bar{X}_1-\bar{X}_2)'S^{-1}(\bar{X}_1-\bar{X}_2) > 0 \qquad (21)$$

then

$$N_a < (X-\bar{X}_2)'S^{-1}(X-\bar{X}_2) \qquad (22)$$

and X also belongs to $\bar{C}_2$. (21) implies

$$(X-\bar{X}_1)'S^{-1}(\bar{X}_2-\bar{X}_1) < [(\bar{X}_2-\bar{X}_1)'S^{-1}(\bar{X}_2-\bar{X}_1)]/2 \ . \tag{23}$$

Note that

$$\bar{C}_1 = \left\{ X: \ (X-\bar{X}_1)'S^{-1}(X-\bar{X}_1) > N_a \right\} = \bar{C}_1^- \cup \bar{C}_1^+ \ , \tag{24}$$

where

$$\bar{C}_1^- = \left\{ X \in \bar{C}_1 : \ (X-\bar{X}_1)'S^{-1}(\bar{X}_2-\bar{X}_1) < 0 \right\} \tag{25}$$

and

$$\bar{C}_1^+ = \left\{ X \in \bar{C}_1 : \ (X-\bar{X}_1)'S^{-1}(\bar{X}_2-\bar{X}_1) \geqslant 0 \right\} \tag{26}$$

are such that

$$\bar{C}_1^- \cap \bar{C}_1^+ = \emptyset \tag{27}$$

and

$$\Pr(X \in \bar{C}_1^-) = \Pr(X \in \bar{C}_1^+) = a/2 \ . \tag{28}$$

It follows from (23), (24), (25), and (26) that

$$\bar{C}_1 \cap \bar{C}_2 = \bar{C}_1^- \cup \bar{C}^+ , \tag{29}$$

where

$$\bar{C}^+ = \left\{ X \in \bar{C}_1^+ : \ (X-\bar{X}_1)'S^{-1}(\bar{X}_2-\bar{X}_1) < [(\bar{X}_2-\bar{X}_1)'S^{-1}(\bar{X}_2-\bar{X}_1)]/2 \right\} \subset \bar{C}_1^+ . \tag{30}$$

Taking into account (27), (28), (29), and (30), we have

$$\Pr(X \in \bar{C}_1 \cap \bar{C}_2) \geqslant a/2. \tag{31}$$

This ends the proof.

For the sake of the numerical illustration, we selected the two random samples of size six ($n_1=n_2=6$):

Sample 1

	X_{11}	X_{12}	X_{13}	X_{14}	X_{15}	X_{16}
a	200	160	188	190	177	210
b	137	118	134	143	127	140
c	52	47	54	52	49	54
d	144	140	151	141	134	149
e	14	15	14	13	15	13
f	102	99	98	99	105	107

and

Sample 2

	X_{21}	X_{22}	X_{23}	X_{24}	X_{25}	X_{26}
a	186	184	208	199	187	188
b	107	108	125	124	123	114
c	49	43	50	46	47	48
d	120	116	125	119	129	122
e	14	16	14	13	14	12
f	84	75	88	78	75	74

drawn from the populations 1 and 2, respectively. The sample means and pooled sample variance-covariance matrix are given in Table 4.1.

TABLE 4.1. Summary of Computations for Random Samples (1 and 2)

Components		a	b	c	d	e	f
Sample Means	$\overline{X}_1'$	187.5	133.2	51.3	143.2	14.0	101.7
($n_1=n_2=6$)	$\overline{X}_2'$	192.0	116.8	47.2	121.8	13.8	79.0
Pooled Sample Variance-Covariance Matrix (S)		198.2	99.9	27.2	37.5	-7.8	33.3
		99.9	76.6	14.0	25.2	-5.7	7.0
		27.2	14.0	7.0	10.3	-1.9	5.6
		37.5	25.2	10.3	30.2	-2.5	.23
		-7.8	-5.7	-1.9	-2.5	1.3	.10
		33.3	7.0	5.6	.23	.10	23.1

Utilizing a computer program to evaluate

$$V_1 = (X-\overline{X}_1)'S^{-1}(X-\overline{X}_1) \tag{32}$$

and

$$V_2 = (X-\overline{X}_2)'S^{-1}(X-\overline{X}_2) \tag{33}$$

for an arbitrary (6 x 1) vector X, we applied the test recommended above to the following data:

Vector of Observations (X)

	from the population 1			from the population 2			from the population 3		
					No.				
	1	2	3	1	2	3	1	2	3
a	191	173	186	211	201	187	158	146	135

(X) (Continued)

	1	2	3	1	2	3	1	2	3
b	131	127	136	122	114	124	141	119	127
c	53	50	56	49	47	49	58	51	52
d	150	144	148	123	130	129	145	140	140
e	15	16	14	16	14	14	8	11	10
f	104	97	111	95	74	88	107	111	108

The test size selected was a=.05 for each application yielding a critical value of

$$\frac{n_i+1}{n_i k} F_{a;p,n_1+n_2-p-1} = \frac{7}{6(.0833)} F_{.05;6,5} = (14)(4.95) = 69.3. \qquad (34)$$

Table 4.2 contains a summary of results.

TABLE 4.2. Summary of Results of Application of the Test Procedure to the Data of X

Species	X	V_1	V_2	Type I Error	Type II Error
1	1	4.46	146.7	No	
	2	7.43	127.1	No	
	3	14.83	201.3	No	
2	1	99.5	16.9	No	
	2	167.5	12.8	No	
	3	47.5	22.0	No	
3	1	105.2	357.3		No
	2	78.4	344.9		No
	3	113.1	404.7		No

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ADF616418

BSCE 20 / WP 19
Helsinki 1990

MAPPING THE BIRDSTRIKE RISK

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SUMMARY

The Bird Movements and Low-Level Working Group shall initiate maps concerning permanent or temporary bird concentration areas for the information of pilots with the purpose of bird hazard prevention and bird protection. The paper gives a survey of existing bird hazard maps and discusses the limits of mapping the birdstrike risk.

1. Introduction

Attempts of mapping the birdstrike risk go back to the early days of the Bird Movement Working Group. The originally planned bird migration maps have been mostly replaced by bird concentration maps considering the difficulties of mapping the temporary peaks of bird migration. Whereas in North America large and medium sized birds migrate along well defined flyways, only few species (e.g. cranes and storks) are restricted to relatively narrow migration routes in Europe. The main part of bird migration runs in broad front, only temporarily concentrated along geographical diversion lines (coast lines, mountain slopes, passes). Therefore the peaks of bird migration can be better described by temporarily limited warnings than by risk areas in bird hazard maps. On the other hand certain breeding, roosting or wintering areas involve a considerable birdstrike risk to low flying aircraft. These areas can be described very well in maps indicating the kind, the period and the altitude of the risk. Therefore BSCE 19 has recommended the issue respectively the updating of national maps according to Annex 15 of the ICAO Aeronautical Information Services. Information concerning bird sanctuaries, and areas of ornithological importance should be compiled to a corresponding European map.

2. Problems in drawing up bird hazard maps

The scientific and practical problems in drawing up bird hazard maps had been clearly described by Karlsson (BSCE 12/WP 13). Bird concentration areas subjectively defined by ornithologists with regard to the number of bird species and individuals present as breeding,feeding or roosting birds must be evaluated from the flight safety point of view. The question is how many birds of which size and behaviour have to be present in a defined area to involve a birdstrike risk. Furthermore the evaluation of these areas must consider the flight pattern, altitude and velocity of different types of aircraft.

Slow aircraft, especially helicopters, can avoid small concentration areas situated in their flight route, whereas fast aircraft cannot take all small concentration areas into account. Furthermore 1500 ft GND are generally the upper limit of high birdstrike risk above bird concentration areas. Therefore only the areas in the vicinity of airfields/aerodromes are dangerous to civilian jet and propaircraft, whereas military aircraft flying at low level and helicopters are endangered by all bird concentration areas.

3. Types of bird hazard maps

Bird concentration areas in the vicinity of airfields/aerodromes should be described at high accuracy considering the temporarily differing numbers of birds and the daily flight patterns. Good examples for this purpose are the airport vicinity maps published in the AIP France RAC 5, 17 September 1984.

Country-wide bird hazard maps are published by many European countries in their national AIPs. Good examples are the Bird Strike Risk Map Belgium (1978), the Mil AIP Denmark RAC 4, and the AIP Netherlands RAC 6. For larger countries detailed information can be hardly included in one map. Either a loss of details must be accepted as in the AIP Germany RAC 3, or a series of maps in a smaller scale is necessary as shown in the "Bird Concentration Areas Sweden", issued by the University of Lund in 1978.

An example of a standardized large-scale bird hazard map called "Birdstrike Danger Areas Europe" issued by the German Military Geophysical Office in 1979 was distributed to all BSCE members. The map includes Central and Western Europe and considers concentration areas of birds (weight generally more than 260 gr) hazardous to aircraft. There is a discrimination between high risk areas with a density exceeding generally 500 birds per sq. km, subdivided with regard to hazards all year, hazards mostly in winter, and hazards mostly in summer (risk period indicated in Roman numerals), and medium risk areas with a density exceeding generally 100 birds per sq. km. In all areas flying below 1500 ft GND will involve a risk.

Maps concerning bird sanctuaries, wildlife reserves or other protected areas of ornithological importance as well as wetland areas of international importance can be published according to special guidelines. A source for such maps may be the Technical Publication No. 9 of the International Council for Bird Preservation "Important Bird Areas in Europe" revised in 1989. In the Federal Republic of Germany a map of protected areas of ornithological importance was distributed to civilian and military air traffic authorities in 1987.

4. Further activities

The Bird Movements and Low-Level Working Group shall initiate maps concerning permanent or temporary bird concentration areas for the information of pilots with the purpose of bird hazard prevention and bird protection.

Guidelines for such maps should be elaborated by the members of the working group. Details of the maps should be decided by the national authorities. The distribution of bird hazard maps should guarantee the practical use of these maps by all air traffic authorities and pilots.

AOF 6116418

BSCE 20 / WP 20

Helsinki, May 1990

BIRD STRIKES ANALYSIS IN ESTONIA 1951 - 1988

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SUMMARY

About 370 birdstrikes reported with 12 types of aircraft of Estonian Civil Aviation Department between 1951 and 1988 have been analysed. The analysis includes strike rate for aircraft types and airports (partly based on aircraft movements), bird species and weight, part of aircraft struck, effect of strike.

The paper shows that gulls were involved in 61 % of the incidents where the bird species was known, and that only 3 % of bird strikes involves birds of over 4 lbs. The major effects have been damage to 20 engines, 2 precautionary and 1 forced landings.

INTRODUCTION

The general aviation-ornithological characteristic of the Soviet Baltic region with respect to others regions of the USSR was shown in article of Drs. A.I. Rogachev and V.V. Khodchenko (Rogachev, Khodchenko, 1983). Analogous characteristic of Estonia with respect to Latvia and Lithuania was shown by author at the conference "Baltic Birds - V" in Riga in 1987 (Shergalin, in press). In this report detailed analysis of collisions between birds and aircraft of the Estonian Civil Aviation Department (ECAD) is given.

Data for analysis has been kindly placed for my disposal for 1951-1976 years by Dr. V.E. Jacoby, for 1971-1982 - - by Dr. A.I. Rogachev, and for 1982-1988, gathered by author, who began his work as aviational ornithologist in ECAD in 1982 and continues nowadays. I am very thankful to Drs. V.E. Jacoby and A.I. Rogachev for this information.

In Estonia total strike rate per 10 000 movements in 1986 was 10,2; in 1987 - 7,5; in 1988 - 9,1; in average for period 1986-1988 - 9,0. So high indices ranks Estonia among such countries with traditionally high danger for aviation from birds: Switzerland, Germany, Netherlands (Thorpe, 1984).

DISTRIBUTION OF BIRD STRIKES DURING STUDY PERIOD   TABEL 1

Year	Number of strikes	Year	Number of strikes	Year	Number of strikes	Year	Number of strikes
1951	1	1966	9	1974	2	1982	9
57	1	67	6	75	5	83	20
58	2	68	24	76	7	84	22
59	1	69	12	77	11	85	25
60	4	70	17	78	7	86	37
63	2	71	5	79	8	87	33
64	1	72	4	80	13	88	42
65	4	73	2	81	11	Total*	350

* Table does not include 21 Strikes,when year of Strike was defined unexactly.

Table 1 includes not only bird strikes, reported by pilots and ground personal (1951-1988), but also remains, which were founded on runway or it's surroundings (1983--1988). Relation between number of reported birds strikes and founded remains of birds on runway during last years was next:

NUMBER OF REPORTED BIRD STRIKES AND REMAINS TABLE 2

	1986	1987	1988	Total	%
remains	9	7	9	25	22,3
reported	37	33	42	112	100,0

BIRD STRIKES ACCORDING TO SEASON TABLE 3

Month	Pentades						Pentade unknown	Total	%	% AERO-FLOT
	I	II	III	IV	V	VI				
January		1						1	0,3	2
February										3
March	1		1					2	0,6	5
April	1			2	5	4	12	24	7,4	9
May	4	3	4	6	9	2	9	37	11,4	10
June	4	2	5	5	7	7	16	46	14,2	11
July	9	15	19	7	8	12	19	89	27,4	12
August	10	7	11	6	9	2	10	55	16,6	14
September	3	4	5	2	2	4	16	36	11,1	15
October	2	3	3	2	6	2	5	23	7,1	12
November			4		2	3		9	2,8	4
December		1			2	1		4	1,2	3
Total	34	36	52	30	50	37	87	326	100	100

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* Here and further data, concerned "Aeroflot" are taken from manual Rogachev A.I., Lebedev A.M. "Ornithological flight security." Moscow, "Transport", 1984. 126 p.

DISTRIBUTION OF BIRD STRIKES DURING THE DAY TABLE 4

Hours	Strikes Number	% from 220	Hours	Strikes Number	% from 22o
00.01-01.00	5	2,3	12.01-13.00	13	5,9
-02.00	6	2,7	-14.00	12	5,5
-03.00	3	1,4	-15.00	13	5,9
-04.00	0	0	-16.00	12	5,5
-05.00	3	1,4	-17.00	7	3,2
-06.00	2	0,9	-18.00	7	3,2
-07.00	2	0,9	-19.00	16	7,3
-08.00	12	5,5	-20.00	6	2,7
-09.00	23	10,5	-21.00	8	3,6
-10.00	21	9,6	-22.00	10	4,6
-11.00	13	5,9	-23.00	7	3,2
-12.00	13	5,9	-24.00	6	2,7

In the daytime 257 collisions occured, at night - 46, at dawn - 8, at dusk - 11.

DISTRIBUTION OF STRIKES BY AIRCRAFT TYPE TABLE 5

Aircraft type	Number of Strikes	% Based on 327	Aircraft type	Number of Strikes	% Based on 327
Tu-134	88	26,9	Li - 2	4	1,2
An - 2	86	26,3	Jak - 12	2	0,6
Jak - 40	59	18,0	Super-aero 45	2	0,6
Il - 14	47	14,4	An - 26	1	0,3
Tu - 124	31	9,5	An - 28	1	0,3
An - 24	5	1,5	Mi - 2	1	0,3

DISTRIBUTION OF STRIKES BY AIRCRAFT TYPE

TABLE 6

Aircraft type	Number of strikes	% based on 327	Aircraft type	Number of strikes	% based on 327
Turbojet	178	54,4	Piston	141	43,1
Turboprop	7	2,1	Helicopters	1	0,3

In average strike rate per 10 000 movements during 1977-82 and 1986-88 for aircraft Tu-134 was 16,6; for Jak-40 - 8,7; for An-2 - 9,9. In last case true index must be less than 9,9, because total number of strikes with this aircraft type was taken into consideration, while number of movements during aviational-chemical works (ACW) was not included.

THE BIRD SPECIES THAT COLLIDE WITH AIRPLANES IN DIFFERENT AIRPORTS

TABLE 7

Bird Groups Names	Tallinn	Kuressaare	Kärdla	Tartu	Pärnu	Aviational-chemical works
Pigeons and Doves	2	0	0	2	1	2
Gulls	124	31	12	3	4	18
Waterfowl (ducks, geese)	5	2	3	0	1	4
Small passeriformes (Starlings, Skylarks, Swallows)	26	2	2	1	1	17
Birds of prey	4	1	0	1	0	0
Corvidae (Crows, Rooks, Jackdows)	6	1	1	0	0	0
Swifts	6	0	0	0	0	0
Owls	2	0	0	0	0	0
Lapwing	7	2	2	1	2	2
Partridge	4	1	0	1	0	0
Black Grouse	0	0	0	0	0	2
Total	186	40	20	9	9	45

In this report 369 strikes are analized, including 341 collisions on the territory of Estonia. 279 strikes or 75,2 % occured in airports, 29 or 7,8 % near airports, 48 or 12,9 % outside of airports and 15 or 4,0 % occured in unknown place.

STRIKE RATE IN DIFFERENT AIRPORTS TABLE 8

Airport	Number of movements					Number of strikes				
	77-82	86-88	1986	1987	1988	77-82	86-88	1986	1987	88
Tallinn	103578	60984	17242	17636	26106	32	65	25	19	21
Kuressaare	16532	8710	2994	2892	2824	9	5	2	-	3
Kärdla	9736	4972	1800	1596	1576	5	11	1	1	9

Airport	Strike rate per 10 000 movements					
	66-69*	77-82	86-88	1986	1987	1988
Tallinn	4-6	3,4	10,7	14,5	10,8	8,1
Kuressaare	34-42	5,5	5,8	6,7	-	10,7
Kärdla	-	5,2	22,0	5,6	6,3	57,1

*Jacoby, V.E. Bird strikes in the USSR - Proc. World Conf. Bird Hazards to Aircraft, Kingston, Ontario, 2-5 Sept. 1969. National Research Counsil of Canada, Ottawa, pp. 101-109.

During study period the greatest index was in Kärdla airport in 1988 - 57,1 strikes per 10000 movements. As far as we know, this airport may be considered the most dangerous airport in respect of birds worldwide.

BIRD STRIKES ACCORDING TO ICAO CATEGORIES TABLE 9

ICAO Category	Number of Strikes	% from 369
A	79	21,4
B	279	75,6
C	11	3,0
D	-	-

BIRD STRIKES ACCORDING TO SPECIES

TABLE 10

Bird Groups Names	Number of Strikes	% from 349	% AEROFLOT
Doves and Pigeons	10	3	25
Gulls	214	61	18
Waterfowl (ducks, geese)	20	6	14
Small passeriformes (Starlings, Skylarks, Swallows)	68	19	14
Birds of prey	9	3	13
Corvidae (Crows, Rooks, Jackdaws)	10	3	6
Swifts	5	1	3
Owls	2	1	3
Storks and Cranes	0	0	2
Others	11	3	2
Total	349	100	100

BIRD STRIKES TABLE 11

Scientific Name	English Name	Weight Cate-gory	Number of Incidents	Mean Number hit birds	Number of strikes, when number of birds was known
1	2	3	4	5	6
Anseriformes					
Anser Briss	Goose	C	5	1,0	5
Anser anser sive fabalis	Grey lag or Bean Goose	C	1	1,0	1
Anser albifrons	White-fronted Goose	C	1	1,0	1
Anas L.	Duck	B	6	1,5	4
Anas platyrhynchos	Mallard	B	4	2,2	4
Anas crecca sive querquedula	Teal or Garganey	B	1	1,0	1
Somateria molissima	Eider	C	1	1,0	1
Mergus merganser	Goosander	C	1	1,0	1
Apodiformes					
Apus apus	Swift	A	5	1,0	4
Apus apus sive hirundinidae	Swift or Swallow	A	6	1,0	4
Charadriformes					
Vanellus vanellus	Lapwing	B	16	2,1	13
Laridae	Gull	B	92	3,0	57
Larus melanocephalus	Mediterranean Black-headed Gull	B	1	1,0	1
Larus ridibundus	Black headed gull	B	74	6,2	60
Larus fuscus sive marinus	Lesser black-backed or Great bl.-backed Gull	B	2		
Larus argentatus	Herring gull	B	25	1,8	17
Larus marinus	Great black-backed gull	B	3	1,0	2

(continued)

1	2	3	4	5	6
Larus canus	Common gull	B	15	1,3	13
Larus canus sive argentatus	Common or Herring gull	B	2	-	-
Columbiformes					
Columba L.	Pigeon	B	1		
Columba livia rustica	Racing pigeon	B	8	21,6	5
Streptopelia decaocto	Collared Turtle-Dove	B	1	1,0	1
Falconiformes					
Accipitridae		B	1	1,0	1
Milvus Lac.	Kite	B	1	1,0	1
Accipiter gentilis	Goshawk	B	1	1,0	1
Accipiter nisus	Sparrow hawk	B	1	1,0	1
Buteo lagopus	Rough-legged Buzzard	B	1	1,0	1
Buteo buteo		B	2	1,0	2
Falconiformes	Buzzard	B	1	1,0	1
Falco tinnunculus	Kestrel	B	1	1,0	1
Galliformes					
Lyrurus tetrix	Black grouse	C	2	1,0	2
Perdix perdix	Partridge	B	6	4,3	6
Passeriformes					
Passeriformes excluding Corvidae		B	1	1,0	1
Hirundo rustica	Swallow	A	1	2,0	1
Delichon urbica	House martin	A	1	1,0	1
Alauda arvensis	Skylark	A	7	1,0	6
Hirundo rustica sive Delichon urbica	Swallow or House martin	A	22	1,2	18

(continued)

1	2	3	4	5	6
Motacilla alba	White Wagtail	A	2	2,5	2
Lanius excubitor	Great Grey Shrike	A	1	1,0	1
Sturnus vulgaris	Starling	A	9	18,8	4
Corvidae sive Corvus sp.	Crow	B	1		
Pica pica	Magpie	B	1	1,0	1
Corvus monedula sive cor. cornix	Jackdaw or Hooded Crow	B	1	2,0	1
Corvus frugeligus	Rook	B	1	2,0	1
Corvus corone cornix	Hooded crow	B	6	1,0	2
Oenanthe oenanthe	Wheatear	A	1	1,0	1
Turdus L.	Thrush	A	1	1,0	1
Ploceidae	Passer	A	1		
Fringillidae		A	1		
Acanthis flammea	Mealy Redpoll	A	1	5,0	1
Emberiza citrinella	Yellow Hammer	A	1	1,0	1
<u>Strigiformes</u>					
Strigidae L.	Owl	B	1	1,0	1
Asio flammeus	Short-eared Owl	B	1	1,0	1
Strix aluco	Tawny Owl	B	1	1,0	1

Bird species was exactly identified in 203 collisions (60,5 %). Victims of strikes was identified to genus in 15 cases (4,5 %), to family - 97 (29,0 %), order - 20 (6,0 %). Determination of the bird species involved in difficult cases was done in the Estonian Nature Museum.

Age of birds was identified in 166 cases. In 110 collisions adult birds took part, and in 56 collisions - young birds or 33,7 % from total number. Part of strikes with young birds from total number for gulls in whole - 10,3 % (n=29), Herring Gulls - 50,0 % (n=18), Common Gulls - - 73,3 % (n=15), Great Black-backed Gulls - 50,0 % (n=2), Lapwings - 16,7 % (n=6).

FLIGHT STAGE DURING BIRD STRIKES

TABLE 12

Phase of flight	ECAD	% from 346	% AEROFLOT
Rolling	3	0,8	1
Take-off run and landing roll	87	25,1	5
Take-off	101	29,2	13
Climbing	11	3,2	25
En route	40	11,6	5
Descent	4	1,2	39
Approach	100	28,9	12

AIRCRAFT SPEED DURING BIRD STRIKES

TABLE 13

	Speed of aircraft (km/h)						
	to 100	100-150	150-200	200-300	300-400	400-500	over 500
Number of strikes	19	80	116	127	14	2	3
% based on 358	5,3	22,4	32,4	35,5	3,9	0,6	0,8
in Estonian CAD	5,3		89,4			4,5	0,8
% in AEROFLOT	3		71			25	1

AIRCRAFT ALTITUDE DURING BIRD STRIKES

TABLE 14

Altitude (m)	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Month un-known	Total number of strikes	% based on 360
0-100	1	1		17	33	42	73	47	29	16	6	4	38	307	85,3
101-400			2	5	5	6	4	5	5	6	2		5	45	12,5
401-1000							1	2		1			1	5	1,4
1001-2000							1							1	0,3
2001-5000 and above									1	1				2	0,6

NUMBER OF BIRDS SEEN

TABLE 15

Number of birds seen	Number of strikes	% based on 114	Number of birds seen	Number of strikes	% based on 114
2-10	76	66,7	41-50	3	2,6
11-20	13	11,4	51-100	8	7,0
21-30	8	7,0	more 100	3	2,6
31-40	3	2,6	unknown	37	-

NUMBER OF BIRDS STRUCK

TABLE 16

Number of birds struck	Number of strikes	% based on 113	Number of birds struck	Number of strikes	% based on 113
1	30	26,5	11-20	2	1,8
2	34	30,1	21-30	3	2,7
3	15	13,3	31-40	1	0,9
4	12	10,6	more 40	2	1,8
5-10	14	12,4	unknown	38	-

Crew recorded bird strikes in 211 cases. This number includes 24 cases, when crew observed birds in the rays of landing lights at night. In 39 cases crew did not record bird strikes (15,6 % from total information with this parameter).

The distance of bird location by crew was 1-1750 m, in average 265 m (n=41). Analogous parameter at night was 50-250 m, in average 150 m(n=4).

In 128 cases crew felt the blow, in 53 did not feel (29,3 % from total number of known collision with this parameter. In 25 cases birds have been observed by crew, but crew simultaneously did not feel the blow (11,9 % from total number of collisions (n=211), when birds have been observed by crew). In 11 cases birds were not observed by crew simultaneously felt the blow (8,6 % from total number of cases with acoustical confirmation of bird strikes).

BIRD STRIKES ACCORDING TO AIRCRAFT PART

TABLE 17

Aircraft part	Part struck		Part damaged		Part with damage %
	Total	% based on 367	Total	% based on 117	
Radome	7	1,9	-	-	-
Windwhield	24	6,5	3	2,6	12,5
Nose	25	6,8	4	3,4	16,0
Engine	65	17,7	24	20,5	36,9
Propeller	19	5,2	1	0,9	5,3
Wing/Rotor	106	28,9	48	41,0	45,3
Fuselage	29	7,9	4	3,4	13,8
Landing gear	27	7,4	4	3,4	14,8
Tail	1	0,3	1	0,9	100,0
Lights	16	4,3	13	11,1	81,3
Other part	48	13,1	15	13,9	31,3
Part unknown	121	-	-	-	-

Number of damaged aircraft parts	1	2	3	4	5
Number of strikes	165	33	15	6	2

Thus, during 1 bird strike (based on 221 strikes) birds damaged simultaneously 1,4 different elements of aircraft.

EFFECT on FLIGHT

TABLE 18

Effect on flight	Number of strikes	% based on 394
None	325	82,5
Exist	69	17,5
Precautionary landing	2	0,5
Engine(s) shutdown	4	1,0
Forced landing	1	0,3
Vision obscured	25	6,3
Other effect	37	9,4

SERIOUS BIRD STRIKES WITH REMOVAL OF JETS

TABLE 19

Date	Aircraft type	Bird species	Flock or single bird	Airport or routine	Phase of flight	Speed (km/h)	Altitude (m)	Number of removal jets
...09.63	Tu-124	Starling	flock	Tallinn	Take-off	310	15	1
...68-69	Tu-124	Gull	flock	Tallinn	Take-off	?	?	1
11.09.71	Tu-124	Herring Gull	flock	Tallinn	Take-off	260	4	2
14.09.71	Tu-124	Herring Gull	flock	Tallinn	Take-off	320	200	2
15.09.71	Jak-40	Gull	?	Tallinn	Take-off	300	200	1
......71	Tu-124	Gull	flock	Tallinn	Take-off	?	?	2
10.05.74	Tu-124	?	?	Tallinn	Take-off	300	100	1
07.09.75	Tu-134	Gull	flock	Tallinn	Take-off	?	?	1
23.07.77	Jak-40	Gull	?	Kärdla - Tallinn	?	?	?	1
19.07.80	Jak-40	Gull	flock	Kärdla	Landing	180	1	1
04108.80	Jak-40	Gull	flock	Kärdla	Landing	160	10	1
30.06.81	Tu-134	Gull	flock	Tallinn	Landing	?	3	1
08.12.81	Jak-40	Duck	flock	Kärdla	Landing	200	15	1
06.01.83	Jak-40	Mallard	flock	Kärdla	Landing	210	50	1
23.08.86	Tu-134	Herring Gull	?	Tallinn	Landing	320	300	1
12.07.88	Tu-134	?	?	Adler-Tallinn	?	?	?	2
30.09.88	Jak-40	Rough-legged Buzzard	1	Minsk-I	Take-off	310	280	1

SERIOUS STRIKES WITH MORE THAN 20 BIRDS INVOLVED

TABLE 20

Date	Time	Aircraft type	Airport	Bird species	Phase of flight	Number of birds struck	Number of birds seen
1957-60	?	Il-14	Tallinn	Starling	Landing	70	70
spring 68	?	Il-14	Tallinn	Black-headed Gull	Take-off	36	50
not winter 71	?	Tu-124	Tallinn	Black-headed Gull	Take-off	50	50
the beginning of 70's	?	Jak-40	Riga	Gull	Landing	23	23
...07.77	?	An-2	ACW point	Black-headed Gull	?	64	100
...06.79	02.00-03.00	Tu-134	Tallinn	Black-headed Gull	Landing roll	23	30
30.06.80	19.40	An-2	ACW point	Pigeon	ACW	100	100
30.04.85	04.48	Tu-134	Tallinn	Black-headed Gull	Landing	32	40
09.09.85	08.45	Tu-134	Tallinn	Black-headed Gull	Landing	27	70

CONCLUSIONS

1. During 1983-1988 in average 30,0 bird strikes occured every year with aircraft of ECAD.

2. Total strike rate per 10000 movements in Estonia is very high: in 1986-88 in average 9,0.

3. The most dangerous month is July - 27,4 % from total strikes number.

4. The most dangerous hour is during 08-09.00 - 10,5 % from total strikes number. In the day time 257 collision occured, at night - 46.

5. Among aircraft, which are exploited by ECAD, the most dangerous for birds based on strike rate per 10000 movements is Tu-134, the least - Jak-40. Absolutely, more often strikes occured with Tu-134 (26,9 % of total nomber) too. 54,4 % collisions were recorded with turbojet aircraft.

6. 279 strikes of 75,2 % from total number occured in airports. The most dangerous airport absolutely is Tallinn, but based on strike rate per 10000 movements during 1986-1988 was Kärdla.

7. The most dangerous for aviation in all Estonian airports group of birds - gulls (61 % from total number). More often collisions occured with birds of "B" ICAO category - - 75,6 %.

8. The most of all strikes were recorded during take-off - - 29,2 %.

9. 35,5 % from all strikes were recorded with speed of aircraft within the limits of 200-300 km/h.

10. 85,3 % from all strikes were recorded at altitude less than 100 m.

11. More often (66,7 % from all cases) flocks consist of 2-10 birds before strike.

12. The most of all 2 birds (30,1 % from all cases) struck aircraft. Simultaneously, in average 1,41 elements of aircraft got the blow.

13. More often birds struck in wings of aircraft - 28,9% from all cases. 45,3 % from all blows in wings were with damage.

14. Effect on flight were existed in 17,5 % cases.

REFERENCES

Thorpe, J. Analysis of bird strikes reported European airlines 1976-1980. BSCE/17 WP3.

References on papers of soviet ornithologists can find in the full soviet bibliography about aviation and radar ornithology 1982-1990, which is available, as other working paper at this BSCE meeting.

ADF616420

BSCE 20 / WP 21

Helsinki, May 1990

RESULTS OF ORNITHOFAUNA STUDY AT THE SOME SOVIET AIRFIELDS 1972 - 1988

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SUMMARY

The paper shows results of ornithofauna investigation in 14 soviet airports, according to published data mainly. These data were published in rare editions with limited circulation, often difficult of access.

64 bird species were identified among victims of air-traffic. Species and quantitative structure of about 590 victims of collisions are shown in Table 2. Information in different columns of this table don't recommend compair, because these columns concerned different stretchs of time.

Ordinal number of column in Table 2 corresponds to ordinal number of line in Table 1. Succession of bird species in Table 2 is given according to "Catalogue of birds of the USSR" by A.I. Ivanov. Leningrad, "Science", 1976. 276 p.

References for this report are absent, because it may be found in full soviet bibliography about aviation and radar ornithology 1982-1990, other working paper of this meeting.

NUMBER OF BIRD SPECIES IN REPORTED STRIKES AND BIRD REMAINS AND NUMBER OF BIRD SPECIES, RECORDED ON AERODROMES

TABLE 1

N°	Airport	Number of species - victims of strikes	Number of species and families, recorded on aerodrome	Study period	References
1	Alma-Ata	21	140 species, 33 families	1976-77	Goncharov et al 1984 Sema et al. 1984
2	Buhara	12	85 species, 35 families	1976-78, 1980-81	Dzhabbarov et al. 1982
3	Kaunas	2	71 species	1972-75 and later	Pjatrajtis et al. 1984
4	Krasnodar	14		1973-88	Lashtabega,pers.comm.
5	Palanga	5	124 species	1972-75 and later	Pjatrajtis et al., 1984
6	Perm	7	70 species, 10 orders, 52 species nest on aerodrome and it's vicinity (R=3 km)	1976, 84, 1986-87	Shurakov et al., 1989
7	Samarkand	12	73 species, 32 families	1980	Dzhabbarov, 1984
8	Saransk	19	90 species	1982-86	Lysenkov, 1988
9	Tashkent	21	39-56 species in spring, 26-37 - in summer, 24-37 in autumn, 15-20 in winter	1976-77	Ostapenko et al., 1984

(continued)

1	2	3	4	5	6
10	Ulyanovsk	11	96 species, in winter - 19, in spring - 76, in summer - 50 species (21 nest), in autumn - 62	1985-86	Borodin, 1986
11	Vilnius	11	41 species	1972-75 and later	Pjatrajtis et al., 1984
12	Leningrad	13	62 species	1985-87	Lobanov, pers.comm.
13	Ashkhabad		70 species, 11 orders, 141 species nest on aerodrome and it's vicinity, 33 settled, 61 migrant 38 winter species	1984	Eminov et al., 1987
14	Ufa		21 species, 5 orders	1983	Klysov et al., 1984

BIRD SPECIES INVOLVED BIRD STRIKES

TABLE 2

	1	2	3	4	5	6	7	8	9	10	11	Total	12
Cygnus olor				1								1	
Anser albifrons				5								5	+
Anas platyrhynchos											2	2	+
Anas querquedula						1						1	
Accipitridae				2								2	
Milvus migrans										5	1	6	
Buteo lagopus				2								2	
Circus pygargus								3				3	
Falco tinnunculus		1			12			4		1		18	
Falco columbarius									1	1		2	+
Falco vespertinus										3		3	
Falco subbuteo	1					1						2	
Perdix perdix											2	2	
Coturnix coturnix	5								1			6	
Lyrurus tetrix													+
Fulica atra	1											1	
Burhinus oedicnemus									1			1	
Charadrius hiaticula													+
Charadrius dubius				1					2			3	
Tringa totanus								1				1	
Phylomachus pugnax						3						3	
Calidris ferruginea						1						1	
Calidris alpina						2						2	
Gallinago Gallinago									1			1	
Larus canus						7				3		10	+
Larus argentatus				14								14	+
Larus fuscus										1		1	+
Larus ridibundus						2			1			3	+

(continued)

	1	2	3	4	5	6	7	8	9	10	11	Total	12
Chlidonias leucoptera								2				2	
Columba livia	5			8			2	12	11		8	46	+
Streptopelia turtur							8		3			11	
Streptopelia senegalensis	1								1			2	
Athene noctua		1						2				3	
Asio otus	1			3				27				31	+
Asio flammeus	2							17	1	1		21	+
Caprimulgus europaeus	1							5		1		7	
Caprimulgus aegyptius		1										1	
Apus apus		1				1	7	4	19	4	1	37	+
Merops apiaster	1	1					1		3			6	
Coracias garrulus							1					1	
Upupa epops									2			2	
Galerida cristata				1					2			3	
Alauda arvensis	3				2		1	15		5		26	
Eremophila alpestris	25											25	
Riparia riparia	2											2	
Hirundo rustica	19	4					14		7		2	46	
Hirundo daurica									4			4	
Motacilla flava	4*							4	1			9	
Motacilla alba	2	2						9	1			14	
Lanius minor	2											2	
Saxicda rubetra								4				4	
Oenanthe oenanthe								3				3	
Turdus pilaris	1			1								2	
Remiz pendulinus							1					1	
Plectrophenax nivalis								1				1	
Passer domesticus	2											2	
Passer indicus	5											5	
Passer hispaniolensis	2											2	
Passer montanus	2	8					16		3			29	

(continued)

	1	2	3	4	5	6	7	8	9	10	11	Total	12
Sturnus vulgaris				5			1				1	7	
Acridotheres tristis							2					2	
Corvidae					2						1	3	
Pica pica bactriana		1										1	
Corvus monedula								7				7	
Corvus frugilegus			1	31				10	1	1	1	45	
Corvus cornix				1				9	1			11	
Unknown species			4		1						1	6	
Laridae			8	41								49	
Small Passeriformes											14	14	
Total	87	20	5	83	58	18	54	138	67	26	34	590	

ADF 616 421

BSCE 20 / WP 22

Helsinki, May 1990

SOVIET BIBLIOGRAPHY ABOUT AVIATION AND RADAR ORNITHOLOGY

1982 - 1990

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ABSTRACT

This bibliography compiled for acquintance of foreign colleagues with literature about aviation and radar ornithology after 16th BSCE meeting (Moscow, 1982). This literature been published mainly in rare, separate editions with limited circulation, as a rule, only in Russian, without summaries. In other cases language is shown. Reports of soviet specialists on BSCE meetings and other articles in foreign languages were not included here. Bibliography covers 160 reports of 92 soviet specialists.

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AD F 66 422

BSCE 20 / WP 23

Helsinki 1990

BIRD OBSERVATION BY THE
SKYGUARD SEARCH- AND TRACKING RADAR

Video tape of the

German Federal Armed Forces

presented by

J. Becker

German Military Geophysical Office

SUMMARY

The SKYGUARD search- and tracking X-Band radar of the manufacturer Contraves is normally used by the German Air Force for the surveillance of low flying aircraft. In fall 1989 the system was tested for its suitability for recording the flight paths of birds in an area north of Munich. Gulls, lapwings, ducks,and crows could be tracked upto a distance of 8 km depending on the altitude of the flock and the absence of obstacles. The longest track lasted more than 8 minutes and run over more than 9 km. The altitudes of the birds varied between 30 m and 600 m, but mostly between 100 m and 300 m. During daylight the bird species could be identified by a TV-camera with a focal length of 1000 to 4200 mm.

ADF 616423

BSCE 20 HELSINKI
WORKING PAPER 24

PROPOSAL FOR THE ESTABLISHMENT OF A EUROPEAN CENTRE FOR THE IDENTIFICATION OF BIRD REMAINS

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ABSTRACT

Proper identification of bird remains is essential and fundamental to bird strike statistics. During the last meetings of BSCE a growing interest in the methods of identification was noticable, resulting in the establishment of the Working Group "Bird Remains Identification". The next step forward and one of the major goals of the newly formed Working Group should be the standardization of identification methods employed in different countries. One of the possible ways is to concentrate existing expertise and subsequently make it available to all organizations that have identification problems. In this paper it is therefore suggested to establish a European Centre for the Identification of Bird Remains.

INTRODUCTION

Bird Strike problems are international in scope. Airplanes and birds both cross national boundaries in their wanderings. The very reason for the existence of the Bird Strike Committee Europe is the wish to tackle the problem by international cooperation of airports, airliners, air forces, and pilot organizations with engineers and biologists in order to reduce the number of collisions between birds and aircraft as much as possible.

In many countries bird strike reporting systems are in operation in order to get an insight into the bird hazard. However, standards of reporting vary considerably among different countries and hence the accuracy and reliability of bird strike statistics may differ between countries, airline companies, and national air forces. If bird strike statistics are ever to be standardized internationally, it is evident that much work has to be done, firstly by improving standards of identification and next also in the field of education and motivation of pilots, airfield personnel and engineers. To obtain the best possible insight in bird hazard, all strikes should be reported as fully and accurately as possible, and even the smallest bird remains should be collected. From their side, biologists have to promote the expertise available in the bird remains identification services. On several occasions the possibilities of feather identification have been illustrated (Brom & Buurma 1979, Laybourne 1984, Brom 1988).

IDENTIFICATION AT THE ZOOLOGICAL MUSEUM AMSTERDAM

In 1960, the department of ornithology at the Zoological Museum Amsterdam became involved in bird strike research when Prof. Dr K.H. Voous agreed to identify feathers for the RNLAF. Since then, a bird strike reporting scheme has been in operation. All bird remains received have been permanently stored at the museum. This collection amounts to more than 2100 samples (Fig. 1). At first, identifications were made by comparison with bird skins in the collection (Figs. 2 & 3). In the Seventies, it became apparent that a much higher proportion of the remains could be identified by microscopical and submicroscopical techniques. These are now applied routinely, not only to bird strikes that cause damage, but also to very small amounts of material (Fig. 4), e.g. found during engine checks. By quickly reporting the results, those finding such remains are induced to report as best they can. Consequently, the RNLAF now disposes of statistical data that are as unbiased as possible. The effect that accurate identification methods have on bird strike statistics has been demonstrated unambiguously (Buurma & Brom 1979, Brom 1984, 1988, Buurma et al. 1984).

PROBLEMS WITH REPORTING

Several factors may account for defective reporting of bird strikes and hence for unreliable or biased statistics (e.g., Blokpoel 1976, Buurma & Brom 1979, Thomas 1988):

1) Bird strike reports originate from different sources, mostly from pilots, groundstaff, or engineers, and the quality therefore depends on the dedication and ornithological knowledge of these people. This can to some extent be mended by the obligatory use of standard reporting forms compelling reporters to pay attention to the relevant details.

2) The importance of collecting bird remains may not be equally or fully understood by everyone who is in the position to retain these remains for identification. Furthermore, some organizations are only interested in the exact identification of the species involved in case the bird strike has caused damage to the aircraft, while others as a routine collect all remains that can be detected. A reliable report to those responsible, produced quickly after the event, may increase collecting effort and keep it high.

3) From the questionaire which has been circulating during BSCE 19 in Madrid it can be concluded that the identification standards differ enormously among countries. In some countries the birds involved are identified by airfield personnel only, in others identification services are available where professional biologists analyse bird remains. The use of light- and scanning electron microscopy (LM & SEM) makes sure that small remains are as seriously treated as easily recognizable ones.

The main conclusion of more than a decade of study of RNLAF bird remains is that if identification is performed without thorough examination of the remains by professional biologists, bird strike statistics are seriously biased by an over-representation of easily recognizable bird species.

If bird strike reporting is to be standardized internationally, it is evident that much work has to be done, especially in the field of information and motivation of pilots, airfield personnel and engineers. To obtain the best possible insight in bird hazard, all strikes should be reported as fully and accurately as possible, and even the smallest bird remains should be collected. From their side, biologists will have to make available their expertise in well-organized and smoothly running identification services.

Several techniques are available for the analysis of bird remains (see review in Brom 1988), but for routine purposes the most effective method at present is the study of the microstructure of feathers by light- and scanning electron microscopy (Figs. 5 & 6) in combination with the use of a reference collection of bird skins (Figs. 2 & 3). Especially in the structure of downy barbules many diagnostic characters are found (Chandler 1916, Laybourne 1984, Brom 1986). By this method, bird strikes can always be confirmed by the presence of feather remains in the samples. In 4% (n=1659) only identification as "bird" is possible, but in all other cases the remains can be assigned to order level (e.g. "Passeriformes - songbirds"), from which 71% are identified to family (e.g. "Laridae - gulls"), 64% to genus (e.g. "Columba- pigeons") and 58% to species (e.g. "Apus apus - Swift"). In a number of cases, an indication of the weight of the bird can be obtained, even if exact identification to species is not possible (Brom 1986). This is important since weight is a key factor in the analysis of bird strikes.

IDENTIFICATION AND THE ROLE OF BSCE

During BSCE 19 in Madrid the participants of the sub-group on feather identification agreed on two major conclusions:

1) Proper identification of bird remains is essential and fundamental to bird strike statistics;

2) Within BSCE is a growing interest in the methods of identification and a need to establish contacts between people working in this field.

These conclusions have resulted in the foundation of BSCE's Working Group "Bird Remains Identification", which can be considered as a recognition of the role identification should play in the analysis of the bird strike problem. Proper identification of bird strike remains is indispensible as a diagnostic tool. Only when it is well known which species cause the worst problems, intelligent measures can be taken towards the solution of these problems.

So, the next step forward and one of the major goals of the newly formed Working Group should be the standardization of identification methods employed in the different countries. In order to achieve this and to improve existing methods, the following strategy can be followed.

In those countries where already exists a national centre for identification, this continues to operate, but in a standardized way. In cases where sophisticated techniques are needed to solve the problem or where an independent outside expert opinion is needed, a European Centre could step in. Such a European Centre would to a certain extent constitute a second-line facility. Countries where no central identification of bird remains takes place at present should either establish their own national centre or else directly go to the European Centre. In this way the European Centre could be a first-line facility, such as the Zoological Museum Amsterdam has been for the RNLAF for three decades. The identification problems in Europe and neighbouring countries are so similar that a joint service can effectively deal with difficult cases. This is effective because sophisticated techniques have to be developed only once, because new developments can be incorporated quickly, and because continuity of expertise can be guaranteed. In the next sections a proposal for establishing a centre for the identification of bird remains is presented.

AVAILABLE EXPERTISE

At the Zoological Museum Amsterdam (Institute of Taxonomic Zoology) the feather structure of many birds of different taxonomic groups has been studied in detail. Currently, this research programme is partly funded by the Netherlands Science Council NWO, because the programme focuses on the implications these findings have for the reconstruction of avian phylogeny (Brom 1987). Briefly, many groups of birds are easily recognized, such as ducks, parrots, pigeons, or kingfishers, but we have little idea how these groups are evolutionary related. Recently, for example, the phylogenetic relevance of characters such as "flexules" or "villi" for avian taxonomy has been studied (Brom & Visser 1989, Brom 1990).

It is evident that also the practical side, the analysis of bird strikes, greatly benefits from these studies since new diagnostic characters become available. If both types of research are combined they will support and reinforce each other. The presence of a large bird skin collection, LM and SEM facilities and an extensive library with literature on feather research further contribute to the optimal conditions needed for proper identification. Currently, our literature database on feather research comprises more than 800 references. Moreover, the museum is part of a university faculty, which facilitates access to sophisticated laboratory techniques. It is therefore suggested to establish an identification centre at the Zoological Museum Amsterdam.

CONDITIONS FOR AN IDENTIFICATION CENTRE

If the foundation of a European Centre for Identification of Bird Remains is considered desirable, this centre has to meet some requirements. Three main groups of conditions can be distinguished.

1) A European Centre should have a surplus value. A surplus value is manifest in:
    - Standardization of procedures, identifications and reporting.
    - A guaranteed quality for a reasonable price.
    - An assured continuity of expertise.
    - An adequate infrastructure (presence of reference collections: bird skins, photographs, slides, literature etc.) within a research institute.

2) A European Centre should provide reliable service. The Centre should inspire confidence by:
    - Independent expertise of high standard.
    - Fast identifications with detailed reports.

3) Agreements should be concluded between the Centre and those making use of its services.

Of course, it will always be possible to have bird remains identified at the centre at a specified price per identification, depending on the amount of work invested. However, both the continuity and the possibilities for developing new and better identification techniques will be more firmly based if aviation authorities in various countries should decide to make an agreement with the identification centre. Such an agreement would entitle them to the right of having the problematical identifications carried out at the centre or, alternatively, to a full first-line service.

Agreements should by preference be based on contracts, with attention to a proper financial calculation (which should be negotiated by the client and the Faculty of Biology at the Amsterdam University). In the long run, a European Centre would have difficulties to survive if it only depended on ad hoc identification of bird remains. This would be a rather weak basis for a professional organization, considering the above mentioned requirements. So the centre needs the support of BSCE members to guarantee that it eventually will become fully fledged.

ORGANIZATION

The Faculty of Biology at the Amsterdam University is willing to establish an identification centre for bird remains at the Zoological Museum. The faculty will place the centre under the responsibility of the museum director, as an organizationally recognizable unit on its premises. Contracting clients might in future prefer a different legal construction, e.g. making a Foundation (under Dutch law) with the contracting aviation authorities being represented on the board. This foundation could then conclude a housing agreement with the faculty.

Bird remains collected after bird strikes which are to be identified at the centre should be sent as complete as possible. The identification result can be reported by mail within a fortnight, but, if urgently desired, on the day of receipt by telephone or fax. The material (both remains and microscopic preparations) will be stored for further reference in the collections of the Zoological Museum.

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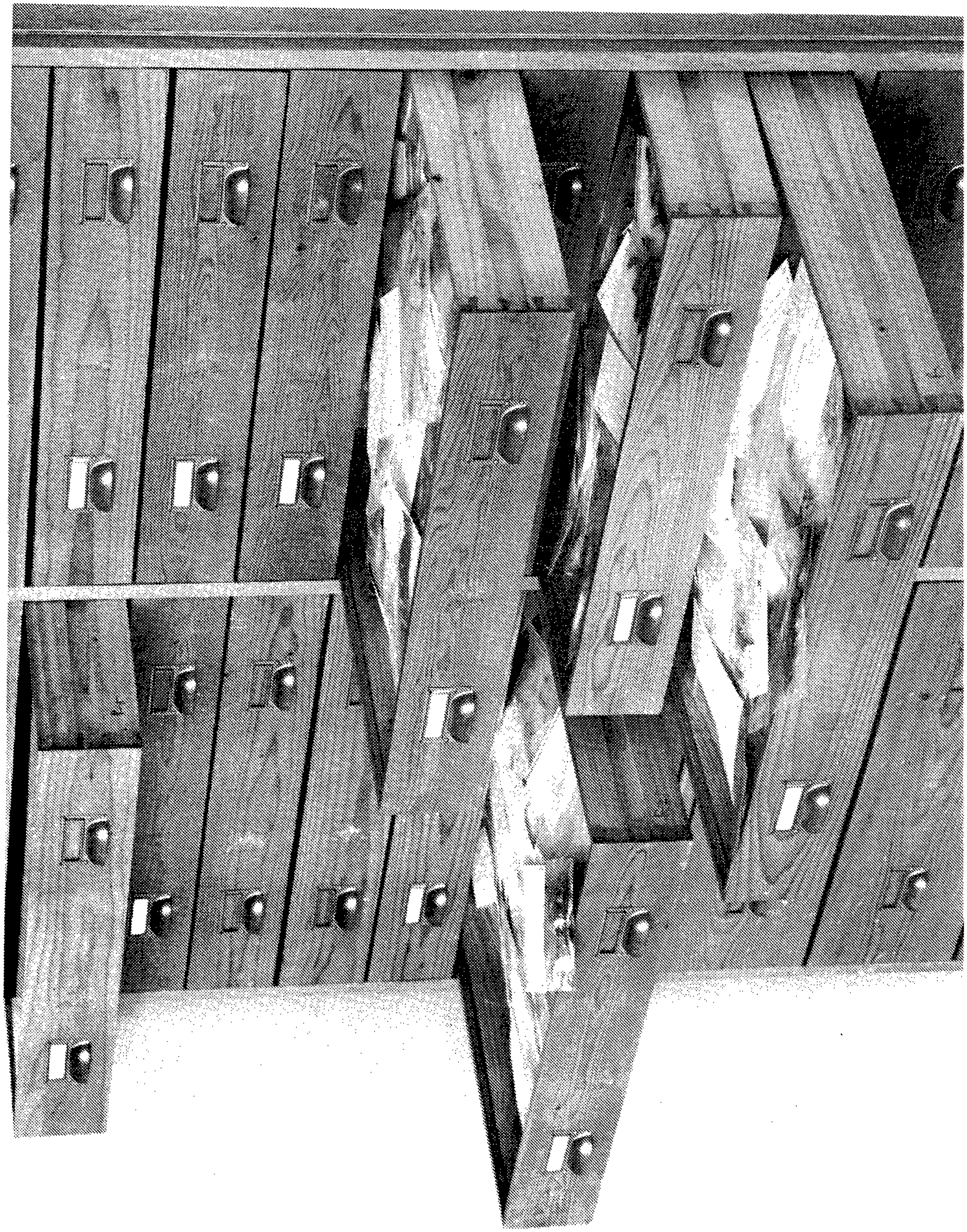

Figure 1. Collection of RNLAF bird remains 1960-1990.

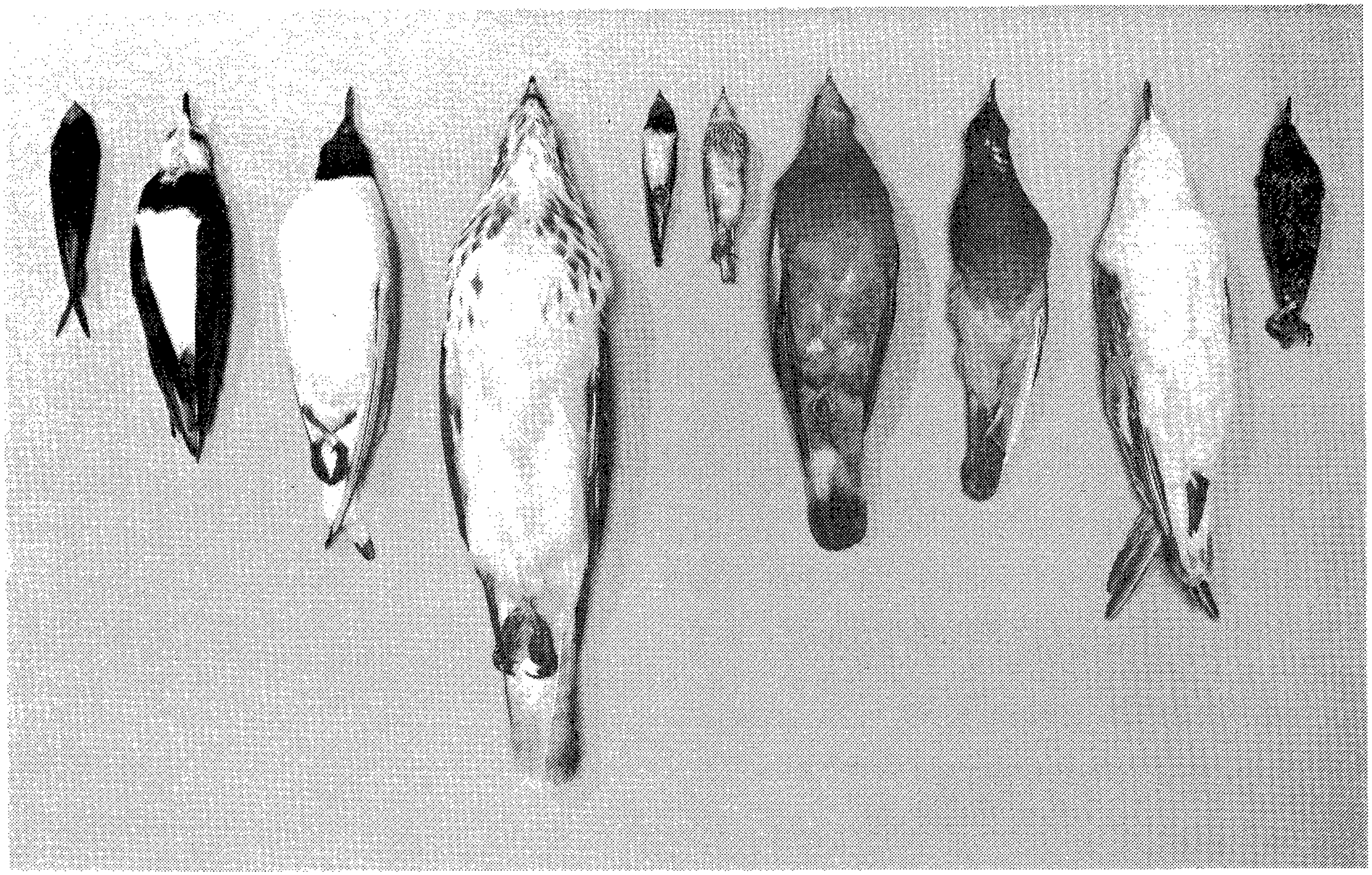

Figure 2. Bird skins in the ZMA collection, from left to right the species most frequently involved in RNLAF bird strikes: Swift, Lapwing, Black-headed Gull, Buzzard, Swallow, Skylark, Wood Pigeon, Feral Pigeon, Common Gull and Starling.

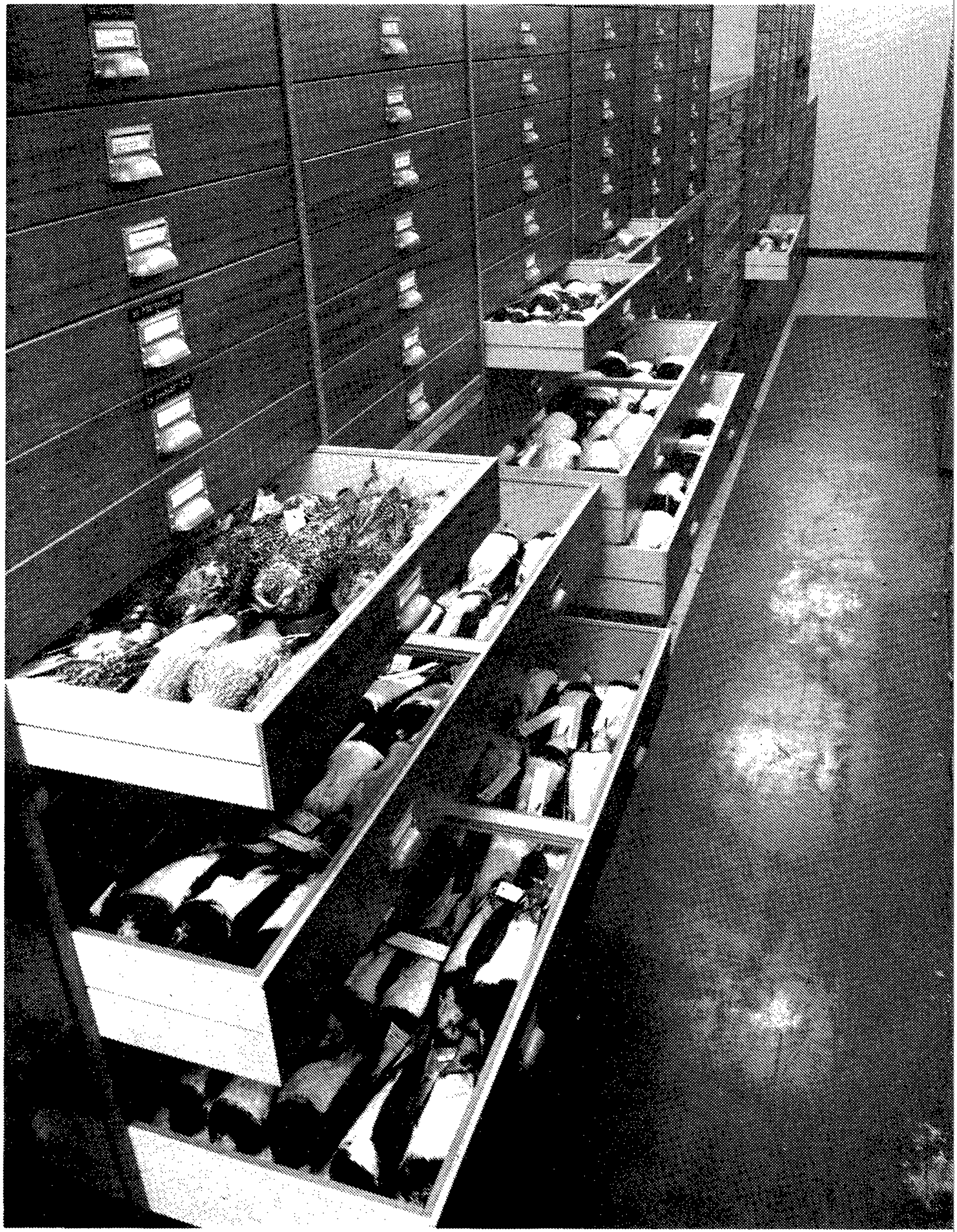

Figure 3. Bird skins in the ZMA collection.

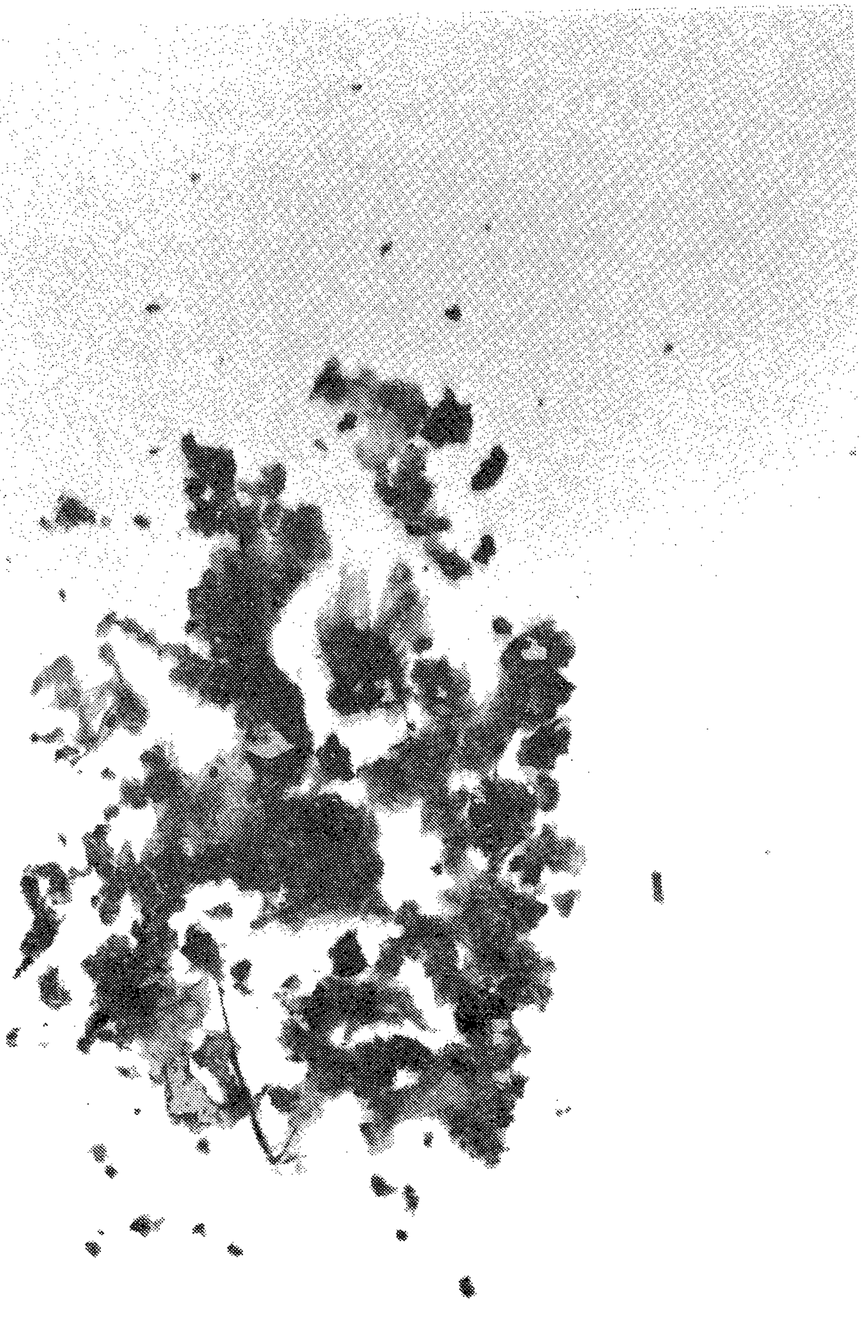

Figure 4. Small bird remains, in this case from Swift.

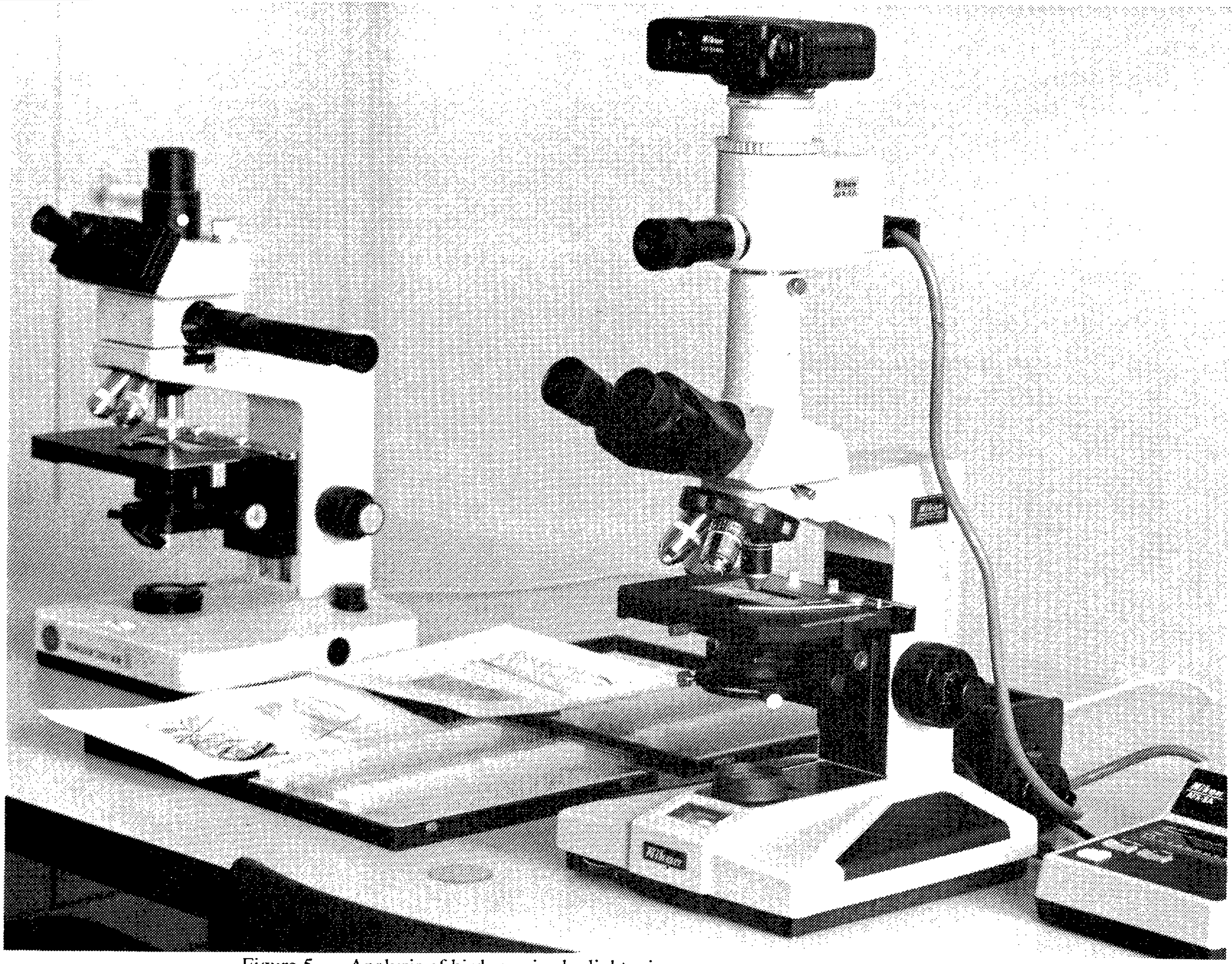

Figure 5. Analysis of bird remains by light microscopy.

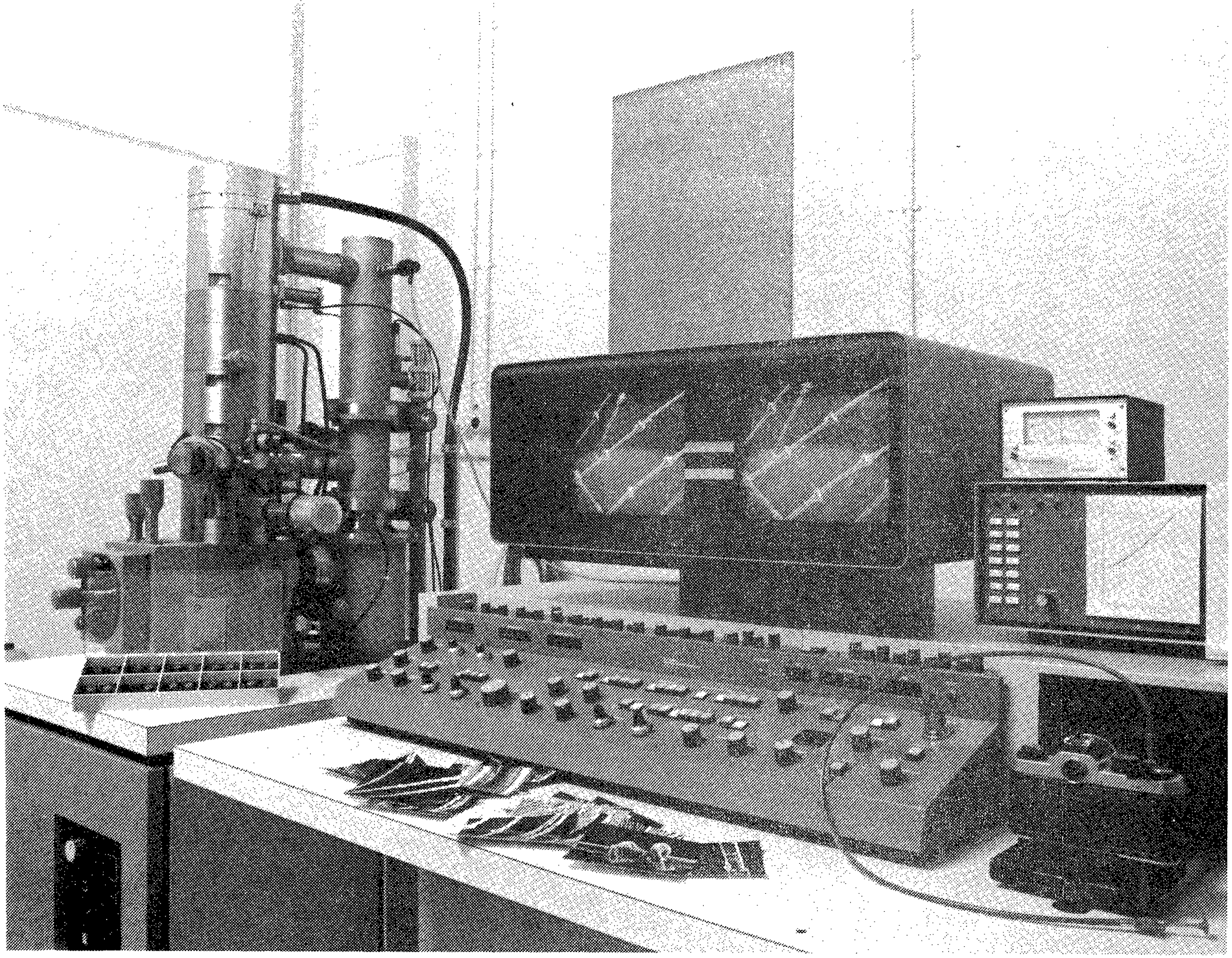

Figure 6. Analysis of bird remains by scanning electron microscopy.

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BSCE 20 / WP 25

Helsinki May 1990

FINNISH AIR FORCE BIRD STRIKE SUMMARY 1981- 1989

Finnish Air Force Hq
Flight Safety Office
SF 41161 TIKKAKOSKI

Introduction

The Finnish Air Force recorded 199 bird strikes during 1981 - 1989. These strikes caused neither aircraft losses nor injuries, but 30 strikes resulted in damages of various degree to aircraft.

During the period covered by this summary, annual number of bird strikes has varied between 10 and 32, the figure approaching 30 around the mid-decade. Althoug the increase in the number of strikes has been modest during the past few years, damages caused by strikes have increased markedly, due to fast low-lewel flights which have increased significantly after the introduction into service of Hawk trainer.

1 Bird strikes by Impact Location

Table 1 shows the percentage of bird strikes by various parts of aircraft. Almost every third bird that strikes an aircraft hits the windscreen or cockpit area, while in 85% of the strikes wings and other frontal surfaces are affected; yet no windscreen has been completely destroyed.

TABLE 1 **Bird strikes by impact location 1981–1989**

Impact location	Percent of total
Windscreen/canopy	31.1
Engine / cowling / air intake	25.2
Wing	17.9
Radome/nose	10.5
Fuselage	5.0
Landing gear / external tanks / pods	7.8
Other	2.5

2 Bird Strikes by Aircraft

Figure 1 shows the percentage of bird strikes by aircratf type. Trainers were involved in 60 % of the strikes; for example, during 1989 the number of strikes suffered by trainers was three-fold per each flying hour when compared with fihgters. This is partly explained by the fact that trainers fly more at low altitudes, ie. at the same height with birds.

3 Bird Strikes by Phase of Flight

Figure 2 shows the percentage of bird strikes by phase of fligth. A difference from civil flight operations is evident: most (57,5%) of the strikes suffered by Air Force aircraft occur during cruise outside the vicinity of aerodromes. This fact is related to the nature of operations, ie. military aircraft fly relatively low and fast. Just impacts at high speeds have the most devastating effects.

4 Bird Strikes by Altitude

Figure 3 shows the percentage of bird strikes by altitude. Two thirds of all strikes occur at below 500 ft (150 m), this figure includes strikes during take-off, approach and landing at the foregoing altitude. Of the strikes that occur below 500 ft (150 m) 45% take place in the vicinity of aerodromes and 55% during cruise. The highest altitude at which a bird has been encountered is 3,600 ft (1,100 m).

5 Times of Day and Year when Bird Strikes Occur

Figure 4 shows the percentage of bird strikes by month. More than two thirds of the strikes occur during summer months (ie. June, July and August),the peak month being August, in which one third of all strikes are recorded. Only a few strikes are recorded in winter.

Only 2% of strikes occur at night, for two reasons: relatively few low-level flights are made in the dark, and the number of birds flying at operating altitudes at night is small compared with daylight hours.

6 Birds Involved in Strikes

The most common birds involved in strikes are swallows, gulls and lapwings. Of these, gulls have been the most troublesome, owing to their relatively great size. Gulls are met in the vicinity of bodies of water, because low-level flights are frequently directed into these rather sparsely inhabited areas, with no respect of the bird strike hazard. Also, individual strikes by birds belonging to more than ten other species have been recorded.

7 Damages Caused by Bird Strikes

In approximately 30 % of the bird strikes, the power plant or air intake has sustained damages and in some cases strikes have entailed repairs of engines or engine components (modules). The most severe damages, however, have been various internal and external penetrations of the air intake -in one case, a frame between the air intake and fuselage was ripped. Damages always result in significant repair and other costs, too. Other impacts with frontal surfaces and aircraft have caused windscreen replacements and dents of various kinds in the nose, fuselage or wings.

Conclusion

Finnish Air Force bird strike summary in 1981 -1989 should be deemed satisfactory, because strikes have not caused any fatalities or aircraft losses. None-theless, the most worrying trend that is evident in the summary is the fact that the severity of damages is growing, due to increases in low-level flights and flying speeds. The year 1989, in particular, highlighted the growing probability of having an aircraft accident caused by a bird strike; an accident of this kind is almost in the offing, unless the trend is reversed.

As early as late 1989 and early 1990 the Finnish Air Force Headquarters has issued directives aimed at reducing the number of bird strikes and ensuing damages. To this same end, the Finnih Air Force is also continuing co-operation with the National Board of Aviation of Finland.

FIGURE 1

BIRD STRIKES BY AIRCRAFT TYPE 1981 – 1989

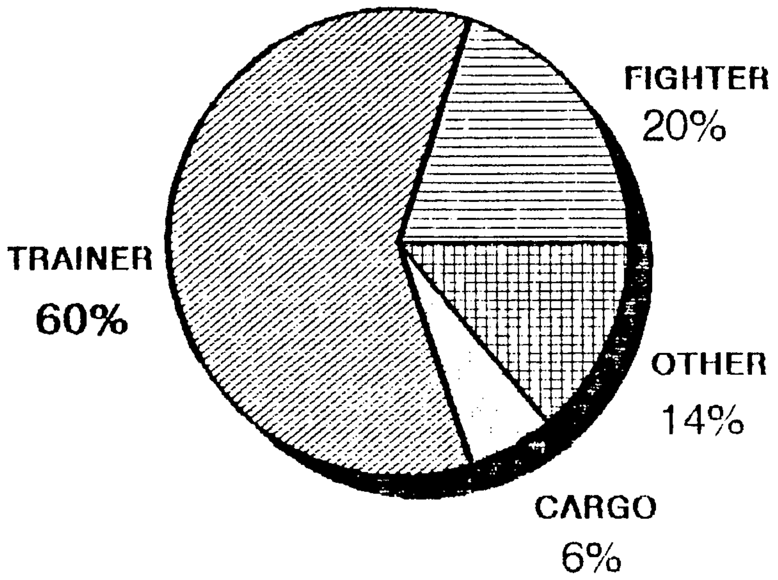


FIGURE 2

BIRD STRIKES BY PHASE OF FLIGHT 1981 – 1989

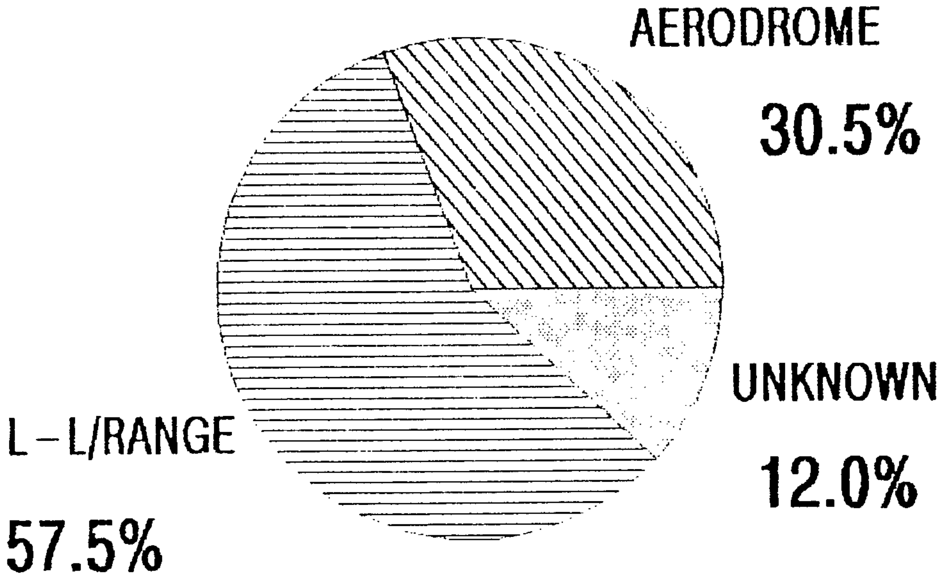


FIGURE 3

BIRD STRIKES BY ALTITUDE

1981 – 1989

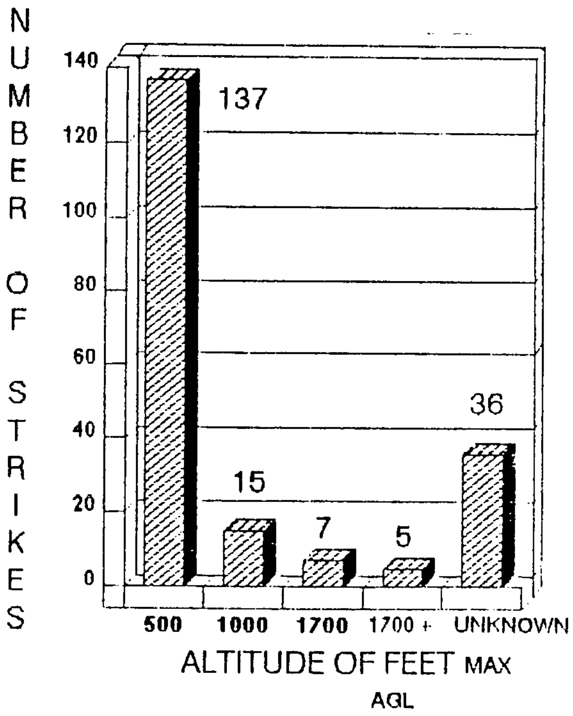
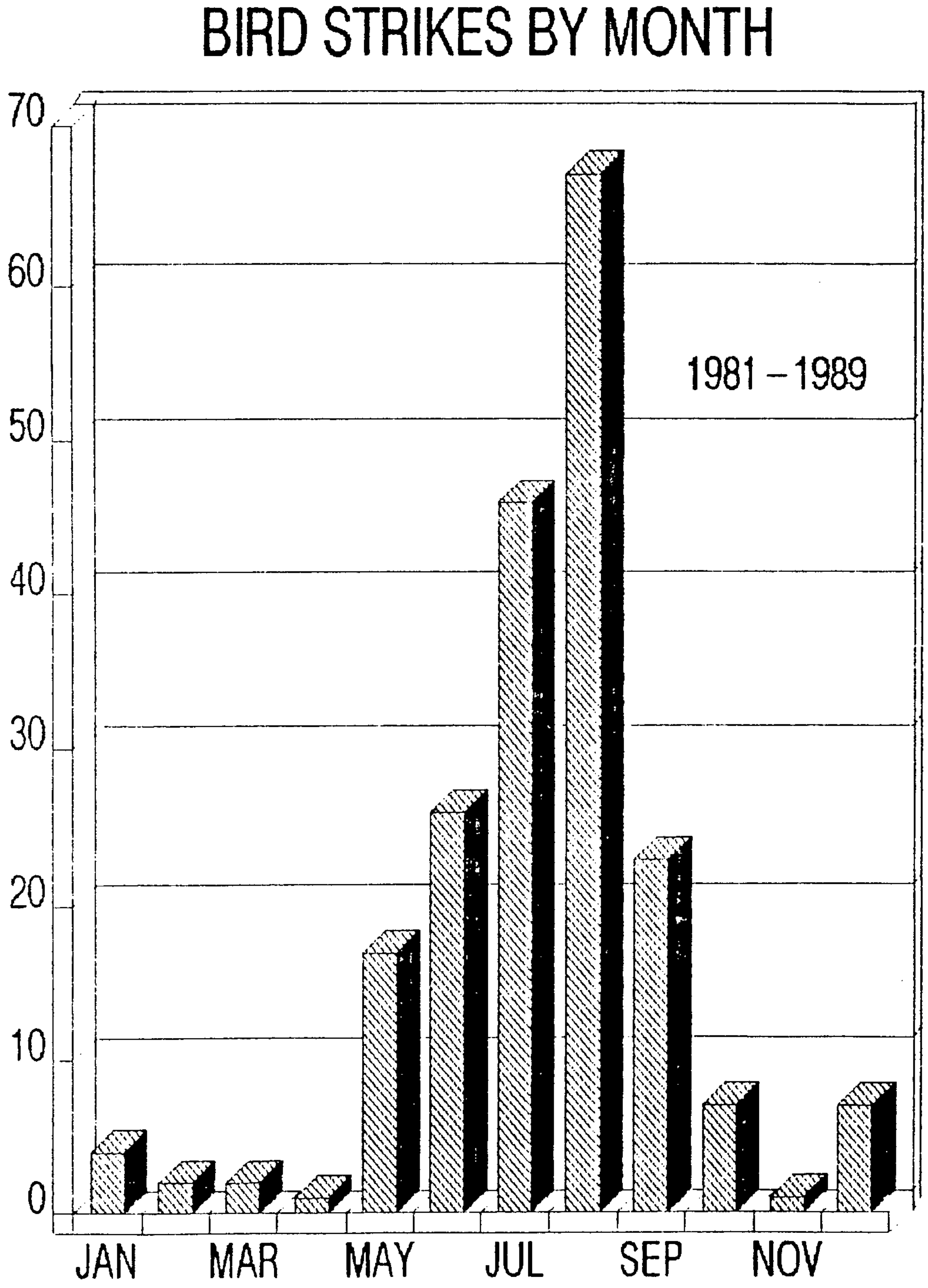


FIGURE 4


BIRD STRIKES BY MONTH
1981 – 1989
70
60
50
40
30
20
10
0
JAN
MAR
MAY
JUL
SEP
NOV

A DF 616425

BSCE/20
WP 26
Helsinki 1990

BIRD CONTROL ON AERODROMES

FRENCH REGULATION

Presented by Mr. Ph. VUILLERMET and Mr.JL BRIOT

(DNA: 143 R. Blomet 75015 Paris)

(STNA: 246 R. Lecourbe 75015 Paris)

Summary:

This information paper deals with the new regulation regarding bird control on French aerodromes.

Under the authority of French civil aviation authority "DGAC", this service will be provided on 143 Airports. The paper describe - the reasons why this policy was implemented - the organisation of the service in terms of personnels, equipements, procedures - the role of the differents partners as far as funding is concerned.

French regulations concerning the birdstrike hazard

General

The birdstrike hazard - a complex and difficult problem - remains a major preoccupation since from the safety viewpoint the prevention of birdstrikes is a delicate area where the risk of an incident - or even accident - is always present, and every year results in significant costs for the airlines.

Experience acquired in recent years concerning the prevention and combating of the hazard, combined with a redefinition of personnel deployment and role distribution, led the civil aviation administration to create a national birdstrike hazard prevention policy.

This political will was given concrete form on 24th July 1989 by the signing of a ministerial decree and a ministerial application instruction.

1) CONDITIONS GOVERNING IMPLEMENTATION OF THE REGULATIONS

Setting up program for preventing and combating the birdstrike hazard implies a good knowledge of the national and local ornithological situation, appropriate equipment and specialist personnel.

1.1 Knowledge of the ornithological situation

- A large number of studies and observations carried out nationally and locally has given the experts complete and detailed knowledge of the ornithological situation.

- Permanent collection of data on incidents and accidents over an extended period of time gives the experts invaluable information for assessment of the situation. For several years now, this nationwide collection of data has constituted an essential statistical source since it allows definition of the resources for preventing and combating the hazard specific to each airfield.

1.2 Resources for preventing and dealing with the hazard

- Whether pyrotechnic or acoustic, the resources used today have proven their effectiveness.

- The hazard prevention and combating techniques tested in real conditions can be extended and adapted to each platform on which a birdstrike hazard exists.

1.3 Personnel deployment

. The resources used require specialist personnel, available for fast and efficient reaction to any hazardous situation.

. These personnel have to work in close cooperation with the air traffic controllers working in the Control Tower.

2) MAIN CHARACTERISTICS OF THE REGULATIONS

The main characteristics of French regulations regarding the birdstrike hazard lie in the definition of a nationwide organization and a distribution of roles among the State and the airport operators.

2.1 Nationwide organization

. The organization and structures apply to the 145 mainland and overseas airfields handling commercial or similar traffic.

. Depending on the birdstrike situation, each of these airfields is assigned personnel and resources. The airfields are split into 5 categories.

. A team comprising the following is set up for each airfield:
  . a local coordinator,
  . the Control Tower ATC staff,
  . an operative available full time or on request (except category A airfields).

. Implementation of these regulations will be spread over two years, from 19th August 1989 to 19th August 1991.

2.2 Distribution between State and operators

2.2.1 Operators

. Personnel: the airfield operator is responsible for the field operatives. These field operatives are functionally responsible to the State representative.

. Equipment: the operator is responsible for the operation of the non-specialist equipment and for fitting out the platform.

2.2.2 State

. Personnel: the state personnel responsible for birdstrike prevention are local coordinators and controllers. The operatives are trained and approved by the State.

. Equipment: The state is responsible for acquiring specialised fixed and mobile equipment.

2.3 Estimation of costs

- For a category E airfield, the annual cost to the operator amounts to about 620,000 F (120,000 operating costs and 500,000 personnel costs). The State acquires and installs the specialised equipment, valued at about 300,000 F (cross-country vehicles, lines of noisemakers).

- The table in appendix 1 gives a cost estimate for the other airfield categories.

3) TECHNICAL ASPECTS

The basic point of these new texts is the assignment to each French airfield of a level of protection corresponding to precise anti-birdstrike resources. These levels - specified in appendix 2 - were drawn up by the Service Technique de la Navigation Aérienne (S.T.N.A.) according to the probability of birdstrikes.

They take account of:

- the local ornithological situation,
- the volume of commercial or similar traffic,
- the most frequent types of aircraft.

Analysis of birdstrikes over the last 10 years on each of the airfields was of great assistance to us in drawing up this list, which can be modified at any time should any of the criteria change - or if we find that we have made a mistake!

Each airfield appoints a Local Coordinator, or "mister birdstrike" in charge of applying recommendations concerning:

- environmental actions,
- deployment of the birdscaring resources,
- transmission of aeronautical information to the users.

3.1 Environmental actions

These measures are designed to make the airfield inhospitable to the birds and are specified by an S.T.N.A. expert after a special study (see video cassette) or on the occasion of personnel instruction visits. They concern changes to the techniques for upkeep of grassy areas, cultivated areas, drainage, etc., adapted to the ornithological, climatic and pedologic conditions of each airfield.

3.2 Birdscaring means

The three manual methods of birdscaring adopted are:

- distress calls broadcast by on-board synthesizers (photo 1),
- pyrotechnics: double-detonation cartridges, pistols and fire-cracker rockets (photo 2),
- hunting shotguns and lead cartridges (photo 3) reserved for species for which the Environment Ministry allows hunting.

On certain airfields, noisemakers are permanently installed along the runway if the STNA considers it necessary (photo 4).

All the other methods tried in the past have proved impossible to use practically and simply (hawks, scale models).

For category E airfields (see table in appendix 3), the three manual methods should be used full-time, all year round (daylight hours) by authorized personnel with a cross-country vehicle (photo 5). The protection period is reduced to 6 months for category D airfields. A category C airfield has the same equipment as a D airfield, except for the vehicle which is not cross-country. Intervention is only at the request of the control tower or a pilot. Only pyrotechnics are usable one request in category B. For small category A airfields, no birdscaring means are provided for: only information on the birdstrike risk is given to the pilots.

Authorization of birdstrike hazard personnel is given on each airfield with theoretical and practical instruction organized by the STNA. This instruction mainly concerns the correct use of the equipment, recognition of birds which can be shot (photo 6), the benefits of an ecological diagnostic and birdstrike reports.

3.3 Aeronautical information

This information is specified in appendix 6 to the regulatory texts of 24/7/89, and comprises:

- permanent information published in the AIP France (migration maps, local movements on the airfields, anti-birdstrike resources in service on the airfields),
- migration forecasts or observations of bird movements or concentrations on the airfields (Notam, BWM),
- real time information either by voice link or on the ATIS.

Application of all these new measures in the coming two years should contribute to a satisfactory level of safety in the French airports.

Appendix 1

Estimate of costs/year in FF

Level of resources	OPERATOR		STATE		AD number of group (Weather)	TOTAL in MF
	Personnel	Operations	Personnel	Operations		
E	500,000	120,000	---	100,000	4	2.88
D	250,000	90,000	---	70,000	5	2.05
C	ND	30,000	---	15,000	30	0.35
B	ND	5,000	---	---	48	0.24
A	---	---	---	---	26	

APPENDIX 2

RESOURCES FOR COMBATING THE BIRDSTRIKE HAZARD ON CIVIL AIRFIELDS HANDLING COMMERCIAL OR SIMILAR TRAFFIC (MAINLAND)

LFBA	AGEN	B
LFKJ	AJACCIO	C
LFCI	ALBI	B
LFMS	ALES	A
LFAY	AMIENS	A
LFRA	ANGERS	B
LFBU	ANGOULEME	A
LFLP	ANNECY	B
LFCH	ARCACHON	A
LFMO	AUBENAS	A
LFLW	AURILLAC	B
LFLA	AUXERRE	B
LFMV	AVIGNON	B
LFSB	BALE-MULHOUSE	C
LFKB	BASTIA	C
LFOB	BEAUVAIS	C
LFBE	BERGERAC	B
LFMU	BEZIERS	B
LFBZ	BIARRITZ	C
LFBD	BORDEAUX	E
LFLD	BOURGES	A
LFRB	BREST	C
LFBV	BRIVE	B
LFRK	CAEN	C
LFCC	CAHORS	A
LFAC	CALAIS	B
LFKC	CALVI	C
LFMD	CANNES	C
LFMK	CARCASSONNE	B
LFLH	CHALON C.	A
LFLB	CHAMBERY	C
LFQV	CHARLEVILLE	B
LFLX	CHATEAUROUX	C
LFPX	CHAVENAY	B
LFRC	CHERBOURG	C
LFOU	CHOLET	B
LFLC	CLERMONT	B
LFGA	COLMAR	B
LFPK	COULOMMIERS	A
LFLJ	COURCHEVEL	A
LFRG	DEAUVILLE	C
LFAB	DIEPPE	A
LFRD	DINARD	C
LFGJ	DOLE	C
LFSG	EPINAL	B
LFKF	FIGARI	B
LFNA	GAP	A
LFRF	GRANVILLE	B
LFLG	GRENOBLE VERSOUD	B
LFLS	GRENOBLE ST-GEOIRS	B
LFEY	ILE D'YEU	B
LFRE	LA BAULE	B
LFRO	LANNION	C
LFBH	LA ROCHELLE	C
LFRI	LA ROCHE/YON	B
LFOV	LAVAL	B
LFOH	LE HAVRE	C
LFRM	LE MANS	B
LFHP	LE PUY	B
LFAT	LE TOUQUET	C
LFQQ	LILLE	C
LFBL	LIMOGES	B
LFLY	LYON-BRON	C
LFLL	LYON-SATOLAS	E
LFPL	LOGNES	B
LFLM	MACON	A
LFML	MARSEILLE	E
LFQJ	MAUBEUGE	A
LFPE	MEAUX	A
LFPM	MELUN	B
LFQT	MERVILLE	B
LFBK	MONTLUÇON	B
LFMT	MONTPELLIER	C
LFRU	MORLAIX	B
LFHB	MOULINS	A
LFGB	MULHOUSE	A
LFSN	NANCY	B
LFRS	NANTES	C
LFQG	NEVERS	A
LFMN	NICE	E
LFBN	NIORT	A
LFEC	OUESSANT	B
LFPG	PARIS CDG	D
LFPB	PARIS LE BOURGET	D
LFPO	PARIS ORLY	D
LFBP	PAU	C
LFBX	PERIGUEUX	A
LFMP	PERPIGNAN	C
LFBI	POITIERS	B
LFPT	PONTOISE	B
LFKO	PROPRIANO	A
LFRQ	QUIMPER	C
LFQA	REIMS.P	A
LFRN	RENNES	C
LFLO	ROANNE	A
LFDN	ROCHEFORT	B
LFCR	RODEZ	B
LFOP	ROUEN	B
LFCY	ROYAN	A
LFRT	ST-BRIEUC	C
LFPZ	ST-CYR	B
LFMH	ST-ETIENNE	B
LFRZ	ST-NAZAIRE	C
LFGC	STRASBOURG.N	A
LFLN	ST-YAN	C
LFBT	TARBES	D
LFBO	TOULOUSE	D
LFPN	TOUSSUS LE NOBLE	B
LFQB	TROYES	B
LFLU	VALENCE	B
LFAV	VALENCIENNES	A
LFRV	VANNES	B
LFLV	VICHY	B

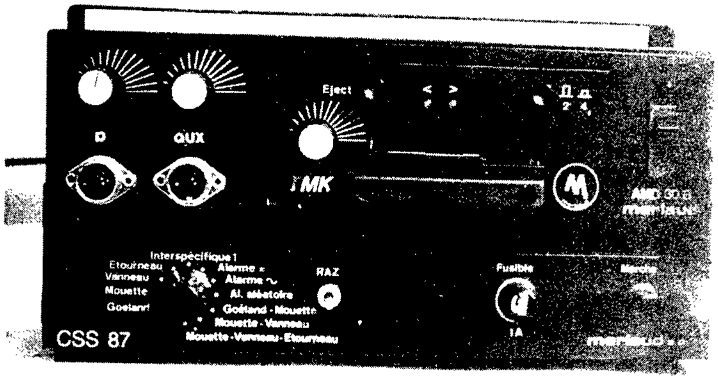
Appendix 3

MINIMUM EQUIPMENT REQUIREMENTS

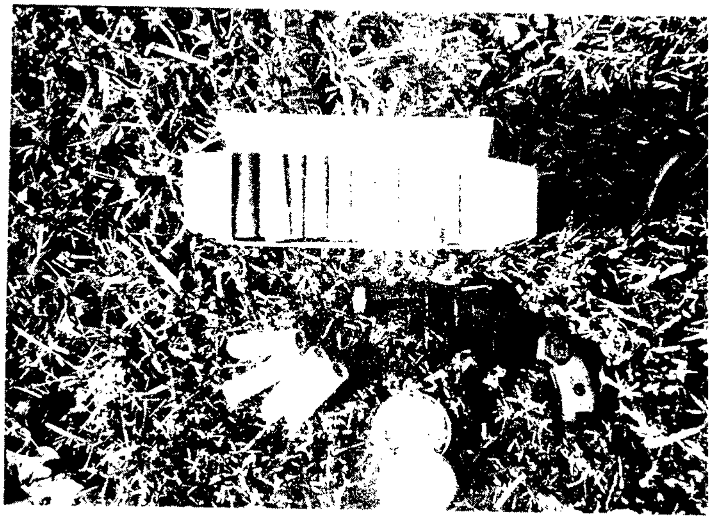
LEVEL OF MEANS	PERSONNEL	MOBILE RESOURCES				FIXED RESOURCES *
		VEHICLE	DISTRESS CALL GENERATOR	PYROTECHNIC RESOURCES	HUNTING	
E	1 LC 1 OP1 all year round	1 light vehicle specialising in combating birdstrikes **	1	2 pistols + firecracker rockets	2 12-bore guns or 16-bore guns + lead cartridges	Distress calls Remote controls Noisemakers
D	1 LC 1 OP1 seasonal + 1 OP2 the rest of the year	1 light vehicle specialising in combating birdstrikes **	1	2 pistols + firecracker rockets	2 12-bore guns or 16-bore guns + lead cartridges	Distress calls Remote controls Noisemakers
C	1 LC 1 OP2	1 vehicle equipped for combating birdstrikes usable on request	1	1 pistol + firecracker rockets	1 12-bore gun or 16-bore gun + lead cartridges	Distress calls Remote controls Noisemakers
B	1 LC 1 OP2	1 vehicle		1 pistol + firecracker rockets		
A	1 LC	Only information on bird activities is provided				

LC: Local Coordinator
OP1: Operative permanently present for combating the birdstrike hazard
OP2: Operative available on request for combating the birdstrike hazard

* : The choice of resources and their deployment is studied by the STNA for each airfield.
**: The type of vehicle is decided jointly with the LC, the STNA and the field operator.

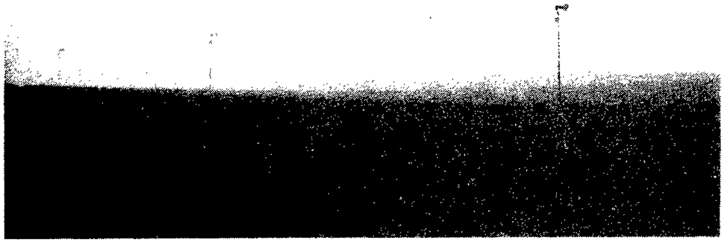


1. DISTRESS CALL SYNTHESIZER

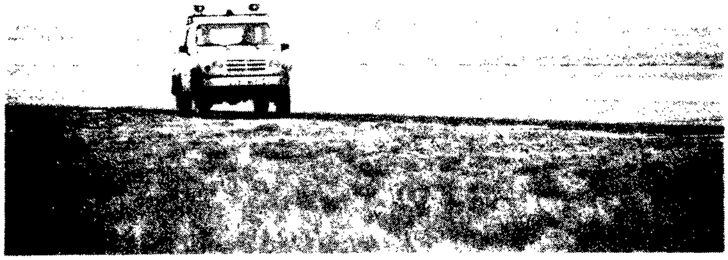


2. PISTOL AND SHELL CRACKERS

3. SHOTGUNS

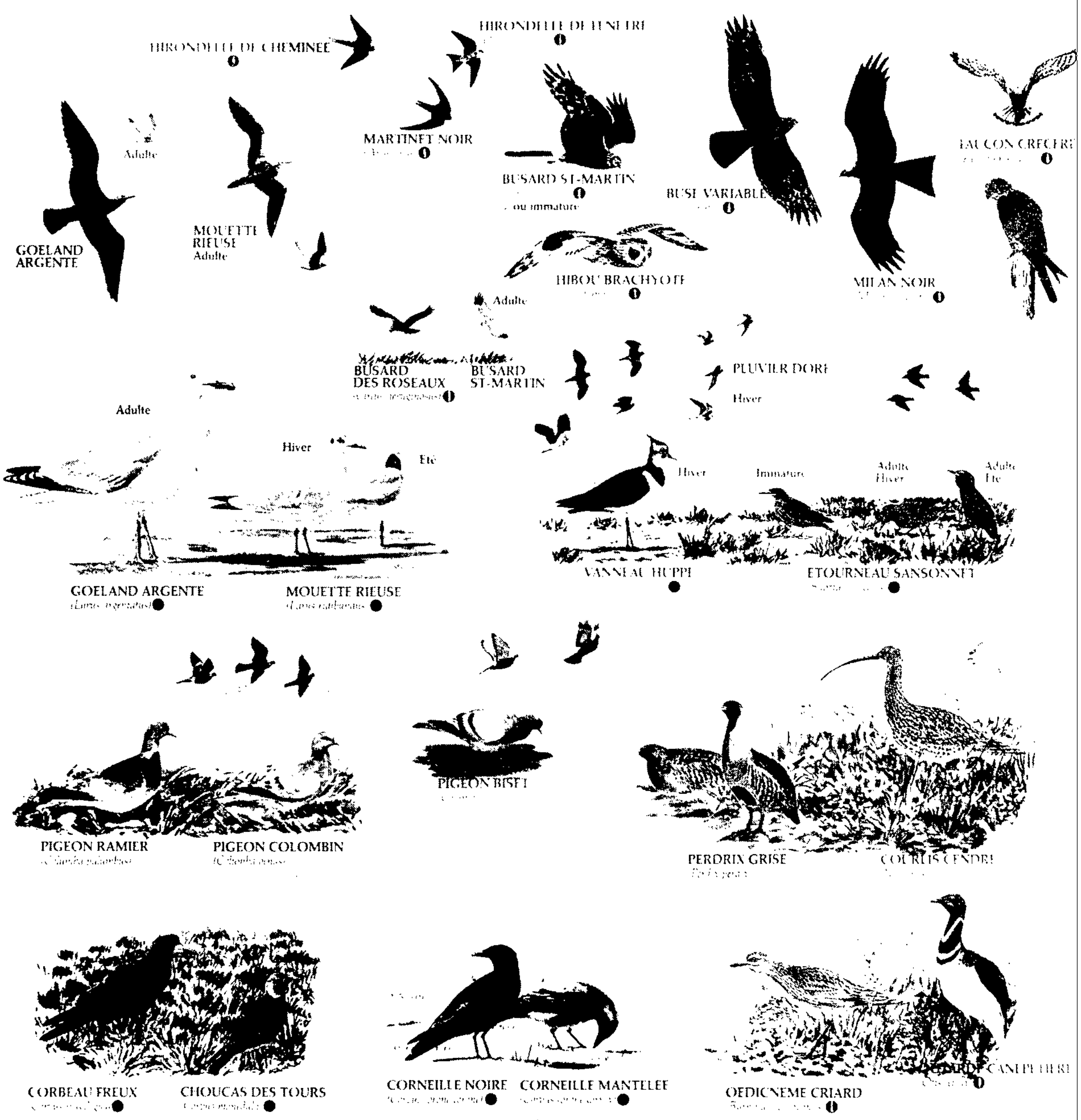


4.NOISE GENERATORS AT LFPG



5.MOBILE UNIT AT LFPO

OISEAUX ET AEROPORTS



Les oiseaux font partie de l'environnement aéronautique.
Connaître chaque espèce permet d'agir sur leur comportement.
APPRENEZ A LES CONNAITRE

MINISTERE DE L'EQUIPEMENT
DU LOGEMENT
DES TRANSPORTS
ET DE LA MER

DIRECTION GENERALE DE L'AVIATION CIVILE
SERVICE TECHNIQUE DE LA NAVIGATION AERIENNE
SUBDIVISION [illegible]
246 RUE LECOURBE [illegible] PARIS
TELEPHONE 40.43.40 [illegible]

AOF616426

BSCE / WP 27

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Office for the Prevention of
Damage Caused by Wildlife

REPORT
ON
HWH Airport Lawn Mower Type HS-2 TRIPLEX
AND EXPERIENCE
GATHERED AT AALBORG AIRPORT, DENMARK

By

Niels Ejnar Petersen

Research Assistant

Introduction

For years, Danish airports and airbases have been trying to find more efficient ways to maintain their vast grass areas. Aalborg Airport, Denmark, has now found a very satisfactory solution to this problem. This report was written in order to inform other airports and airbases of the method, and it is our hope that it may serve as a source of inspiration or even as the basis for a decision to introduce the novel method.

History and objectives

Lawn mowing at Aalborg Airport used to be covered by a contract with a manufacturer of green pellets. This setup was unsatisfactory for several reasons, and when the contract was discontinued the airport looked for other solutions to the lawn mowing problem. The airport decided to be in charge of lawn mowing itself and examined the market for suitable lawn mowers. One machine was commissioned for a trial period but without satisfactory results. The airport already operated a HWH flail mower with a single flail mover section. This mower had proven excellent performance and it was thought that a wider HWH model would be the right solution. A contact was made to HWH Production A/S, a Danish manufacturer, and the parties agreed to go ahead with the development work.

Development

The development work was carried out as a joint effort by Aalborg Airport and HWH Production A/S ensuring that the airport's requirements were incorporated in the new lawn mower. In principle the lawn mower consists of three standard HWH flail mowers which have been built together. HWH has developed the hydraulic driving line which is required for the flail mowers. This driving line was developed and fitted to the tractor in such a way that it could satisfy the airport's wishes to operate other tools as well.
The HWH Airport Lawn Mower Type HS-2 TRIPLEX--the name of the machine--has been fitted on a newly developed Deutz tractor, model IN-trac 6.30. This tractor is an absolute novelty, and Aalborg Airport was not only the first Danish buyer, but this tractor was the first one to be released for export from the W.German manufacturer after two years of test driving.

Technical description

HWH Airport Lawn Mower Type HS-2 TRIPLEX is a front-end fitted hydraulic flail mower consisting of three flail sections. The two wing sections can be moved to an upright position to facilitate transport. During operation the flail sections are mounted in such a way that they always maintain a horizontal operating position, regardless of the tractor's inclination. The suspensions are moveable to allow the flail sections to always follow the ground surface. Mounting on the tractor is obtained by means of an A-frame and hydraulic hose quick coupling. The hydraulics are driven by an external power unit suspended at the rear-end tractor three-point hitch, driven by the PTO shaft. The inner side of the flail section shield features a replaceable corrugated lining designed to ensure that the cut-off grass is whirled back to the flails. Owing to this feature the grass is completely shredded, and the high peripheral speed of the flails effectively blows the shredded grass downward between the grass stubs. The tractor's front lift features a system for variable surface contact pressure, patented by HWH Production A/S, Denmark. The load distribution is controlled from the cabin and is monitored directly on a visual control dial.

Technical specifications:
HWH Airport Lawn Mower Type HS-2 TRIPLEX

Flail sections:	3 sections of 1.9 m	Cutting speed:	5-6 km/h at min. output
Operating width:	5.7 m	Cutting height:	5-30 cm
Total width:	6.2 m	Coupling:	Std. Accord - A frame
Transporting height:	approx. 3.6 m	Driving station:	240 l/min - 200 bar
Weight:	2,200 kgs	Number of flails:	62 per section
Power requirement:	min. 90 kW engine	Flail revolutions:	Optimally 1900-2000 RPM

The tractor is a Deutz IN-trac 6.30. Being a forwarder tractor, the engine is positioned below the cabin behind the front axle. This tractor features 4-wheel drive, wheels of identical size and 50/50 weight distribution. It is front-wheel controlled and has front and rear lift and PTO. The engine is a 6-cylinder, air-cooled 85 kW diesel with mechanical transmission. A small bed is mounted above the rear axle for tools.

The Deutz IN-trac series differs from the competition by having a unique placing of the cabin which affords an excellent view of front-end fitted tools. The Deutz tractor has a very large glass area, particularly in the forward direction but also downward and in the sides. Other tractors could have been used for the HWH Airport Lawn Mower Type HS-2 TRIPLEX. The only requirement is an engine output of approx. 90 kW, and it is an obvious advantage with optimum view of the mower sections. A Mercedes-Benz Unimog model U 1300L with a 6-cylinder 96 kW diesel engine could be applied as well as a farm tractor with a reversely-mounted operator's seat and the mower mounted on the rear lift.

Technical specifications:
Deutz IN-trac 6.30

Engine:		Dimensions:	
Output:	85 kW at 2400 RPM	Length:	5184 mm
Number of cylinders:	6 (air cooled)	Width:	2390 mm
Volume:	6128 ccm	Height:	3130 mm
Max. torque:	384 Nm at 1600 RPM	Axle base:	2703 mm
Torque inclination:	13%	Clearance:	530 mm
Transmission:		Weight:	6500 kgs
Speeds:	32 forward, 8 reverse	Hydraulics:	
Driving speed:	0.42-30.0 km/h	Pumping capacity:	58.5 l/min - 175 bar
PTO:		Lifting capacity,	
Output:	75.5 kW	front/rear:	4400/5100 da/N
Front:	1000 RPM		
Rear.	540/1000 RPM		

Technical specifications:
Mercedes-Benz Unimog model U 1300L

Engine:		Dimensions:	
Output:	96 kW at 2800 RPM	Length:	5110 mm
Number of cylinders:	6	Width:	2300 mm
Volume:	5675 ccm	Height:	2610 mm
Max. torque:	363 Nm at 1600 RPM	Axle base:	3250 mm
Transmission:		Clearance:	440 mm
Speeds:	8 forward, 8 reverse (creep speed)	Weight:	3900 kgs
Driving speed:	6.0-79.0 km/h		

Experiences

Aalborg Airport has gathered experiences during a trial period in 1988 and a full season in 1989. The tractor has performed without any problems, the only interruption being a material fault on a part which was replaced under the guarantee. The tractor and the mower thus bear witness of good workmanship and a fully developed quality.
Similarly, the mowing quality fully satisfies expectations. As the mower is front-end mounted, the grass is untouched before mowing, and together with the variable surface contact pressure system, which distributes the weight of the heavy machine evenly on all supporting points, this ensures that the grass rises immediately after mowing. The shredded grass is injected by the flails between the grass stubs. Thanks to this technique, the grass does not become yellow, and the fine micro climate at the grass roots ensures rapid growth. Humus is added to the soil, and earthworms and micro organisms thrive well in this humus layer. The soil is ventilated and the water balance is improved. The result is a much healthier lawn. The need for fertilizers is essentially reduced as a consequence of the improved micro climate and because bio mass is not removed from the area.

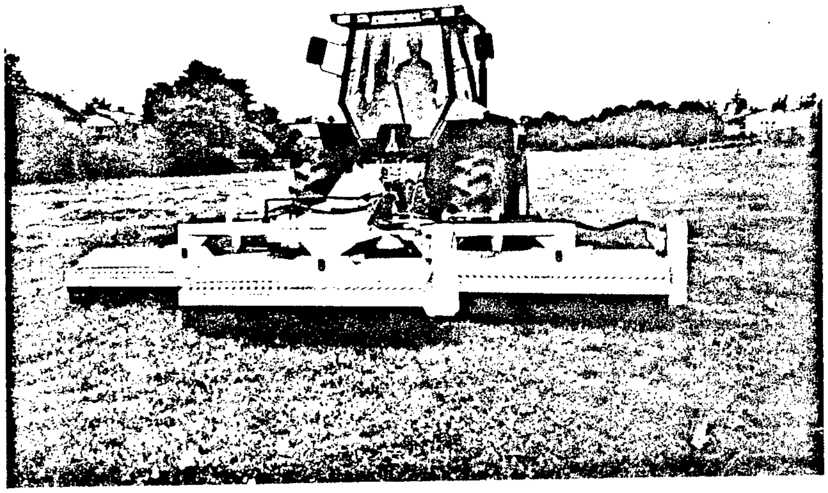
Aalborg Airport has approx. 250 hectares of lawn which needs mowing. During 1989 this area was mowed three times and work consumed 90, 92 and 92 tractor hours. However, approx. 90 hours represents only actual mowing time, and it should be expected that some time is spent on daily cleaning. Particularly in dry weather the lawn mower leaves plenty of cleaning to be done as the tractor becomes covered by shredded grass and earth particles. The total consumption of time including preparing, mowing, cleaning and service totalled 30 days per time. This equals a performance ratio of 2.8 hectares per driving hour and 1.5 hectares per hour, equal to approx. 12 hectares per working day. It is estimated that 1989 was an average year regarding the growth conditions for grass.

PRODUCTION AND SALE

The HWH Airport Lawn Mower Type HS-2 Triplex is produced and sold by:

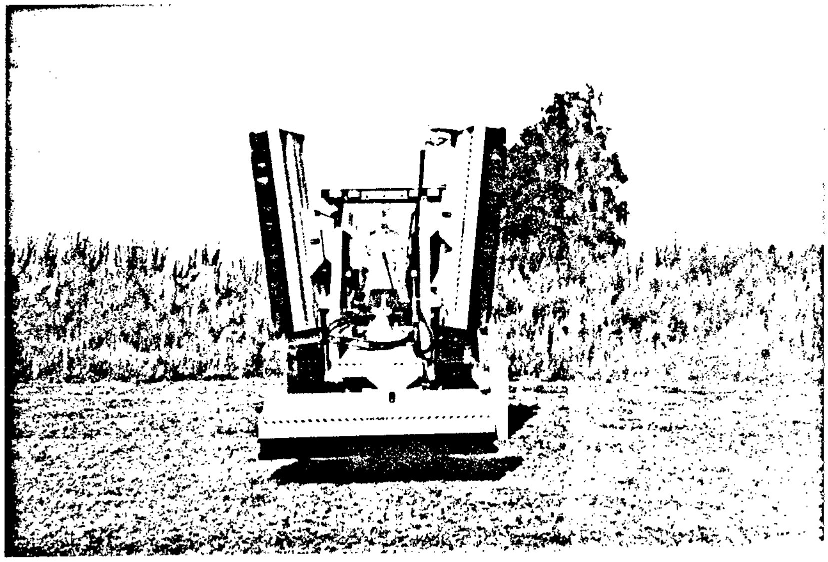
HWH production a/s
Østergade 73
DK-9560 Hadsund
Denmark

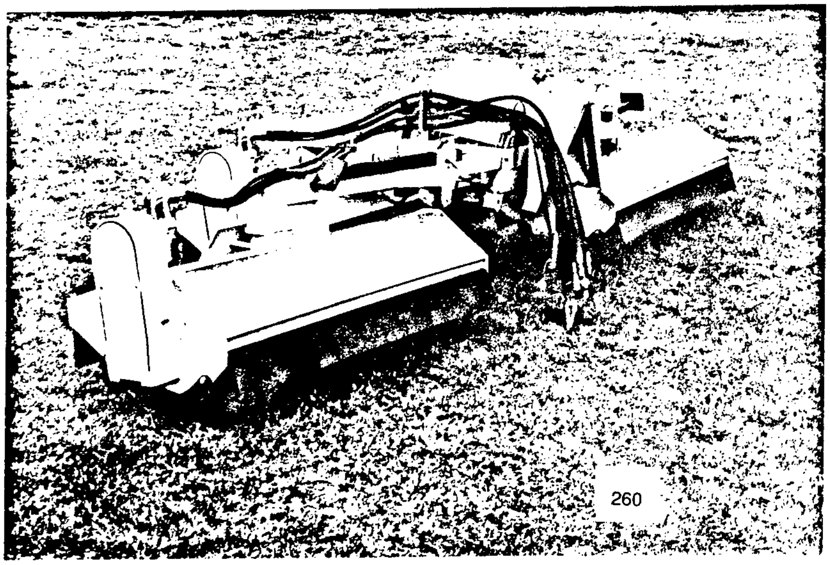
Tlf. nr. + 45 98 57 47 66
Fax. nr. + 45 98 57 49 77



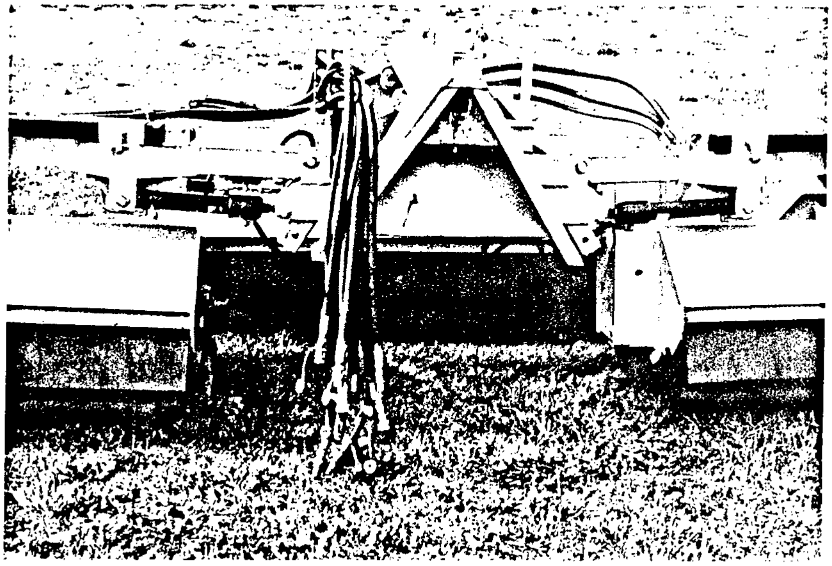
HWH's airport lawn mower type HS-2 Triplex here mounted on a Deutz IN-trac 6.30. It can of course be mounted on any other vehicle with enough motor effect.

HWH's airport lawn mower type HS-2 Triplex in transport position. The same space-saving position is of course usable when demounted by using the built-in supporting legs.



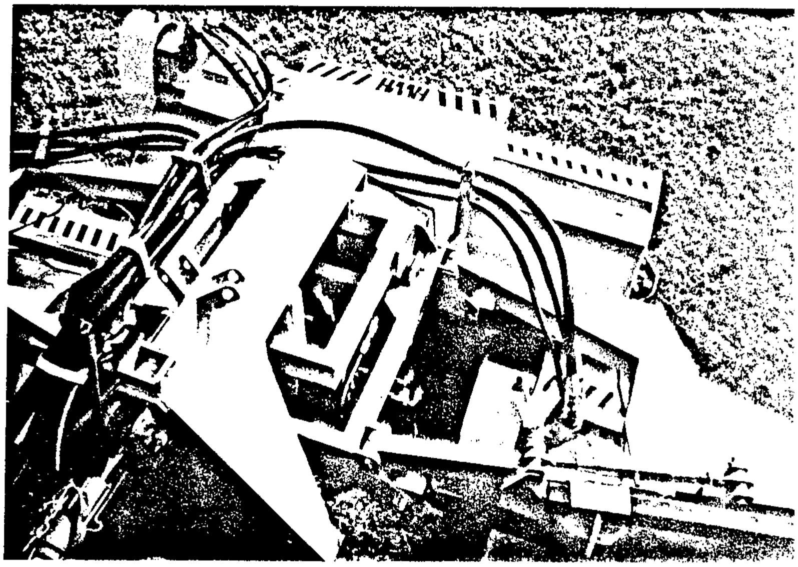


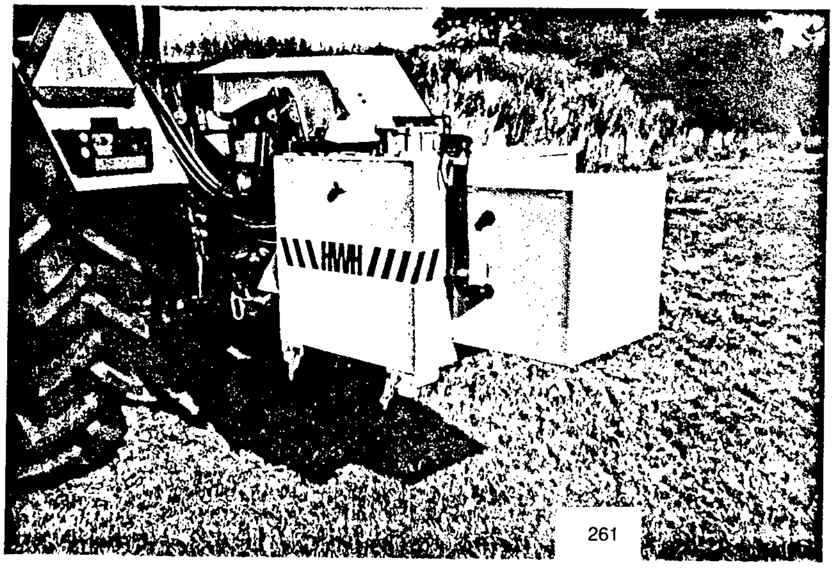
HWH's airport lawn mower type HS-2 Triplex is made of 3 pcs. 1.90 m or 2.40 m cutting units. They are with the special knives and built-in wear plates designed to fulfil the special demands of the airports for mowing.



HWH's airport lawn mower type HS-2 Triplex is with the integrated A-frame coupling very easy to couple and uncouple. In spite of its size and weight it only takes a few minutes.

HWH's airport lawn mower type HS-2, special Triplex suspension that is built together with the A-frame coupling enables each cutting unit "float" on the grass by use of the patented variable surface contact pressure.





HWH's hydraulic power pack, here shown in PTO-version inclusive of A-coupling and oil cooler. It can be delivered in other different versions according to the customer's wish.

AOF616427

BIRDSTRIKE COMMITTEE EUROPE

BSCE 20/WP28

Helsinki,
21-25 May 1990

ANALYSIS OF BIRD STRIKES REPORTED BY EUROPEAN AIRLINES 1981-1985

John Thorpe - UK Civil Aviation Authority
Safety Regulation Group

SUMMARY

Birdstrikes reported world-wide between 1981 and 1985 by European airlines from 12 countries have been analysed. The analysis of over 7500 strikes includes the annual strike rate for countries, aircraft types and airports, all based on aircraft movements. It also covers bird species, weights and damage, part of the aircraft struck and the effect of the strike.

The Paper shows the overall strike rate was 5.7. per 10,000 movements, slightly higher than previously. Gulls were involved in 40% of incidents where the type of bird was known, slightly lower than before. Only 1.3% of bird strikes involved birds over 1.8 kg (4 lb). About 1.3% of incidents resulted in multiple engine strikes i.e. about 1 in every 75,000 flights. There were no deaths, injuries or aircraft losses but 488 engines were damaged. There was insufficient data to produce meaningful information on the cost of bird strikes.

CONTENTS

1. **INTRODUCTION**

2. **SCOPE**

3. **DISCUSSION**

4. **CONCLUSIONS**

This study is based upon information supplied and the accuracy and detail are only as good as that reported. This Paper is the work of an individual author and may not reflect the final views of the UK Civil Aviation Authority.

1. INTRODUCTION

In order that a common basis for the analysis of bird strike data could be agreed, a Working Group of Bird Strike Committee Europe was formed in 1972, led by a representative for the United Kingdom Civil Aviation authority Safety Regulation Group at Gatwick. Papers covering the individual years 1972 to 1985 inclusive have been presented to BSCE meetings and a series of 5-year papers have been published. A paper using data from 1972 to 1975 which was presented at the Third World Conference on Bird Hazards in Paris, October 1977 was later published as CAA Paper No 77008. It included aspects which are consistent from year to year and do not need to be repeated in this paper, eg month of year, time of day, airspeed, altitude and flight stage. A paper covering the years 1976 to 1980 was published as CAA Paper No 84019. This paper covers the years 1981 to 1985.

1.2 Appendix 1 contains Tables of data relating to this paper.

1.3 Appendix 2 provides brief details of world-wide bird strike incidents resulting in loss of life/crash of transport aircraft and executive jets, from 1960 to 1989.

2. SCOPE

For the following reasons, the analysis only includes civil aircraft of over 5700 kg (12,500 lb) maximum weight, and executive jets which weigh just less than 5700 kg , eg Lear and Citation:

- the airworthiness requirements relating to bird strikes are different for the smaller general aviation class of aeroplanes,
- much more is known about the reporting standards of operators of transport types, and the movement data is more readily available than that of air taxi or private owner aircraft,
- aircraft of less than 5700 kg are in general, much slower with a different mode of operation, requiring less airspace, and a noticeably different strike rate would be expected.

3. DISCUSSION

3.1 Annual Rate / Country (See Table 1)

a) Information has been obtained from 14 European countries of which 8 have been able to provide full information every year. Some countries have not been able to provide data for every Table, so the totals from Table to Table may not be consistent.

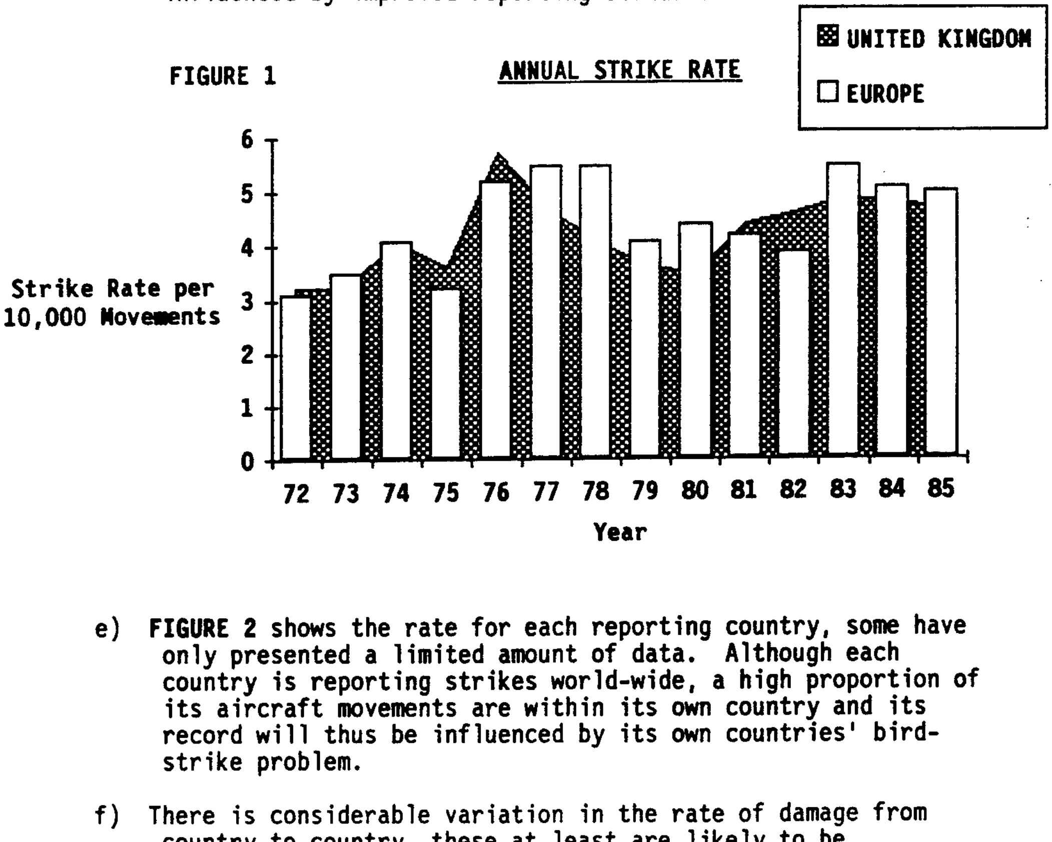
b) The strike rate reported by each country is significantly influenced by two major factors:-

- reporting standard
- the bird strike problem at airports within that country and that country's airlines route structure.

c) The overall strike rate for the 7544 incidents (and 15 million aircraft movements) contained in the analysis is 5.7 per 10,000 movements (two movements per flight). This is somewhat higher than the rate of 4.7 recorded in the previous 5 year period (3.5 between 1972 and 1975). This is in spite of the fact that two of the most efficient reporting countries Germany and Switzerland have only been partially included; thus a lower rate could have been expected. It therefore indicates either an improved overall reporting standard or a general upward trend in bird strikes.

d) **FIGURE 1** shows the annual strike rate for each year for the past 14 years. The UK data (which comprises about 30% of the European data) is shown for comparative purposes. There appears to be a general upward trend, which could have been influenced by improved reporting standards.

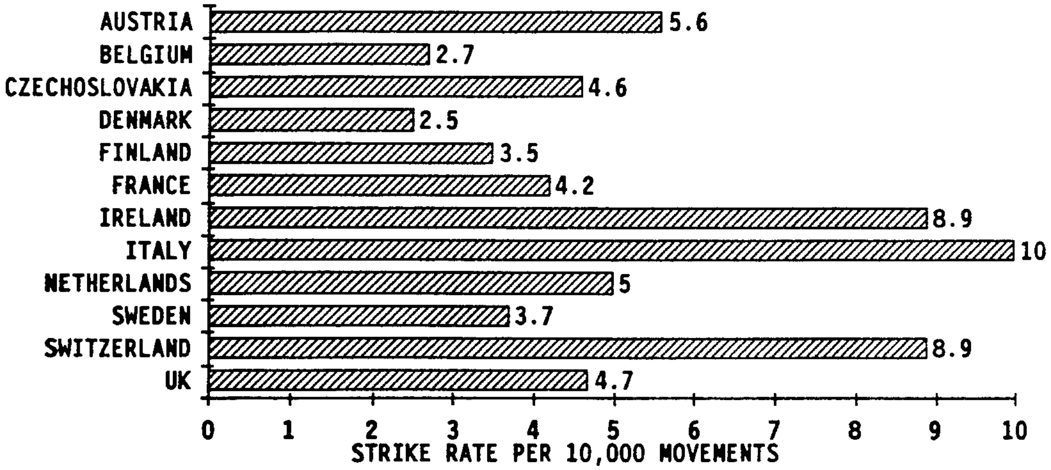
FIGURE 1 **ANNUAL STRIKE RATE**



e) **FIGURE 2** shows the rate for each reporting country, some have only presented a limited amount of data. Although each country is reporting strikes world-wide, a high proportion of its aircraft movements are within its own country and its record will thus be influenced by its own countries' bird-strike problem.

f) There is considerable variation in the rate of damage from country to country, these at least are likely to be consistently reported by each country, and about one in ten strikes cause damage. Thus countries which exhibit a damage rate significantly greater than one in ten, may not be reporting all of their non-damaging strikes.

FIGURE 2 STRIKE RATE BY REPORTING COUNTRY - 1981 to 1985

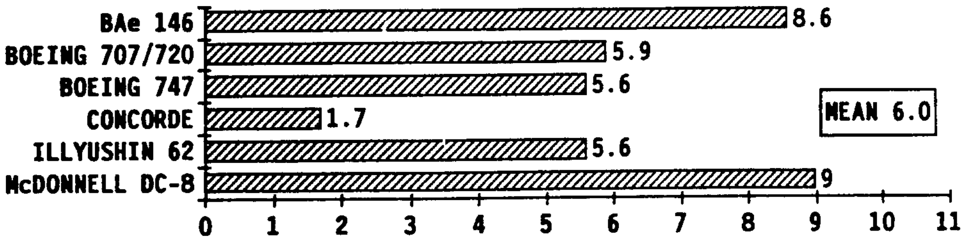


3.2 <u>Aircraft Type</u> (See Table 2)

a) *Jet Aeroplanes*

i) For several years there has been no consistent correlation between aircraft of similar design. **FIGURE 3** shows that aircraft which appear similar can have very different rates, for example the DC8 (used by eight countries) has a rate of 9.0 compared with the B707 (used by 6 countries) which has a rate of 5.9. Similarly, the DC10 (used by 11 countries) rate is 10.0, much higher than the L1011 (used by only two countries) rate of 5.8. It therefore appears that there is little meaningful correlation between individual aircraft type and strike rate. However, the strike rate for twin-engined, three engined and four engined does follow a logical progression based on frontal area.The group of aircraft which are wide-bodied, have a considerably higher strike rate than the group of narrow bodied aircraft.

FIGURE 3 **FOUR-ENGINED JET AEROPLANES**



THREE-ENGINED JET AEROPLANES

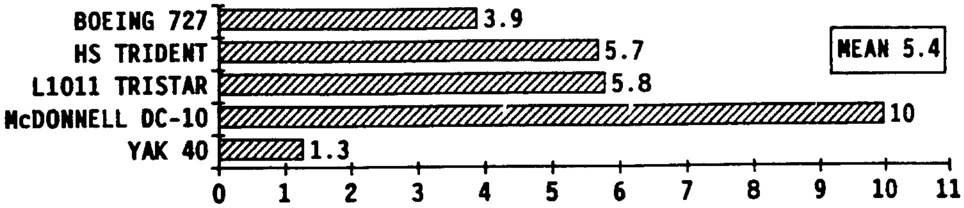
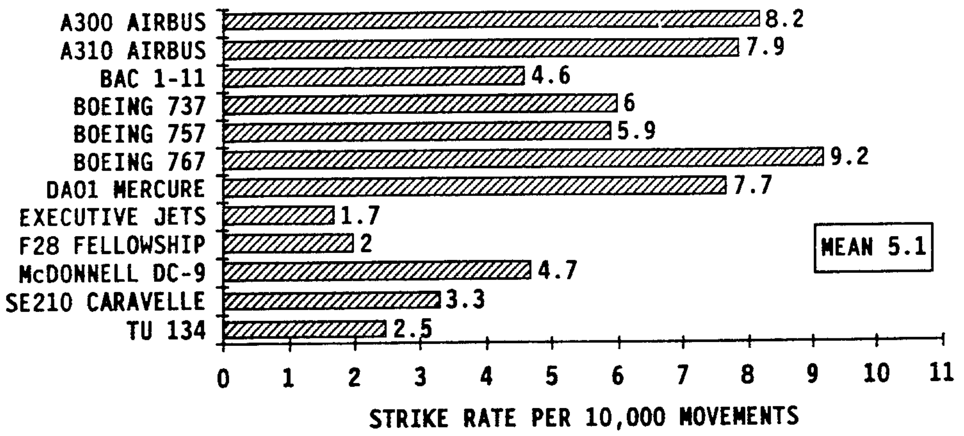


FIGURE 3 Cont'd TWIN-ENGINED JET AEROPLANES



ii) **Table 2** shows that there is considerable variation in the damage rate for each aircraft type, factors such as frontal area, vulnerability and position of engines are likely to influence the results.

The DC10, A300, A310 and TU134 have damage rates that are greater than average, whilst the Trident (now out of service), BAC1-11, DC9, F28 and HS125 have below average rates. The latter are all rear engined aircraft and it demonstrates the protection from the most frequent type of engine damage that this layout provides.

b) *Turboprop and Piston Aeroplanes*

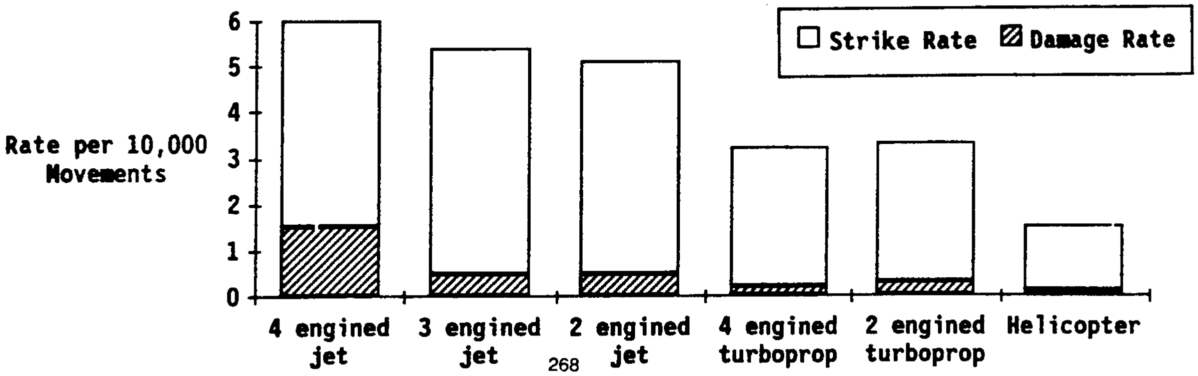
About 15% of movements are by turboprop aeroplanes, which have an overall strike rate of 3.5. The damage rate of 0.3 is lower than that for jets possibly because the operating speeds are lower. The number of piston engined aeroplanes in use is so small that they can be ignored.

c) *Helicopters*

Because helicopters mainly fly at low altitude where birds are most frequently found, they are continuously exposed to the risk of a strike, thus rates have been based on flying hours. The rate for the 500,000 hours is 1.5 per 10,000 hours. This low rate may be due to the comparatively low speed, high forward noise levels and protection provided by the main rotor. The damage rate at 0.1 per 10,000 hours is very low.

d) **FIGURE 4** summarises the strike rate and damage rate for each group of aircraft.

FIGURE 4 RATES FOR TYPES OF AIRCRAFT - 1981 to 1985



3.3 **Aerodromes** (See Table 3)

a) Aerodrome data is of particular importance as it may indicate where bird control measures need to be taken. Some countries were able to provide aerodrome movement data for their nationally registered aircraft, so that a national rate has been quoted. For others only the total number of strikes at each aerodrome, reported by all European sources is available in the absence of movement data.

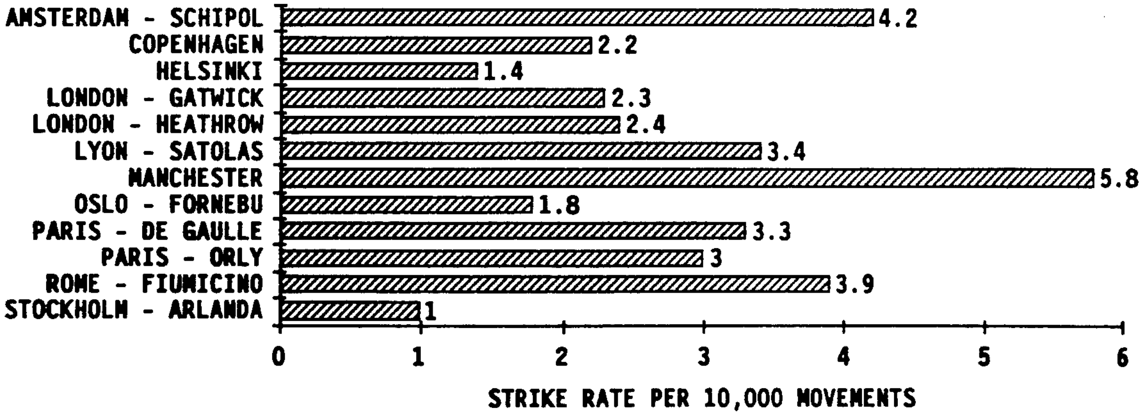
b) Strikes reported on aerodromes are influenced by one or more of the following:

- reporting standards,
- a large bird population, perhaps due to the aerodrome's geographic location,
- the number of aircraft movements,
- the effectiveness of bird control measures,
- a difficult problem in spite of use of correct bird scaring methods,
- local factors perhaps beyond the control of the aerodrome e.g a garbage dump or bird roost site in the vicinity.

Because of the factors listed above , direct comparison of the reported strike rates for different aerdromes could be misleading.

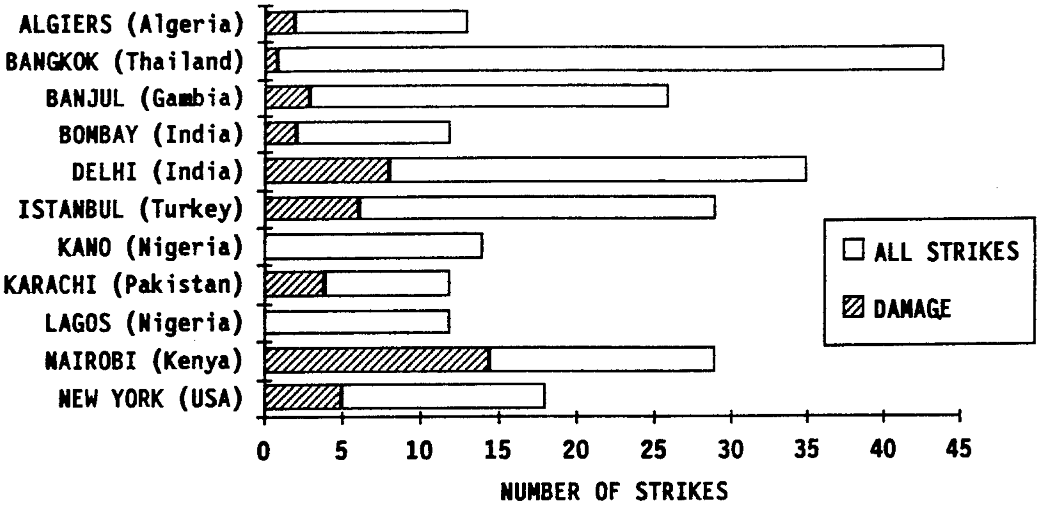
c) **FIGURE 5** shows, where available, the strike rate of each countries busiest airport. It is unfortunate that a number of countries were unable to provide movement data in order to calculate rates.

FIGURE 5 **STRIKE RATE (NATIONAL AIRLINES) AT SELECTED MAJOR EUROPEAN AIRPORTS - 1981 to 1985**



d) **FIGURE 6** shows the non-European airports with the highest total of strikes reported by European Operators. Some of these airports are extensively used by European airlines. There is considerable variation in the percentage of damaging strikes at each airport, Bangkok being very low and Nairobi being very high.

FIGURE 6 NON-EUROPEAN AIRPORTS, TOTAL STRIKES TO EUROPEAN AIRLINES - 1981 to 1985



e) A major problem has been defining what is meant by an airport bird strike. It has been agreed that up to 500ft in the climb and 200ft and below on the approach are ON an airport.

f) Strikes NEAR an airport are between 501 ft and 1500 ft on the climb and between 1000 ft and 201 ft on the approach. Table 4 contains the data collected for strikes near airports for the year 1985.

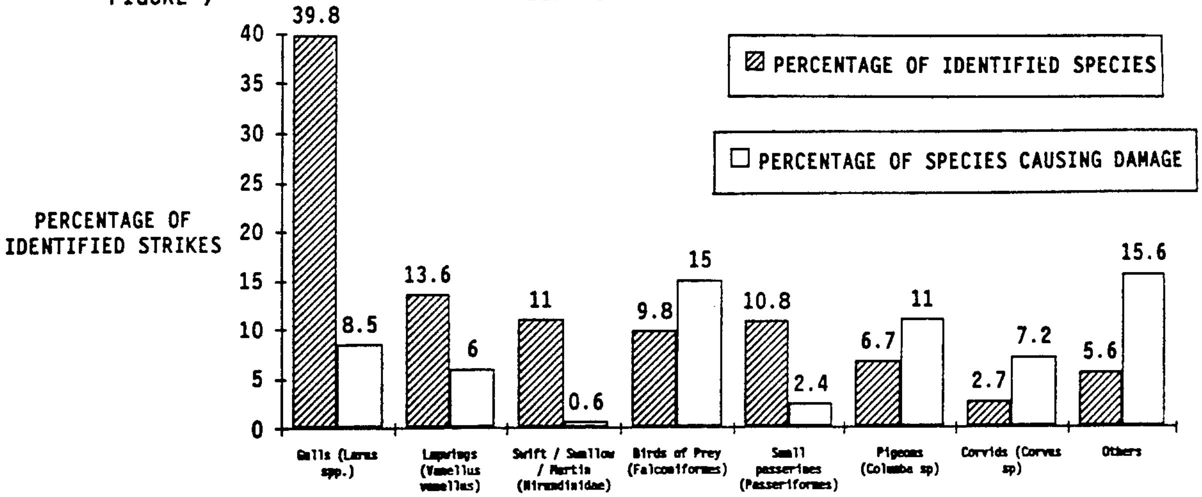
3.4 **Birds** (see Table 5)

a) Some knowledge of the bird species involved was available in 59% of incidents. The identification standard ranged from examination of bird remains by a trained ornithologist, to the fleeting glance of a pilot.

b) **FIGURE 7** shows that Gulls (Larus spp) were involved in 40% of incidents where the birds have been identified. Of these the Black-headed gull comprised 7%. There has been a decrease in gull strikes from 53% to 41.5% in the previous 5 year period. This may indicate the increasing effectiveness of the well known measures for dealing with these birds. The next most frequently struck bird was the Lapwing (Vanellus vanellus) with 13.6%, followed by Swifts, Swallows and Martins at 11.4% and Pigeons at 6.7%. The decrease in Gull strikes from the previous period was offset by an increase in Birds of Prey and in Swifts, Swallows and Martins.

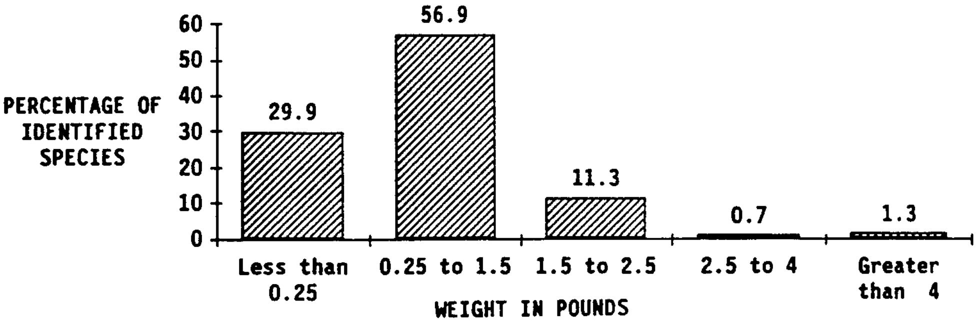
c) Birds of Prey, Pigeons and "other identified birds" are the most damaging as they cause the largest percentage of damage.

FIGURE 7 BIRD SPECIES STRUCK - 1981 to 1985



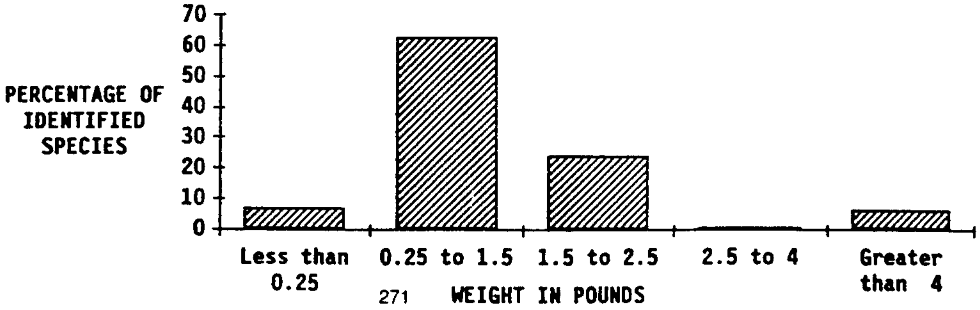
d) From an airworthiness point of view the breakdown of bird weights is a most important feature. Unfortunately Gulls span a weight range from 300 gm to 1.8 kg and fall into three weight categories and have therefore been excluded unless the exact Gull type was known. **FIGURE 8** shows that 30% of birds struck weigh less than 110 gm (¼ lb), 57% lie between 110 and 680 gm (¼ to 1½ lb) 11% lie between 681gm and 1.13 kg (1½ and 2½ lb). Just over 1% of incidents were known to involve birds of greater than 1.81 kg (4 lb)

FIGURE 8 WEIGHT DISTRIBUTION OF IDENTIFIED BIRDS - 1981 to 1985



e) From **Figure 9** it can be seen that in the smaller weight group 29.9% of strikes only result in 8% of the damage, whilst in the ¼ lb to 1½ lb group 62% of the damage results from 56.9% of the strikes. The 1½ to 2½ lb weight group has 23% of the damage from only 11.3% of the strikes, showing aircraft to be vulnerable to this weight category of birds. Over 2½ lb 6.9% of the damage results from 2% of the strikes.

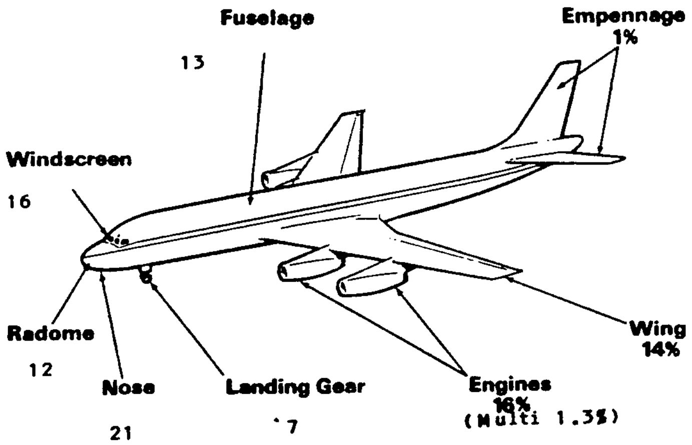
FIGURE 9 WEIGHT DISTRIBUTION OF BIRDS CAUSING DAMAGE - 1981 to 1985



3.5 PART STRUCK (See Table 6)

FIGURE 10 shows the nose, radome and windshield were struck in 48.7% of incidents. Engine strikes accounted for 17.2% of strikes, in which 1.3%, a total of 102 incidents, affected more than one engine and in 59 cases struck all engines. The multiple engine strike rate is about 1 per 75,000 flights. The tail area was very rarely struck. These percentages are influenced by the size of bird involved, since small birds (below ¼ lb) are rarely reported as striking the engines, wing or landing gear, but are more frequently reported on the nose, radome and windshield. By comparison, birds between 110 gm and 1.8 kg most frequently strike propellers, wing, landing gear and multiple engine strikes. The over 1.8 kg birds mostly affect wing, landing gear and one engine.

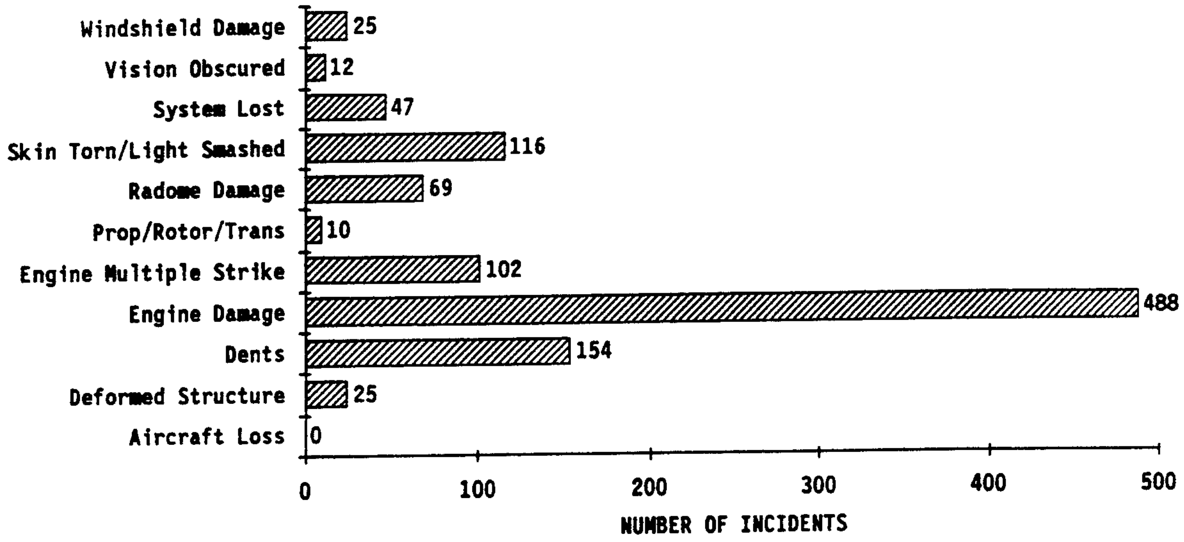
FIGURE 10 **PART STRUCK - 1981 TO 1985**



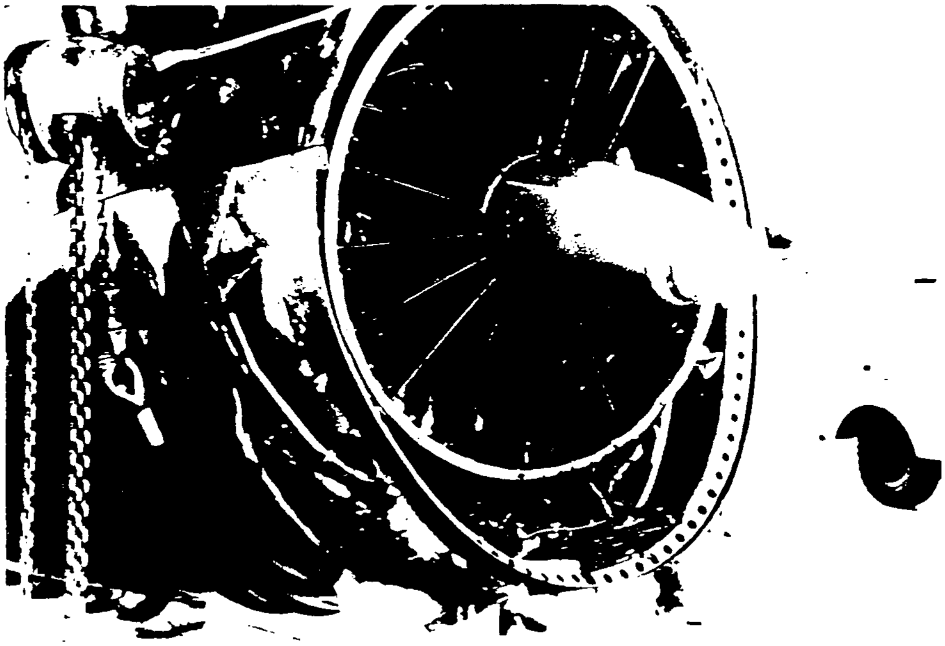
3.6 EFFECT (see Table 7)

a) From **FIGURE 11** it can be seen that there were no deaths, injuries or aircraft losses during this period.

FIGURE 11 **EFFECT OF STRIKE - 1981 to 1985**



One European Airlines JT8D damage, due to a Black-headed gull (Larus ridibundus).



b) A total of 488 engines were damaged such that repair or replacement was necessary (damage which has been dressed out has not been counted). Of the 488 cases, 266 were in twin engined aircraft. It appears that 37% of engine strikes involves damage.

c) Twenty five windshields needed to be replaced, (only 2% of the 1225 windshield strikes). None of these involved windshield penetration.

d) There were 69 cases of radome damage, out of 893 radome strikes (8%). The radome was in most cases only delaminated, some cases are known where it was shattered. The radome strength is usually determined by the dielectric properties necessary for satisfactory operation of the weather radar.

e) Examination of the bird weights shows, not surprisingly, that only 3% of small birds (below 110 gm) caused damage, whereas 38% of strikes with birds over 1.81 kg caused damage (16% for birds between 110 gm and 1.81 Kg).

3.7 COST

Unfortunately, there was insufficient data available to estimate the cost of birdstrikes to European airlines. If the cost of engine repair is conservatively estimated at say, $50,000 US per incident (ranging from one replaced blade to a written off large fan engine , which can cost $8 million), the cost for this alone would be over $24 million US Dollars during the 5 year period. Further information on costs is highly desirable.

3.8 OPERATOR REPORTING (See Table 8)

This table provides a guide to the reporting efficiency and problems of individual airlines (since birds can not read !). It is probable that it is considerably affected by the airport(s) at which the airline has its main base(s).

4. CONCLUSIONS

a) The overall strike rate for the 7544 strikes reported by European Operators from 1981 to 1985 is 5.7% strikes per 10,000 movements. This is somewhat higher than the rate from previous five year periods.

b) There does not appear to be any close correlation between the strike rate and the aeroplane type; however, the strike rate for the group comprising wide-bodied aeroplanes does appear to be slightly above average.

c) The damage rate of rear engined aircraft is 0.25 per 10,000 movements whereas the rate for wing and mixed wing/rear engined is 0.88. This shows the protection from engine damage that the rear engine layout provides.

d) Helicopters have a low strike rate at 1.5 per 10,000 hours, with damage at 0.1 per 10,000 hours.

e) At certain airports there is a high proportion of damage.

f) Gulls were struck more frequently than other birds, being involved in 40% of incidents, somewhat lower than in previous periods which may indicate the effectiveness of measures to deal with these birds.

g) Only 1.3% of strikes were believed to involve birds of greater than 1.8kg (4 lb)

h) 23.7% of the damage was caused by the 11.3% of birds in the 1½ - 2½ lb weight group. Similarly 6.4% of the damage is caused by the 1.3% of birds over 4lb in weight. Small birds cause little damage.

i) The nose area including radome and windshield were struck in 48.7% of incidents, followed by engines with 17.2%.

j) About 1.3% of incidents (102) involved multiple engine strikes, a rate of about 1 in every 75,000 flights.

k) There was no deaths, injuries or aircraft losses during this period.

l) The major consequence was damage to 488 engines, slightly worse than one in every three engine strikes . There was little windshield damage.

m) There is no accurate information on the cost of bird strikes.

n) There is considerable variation in operators reporting standards.

APPENDIX 1

BIRD STRIKE ANALYSIS

EUROPEAN OPERATORS 1981 - 1985

CIVIL AIRCRAFT OVER 5700 KG (12,500 lb) MAXIMUM WEIGHT

Notes:

0.1 The following are excluded from this Analysis:

(a) aircraft of maximum weight 5700 kg (12,500 lb) and under, except for those few executive jets, which have been included, eg Lear and Citation.

(b) all military type and operated aircraft.

0.2 All Tables are for strikes reported world-wide.

0.3 The Total columns of many of the Tables are different, as some countries have not been able to provide full information for every table.

0.4 There are two movements per flight.

0.5 Where the number of incidents, or number of movements are small, and particularly where they are both small, the derived rate should be treated with caution.

TABLE 1 ANNUAL RATE FOR EACH COUNTRY

(A high rate may be due to efficient reporting)

Reporting Nation	Rate per 10,000 Movements					Total Incidents	Damaging Incidents	Total Movements	Rate per 10,000 Movements	
	1981	1982	1983	1984	1985				All Strike	Damaging Strikes
Austria	-	-	4.8	3.7	7.5	87 (2)	3	154,092	5.6	0.27
Belgium	2.1	2.1	2.7	1.4	2.7	154	23	561,922	2.7	0.41
Czechoslovakia	-	2.2	3.6	5.3	6.5	85	21	186,116	4.6	1.12
Denmark	3.1	2.9	2.8	2.1	2.0	248	8	991,561	2.5	0.13
Finland	2.3	3.6	2.1	4.1	5.7	231	18	665,884	3.5	0.27
France	3.2	3.0	4.8	5.1	4.6	1,048 (67)	227 (17)	2,515,097	4.2	0.90
Germany	5.6	3.0	8.3	-	-	1,375(375)	133(140)	1,464,855	9.4	0.91
Ireland	7.7	7.7	10.7	7.2	9.5	287 (19)	N/A	322,592	8.9	N/A
Italy	-	-	9.2	14.1	4.8	457	16	458,088	10.0	0.35
Netherlands	6.2	4.9	4.1	5.1	4.4	460 (6)	77 (1)	925,952	5.0	0.83
Norway	-	-	-	-	-	N/A (273)	(9)	N/A	N/A	N/A
Sweden	3.3	5.0	3.8	3.1	3.5	378	29	1,032,994	3.7	0.28
Switzerland	-	-	9.1	-	8.8	330(153)	13 (6)	371,298	8.9	0.35
United Kingdom	4.4	4.6	4.9	4.8	4.7	2,404(121)	165	5,124,554	4.7	0.32
Total/Mean	4.2	3.9	5.5	5.1	5.0	7,544(1016)	733(173)	14,775,005	5.1	0.5

Notes:

1.1 There are two movements per flight.
1.2 Helicopters are excluded from this Table.
1.3 The figures in brackets are strikes for which no movement data is available.
1.4 * Movement data for Austria, Czechoslovakia, Ireland Italy, Netherlands and Switzerland is from ICAO sources.
1.5 Data from Switzerland is for Swissair jet aircraft only.

TABLE 2 AIRCRAFT TYPE - 1981 to 1985 Data

Aircraft	Number of Countries Reporting	Number of Strikes		Number of Movements	Rate per 10,000 Movements	
		Damage	All		All Strikes	Damage
JET						
McDonnell Douglas DC-8	8	16 (1)	110	122,193	9.0	1.3
BAe 146	1	1	32	37,392	8.6	-
Boeing 707/720	6	18 (2)	104 (2)	175,546	5.9	1.0
Boeing 747	11	133 (10)	456 (9)	813,413	5.6	1.6
Ilyushin 62	1	6	21	37,432	5.6	1.6
Concorde	2	4 (1)	5 (8)	29,289	1.7	1.4
BAC VC10	1	1	1	410	-	-
All 4 Engined Jets	-	179 (13)	729 (19)	1,215,675	6.0	1.5
McDonnell Douglas DC10	11	58 (5)	463 (57)	464,835	10.0	1.2
Lockheed 1011 Tristar	2	13 (5)	128 (5)	220,804	5.8	0.6
HS Trident	1	3	212	368,760	5.7	0.1
Boeing 727	6	45 (15)	551 (15)	1,407,211	3.9	0.3
Yak 40	1	-	3	22,622	1.3	-
All 3 Engined Jets	-	123 (25)	1,365 (77)	2,509,858	5.4	0.5
Boeing 767	1	-	13	14,064	9.2	-
A300 Airbus	8	85 (3)	657 (8)	805,296	8.2	1.0
A310 Airbus	6	15 (6)	100 (21)	126,766	7.9	1.2
DA01 Mercure	1	30	183	239,082	7.7	1.2
Boeing 737	9	159 (29)	1,641 (68)	2,736,494	6.0	0.6
Boeing 757	2	4	7	120,214	0.3	0.6
McDonell Douglas DC-9	11	53 (5)	1,093(258)	2,343,329	4.7	0.2
BAC 1-11	2	11	437	943,366	4.6	0.1
Tupolev 134	1	14	40	160,566	2.5	0.9
Cessna 500/550 Citation	3	2	7	19,276	3.6	1.0
SE 210/212 Caravelle	4	19	119	362,664	3.3	0.5
Fokker F28	4	13	178 (9)	871,469	2.0	0.1
Learjet	6	2 (3)	5 (12)	27,942	1.8	0.7
HS125	3	6	44 (1)	255,390	1.7	0.2
DA20 Falcon	6	1 (11)	1 (17)	11,868	-	-
Gulfstream II	1	-	-	1,978	-	-
SN 601 Corvette	3	- (1)	- (6)	15,914	-	-
Mitsubishi Mu 300	1	-	-	300	-	-
HFB 320 Hansa	1	-	- (3)	-	-	-
VFW 614	1	-	- (1)	-	-	-
All 2 Engined Jets	-	414 (58)	4,589(404)	9,001,978	5.1	0.5
All Jets	-	716 (96)	6,683(500)	12,727,511	5.2	0.6
TURBOPROP						
Short Belfast	1	-	5	5,522	9.1	-
Ilyushin 18	1	-	13	18,884	6.9	-
BAC Viscount	1	8	80 (3)	222,922	3.6	0.4
BAC Merchantman	1	1	4	16,538	2.4	-
DHC Dash 7	4	-	28 (5)	138,288	2.0	-
BAC Britannia	1	-	-	382		-
Canadair CL44	2	-	- (1)	942	-	-
HS Argosy	1	-	-	9,290	-	-
L188 Electra	1	-	- (2)	-	-	-
All 4 Engine Turboprops	-	9	131 (11)	412,768	3.2	0.2

Cont'd.....

BAE Jetstream 31	3	21 (6)	87 (6)	137,294	6.3	1.5
Short SD 330/360	3	4	176 (9)	394,194	4.5	0.1
HS 748	3	11 (3)	143 (3)	329,450	4.3	
Fokker F27/227	7	20	197 (1)	821,913	2.4	0.2
HP Herald	1	2 (1)	27 (1)	163,860	1.6	0.1
Nord 262	2	1 (4)	5 (9)	43,980	1.1	-
ATR 42	1	-	-	6,942	-	
C160 Transall	1	- (2)	- (3)	-	-	-
Gulfstream 1	1	-	- (2)	-	-	-
All 2 Engine Turboprops	-	60 (13)	639 (37)	1,894,073	3.1	0.3
ALL TURBOPROPS	-	69 (13)	770 (48)	2,306,841	3.3	0.3
PISTON						
Douglas DC3 Dakota	1	1	2	20,868	1.0	-
Bristol 170 Freighter	1	-	-	1,918	-	-
ALL PISTON	-	1	2	22,786	0.9	-
UNKNOWN	-	-(240)	-	-	-	-
TOTAL	-	786(109)	7,455(548)	15,057,138	4.9	0.5
HELICOPTERS						
Westland WG 30	1	-	3	7,741	3.9	-
Boeing 234 Chinook	1	-	8	30,671	2.6	-
Sikorsky S61	4	1	57 (11)	317,789	1.8	-
Bell 212/214	2	2	5	43,978	1.1	0.4
AS332L Puma	2	2	8	112,261	0.7	0.2
Westland Wessex	1	-	-	4,008	-	-
ALL HELICOPTERS	-	5	81 (12)	526,448	1.5	0.1

Notes:

2.1 Because of the low altitude of operation, and difficulty in collection of movement data, helicopter operations are quoted in hours.

2.2 The figures in brackets are for aircraft for which movement data is unavailable.

2.3 Where the number of incidents, or the number of movements is small and particularly where they are both small any derived rate should be treated with caution.

TABLE 3 AERODROMES - 1981 to 1985 Data

(A high rate may be due to efficient reporting)

Definition - up to 500ft on climb
- 200ft and below on approach

Country/Aerodrome	Incidents	Movements	Rate per 10,000 Movements	Incidents to Other European Aircraft	Total Damage	Total All
AUSTRIA						
Klagenfurt	6	-	-	-	-	6
Linz	4	-	-	3	-	7
Salzburg	5	-	-	7	-	12
Vienna	46	-	-	22	4	68
Graz	3	-	-	-	2	3
BELGIUM						
Antwerp	4	-	-	-	-	4
Brussels	52	-	-	35	14	81
Ostend	4	-	-	1	1	5
CZECHOSLOVAKIA						
Bratislava	10	15,561	6.4	2	4	12
Prague	29	39,106	7.4	-	6	29
DENMARK						
Aalborg	5	2,370	-	11	1	16
Billund	8	-	-	-	1	8
Copenhagen	67	301,089	2.2	96	8	163
Esbjerg	19	-	-	2	-	21
Karup	-	-	-	1	-	1
Odense	7	2,164	-	-	-	7
Ronne	9	-	-	3	-	12
Stauning	3	-	-	-	-	3
FINLAND						
Helsinki - Vantaa	53	389,962	1.4	2	2	55
Jyvaskyla	4	23,304	1.7	-	-	4
Kajaani	6	14,352	4.2	-	-	6
Kemi	12	39,370	3.0	-	-	12
Kuopio	13	154,412	0.8	-	1	13
Mariehamn	41	31,096	13.1	-	-	2
Dulu	12	72,094	1.7	-	-	12
Pori	10	77,486	1.3	-	1	10
Savomlinna	3	7,164	4.2	-	-	3
Tampere	6	56,520	1.1	-	-	6
Turku	7	129,020	0.5	-	1	7
Vaasa	9	51,060	1.8	-	1	7
Varkaus	3	5,426	5.5	-	-	3
FRANCE						
Ajaccio	6	7,686	7.8	-	-	6
Basle Mulhouse	7	22,263	3.1	3	2	10
Bastia	12	25,880	4.6	-	3	12
Beauvais - Tille	3	103	-	6	1	9
Biarritz	10	5,485	18.2	1	1	11
Bordeaux	24	60,573	3.4	-	1	24
Brest	18	19,182	9.4	1	2	19
Calvi	9	7,413	-	-	-	9
Clermont Ferrand	4	14,921	2.7	-	1	4
Hyenes - Le Octeville	3	2,743	10.9	-	-	3
Grenoble - St Geoirs	7	11,689	6.0	-	-	7
Lille	11	22,372	4.9	-	-	11

Cont'd.....

Le Harve	5	959	-	-	-	5
Lorient - Lan Bihou	5	1,967	-	-	-	5
Lourdes	29	7,285	39.8	14	4	43
Lyon - Satolas	68	183,825	3.4	1	2	69
Marseilles	40	144,751	2.8	7	1	47
Montpellier	26	39,278	6.6	-	2	26
Nice - Cote d'Azur	30	148,405	2.0	8	3	38
Nimes - Garons	9	10,307	8.7	-	3	9
Paris-Chas de Gaulle	106	317,390	3.3	47	16	153
Paris - Le Bourget	17	19,518	-	3	6	20
Paris - Orly	162	546,856	3.0	15	16	177
Pau/Pont	9	11,984	7.5	-	1	9
Perpignan	17	13,382	12.7	-	-	17
St Nazaire	3	1,189	-	-	-	3
St Yan	20	46,620	-	-	-	20
Strasbourg	15	41,514	3.6	-	1	15
Toulouse - Blagnac	96	81,601	11.8	6	12	102
GERMANY						
Berlin	11	-	-	11	1	11
Bremen	22	-	-	2	3	24
Cologne - Bonn	48	-	-	9	5	57
Dusseldorf	137	-	-	17	18	154
Francfurt A M	157	-	-	10	23	167
Hamburg	68	-	-	11	22	79
Hannover	32	-	-	1	4	33
Munchen	4	-	-	2	4	6
Munich	104	-	-	8	10	114
Munster	4	-	-	-	2	4
Nurnberg	12	-	-	-	1	12
Stuttgart	38	-	-	3	14	41
IRELAND						
Cork	32	-	-	4	-	36
Dublin	126	-	-	5	1	131
Shannon	26	-	-	2	1	28
GREECE						
Athens	-	-	-	7	-	7
Corfu	-	-	-	29	-	31
Rhodes	-	-	-	6	-	6
Thessalonika	-	-	-	4	-	4
ITALY						
Bari	3	5,398	5.5	-	-	3
Cagliary	6	12,718	4.7	-	-	6
Catania	7	4,093	17.1	4	-	3
Genoa	8	2,617	-	9	1	17
Milan - Linate	67	111,238	6.0	34	5	101
Milan - Malpensa	8	18,409	4.3	4	2	12
Naples	3	19,016	4.2	6	2	9
Olbia	7	6,784	1.0	2	1	9
Rome - Fiumicino	72	182,216	3.9	22	1	94
Ronchi	4	5,586	-	-	-	4
Turin	-	-	-	4	2	4
Venice	35	23,324	15.0	19	3	54

Cont'd.....

NETHERLANDS						
Amsterdam	147	351,134	4.2	53	39	198
Eindhoven	2	-	-	2	-	-
Mastericht	3	7,334	4.1	-	-	1
Rotterdam	10	18,821	5.3	3	4	13
NORWAY						
Allesund	3	12,225	2.4	-	-	3
Alta	4	13,654	2.9	3	-	7
Bergen	18	74,294	2.4	15	1	40
Bodo	24	105,525	2.3	11	2	35
Honningsvag	6	9,218	6.5	-	-	6
Kristiansond	9	49,947	1.9	-	-	9
Molde	7	18,873	3.7	-	-	7
Oil Rigs	7	-	-	-	-	7
Oslo - Fornebu	46	259,446	1.8	26	-	72
Stavanger	22	129,376	1.7	5	-	27
Tromso	15	72,796	2.1	11	-	26
Trondheim	10	34,875	2.9	2	-	12
PORTUGAL						
Faro	-	-	-	10	-	10
Porto	-	-	-	4	2	4
SPAIN						
Alicante	-	-	-	15	1	15
Barcelona	-	-	-	15	1	15
Gerona	-	-	-	6	1	6
Ibeza	-	-	-	31	3	31
Madrid	-	-	-	11	-	11
Mahon	-	-	-	10	1	10
Malaga	-	-	-	39	4	39
Minorca	-	-	-	7	-	7
Palma	-	-	-	44	5	44
Reus	-	-	-	7	-	7
SWEDEN						
Angelholm	22	25,028	8.0	-	3	20
Gothenburg - Landvetter	13	125,238	1.0	7	2	19
Halmstad	13	16,390	7.9	-	-	13
Kalmar	5	6,494	7.7	1	1	6
Karlstad	6	7,480	8.0	-	-	6
Kristianstad	7	8,152	8.6	-	-	7
Lulea	2	14,218	1	-	3	3
Malmo - Sturup	24	66,834	3.6	8	3	32
Norrkoping	2	1,800	-	1	1	3
Stockholm - Arlanda	51	536,004	1.0	24	1	75
Stockholm - Broma	20	118,700	1.7	-	-	20
Umea	17	42,910	4.0	1	2	18
Vasteras Hasslo	5	4,002	12.5	2	-	7
Visby	13	26,622	4.9	-	-	13
SWITZERLAND						
Beale - Mulhouse	7	31,386	2.2	-	-	7
Geneva	43	74,208	5.8	11	2	54
Zurich	113	128,230	8.8	28	5	141

Cont'd.....

UNITED KINGDOM						
Aberdeen	54	345,515	1.6	-	2	46
Belfast Aldergrove	98	118,380	8.3	3	5	101
Belfast Harbour	11	17,028	6.5	-	2	11
Birmingham	94	118,631	7.9	11	6	105
Blackpool	13	42,246	3.1	2	-	15
Bournemouth - Hurn	22	49,155	4.5	-	4	22
Bristol - Filton	5	-	-	-	-	5
Bristol - Lulsgate	19	30,694	6.2	8	1	27
Cambridge	3	3,461	-	-	-	3
Cardiff - Wales	29	35,136	8.3	1	1	30
Dundee	7	3.142	-	-	-	7
East Midlands	42	95,570	4.4	1	-	43
Edinburgh	72	119,701	6.0	9	3	81
Glasgow	99	201,190	4.9	5	5	104
Guernsey	36	-	-	-	-	5
Hatfield	19	-	-	-	-	19
Humberside	4	7,708	-	-	-	4
Inverness	5	26,022	1.9	-	-	5
Jersey	23	-	-	-	-	4
Kirkwall	11	25,603	-	-	-	11
Leeds - Bradford	32	49,387	6.5	1	1	33
Liverpool	28	86,342	3.2	5	-	33
London - Gatwick	90	383,215	2.3	1	6	91
London - Heathrow	164	671,818	2.4	69	12	233
London - Stansted	35	63,276	5.5	5	-	40
Luton	81	109,109	7.4	-	8	81
Lydd	8	6,791	11.8	-	-	8
Manchester	131	225,190	5.8	8	4	139
Newcastle	76	72,920	10.4	-	2	76
Norwich	35	61,967	5.6	-	-	35
Oil Rigs	33	-	-	-	-	33
Prestwick	6	13.905	4.3	1	2	7
Ronaldsway I of M	60	60,331	9.9	2	-	62
Scatsa	4	9,159	4.4	-	-	4
Southend	5	14,508	3.4	-	-	5
Stornoway	3	2,865	-	-	1	3
Sumburgh	22	77,967	2.8	-	-	22
Tees-side	28	43,879	6.4	-	-	28
USSR						
Moscow-Shera	4	-	-	-	9	9

Cont'd.....

List of Non European Aerodromes where at least two strikes have been reported by European Airlines

Accra (Ghana)	9	(1)
Agadair	4	
Algiers (Algeria)	13	(2)
Arusha (Tanzania)	10	
Bamako (Mali)	4	
Bangkok (Thailand)	44	(1)
Banjul (Gambia)	26	(3)
Bombay (India)	12	(2)
Budapest	3	
Burgas (Bulgaria)	4	(3)
Casablanca (Morocco)	6	(1)
Changi (Singapore)	3	(1)
Colombo (Sri Lanka)	10	
Dakar (Senegal)	7	(4)
Dalaman	35	(8)
Delhi (India)	35	(8)
Doula (Cameroun)	4	
Dar-es Salaam (Tanzania)	6	(2)
Doha (Qatar)	3	(3)
Freetown (Sierra Leone)	6	(1)
Hong Kong (Hong Kong)	4	
Istanbul (Turkey)	29	(6)
Johannesbourg (South Africa)	3	(1)
Kano (Nigeria)	14	
Khartoum (Sudan)	5	(2)
Karachi (Pakistan)	12	(4)
Kilimanjaro (Tanzania)	4	(1)
Kuala Lumpur (Malaysia)	4	
Kigali (Rwanda)	3	(1)
Larnaca (Cyprus)	3	(1)
Las Palmas (Canaries)	7	(12)
Lagos (Nigeria)	12	
Libreville (Gabon)	3	
Lome (Togo)	5	
Malta (Malta)	11	
Monrovia (Liberia)	5	(3)
Mombasa (Kenya)	11	(1)
Monastir (Tunisia	5	(1)
Montevideo (Uruguay)	3	(2)
Melbourne (Australia)	3	(1)
Nairobi (Kenya)	30	(15)
New York JFKennedy (USA)	18	(5)
Panama (Panama)	3	(1)
Rio de Janeiro (Brazil)	6	(2)
Tangier (Morocco)	5	(1)
Tel Aviv (Israel)	8	
Tunis (Tunisia)	10	(3)
Tripoli (Lebanon)	3	(1)

En-Route Strikes	199 (34)
Unknown	139 (13)

Notes:

3.1 Because of the variability in reporting, bird population, aircraft movememt pattern, control measures and features beyond control, any comparison between rates calculated for different aerodromes can be misleading.

3.2 German non-damaging strikes for 1985 NOT included.

3.3 Data on Damaging Strikes NOT supplied by the following

1982 - France
1983 - Austria, Denmark, France, Ireland, Norway.
1984 - Denmark, Ireland, Norway.

3.4 Carcasses found on aerodromes in UK NOT included.

3.5 Aerodromes with 2 strikes or less excluded.

TABLE 4 INCIDENTS NEAR AERODROMES - 1985 Data

Definition - Between 501 ft and 1500 ft on climb
- Between 1000ft and 201ft on approach

Country/Aerodrome	Incidents	Movements	Rate per 10,000 Movements	Incidents to Other European Aircraft	Total Damage	Total All
AUSTRIA						
Salzburg	-	-	-	1	1	1
BELGIUM						
Brussels	3	-	-	-	-	3
BULGARIA						
Burgas	-	-	-	1	-	1
CYPRUS						
Larnaca	-	-	-	1	-	1
CZECHOSLOVAKIA						
Bratislava	4	15,561	2.6	-	-	4
Ostrava	1	4,197	-	-	1	1
Prague	11	39,106	3.1	1	3	12
DENMARK						
Aalborg	1	-	-	-	-	1
Copenhagen	3	61,874	0.6	1	1	4
FINLAND						
Helsinki - Vantaa	2	61,138	0.3	-	-	2
Joesuu	1	3,124	-	-	-	1
Turku	1	10,672	-	-	-	1
FRANCE						
Bastia - Poretta	1	7,323	-	-	-	1
Marseille	1	37,567	-	-	-	1
Paris - Charles de Gaulle	5	64,606	1.4	4	2	9
Paris - Orly	3	118,898	0.3	-	1	3
St Yan	1	-	-	-	1	1
Toulouse - Blagnac	1	17,865	-	-	-	1
GERMANY						
Cologne - Bonn	-	-	-	1	-	1
Dusseldorf	1	-	-	-	1	1
Frankfurt	7	-	-	-	7	7
Hambourg	4	-	-	-	4	4
Munchen	2	-	-	-	2	2
Nurnberg	1	-	-	-	2	2
Stuttgart	1	-	-	-	1	1
IRELAND						
Dublin	-	-	-	1	-	1
ITALY						
Milan - Linate	2	-	-	2	-	4
Milan - Malpensa	1	-	-	-	-	1
Rome - Fiumicino	3	-	-	-	-	3
Venice	3		-	-	-	3

Cont'd.....

SPAIN						
Ibiza	-	-	-	1	-	1
Malaga	-	-	-	2	-	2
Palma	-	-	-	1	-	1
SWEDEN						
Gotenborg - Landvetter	-	37,038	-	1	-	1
Stockholm - Arlanda	-	162,800	-	1	-	1
Kalmar	-	6,494	-	1	-	1
UNITED KINGDOM						
Aberdeen	1	68,773	-	-	-	1
E. Midlands	1	21,001	-	-	-	1
Glasgow	4	39,253	1.0	-	1	4
London - Gatwick	1	93,535	-	-	-	1
London - Heathrow	7	145,987	0.5	-	-	7
Luton	1	22,041	-	-	1	1
Manchester	1	49,570	-	1	-	2
U.S.A.						
New York - J.F.K	-	-	-	2	-	2

TABLE 5 BIRD SPECIES - 1981 to 1985 DATA

Scientific Name	English Name	Weight	Weight/ Category	Number of Incidents		% based on 4620
				Damage	Total	
PODICIPEDIFORMES						
Podicipedidae	Grebe	150 g - 990 g	B	-	1	-
		Total		-	1	-
PROCELLARIIFORMES						
Fulmarus glacialis	Fulmar	750 g	B	-	1	-
PELICANIFORMES						
Pelecanidae	Pelican	up to 6 kg	D	-	2	-
Phalacrocorax sp.	Cormorant	1.7 kg - 2.7 kg	C	1	1	-
Frigata magnificens	Frigate bird	1.4 kg	B	1	1	-
		Total		2	4	-
CICONIIFORMES						
Botaurus stellaris	Bittern	1190	B	-	1	-
Bubulcus ibis	Cattle egret	345 g	B	2	10	-
Ardea sp.	Heron	500 g - 4.5 kg	B	4	12	0.3
Ardea cinerea	Grey heron	up to 1.5 kg	B	2	9	-
Ciconia sp.	Stork	up to 3 kg	C	2	2	-
Ciconia ciconia	White stork	3.4 kg	C	1	3	-
Eudocimus albus	White ibis	830 g	B	-	1	-
		Total		11	38	-
ANSERIFORMES						
Anser sp.	Goose	1.8 kg - 4 kg	C	5	8	-
Cygnus sp.	Swan	4.7 kg - 12 kg	D	-	3	-
Cygnus olor	Mute swan	10 kg	D	-	1	-
Cygnus cygnus	Whooper swan	10 kg	D	-	1	-
Anas sp.	Duck	250 g - 1.3 kg	B	2	25	0.5
Anas platyrhynchos	Mallard	1.1 kg	B	3	14	0.3
		Total		10	52	1.1
ACCIPITRIFORMES						
Milvus sp.	Kite	780 g - 1.0 kg	B	7	20	0.4
Pernis apivorus	Honey buzzard	785 g	B	-	1	-
Milvus migrans	Black kite	780 g	B	9	40	0.9
Neophron percnopterus	Egyptian vulture	2.1 kg	D	1	1	-
Gyps sp.	Vulture	up to 10 kg	C	2	2	-
Gyps bengalensis	Whitebacked vulture	5.3 kg	D	1	1	-
Circus aeroginosus	Marsh harrier	630 g	B	-	3	-
Accipiter sp.	Hawk	up to 1 kg	B	6	46	1.0
Accipiter gentilis	Goshawk	1.0 kg	B	1	7	-
Accipiter nisus	Sparrow hawk	190 g	B	-	13	0.3
Buteo sp.	Buzzard	260 g - 1.3 kg	B	15	72	1.6
Buteo buteo	Common buzzard	800 g	B	9	57	1.2
Aquila sp.	Eagle	1.1 kg - 4.2 kg	C	2	5	-
Aquila chrysaetos	Golden eagle	4.2 kg	D	-	1	-
		Total		53	269	5.9
FALCONIFORMES						
Falconiformes	Bird of Prey	105 g - 1.3 kg	B	1	29	0.6
Falco sp.	Falcon	105 g - 1.3 kg	B	7	54	1.2
Falco tinnunculus	Kestrel	200 g	B	6	94	2.0
Falco columbarius	Merlin	195 g	B	-	2	-
		Total		14	179	3.9

Cont'd.....

GALLIFORMES						
Tetrao tetrix	Black grouse	1.1 kg	B	-	17	0.3
Alectoris rufa	Red-legged partridge	450 g	C	-	2	-
Perdix perdix	Grey partridge	400 g	B	7	40	0.9
Phasianus colchicus	Pheasant	1.1 kg	B	6	18	0.4
		Total		13	77	1.7
GRUIFORMES						
Grus grus	Crane	5.0 kg	D	1	2	-
Tetrax tetrax	Little bustard	180 g	B	-	1	-
		Total		1	3	-
CHARADRIIFORMES						
Haematopus ostralegus	Oystercatcher	500 g	B	2	18	0.3
Charadrius hiaticula	Ringed plover	54 g	A	-	1	-
Pluvialis apricaria	Golden plover	185 g	B	2	17	0.4
Vanellus vanellus	Lapwing	215 g	B	38	625	13.6
Vanellus senegallus	Wattled plover	220 g	B	-	1	-
Calidris alpina	Dunlin	50 g	A	-	1	-
Philomachus pugnax	Ruff	140 g	B	1	3	-
Gallinago gallinago	Common snipe	125 g	B	-	9	-
Gallinago megala	Swinhoe's snipe	150 g	B	-	1	-
Scolopax rusticola	Woodcock	300 g	B	1	3	-
Numenius arquata	Curlew	770 g	B	1	21	0.5
Larus sp.	Gull	280 g	B	109	1186	25.4
Larus melancephalus	Mediterranean gull	280 g	B	-	1	-
Larus minutus	Little gull	120 g	B	-	1	-
Larus ridibundus	Black-headed gull	275 g	B	26	360	7.8
Larus delawarensis	Ring-billed gull	485 g	B	-	1	-
Larus canus	Common gull	420 g	B	3	83	1.8
Larus fuscus	Lesser black backed gull	820 g	B	2	22	0.5
Larus argentatus	Herring gull	1.0 kg	B	12	119	2.5
Larus marinus	Great black backed gull	1.7 kg	B	-	9	-
Rissa tridactyla	Kittiwake	390 g	B	-	1	-
Sterna sp.	Tern	45 g - 570 g	B	3	42	0.9
Chlidonias leucoptera	White winged black tern	57 g	A	-	1	-
		Total		200	2526	54.7
COLUMBIFORMES						
Columba sp.	Pigeon	up to 465 g	B	18	172	3.7
Columba livia	Rock dove	395 g	B	7	19	0.4
Columba livia var.	Homing pigeon	400 g	B	-	7	-
Columba oneas	Stock dove	345 g	B	-	6	-
Columba palumbus	Woodpigeon	465 g	B	10	103	2.2
Streptopelia turtur	Turtle dove	145 g	B	-	1	-
		Total		35	308	6.6
CUCULIFORMES						
Cuculus canorus	Cuckoo	105 g	A	-	1	-
		Total		-	1	-
STRIGIFORMES						
Strix sp.	Owl	160 g - 380 g	B	1	20	0.4
Tyto alba	Barn owl	315 g	B	1	12	0.3
Bubo bubo	Eagle owl	2.8 kg	C	-	4	-
Athene noctua	Little owl	164 g	B	-	1	-
Strix aluco	Tawny owl	480 g	B	-	4	-
Asio otus	Long-eared owl	275 g	B	-	1	-
Asio flammeus	Short eared owl	355 g	B	-	8	-
		Total		2	50	1.1
CAPRIMULGIFORMES						
Caprimulgus europaeus	Nightjar	70 g	A	-	5	-
		Total		-	5	-

Cont'd.....

APODIFORMES						
Apus apus	Swift	40 g	A	1	143	3.1
		Total		1	143	3.1
PASSERIFORMES						
Passeriformes	Perching birds	20 g	A	6	202	4.4
Galerida cristata	Crested lark	40 g	A	-	1	-
Alauda arvensis	Skylark	40 g	A	-	58	1.2
Lullula arborea	Woodlark	27 g	A	-	1	-
Riparia riparia	Sand martin	13 g	A	-	5	-
Hirundo noexena	Welcome swallow	14g	A	-	1	-
Hirundo rustica	Swallow	19 g	A	2	328	7.1
Delichon urbica	House martin	17 g	A	-	27	0.6
Anthus pratenses	Meadow pipit	18 g	A	-	2	-
Motacilla sp.	Wagtail	20 g	A	-	2	-
Motacilla alba	Pied wagtail	23 g	A	-	2	-
Turdus sp	Thrush	60 g - 125 g	A	1	13	0.3
Turdus merula	Blackbird	100 g	A	1	18	0.4
Turdus pilaris	Fieldfare	98 g	A	-	2	-
Turdus philomelos	Song thrush	73 g	B	-	4	-
Turdus iliacus	Redwing	70 g	A	-	2	-
Pica pica	Magpie	220 g	B	-	10	-
Corvus sp.	Crow	up to 530 g	B	4	82	1.7
Corvus frugilegus	Rook	430 g	B	5	27	0.6
Corvus corone corone	Carrion crow	530 g	B	-	5	-
Corvus corax	Raven	1.1 kg	B	-	2	-
Sturnus vulgaris	Starling	80 g	A	4	78	1.7
Passer sp.	Sparrow	18 g - 40 g	A	-	72	1.5
Passer domesticus	House sparrow	40 g	A	-	13	0.3
Fringilla coelebs	Chaffinch	23 g	A	-	3	-
Carduelis chloris	Greenfinch	29 g	A	-	1	-
Carduelis spinus	Siskin	-	-	-	1	-
Carduelis cannabina	Linnet	18 g	A	-	9	-
Plectrophenax nivalis	Snow bunting	35 g	A	-	3	-
Emberiza citinella	Yellow hammer	27 g	A	-	2	-
Molothrus ater	Brown headed cowbird	45g	A	-	1	-
		Total		23	982	21.2
CHIROPTERA						
Chiroptera sp.	Bat	-	-	-	3	-
		Total		-	3	-
UNKNOWN				232	3172	
TOTAL				599		7792

Notes:

5.1. Bird weights and Scientific Names are based on 'Average Weights of Birds' by T Brough of Aviation Bird Unit, Worplesdon Laboratory, Agricultural Science Service, MAFF, Worplesdon, England. The average weight has been assumed.

5.2 The bird categories based on current Civil Airworthiness requirements are:

A	below 110 g (¼ lb)
B	110 g to 1.81 g (¼ lb to 4 lb)
C	over 1.81 kg to 3.63 g (4 lb to 8 lb)
D	over 3.63 kg (8 lb)

5.3 Those birds not positively identified are tabled as Unkown. Except where there is evidence that they are large (C or D).

5.4 Percentages are based on incidents where birds are identified.

TABLE 6 PART OF AIRCRAFT STRUCK - 1981 to 1985 DATA

INCIDENTS PART STRUCK	BIRD WEIGHTS				TOTAL	% BASED ON 7579
	unknown	below 110 g	100 g to 1.81 kg	over 1.81 kg		
Fuselage	325	169	483	14	991	13.1
Nose (excluding radome and windshield)	601	345	611	12	1,569	20.7
Radome	345	195	344	9	893	11.8
Windscreen	435	300	478	12	1,225	16.2
Propeller	7	3	92	2	10	1.4
1 engine struck	410	147	623	25	1,205	15.5
out of 3 struck	-	2	8	-	10	0.1
2 or more of 4 struck	13	2	18	-	33	0.4
all engines struck	10	5	44	-	59	0.8
Wing/Rotor	305	101	641	16	1,063	14.0
Landing Gear	93	52	373	14	532	7.0
Empenage	27	6	42	-	75	1.0
Part unknown	249	129	628	7	1,013	-
TOTAL	2,820	1,456	4,385	111	8,772	100.0

Notes:

6.1 The totals in Table 6 are higher than other tables as several parts can be struck in one incident.
6.2 The percentages are based on incidents where the part struck is known.
6.3 Where both landing gear or both wings are struck, two incidents are recorded.
6.4 110 g = ¼ lb, 1.81 kg = 4 lb. 3.63 kg = 8 lb.
6.5 No data on parts struck available from Netherlands.

TABLE 7 EFFECT OF STRIKE - 1981 to 1985 Data

	BIRD WEIGHTS						
Bird Weight Effect	Unknown	Below 110 gm	110 gm to 1.81 kg	1.81 kg to	Over 1.81 kg	Total	% Based on 5879
Loss of life/aircraft	-	-	-	-	-	-	-
Flight crew injured	-	-	-	-	-	-	-
Engine repairs on:							
2 engined aircraft	78	8	176	4	-	266	4.5
Others	102	10	97	9	4	222	3.8
Windscreen cracked or broken	11	1	12	1	-	25	0.4
Vision obscured*	7	-	5	-	-	12	0.2
Radome Changed	24	1	40	3	1	69	1.2
Deformed structure	6	-	18	1	-	25	0.4
Skin torn/light glass broken	38	6	65	7	-	116	2.0
Skin dented*	61	8	80	5	-	154	2.6
Propeller/Rotor/ transmission damaged	1	-	9	-	-	10	0.2
Aircraft system lost	11	4	30	1	1	47	0.8
Take off abandoned*	14	2	50	1	-	67	1.1
Nil damage	2,196	703	1,931	31	5	4,866	82.8
Unknown	374	116	267	9	1	767	-
TOTAL	2,923	859	2,780	72	12	6,646	100.0

Notes:

7.1 If, for example, skin is torn in two places, or both windscreens are broken, two incidents are recorded.

7.2 The percentages are based on known effects.

7.3* Not counted as damage.

7.4 No data on strike effect available from Netherlands.

7.5 Aircraft Systems lost includes hydraulics, pilot and de-icing.

TABLE 8 AIRCRAFT OPERATORS - 1981 to 1985 Data

A high strike rate may demonstate thorough reporting.

OPERATOR	NUMBER OF INCIDENTS	NUMBER OF MOVEMENTS	RATE PER 10,000 MOVEMENTS
AUSTRIA			
Austrian Airlines	87	146,806	5.9
Tyrolean Airways	2	-	-
BELGIUM			
Air Belgium	-	2,282	-
Delta Air Transport	-	8,294	-
Sabena	109	370,772	2.9
Sobelair	4	26,572	1.5
T.E.A.	13	60,358	2.2
CZECHOSLOVAKIA			
CSA	76 (9)	145,994	-
SLI	2	612	-
DENMARK			
Cimber Air	2	64,620	0.3
Conair	22	35,178	6.2
Gronslandsfly	-	63,022	-
Maersk Air	58	161,118	3.6
SAS	126	432,798	2.9
Sterling Airways	18	165,350	1.1
Other	14	41,176	3.4
FINLAND			
Finnair Oy	245	673,976	3.6
FRANCE			
Air Alsace	2	-	-
Air France	413	1,248,865	3.3
Air Inter	550	929,047	5.9
Eiat	15	-	-
Prive	5	-	-
U.T.A.	49	98,742	5.0
T.A.T.	28	401,736	0.7
Taxis	22	-	-
Others	26	-	-

Cont'd.....

IRELAND			
Aer Lingus	227	-	-
Air Turas	1	-	-
Aviar	10	-	-
ITALY			
Aer Mediterranea	-	43,453	-
Alitalia	224	221,218	10.1
NETHERLANDS			
KLM	313	519,503	6.0
Martinair	7	29,863	2.3
NLM	38	176,760	2.1
Transavia	20 (6)	23,621	8.5
NORWAY			
A/S Morefly	2	-	-
Braathen Safe	42	-	-
Busy Bee	2	-	-
Fred Olsen	2	-	-
Helicopter Service	13	-	-
SAS	192	-	-
Scanair	1	-	-
Wideroe	16	-	-
Others	9	-	-
SWEDEN			
Linjeflyg AB (LIN)	139	465,000	3.0
Ostermans Aero AB	1	7,189	-
Rikspolisstyrelsen (National Board of Police Dep.)	2	11,639	1.7
SAS	234	464,432	5.0
Swedair	4	7, 586	5.3
SWITZERLAND			
Alisarda	3	-	-
Balair	24	-	-
Omo	2	-	-
Swissair	457	-	-

Cont'd.....

UNITED KINGDOM

Air Atlantique	3	10,526	2.9
Air Bridge Carriers	5	24,978	2.0
Air Ecosse	12	38,134	3.1
Air Europe	51	95,432	5.3
Air UK	105	378,212	2.8
Airways Int (Cymru)	4	7,500	5.3
Birmingham Executive	3	19,556	1.5
Bristow Helicopters	21	184,752 hrs	1.1
Britannia Airways	377	356,312	10.6
British Aerospace	31	-	-
British Air Ferries	19	97,078	2.0
British Airways	736	1,907 406	3.9
British Airways Helicopters	38	160,806 hrs	2.4
British Caledonian Airways	237	363,188	6.5
British Caledonian Charter	2	3,663	5.5
British Caledonian Helicopters	5	38,351 hrs	1.3
British Island Airways	2	30,184	0.7
British Midland Airways	139	340,204	4.1
Brymon Airways	7	64,324	1.1
Channel Express	2	18,396	1.1
Dan-Air Services	221	553,394	4.0
Euroair Transport	2	4,160	4.8
Express Air Services	4	12,270	3.3
Ford	8	-	-
Guernsey Airlines	9	20,144	4.5
Heavy Lift Cargo	4	5,522	7.2
Inter City Airlines	4	13,510	3.0
Janus	12	N/A	-
Jersey European	4	10,842	3.7
Lease Air (Genair)	17	44,078	3.9
Logan Air	24	43,372	5.5
Manx Airlines	65	55,614	11.7
McAlpine	4	-	-
Metropolitan Airways	4	12,148	3.3
Monarch Airlines	45	101,562	4.4
North Scottish Helicopters	-	24,191 hrs	-
Orion Airways	57	96,246	5.9
Peregrine	5	1,626	-
Spaceground	5	-	-
Tradewinds Airways	4	12,206	3.3
Virgin Atlantic	-	1,872	-
Other Operators	48	-	-
Unknown	101	-	-

Note 8.1 Leased aircraft are included against the operator.

WORLD-WIDE BIRD STRIKE INCIDENTS INVOLVING CRASH/FATALITY 1960-1989

APPENDIX 2

DATE	AIRCRAFT	LOCATION	PART STRUCK	BIRDS/WEIGHT	OCCUPANTS	DEATHS	OTHER
4.10.60	Lockheed L188 Electra (Allison 501) Flock ingested into 3 engines, aircraft stalled and crashed in harbour	Boston, USA	Engines	Starlings-80gm (Sturnus vulgaris)	72	62	9 serious injuries
15.07.62	Douglas DC3 Co-pilot killed when vulture penetrated windscreen during cruise	Lahore, Pakistan	Windscreen	Vulture-up to 10kg (Accipitriformes)	3	1	
23.11.62	Vickers Viscount (Dart) At 6000ft whistling swan struck and removed left tailplane, aircraft crashed	Maryland, USA	Tailplane	Whistling Swan-6kg (Cygnus columbianus)	17	17	-
28.07.68	Falcon 20 (CF700) Gulls ingested into both engines on take-off causing severe damage, ditching in lake	Lake Erie, USA	Engines	Gulls-280gm to 1.7kg (Larus sp.)	3	-	-
23.07.69	Douglas DC3 Cranes blocked carb intakes on both engines, ditched in sea.	Khar, Ambadu, India	Engines	Cranes - up to 6kg (Grus sp.)	4	-	-
26.02.73	Lear 24 (CJ610) On take off severe power loss on both engines. Aircraft crashed into buildings.	Atlanta, USA	Engines	Cowbirds-44gm (Molothrus ater)	7	7	1 third party serious injury
12.12.73	Falcon 20 (CF700) Gulls* caused severe damage to both engines on take off, crash landed	Norwich, UK	Engines	Gulls* (see note 4)	9	-	1 minor
14.06.75	NA265 Sabreliner (JT12A) Ingestion in both engines on take off, crash landed	Watertown, USA	Engines	Franklin's gull-260gm (Larus pipixcan)	6	-	3 serious injuries
12.11.75	DC10 (CF6) Gulls+ ingested in Eng 3 which exploded, causing severe wing fire, abandoned take off, aircraft burnt out	Kennedy NY,USA	Engine	Gulls+ (see note 5)	139	-	2 serious injuries
20.11.75	HS125 (Viper) Lapwings ingested in both engines on take off, power loss, crash landed destroying car	Dunsfold, UK	Engines	Lapwings-215gm (Vanellus vanellus)	8	-	6 third party deaths
06.02.76	Lear 24 (CJ610) Gulls ingested in both engines, power lost and crashed in field	Bari, Italy	Engines	Gulls-280gm to 1.7kg (Larus sp.)	3	-	-
12.11.76	Falcon 20 Both engines failed just after lift-off, causing aircraft to crash	Naples Florida USA	Engines	Ring-billed gulls-485gm (Larus delawarensis)	11	-	11 serious injuries
04.04.78	B737 (JT8D) Wood pigeon ingested during training touch and go, abandoned take off beyond V_1 and over-ran. Burnt out	Gossellies, Belgium	Engine	Woodpigeon-465gm (Columba palumbus)	3	-	-
25.07.78	Convair 580 (Allison 501) Sparrowhawk ingested in one engine on take off, auto feathered, crashed in field	Kalamazoo, USA	Engine	Sparrowhawk-105gm (Falco sparverius)	43	-	3 serious injuries
07.04.81	Lear 23 (CJ610) At 4000 ft loon penetrated right windscreen killing co-pilot and injuring pilot. Windscreen debris damaged Engine 2 and was shutdown	Lunken, Cincinnati, USA	Windscreen	Loon-3.7kg (Gavia immer)	2	1	1 serious injury
06.12.82	Lear 35 (TFE731) Abandoned take off after V1 after striking gulls. Over-ran, ILS installation injured co-pilot. Engines were not damaged	Le Bourget Paris	-	Black-headed gulls-275gm (Larus ridinbundus)	-	-	1 serious injury
17.08.83	Lear 25 (CJ610) At 500 ft passed through starling flock. Both engines failed. Force landed after striking trees in industrial area	Wilmington, USA	Engines	Starlings-80gm (Sturnus vulgaris)	2	-	-
15.09.88	Boeing 737 (JT8D) Ingestion in both engines at lift off, surging, loss of power. Attempted return, both engines failed. Crashed 10Km from airport during attempted landing in open country but struck river bank and burned. Airport is 5,800ft amsl.	Bahar Dar, Ethiopia	Engines	Speckled pigeon-320gm (Columba guinea)	104	35	21 serious injuries

Notes:

1. Civil register aircraft of 5700kg (12,500lb) and over, together with executive Jet aeroplanes.
2. The part struck relates to the part which was the primary cause of the accident
3. Cases included where aircraft in flight suffered total engine power disruption resulting in a crash

* 4. Common gulls (Larus canus 420g) and Black-headed gulls (Larus ridibundus 275g)

\+ 5. Great black-blacked gulls (Larus marinus 1.7kg), Ring-billed gulls (Larus delawarensis 485g) and Herring gulls (Larus argentatus 1.0kg)

ADF616428

BIRDSTRIKE COMMITTEE EUROPE

BSCE 20/WP29

Helsinki
21-25 May 1990

SERIOUS BIRDSTRIKES TO CIVIL AIRCRAFT 1987-1989

John Thorpe - UK Civil Aviation Authority
Safety Regulation Group

SUMMARY

The Paper contains a sample of detailed histories of accidents and more serious incidents (eg double engine ingestion with damage, holed airframe, fire, windshield damage) for the years 1987 - 1989. The Paper is divided into three sections:-

- Transport Aeroplanes of 5700 kg and over, and Business Jets.
- Aeroplanes below 5700 kg.
- Helicopters.

The incidents have not been analysed although it can be seen that the majority of cases involve engine multiple ingestion including the Ethiopian B737 accident which was the first transport jet fatal accident due to birds. The windshield appears to be the critical area for General Aviation aeroplanes and Helicopters.

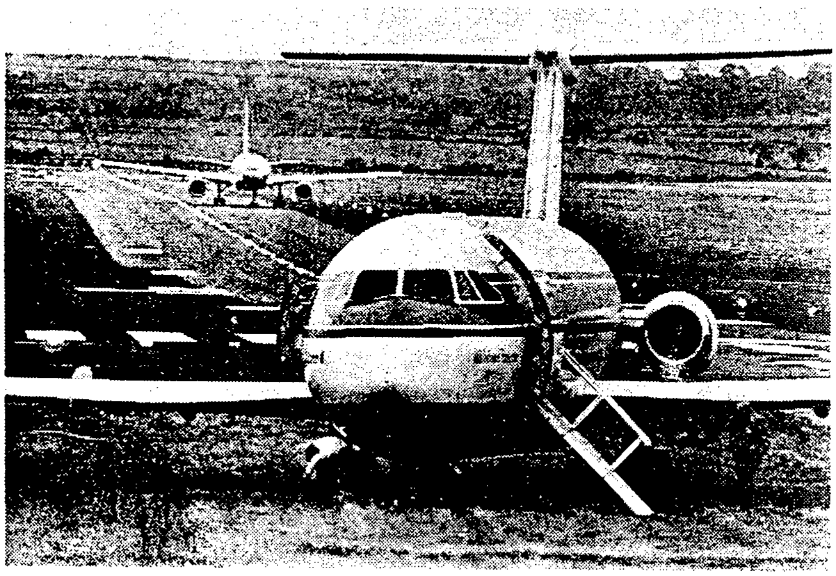
The author would welcome any new or additional information as the Paper is mostly from ICAO, UK and Insurance sources.

SERIOUS BIRDSTRIKE TO CIVIL AIRCRAFT 1987/88/89

AEROPLANES OVER 5700 KG AND EXECUTIVE JETS

Date	Aircraft/ Engine	Regn	Location	Total Aboard	Injury
10.02.87	B737 (JT8D)	N-	Chicago,Midway,USA	-	-
	During take off run at 140 knots struck gulls, damage to Engine 1 and inlet cowl of Engine 2.				
05.03.87	Bandeirante	N890AC	Norfolk, Nebraska USA	5	-
	Flew through flock of geese at 3000ft during descent, striking 3 or 4. Substantial damage to RH tailplane and fin.				
13.05.87	B747 (JT9D)	N-	NY, JFK, USA	-	-
	During approach at 900 ft and 150 knots ducks (Anas sp) struck Engine 1 and 2 and damaged wing leading edge. Engines 1 and 2 replaced.				
13.05.87	B747 (JT9D)	N-	NY, JFK, USA	-	-
	At 280 kts and 800 ft birds damaged Engine 3 nose cowl and compressor. Engine 4 nose cowl, fan cone.				
18.07.87	B737 (JT8D)	VT-EHH	Agra, India	-	Minor
	At 3500 ft, 250 kts struck a Vulture (Accipitritiformes), co-pilots window shattered, slight injury from glass splinters.				
15.08.87	B747	VT-	Rome, Italy	-	-
	On take off struck flock of gulls, ingested in two engines causing fires. Take off abandoned but tyres burst. Airfield personnel extinguished flames.				
16.08.87	B757 (RB211)	G-BIKT	Nr Milan, Italy	-	-
	At 300 ft and 150 kts after take off struck birds, smashing nose light and damaging gear up-lock.				
17.08.87	A300 (CF6)	F-BUAP	Chateau-Bougon, France.	-	-
	Large flock of Black headed gulls (Larus ridibundus Wt. 275 gm) ingested in both engines at 140 kts on take off. Four fan blades changed in Engine 1 and one in Engine 2.				
25.09.87	B720 (JT3D)	ET-AAH	Bole, Ethiopia	-	-
	Flock of doves (columba sp) ingested in Engines 1 and 2, take off abandoned at 110 kts. Both engines changed.				
29.09.87	B720 (JT3D)	ET-AAH	Bole, Ethiopia	-	-
	Flock of doves ingested in Engines 2 and 3 , take off abandoned at 90 kts.				
04.12.87	B737 (JT8D)	VT-EGM	Patna, India	-	-
	During approach at 1700 ft , 170 kts bird tore through skin of LH tailplane.				
13.12.87	Jetstar (TFE 731)	VR-BJI	Coventry, UK	-	-
	At 50 ft on take off, 160 kts, struck flock of Lapwings (Vanellus vanellus at 215 gm). Fan blades damaged on Engines 2, 3, and 4.				
14.03.88	L1011 (RB211)	G-BHBR	Dubai	-	-
	Gulls ingested in Engines 1 and 3. Fuselage and landing gear struck. Engine 3, 2 fan blades damaged.				

27.06.88 BAC1-11 G-AXBB **Newcastle, UK** - -



Passing through 100 kts flock of birds seen ahead of aircraft, Engine 1 ran down. Take off abandoned at 147 kts (From FDR) V_1 = 144. Full reverse and braking but not lift dump used. Over ran by 160 ft. No damage.

08.07.88 B737 (JT8D) VT-EGI **Bhubaneshwar, India** - -

Bird impacted aircraft during climb at 170 kts, 800 ft. No. 4 window inner pane cracked. Returned.

15.09.88 B737 (JT8D) ET-AJA **Bahar Dar, Ethiopia** 104 35 killed
27 serious
42 minor

During take off run at airport 5730 ft amsl crew saw two large birds of prey at far end of runway. Between V_1 and V_R saw pigeons over runway and suffered multiple strikes in both engines. Both engines were surging with loss of EPR and very high EGT, gear was retracted, full power applied and slow climb made for circuit and return. Reached maximum altitude of 7,100 ft and 190 kts. On base leg about 3½ minutes after take off, both engines failed and a forced landing wheels up attempted in open country 10 km SW of airport. The aircraft slid into a small river bank, disintegrated and burned.

An Ethiopian Notam Issued 5th September 1988 (C077) warned of bird hazards, vehicle cleared birds from runway but the Speccled pigeons (Columba guinea wt, 320 gm) may have been alarmed by the Birds of Prey seen by the crew. Airport had 2 or 3 jet movements per week. Believed 10 to 16 birds ingested in each engine causing fan damage. Surging led to subsequent failures.

18.09.88 B737 (JT8D) N197QQ **Vaernes, Norway** - -

Climbing through 1000 ft at 190 kts a gull caused a 40 cm crack and some delamination of middle layer of RH front windshield. Returned.

13.10.88 L1011 (RB211) G-BHBO **Nr Philadelphia, USA** - -

At 5,000 ft, 250 kts, struck flock of ducks (Anus sp). Engine 1 TGT rose to 890^0 accompanied by very severe vibration - Engine shut down. Due to loss of oil on Engine 3, aircraft diverted to New York. Engine 1 was changed due to intermediate pressure compressor damage and subsequent secondary damage. Engine 2 was boroscoped and minor damage was found to an HP6 compressor blade. Nose cowl and fan blades were changed on Engine 3 . This engine was removed from service later due to high oil consumption resulting from damage associated with this birdstrike.

24.10.88 **B757 (RB211) D-AMUT Lanzarote, Spain** - -

At 152 kts during the take off run struck a flock of gulls in both engines. Returned for overweight landing, 4 fan blades were replaced in each engine.

25.10.88 B747 (JT9D) **AP-BCL Istanbul, Turkey 433** -

Struck gulls just after take off, birds were ingested in Engines 3 and 4. 40 tonnes of fuel jettissoned. Lower fuselage damaged, both engines changed.

31.10.88 **B747B (CF6) 5R-MFT Nairobi, Kenya** - -

Abandoned take off at 140 kts after birds were struck. 16 flat tyres, all fusible plugs melted.

02.11.88 **AN24 (IVCHENKO) SP-LTD Rzeszow, Poland 29 1 dead**

Engine failure following possible birdstrike on final approach. Force landed in field, damaged and caught fire after striking ditch.

07.11.88 **B737 (JT8D) LV-JTO Mar del Plata**
Argentina - -

At 15 ft just after take off struck flock of brown hooded gulls, (Larus maculipennis). Ingestion in Engines 1 and 2, first and second stage blades and internal damage. Cost 475,000 US Dollars.

16.11.88 **A300B (CF6) D-AHLZ Munich, Germany** - -

During take off run at 140 kts struck flock of gulls damaging fan blades in Engine 1 bird remains in Engine 2. 30 dead birds on runway.

20.12.88 **B747 (CF6) F-GCBK Paris, CDG, France** - -

At 40 ft just after lift off struck Lapwings (Vanellus vanellus at 215 gm). 40 tonnes of fuel jettissoned and returned. One fan blade damaged in Engine 1 and 4 in Engine 3.

20.12.88 **B737 (CFM 56) PH-BDM Amsterdam,**
Netherlands - -

During landing flare, 120 kts, struck flock of Lapwings (Vanellus vanellus). Further down runway struck another flock. Both engines boroscoped, reported both damaged

13.04.89 **B747 ZS- Windhoek,**
S. Africa 360 -

Abandoned take off run after bird flew into engine. A number of tyres deflated.

25.05.89 **A310 (CF6) VT- Delhi, India 270** -

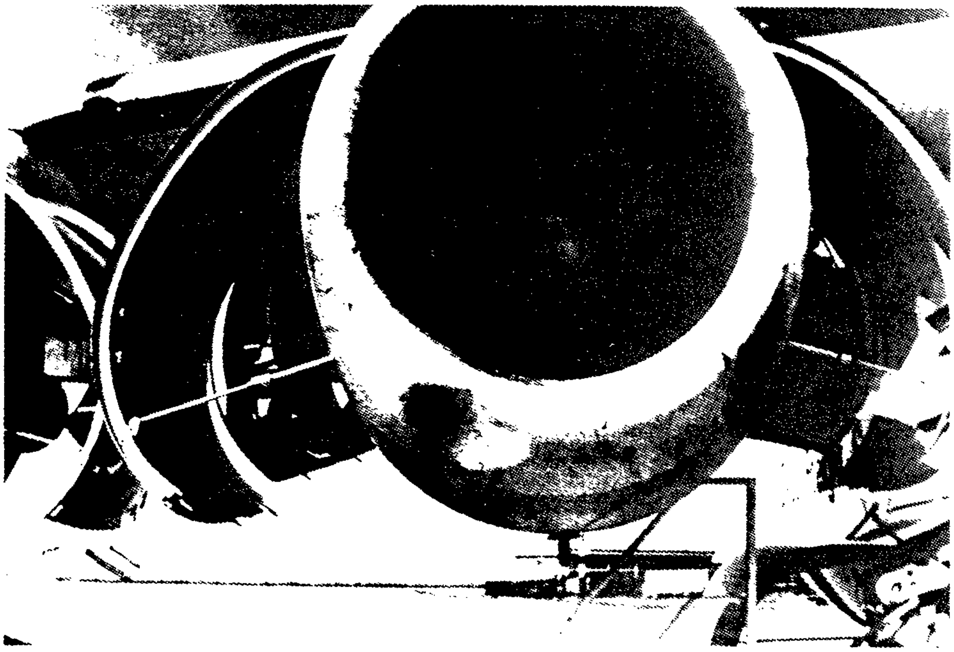
Struck vulture at 4,000 ft shortly after take off. Nose, pressure bulkhead and radar extensively damaged.

31.05.89 B737 (CFM56) G-BNNK **Venice, Italy** - -

At rotation multiple gull strikes. Captains ASI fell to below 60 kts, airframe vibration. Engine parameters appeared normal apart from Engine 2 oil contents falling from 80 - 50 %. No.1 Flight Attendant reported high noise level. Due to Captain's workload First Officer continued Standard Departure. FL100 reached and Engine 1 vibration level increased form 1½ - 2 . Decided to return. Captain flew descent, First Officer took over on Finals. Oil contents recovered on Finals. First Officer was on first flight in -400 series.

07.06.89 BAe 146 (Alf 502) G-TNTJ **Genoa, Italy** - -

At rotation on a midnight take off from runway 11, a huge flock of gulls rose from the surface and hit the aircraft all over. All engines lost power and No 3 shutdown. Climbed to 1,000 ft for circuit and overweight return. There were 57 strikes to airframe from the Mediterranean Herring Gulls (Larus argentatus wt 1 kg) Three engine nose cowls damaged and all 4 engines changed.



Engine 1 most fan blades damaged.
Engine 2 two fan blades broken with penetration of casing, core damage. Fuel oil exchanger mountings adrift , both fire bottle found blown.
Engine 3 three fan blades bent, most have tip bends , HP compressor stators bent.
Engine 4 two fan blades badly bent ,core damage, bypass duct stators 60% separated.
There were various airframe dents.

28.06.89 B737 VT **Delhi, India** - **Injury**

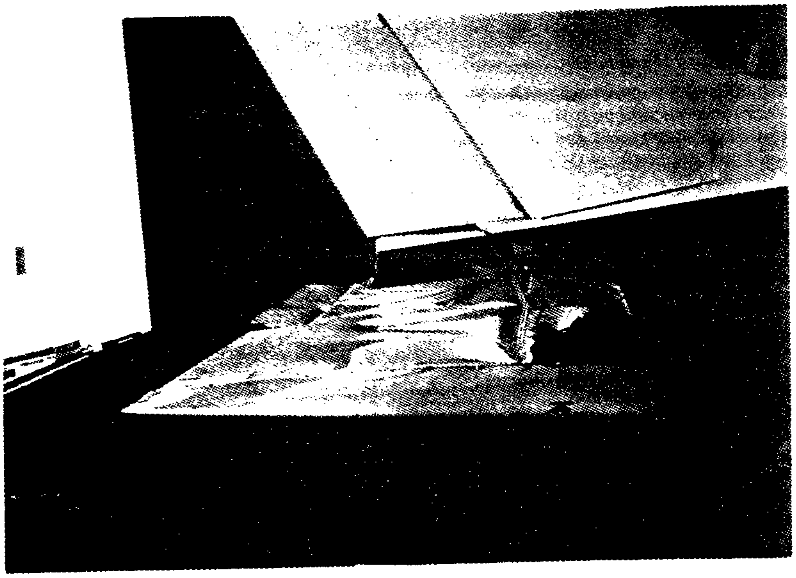
Flock of birds smashed into cockpit injuring co-pilot . Aircraft returned . Cost 100,000 US Dollars.

10.08.89 A320 (CFM56) VT-EPE **Delhi , India** - -

During final approach, 2500 ft, 250 kts, a vulture (accipitriforme) hit the top of the captain's panel of the windshield, this was cracked but not penetrated and frame distorted.The impact caused loss of information on 4 of the 6 CRT displays and Engine 2 LP fuel valve cut out, causing engine to shut down. Single engine procedure flown without any information on the screen about the failure. After landing the captains navigation screen also failed. Bird identified from two feathers jammed in wind shield mounting as an Indian white-backed Vulture (Gyps bengalensis wt 4.5 kg).

AEROPLANES OF 5700 KG AND BELOW

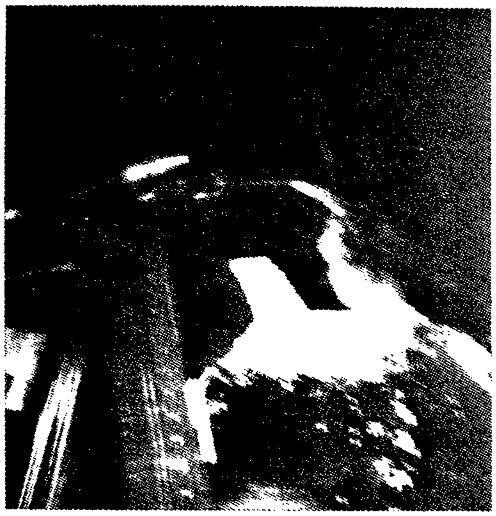
Date	Aircraft/ Engine	Regn	Location	Total Aboard	Injury
11.03.87	C303	G-BJZK	Shoreham, UK	-	-
	Pigeons (columba sp) struck wing jamming flaps in down position.				
13.05.87	NA-680	ET-ADQ	Bole, Ethiopia	-	-
	A bird struck RH side of windshield , destroyed at 500 ft on approach.				
09.07.87	C210	VH-WRD	Roper Bar Australia	-	Minor
	A kite (Milvus sp) smashed the windshield on final approach at 600 ft , 90 kts.				
09.08.87	PA25	VH-FAL	Batchelor, Australia	-	Minor
	Struck two hawks shortly after take off while towing glider. One hawk penetrated windshield hitting pilot, speed 50 kts.				
12.09.87	TB10		Kfar-Tavor Israel	-	Minor
	In cruise at 2500 ft, 110 kts, a Honey Buzzard (Pernis apivorus wt 785 gm) broke windshield and entered cabin , pilot scratched by splinters.				
24.11.87	Osprey Homebuild	VH-LII	Cape Liptrap Australia	-	Destroyed
	At 70 kts just after take off struck a bird, shattering windshield, pilot vision pilot vision impaired by wind blast. After landing and shutting down found back of aircraft on fire, vacated before aircraft was destroyed. Believe bird damaged fuel line allowing fuel to spray on hot exhaust.				
02.08.88	Beech 58	F-BXOP	Medis, France	-	Minor
	Just before landing , at 20 ft and 110 kts, the windshield was smashed by a Herring Gull (Larus argentatus wt. 1 0 kg)				
28.09.88	C207	VH-NIV	Nr Oenpelli Australia	-	Minor
	While en route at 650 ft pilot saw bird just before impact. Windshield penetrated striking p				



Canadian Incident, Cessna Tailplane struck by American Eagle (Haliaectus levcocephalus wt 5.1 kg)

HELICOPTERS

Date	Helicopter	Regn	Location	Total Aboard	Injury
26.04.87	Bo105	D-HAYA	Nr Coblence Germany	-	-
	A dove (columba sp) broke windshield , 105 kts at 800 ft.				
28.06.87	**Hughes 500**	**G-TMJH**	**Booker, UK**	-	-
	During approach a swallow (Hirundinidae) damaged windshield				
30.07.87	**Bell 212**	**G-BFER**	**Nr Unst, UK**	-	**Minor**
	While on finals at 300 ft and 105 kts at dusk struck a Gannet (Sula basana wt. 2.9 kg). Top RH corner of Captain's windshield penetrated and entered cockpit. Co pilot landed helicopter as Captain's screen obscured. Crewmen required medical attention for glass particles in eye.				



Date	Helicopter	Regn	Location	Total Aboard	Injury
06.06.88	**Bo105**	G-BEZT	**Nr Tingwall, UK**	-	-
	At 110 kts, 1000 ft struck gull smashing one overhead perspex panel. Some remains in oil cooler.				
10.07.88	**AS365 Dauphin**	**G-BLUN**	**Oil Rig, UK**	-	-
	Lapwing caused 20 mm long by 5 mm deep gash on top edge of rotor tip.				

END

ADF616429

BSCE 20 / WP 30
HELSINKI 1990

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 structures to bird impacts. However, the aircraft parameters were deliberately omitted from the analyses primarily because aerodrome staff have no influence over them and they are, therefore, of little immediate practical interest.

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.

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

The work described in this paper was carried out under contract to the CAA, Chief Scientist Division. I would like to thank John Thorpe, Head of the Safety Promotion Section within the Safety Regulation Group of the CAA, for allowing access to the UK civil birdstrike database under his custodianship, and for helpful discussions on many aspects of the work. I would like to thank Trevor Brough, Nigel Horton and Ian Inglis for useful discussions about various aspects of the paper.

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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.

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	116-390
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 1963, Milsom and Rochard 1987, ADAS unpublished. Note 2 - data from Brough 1983.

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.

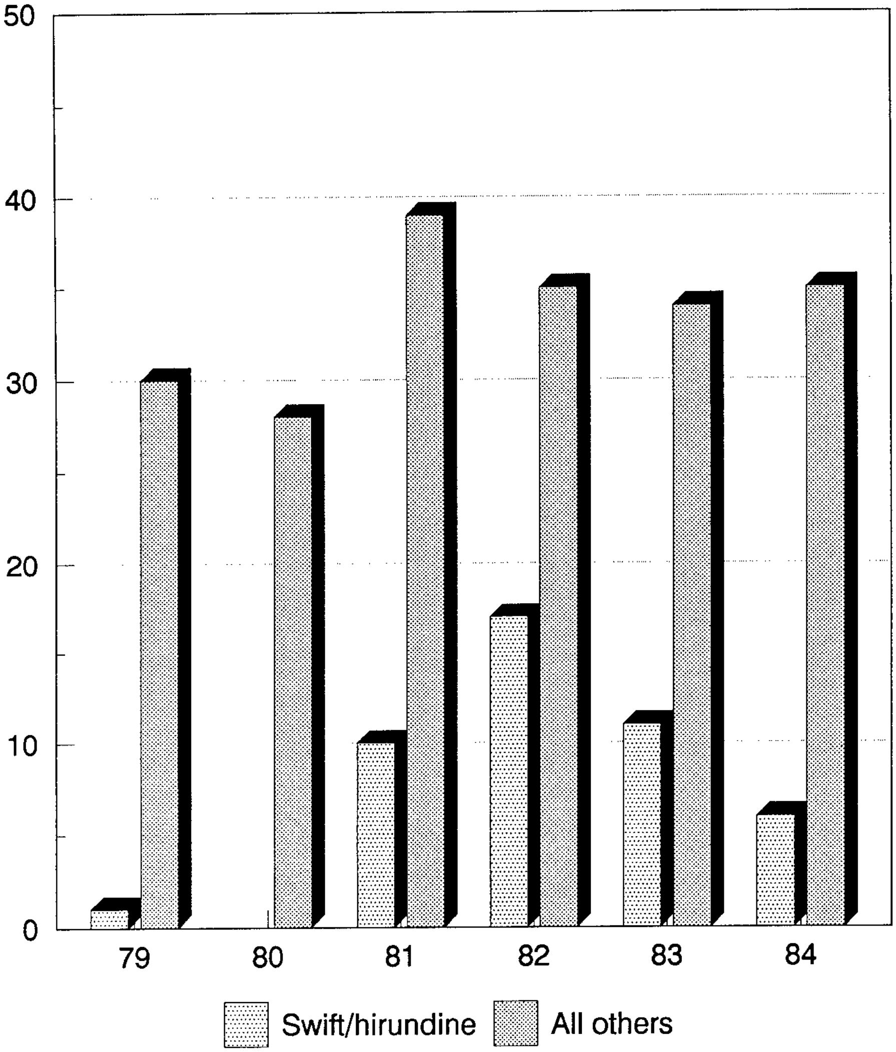
Note: 1 - (see Table 3 for species list).

Table 5. Guide 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

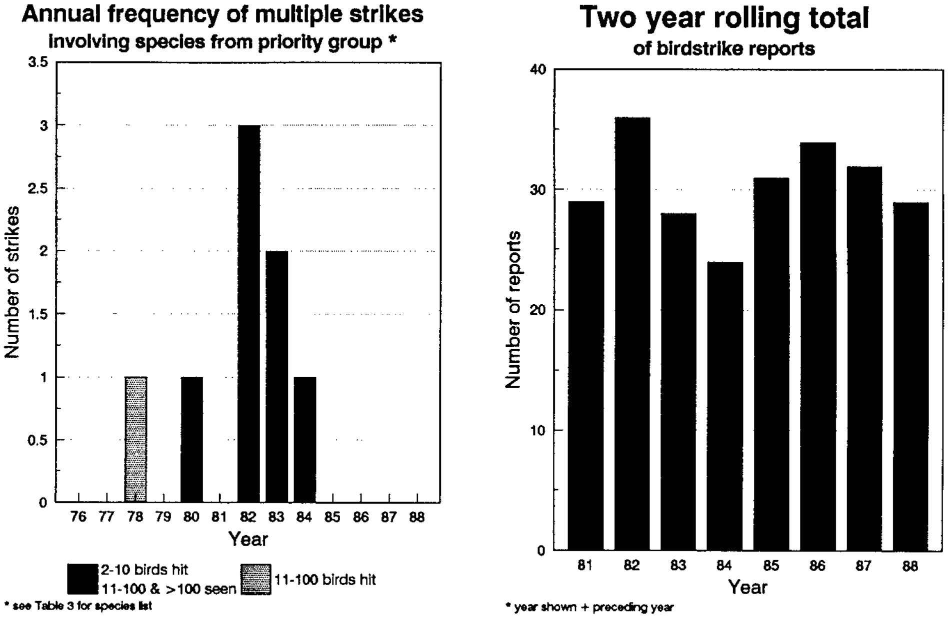
Figure 1

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



Annual frequency of multiple strikes involving species from priority group *

* see Table 3 for species list

Two year rolling total of birdstrike reports

* year shown + preceding year

Trend in percentage strikes involving species with mass less than 110g

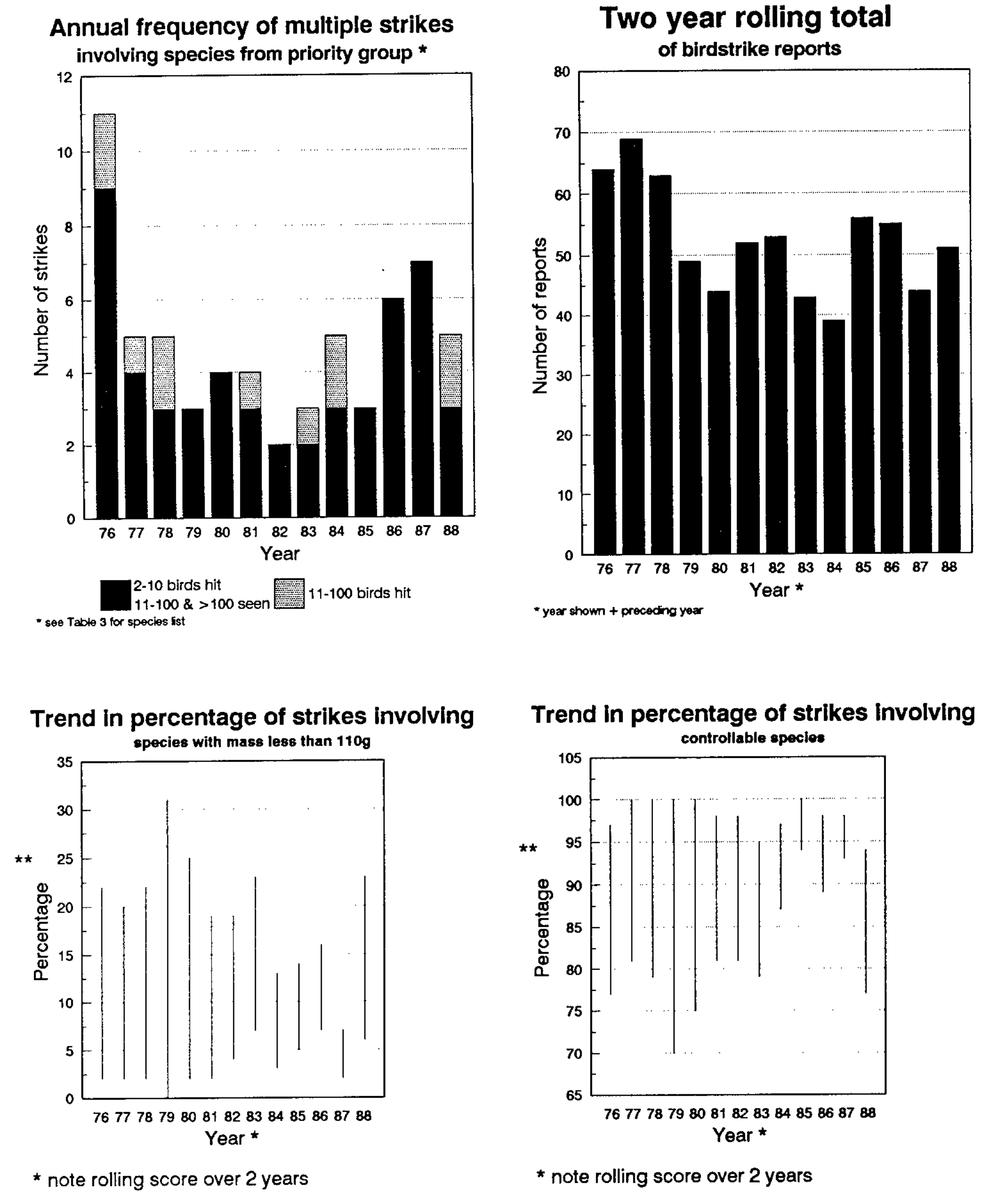
* rolling score over 2 years

Trend in percentage strikes involving controllable species

* rolling score over 2 years

** 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.

ADF616430

BSCE 20 / WP 31

HELSINKI 1990

ADVISING ON AERODROME BIRD CONTROL, SOME REQUIREMENTS AND COMPLICATIONS

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SUMMARY

Aerodrome advisors have a responsibility to the aerodromes they are advising and must be qualified, experienced and conversant with current research and development. This paper illustrates these requirements and gives examples of misconceptions arising out of apparently sound advice.

NB. This paper reflects the author's views.
It should not be taken to represent
the official view of any UK Government Department or Agency.

1. INTRODUCTION

The monitoring of bird control effort on aerodromes is undertaken in many countries. Assessment of standards is complicated by the variety and complexity of operations on individual aerodromes. The author has been responsible for 20 years for assessing standards of bird control on behalf of the Ministry of Defence (MOD) and the Civil Aviation Authority (CAA). The qualities necessary for an advisor are identified and some common misconceptions found on UK aerodromes are discussed in this paper.

2. WHAT THE ADVISOR NEEDS TO KNOW

The fundamental prerequisite for an advisor is to have a comprehensive knowledge of bird biology and control so that a reliable and informed interpretation can be made of the general situation on the airfield during the short time generally available for an inspection. The use of a tick box check list gives only a superficial picture of the bird control situation and is thus inadequate. The specialist advisor should be able to identify not only existing problems but also potential problems for the future.

> ***The advisor must have full and current knowledge of all aspects of aerodrome bird control***

3. APPROACH

When visiting an aerodrome, the advisor's approach has to adapt to meet the level of staff being inspected. It is important to gain the confidence of all staff by dispelling the notion of an 'expert inspector' looking for trouble. The purpose of any visit is not so much to find faults, but to provide positive guidance and encouragement, wherever possible, to further flight safety. At the operator level, most aerodrome staff in the UK have attended 'Bird Control on Aerodromes' courses run by the Aviation Bird Unit (ABU). Therefore, they know the inspecting officer as a lecturer and recognise his knowledge and authority in the field.

> ***It is imperative that the advisor has credibility and the confidence of the staff being inspected.***

4. SURVEYS VERSUS STANDARDS CHECKING

In the UK, visits to aerodromes by Aviation Bird Unit personnel are classed as "surveys" for civil aviation and "standards checking" for military. As the same advisor is involved in each, the approach is the same. However, there is a difference between the two options. The former is specified as providing a positive way forward for an aerodrome to meet the minimum criteria whereas, the latter is often regarded by individual aerodrome operators as a fault finding exercise. Whatever the visits are called, they should all have the common aim of furthering safety.

> ***All visits should be regarded by aerodromes as a positive move to further flight safety.***

5. MEDIATOR/CATALYST

During the intensive surveys of UK aerodromes in the early 1980's, it became evident that many apparent bird control problems arose because of a lack of communication between all the agencies involved on the aerodrome. During each visit, the problem was discussed in detail and the advisor then became a mediator between the different factions. Thus, it follows that the advisor must interview as many staff as possible, for as long as necessary during the visit to iron out any conflicting viewpoints which have resulted from the problem not having been adequately addressed previously.

> ***The advisor must spend enough time on the aerodrome to discuss the problems with all the agencies involved.***

6. RESPONSIBILITY

Obviously, the advisor has to be responisble for any actions he undertakes and recommendations given. Although safety is the prime concern, he must also recognise such things as the general financial state of the aerodrome before recommendations are made which could impose a severe financial load on the aerodrome. For example, it would be imprudent to recommend the employment of full-time staff solely for bird control on an aerodrome where other functions are undertaken by a multi-role organisation and it is known that such a recommendation would effectively be ignored. Also if one impractical course of action is recommended in a series of attainable actions, it will tend to undermine all the recommendations and thereby nullify the objective of the visit.

> ***It is unrealistic for an advisor to propose impractical courses of action. Any such proposals reduce the credibility of the advisory function.***

7. TRAINING

As the advisor has regular contact with a variety of aerodromes, the 'local' knowledge so obtained is of value to participants on training courses, as the theoretical solutions can be illustrated from 'real' aerodrome situations. Also, as mentioned above, any demonstration of expertise serves to make the advisory role credible. However, by nature of his permanence compared to many aerodrome staff who, especially in military aviation, tend to be more mobile, his knowledge of past situations will prevent aerodrome staff wasting resources by trying to re-invent the wheel, which detracts from their primary task.

> ***An advisor must have comprehensive knowledge of individual aerodromes and their problems.***

8. THE IDEAL

There is an inherent danger that an individual advisor might gradually develop exaggerated ideas of how bird control should be carried out. This can partly be avoided by being a member of a group. Advisors must be adaptable and able to incorporate new ideas into their advice. This can be achieved only by keeping informed about current developments. Ideally, the advisor will benefit from having personal research experience and maintaining close contact with research bodies.

The current service provided in the UK is borne of many man-years work in the field and allows for routine updating as research findings are produced.

Advice must be based on a sound R&D base.

9. COMMON MISCONCEPTIONS

Following the production of a comprehensive and largely confidential ABU report to the MOD and CAA on standards in bird control on aerodromes (Rochard and Horton 1984), several of its major recommendations have been incorporated into advice given during training courses and aerodrome visits. Some of the recommendations for bird control, and some misconceptions surrounding them, are considered briefly below.

a. The aim must be a bird-free aerodrome.

This philosophy is based on the fact that serious damage can be caused by a single bird. However, making this recommendation caused problems as some aerodrome managements were under the false impression that it should be taken literally and that no birds should be present at any time on the aerodrome. As this is, of course, totally unattainable some tended to despair of the whole concept of bird control as this primary objective was impossible. Thus, some definition is necessary. In essence, it means that the aerodrome should be maintained as a hostile area for the known problem species; gulls (Laridae), lapwings *Vanellus vanellus* etc, where they will not be allowed to congregate routinely.

Although periods of high risk may be identified in general terms and for individual aerodromes, there are no times of the day or night when birds will definitely not be present. This implies a basic standard:

b. Bird control must be effective throughout the aerodrome operating hours.

This has been taken by some to mean that bird control is related to air traffic and can be relaxed when aircraft movements are low. In reality what is being recommended is that birds should have been dispersed where possible before aircraft movements begin, and prevented from returning during operating hours. From this it follows that:

c. The period when bird control is available must be related to bird activity, not aircraft activity, if significant and permanent reductions in aerodrome bird populations are to be achieved.

This is an important concept for the smaller aerodrome where full-time bird control is not possible. Peak periods of bird activity are generally known and it is necessary for limited resources to be used during these periods as a minimum and, thereafter, when other duties allow.

The main purpose of this section is to illustrate that the advisor must take care when wording what, to him, is a simple concept. It is only simple to him because of his experience and he must recognise that others do not possess the same level of specialism. However, the major misconception in aerodrome bird control is that it involves two functions; *detection and dispersal*. Detection has been the poor relation of dispersal since bird control was introduced on aerodromes.

Yet it is clear that, no matter how well trained and equipped the dispersal team, the problem cannot be effectively reduced unless infestations can be quickly detected over the whole aerodrome. Where bird control is instigated by ATC for example, viewing distances of c. 1km would be common. At this range, birds the size of starlings *Sturnus vulgaris* and lapwings cannot always be seen in good visibility and are effectively invisible when it is raining. Therefore, reliance on fixed point observations is not effective for detection and it follows that:

> *d. Efficient detection can only be maintained by constant surveillance by a mobile observer.*

Thus, as the bird controller must be constantly available to disperse birds, the only logical arrangement is for the functions to be combined. This also results in minimal delay between detection and dispersal.

10. CONCLUSION

Practical bird control advice requires:

a. Comprehensive knowledge of the subject derived from sound R&D.

b. First-hand experience of problems on individual aerodromes.

c. The co-operation of aerodrome staff, which is more easily obtained if the advisor is widely experienced.

d. Finally, an appreciation by all involved, that the aim is to further flight safety.

11. ACKNOWLEDGEMENTS

Most of these personal views are the result of the author's advisory role on the UK aerodromes which was undertaken on contract to the Ministry of Defence and Civil Aviation Authority.

12. REFERENCES

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ADF616431

BSCE 20 / WP 32

HELSINKI 1990

DISTINGUISHING BETWEEN DUCKS, GEESE AND SWANS BY MEANS OF FEATHER MICRO-BIOMETRICS

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SUMMARY

Use of a comparison microscope allows relatively easy separation of ducks from geese from swans because of easily seen differences in relative sizes of feather barbule features. However, such differences are difficult to detect using a single microscope and a simple biometric method is described which separates these groups using three measurements with an accuracy of 88%.

Such a method may also be of use in breaking down the weight ranges of other Orders and examples are discussed.

INTRODUCTION

Basic microscopic identification methods for feather fragments to ordinal level have been described by Chandler (1916), Day (1966) and Brom (1980) and individuals working in the field have developed their own identification keys, which allow the major groups to be separated at least to ordinal level. When attempting to identify birds involved in collisions with aircraft, circumstantial evidence, such as time of year and location etc, can help in determining the species and thereby ascribing the probable weight. However, aero-engine manufacturers are seeking greater accuracy in weight estimates for birdstrike remains identification and this paper describes a biometric method to separate Anseriformes, which are easy to separate from other orders of birds, into ducks (383-3600g), geese (1300-5150g) and swans (4700-11000g) (Brough 1983). Such a method is not usually necessary for those using a comparison microscope as feathers from the different groups can be compared and differences visibly detected. However, any differences are difficult to detect using a single microscope and this method will, therefore, be of use.

METHOD

Basal barbules of basal barbs taken from breast feathers of a number of Anseriformes species of different groups (Table 1) were mounted on microscope slides and the following features were measured using an eyepiece graticule:-

1. The base length, from the base of the barbule ie, where it joins the barb, to the distal end of the first well developed node (Fig 1). The first rudimentary swelling was ignored.

2. The width of the first well developed node, measured at its widest point.

3. The first internode length measured from the end of the first developed node to the distal end of the second developed node.

Barbule length was not used as an identification feature as natural abrasion often resulted in the tip of the barbule breaking off. One hundred measurements of each feature were taken from a number of different feathers, from more than one bird.

These measurements were analysed using SPSS DISCRIMINANT (Nie *et al.* 1975). The aims of this analysis were to determine whether it was possible to discriminate between two or more groups, in this case ducks, geese and swans, using standardized measurements of feather structure base length (BL), node width (NW) and internode length (INL) from samples of known origin and, if it was, to attach confidence limits to the predictive model. For examples of the use of discriminant analysis in biometric studies, see (Green 1982, Wood 1987, and Summers, Nicholl, Underhill and Petersen 1988). The probability of correct classification is expressed as predicted group membership (PGM%). The analysis assumes a normal distribution ie. that the mean value of any variable is distinct between groups and normally, a PGM% of 70% reveals a significant difference between the groups. However, it was decided arbitrarily, to increase the accuracy of the separation, that any PGM% of less than 75% would not be of use as a practical separation tool.

Having discovered that the three groups were distinct using known feathers, the analysis can be used as a predictive tool to assign one measurement of the three variables of an anseriforme feather of unknown species to one of the three groups using Fisher's linear discriminant functions, automatically produced by the analysis, as the basis of separation equations and the PGM% as a measure of accuracy.

Similar measurements of feathers taken from different areas of a single mallard were used to determine whether individual variation between different feathers would reduce the accuracy of the prediction.

RESULTS

The results revealed a high degree of separation (88.09%) between ducks and geese and swans (Table 1). The measurements clearly separated ducks from geese and swans (PGM% 97.2%), but the geese and swans had less significant classification results indicating that the two could be confused on occasions. Separation of genera and species was less successful with respective PGM% results of 47.43% and 39.26%, showing that the structures measured do not vary sufficiently to provide a worthwhile distinction at these levels.

Examination of feathers from various areas of a single mallard also showed a significant variation with a final PGM% of 76.25% (Table 2). This appears to be related to the size of the feathers since the mean values for each variable show the largest feathers from the back have the largest overall length and the under-wing coverts the smallest. However, when all the data were grouped and compared against the other anseriforme data, the result indicated that all were "ducks". Thus although individual variations occur with feathers from a single species, the main groups are so different that no confusion results.

USE IN BIRDSTRIKE REMAINS IDENTIFICATION

The relatively simple method described above shows that, by using a single microscope, remains from a birdstrike involving an anseriforme species can be identified to a group with a reasonable degree of accuracy thus reducing the large possible weight range of the original Order.

Fisher's linear discriminant functions (Table 3), provide the basis of separation equations. These can be computed manually from one set of measurements of the anseriforme barbule, or the single set of measurements can be assigned to the correct group using the Basic programme at Appendix 1.

REDUCING THE WEIGHT RANGES OF OTHER ORDERS

Due to the success in breaking down the Order Anseriformes into smaller weight range groups of ducks, geese and swans, students working with the Aviation Bird Unit have used similar methods in attempts to sub-divide other orders with large weight ranges.

Passeriformes (song or perching birds) are being increasingly submitted for identificaiton as aerodrome staff are becoming more interested in the task and in finding the relatively small remains, especially from *en route* birdstrikes. The possible weight range in the UK with this Order is 9-1150g, which again is of little use to engineers attempting to correlate damage with bird weight and aircraft speed.

Using four measurements; base length (BL), internode length (INL), node width (NW) and barbule width (BW) (Fig 2), no separation into families was possible. However, it was found that the Order could be split into corvids, the heaviest birds with a weight range of 160-1105g, and other passerines weighing 9-160g, with an accuracy of 78.16%. The Basic programme for this technigue is at Appendix 2.

Unfortunately, there has been no success using similar techniques to separate gulls (Laridae), which is the group of birds most frequently involved in UK birdstrikes, or pigeons (Columbidae), which are increasingly struck *en route*, into weight categories.

ACKNOWLEDGEMENTS

This work was carried out under contract to the Ministry of Defence and the Civil Aviation Authority to whom all thanks are due. Also I would like to thank the ABU students who have spent many hours staring down a microscope measuring feather structures.

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Figure 1. DIAGRAMMATIC STRUCTURE OF A TYPICAL ANSERIFORMES BARBULE, SHOWING MEASUREMENTS TAKEN

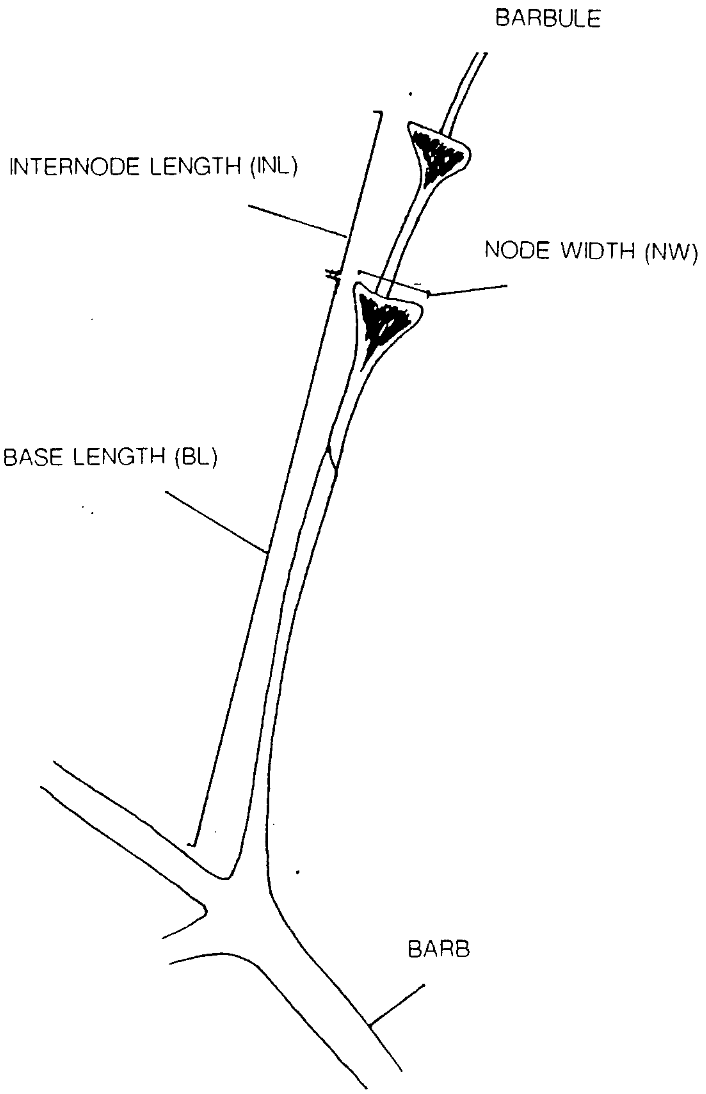

Figure 2. DIAGRAMMATIC STRUCTURE OF A TYPICAL PASSERIFORMES BARBULE, SHOWING MEASUREMENTS TAKEN

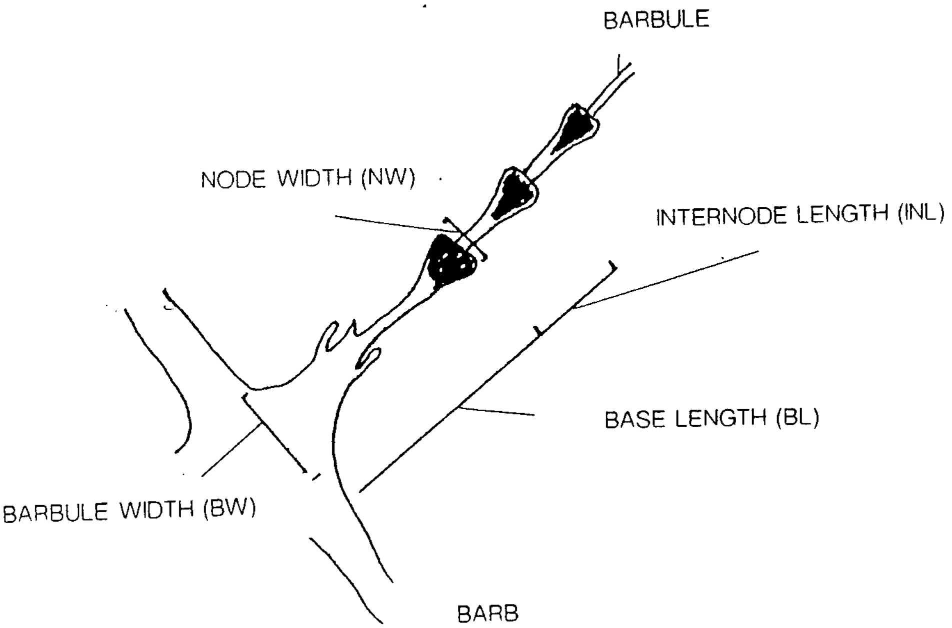

Table 1: DISCRIMINANT ANALYSIS RESULTS ATTEMPTING TO SEPARATE ANSERIFORMES INTO GROUP, GENUS AND SPECIES

GROUP	PGM%	GENUS	PGM%	SPECIES	PGM%
DUCK	97.2	ANAS	51.5	Teal *A. crecca*	6
				Shoveler *A. clypeata*	1
				Wigeon *A. penelope*	28
				Mallard *A. platyrhynchos*	60
		TADORNA	41.0	Shelduck *T. tadorna*	48
		AIX	49.0	Mandarin *A. galericulata*	45
		SOMATERIA	27.0	Eider *S. mollissima*	26
		AYTHYA	42.5	Pochard *A. ferina*	16
				Tufted duck *A. fuligula*	15
		MELANITTA	40.0	Scoter *M. nigra*	48
		BUCEPHALA	22.0	Goldeneye *B. clangula*	33
		MERGUS	46.0	Red-breasted merganser *M. serrator*	37
				Goosander *M. merganser*	58
GOOSE	79.3	ANSER	37.3	Pink-footed goose *A. brachyrhynchus*	24
				White-fronted goose *A. albifrons*	31
				Greylag *A. anser*	56
		BRANTA	59.7	Brent goose *B. bernicla*	53
				Barnacle goose *B. leucopsis*	44
				Canada goose *B. canadensis*	69
		CHLOEPHAGA	27.0	Upland goose *C. picta*	58
SWAN	69.0	CYGNUS	85.3	Whooper Swan *C. cygnus*	53
				Mute Swan *C. olor*	3
				Bewick's swan *C. columbianus*	31

OVERALL PREDICTED GROUP MEMBERSHIP:-	
	GROUP :- 88.09%
	GENUS :- 47.43%
	SPECIES:- 39.26%

Table 2: **GROUP MEANS FROM DIFFERENT AREAS OF A SINGLE MALLARD**

LOCATION	**BASE LENGTH (microns)**	**NODE WIDTH (microns)**	**INTERNODE LENGTH (microns)**
BREAST	678.1	17.6	34.8
BACK	917.3	18.2	35.5
NECK	767.0	17.7	32.8
UNDER-WING COVERTS	657.6	14.8	36.1

Predicted Group Membership:- 76.25%

Table 3: RESULTS FROM A DISCRIMINANT ANALYSIS OF FEATHER PARAMETERS USED TO SEPARATE DUCKS FROM GEESE AND FROM SWANS

Group means:-

	BASE LENGTH +/-SD (microns)	NODE WIDTH +/-SD (microns)	INTERNODE LENGTH +/-SD (microns)
DUCK	578.79+-177.36	16.47+-2.81	32.34+- 6.43
GOOSE	390.68+- 71.10	13.22+-2.66	62.77+-13.05
SWAN	284.64+- 62.09	13.16+-2.42	49.54+- 8.68

Fisher's linear discriminant functions:-

	DUCK	GOOSE	SWAN
BASE LENGTH	2.35377×10^{-2}	1.844289×10^{-2}	1.280905×10^{-2}
NODE WIDTH	2.140961	1.779903	1.660221
INTERNODE LENGTH	4.211884×10^{-1}	7.596760×10^{-1}	5.921977×10^{-1}
CONSTANT	-32.23771	-40.07710	-28.29570

Percent of "grouped" cases correctly classified = ***88.09%***

Appendix 1.

BASIC PROGRAMME USED TO SEPARATE DUCKS, GEESE AND SWANS

```
10 REM ANSERIFORMES IDENTIFICATION PROGRAMME

20 PRINT "INPUT BL, NW, INL, IN MICRONS, SEPARATED BY COMMAS"

30  INPUT A, B, C

40 X= (0.235377*A) + (2.140961*B) + (0.4211884*C) - 31.23771

50 Y= (0.01844289*A) + (1.779903*B) + (0.7596790*C) - 40.0771

60 Z= (0.01280905*A) + (1.660221*B) + (0.591977*C) - 28.2957

70 IF X>Y AND X>Z GOTO 100

80 IF Y>X AND Y>Z GOTO 120

90 IF Z>X AND Z>Y GOTO 140

100 PRINT "DUCK":X

110 GOTO 150

120 PRINT "GOOSE":Y

130 GOTO 150

140 PRINT "SWAN":Z

150 END
```

Appendix 2.

BASIC PROGRAMME FOR PASSERIFORMES SEPARATION

```
10 REM PASSERIFORMES IDENTIFICATION PROGRAMME

20 PRINT "INPUT INL, BL, NW, BW SEPARATED BY COMMAS"

30 INPUT A, B, C, D

40 Y= (0.3350435*A) + (0.09216676*B) + (2.55595*C) - (0.1333225*D) -
       20.30879

50 Z= (0.5052046*A) + (0.0978210*B) +  (3.04599*C) - (0.1040325*D) -
       29.9028

60 IF Y>Z GOTO 80

70 IF Z>Y GOTO 100

80 PRINT "OTHER PASSERINE (9-160g)":Y

90 GOTO 120

100 PRINT "CORVID (160-1105)":Z

120 END
```

ADF616432

BSCE 20 / WP 33
HELSINKI 1990

NOCTURNAL BIRD PROBLEMS ON AERODROMES

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SUMMARY

This paper describes an attempt to identify the pattern of occurrence of birds on UK aerodromes by night. The results of an enquiry covering 31 aerodromes indicate that the problem is diverse. Most aerodromes reported the presence of birds by night but on only one were they present consistently. There are indications that, at least on occasions, bird numbers may be influenced by precipitation, moon phase, tide states and winds. The dangers presented by birds at night are increased by their intermittent occurrence and the difficulty of detection.

1. INTRODUCTION

As a result of a number of birdstrikes on aerodromes by night, the Ministry of Defence asked the Aviation Bird Unit (ABU) to investigate the situation. Although birds occur on aerodromes at night, they are difficult both to detect and study. In order to minimise the birdstrike problem, it is necessary to establish what species are present, where and when, and to devise means of controlling their numbers.

The approach adopted, therefore, was to attempt to identify typical situations suitable for closer study. It was hoped that survey data would reveal periods when birds were likely to be numerous so that aerodrome controllers could be warned and be on their guard. It was also expected that detailed observations would be possible on how birds responded to scaring measures by night. These expectations have not all been fulfilled but this paper describes what has been discovered so far.

2. AERODROME ENQUIRIES

In 1984, bird controllers at 25 RAF airfields were asked whether gulls (Laridae), which were considered to create the most likely problem, occurred on their airfields at night. The answer was not known at five aerodromes and was affirmative in only nine of the remainder. The only common pattern in the replies was that gull presence was intermittent and three stations mentioned July or August as the times of occurrence.

A more comprehensive survey was carried out between 1 October 1986 and 31 March 1987 in order to identify suitable study sites. In this, operators present on both military and civil aerodromes at night were asked to record the numbers of birds seen during routine duties. The data were computerised and average numbers of birds seen for each week were derived. Records within two hours of sunrise and sunset were disregarded because gulls, for example, may leave their nocturnal roost sites (normally on lakes, reservoirs or estuaries) before daybreak and arrive on aerodromes before it is light (Horton 1986). Some people infer erroneously that the birds have been present on the aerodromes all night.

Completed report forms were received from 31 aerodromes, about half military and half civil. Some aerodromes managed to provide data for all nights for the whole 26 weeks, some provided a useful sample each week for the whole period and others for shorter periods. As there are inherent difficulties in both detecting and counting birds by night, the figures obtained are best regarded as minima and counts of zero as no birds seen rather than none actually present.

Since the end of the survey, data continued to be collected on a small number of military aerodromes. Data from two of these have been especially useful and have been analysed separately.

3. INCIDENCE OF BIRDSTRIKES BY NIGHT

Analysis of 4971 birdstrikes on the Civil Aviation Authority's database for 1976-87indicates that, where times of occurrence are known, 8.7% were at night. The predominance of daytime incidents reflects the fact that most birds and aircraft movements are diurnal. For the 57 aerodromes which recorded any birdstrikes in the 12-year period, the annual average number of strikes per aerodrome was 7.3 and the annual average number of night-time strikes was 0.6. Of the 57 aerodromes, 24 recorded only one nocturnal strike each in the 12-year period. The greatest number of nocturnal strikes was reported from London Heathrow but even here the number averaged only 4.4/year.

Analysis of the data by month shows a distinct seasonal trend, most strikes occurring from August to January inclusive (Fig. 1).

4. GENERAL RESULTS OF THE SURVEY

4.1 Gulls

Gulls were reported from 21 (68%) of the aerodromes. The numbers of aerodromes on which gulls were recorded according to month are shown in Fig. 1. Most aerodromes recorded gulls in October when the greatest numbers were also seen. In most cases the numbers of birds were rather small or they were not seen regularly. At London Heathrow, however, gulls were present throughout the survey and the largest weekly average was 2300 (Fig. 2).

Gulls occurred fairly regularly on only six other aerodromes, generally between October-December/January. On a few occasions the numbers of birds seen reached the low hundreds but there were usually less than five. At one of these aerodromes, many nights elapsed when no, or few gulls were seen and then several hundred occurred for only one or two nights.

4.2 Waders

Waders (generally lapwing *Vanellus vanellus*, golden plover *Pluvialis apricaria*, curlew *Numenius arquata* and oystercatcher *Haematopus ostralegus*) were seen at night on 20 (65%) of the aerodromes usually in small numbers (cf Milsom & Rochard 1981) and rarely over 100. They occurred most frequently in November when the greatest numbers were also recorded (Table 1).

5. ANALYSIS OF DATA FROM RAF KINLOSS AND RAF LOSSIEMOUTH

Data from Kinloss and Lossiemouth were comprehensive and extensive and birds were relatively abundant. These data were, therefore, suitable for individual examination. Both aerodromes are situated on the coast in NE Scotland and are subject to influences not found at sites inland.

5.1 Effects of precipitation

In each of the four seasons at RAF Kinloss, gulls were more numerous at night during wet rather than dry conditions. This difference was not statistically significant during the summer (May-July) and autumn (August-October) but it was highly significant during the winter (November-January) and spring (February-April) (Fig. 3). A similar situation was found to occur at RAF Lossiemouth except that no data were available for the summer (Fig. 4). Waders (generally lapwing, curlew and oystercatcher) were also found to be more numerous during wet conditions at Kinloss although the difference was not statistically significant for the summer (Fig. 5). Although other factors may be involved, rainfall has often been observed to improve conditions for birds which feed on soil invertebrates.

5.2 Influence of the moon

The influence of moon phase was examined because it may affect the amount of light available for feeding at night. However, a comparison of gull numbers around full moon, new moon and intermediate phases at Kinloss revealed no clear cut pattern except for a significantly greater proportion of birds present during full moon in winter (Fig. 6). Even if moon phase does influence numbers via light intensity, its effects on aerodromes may be moderated to some extent by artificial sources of illumination and certainly by cloud cover for which no allowance has yet been made.

Waders at Kinloss in all seasons were more numerous during full moon than during new moon (Fig. 7). These differences were not statistically significant, however, although they were close to being so in the autumn and winter periods. In as much as waders are more likely than gulls to feed on aerodromes by night if the conditions are right, their numbers would be expected to be influenced by moon phase more than those of gulls (Milsom & Rochard 1987).

5.3 Effect of tide

In addition to its potential to influence bird numbers on aerodromes by night through available illumination, the moon may perhaps at coastal aerodromes also exert an influence via the tides because birds which are not adapted to swimming will be forced off the inter-tidal areas by rising tides, especially high water springs. A trend in this direction was not found in the case of gulls at Kinloss in spring. A small non-significant tendency in the predicted direction was found in the winter, however, and a significant difference occurred in the autumn (Fig. 8). Gulls, of course, are adapted to swimming and may not therefore be so responsive to tidal changes. The extent, moreover, to which they feed on the inter-tidal areas in this locality is unknown.

Although a stronger association was expected in the case of waders, no significant differences were found. Waders were less numerous than gulls at Kinloss and the extent to which they fed on the inter-tidal areas was also unknown.

5.4 Effect of onshore/offshore winds

Wind direction *per se* is unlikely to influence bird numbers on aerodromes. However, in coastal situations birds might be driven ashore, especially by strong onshore winds. The data for Kinloss suggest that gulls occurred more frequently with onshore than offshore winds in spring and autumn although the difference was statistically significant only for spring (Fig. 9). In winter, by contrast, there was a tendency for more birds to be present during offshore than onshore winds. At Lossiemouth, gulls also occurred significantly more frequently in the spring during onshore than offshore winds, the differences in the other periods being non-significant (Fig. 10). That these differences were not more marked is perhaps not surprising as adverse conditions at sea due to strong winds might occur with almost any wind direction. The effects of strong versus light winds have not been investigated.

Waders, which do not alight on water, were not expected to be influenced by wind direction and this proved to be the case (Fig. 11).

6. GENERAL DISCUSSION

Perhaps the most characteristic feature of bird occurrence on aerodromes at night is its diversity, ranging from one airport which, throughout the winter, has many hundreds of gulls roosting on it by night to other aerodromes which have none. There are no examples of regular gull occurrences in small numbers. Even at RAF Kinloss, where gulls may occur at night in hundreds, they are not present consistently.

The situation at Heathrow is clearly unusual. The number of birds present each night is fairly consistent which suggests that the same individuals keep returning. In this respect, the problem seems similar to that described at Nice Airport by Laty (1974). The birds occupy illuminated aprons amongst the buildings of the terminal area which is not typical of gull roost sites. The more usual inland roost sites, on reservoirs, are abundant in this vicinity and the majority of gulls in the area frequent them. Moreover, the birds on the airport generally arrive at the roost several hours after normal dusk gull roost movements have ended. Attempts, often very labour intensive, have been made by BAA to dispel the gulls from the airport but relocation within the aiport boundary has usually been the only result. During the 1989-90 winter however, the birds were successfully dispersed by taking determined steps to counter them at the beginning of the season. Intriguing although the Heathrow roost was, because of the airport's size, complexity, activity and necessary security restrictions, it was not a convenient place for biological investigations.

The survey findings confirm that gulls constitute the greatest nocturnal bird problems, but five of the 31 aerodromes recorded the presence of waders but no gulls. Furthermore, gulls are more prone to alighting on runways than are waders.

Some of the data indicated that wet conditions increase nocturnal bird numbers. Full moon may, on occasions, be significant as may the tide state. But the effect of onshore/offshore winds at coastal aerodromes appears to be variable. So far, these factors have only been considered on their own. Combinations of factors might prove important. As an example, J R Allan (unpub.) has found up to 10,000 gulls on Blackpool Airport during high spring tides combined with strong onshore winds. No gulls were found during high water springs in the absence of strong winds. Circumstances such as these may profoundly affect bird numbers on aerodromes at night: they will be identified only through good record keeping.

There is much yet to be learnt about birds on aerodromes at night. Their sporadic occurrence emphasizes the need for constant vigilance, especially as means of detection are not simple. Dispersal techniques require study. The current recommendation is that the sealed surfaces of the airfield should be inspected prior to each aircraft movement. Any birds found should be discretely and quietly moved onto the grass areas trying not to disturb other birds possibly already there. Indications from the present data suggest that extra vigilance in the form of continuous patrolling will be necessary in autumn and winter, especially during wet weather.

ACKNOWLEDGEMENTS

Much of the work reported here has been carried out under contract to the Ministry of Defence and the Civil Aviation Authority to whom all thanks are due. The authors are indebted to the 31 aerodromes which supplied the data on which the paper is based. Special thanks are due to Airfield Wildlife Management for the extensive data from RAF Kinloss and RAF Lossiemouth. Tim Milsom has kindly assisted in the preparation of the paper.

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Table 1. NUMBER OF AERODROMES ON WHICH GULLS AND WADERS WERE RECORDED AT NIGHT BY MONTH

	Number of aerodromes at which			
	GULLS		WADERS	
	WERE SEEN	WERE IN MAX NOS	WERE SEEN	WERE IN MAX NOS
OCTOBER	17	10	17	4
NOVEMBER	15	3	22	11
DECEMBER	12	2	17	9
JANUARY	10	3	9	1
FEBRUARY	13	2	9	1
MARCH	9	3	7	0

Sample size N = 31

Figure 1

Night strikes at UK civil aerodromes 1976-87

frequency by month

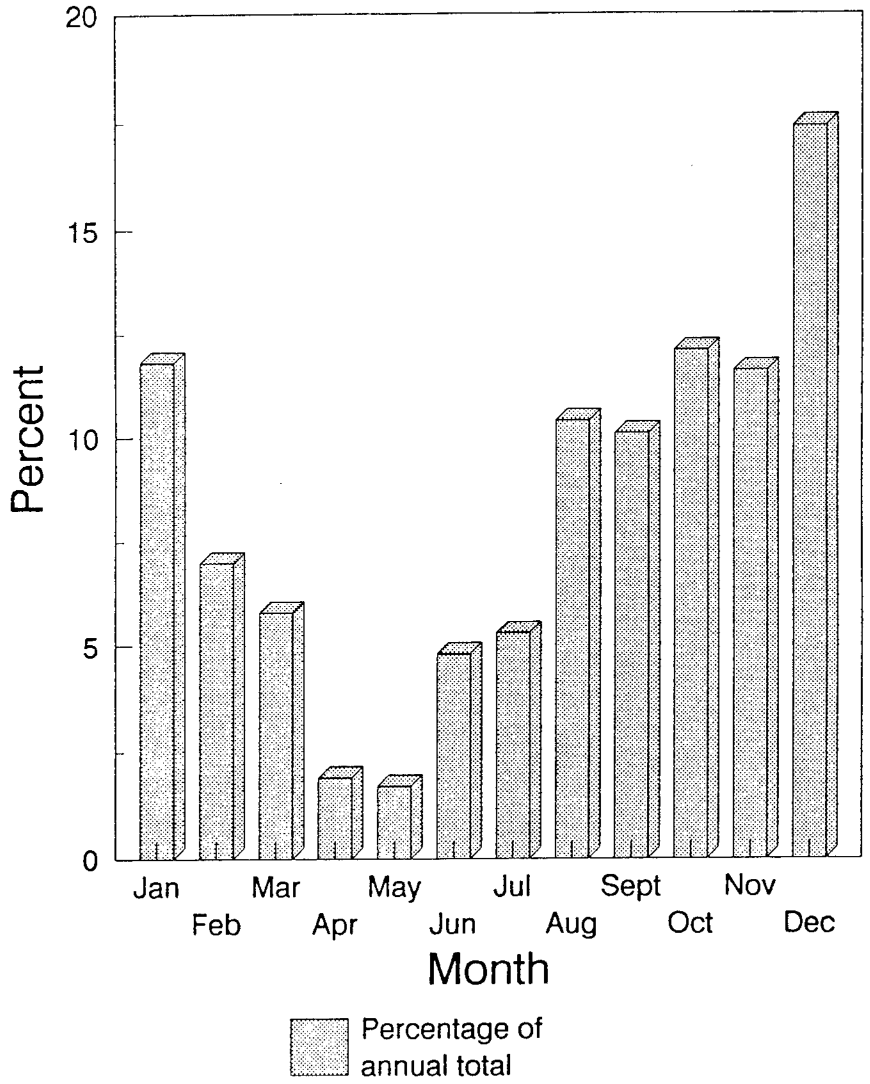


Figure 2

Gulls at night at London Heathrow

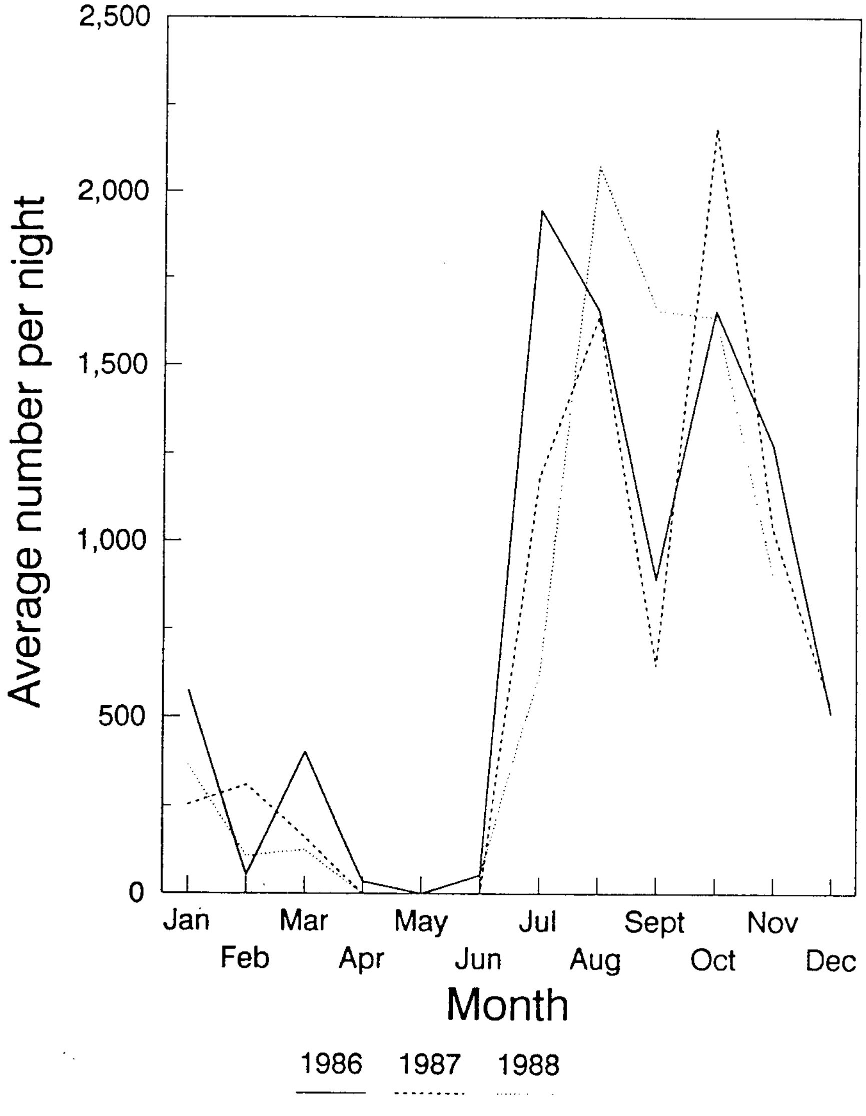
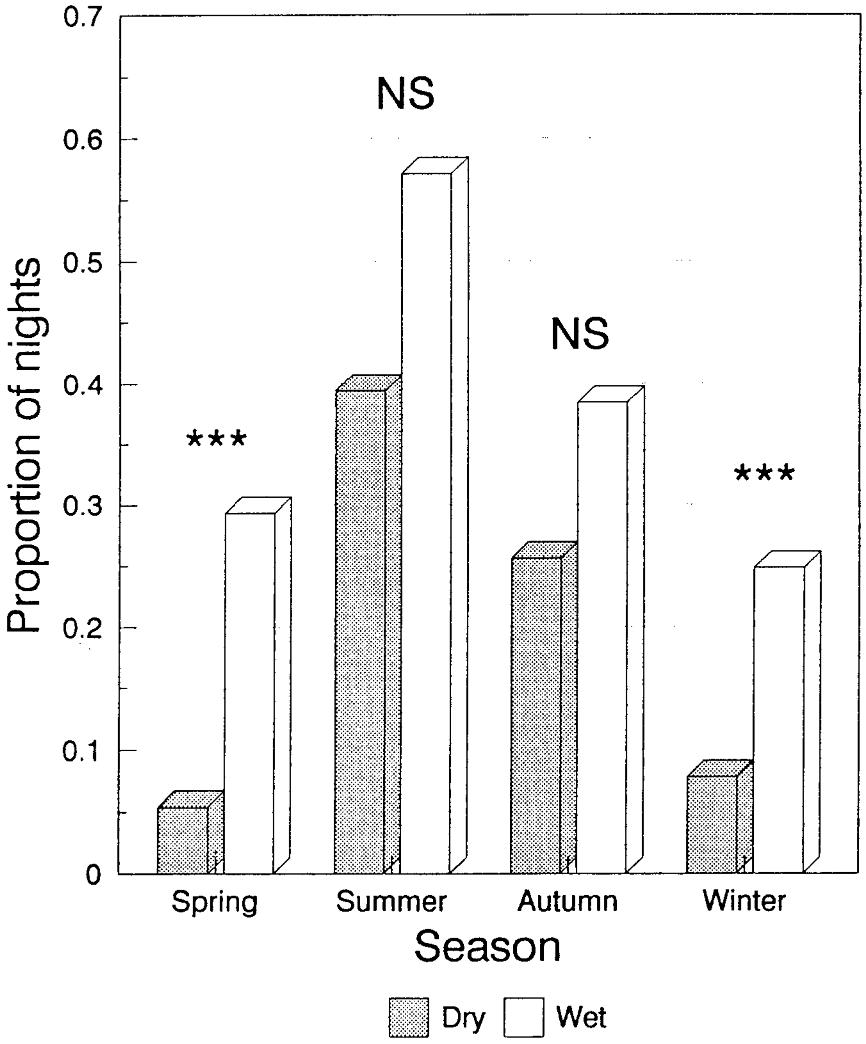


Figure 3

Effect of rainfall on gull numbers

at night at RAF Kinloss

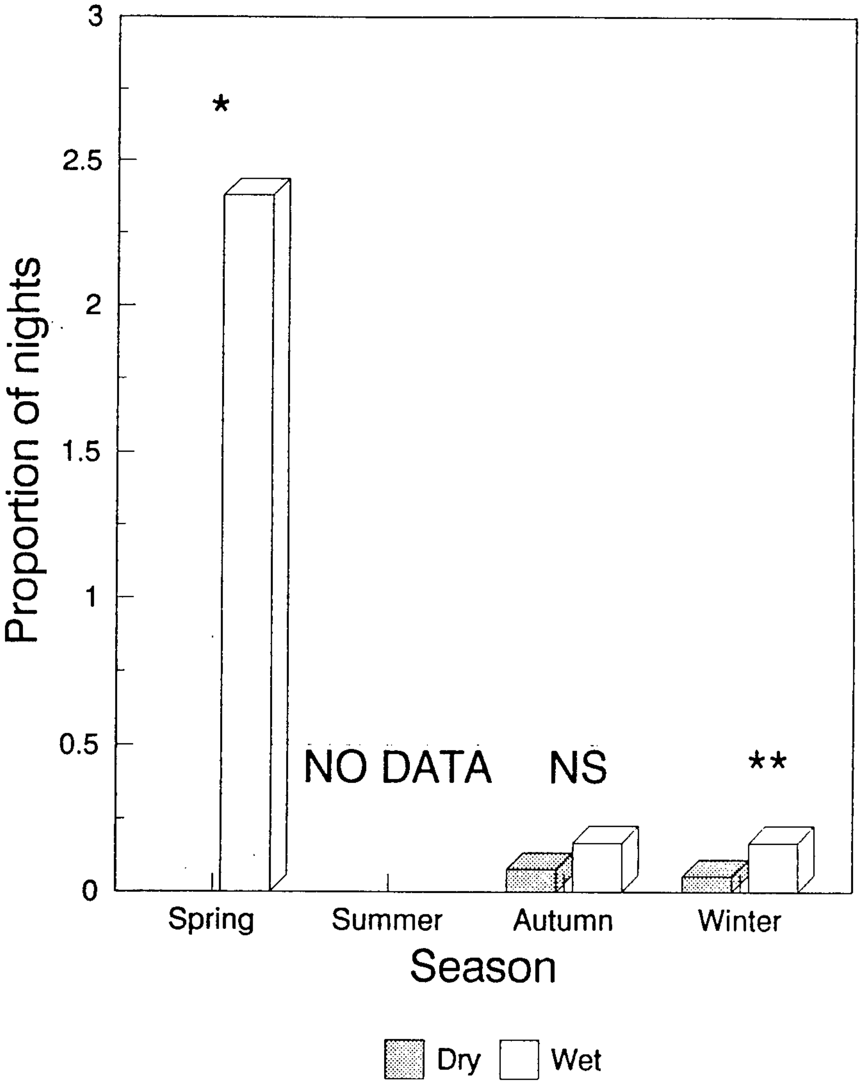


NS = not sig. *** = P<0.001

Figure 4

Effect of rainfall on gull numbers

at night at RAF Lossiemouth

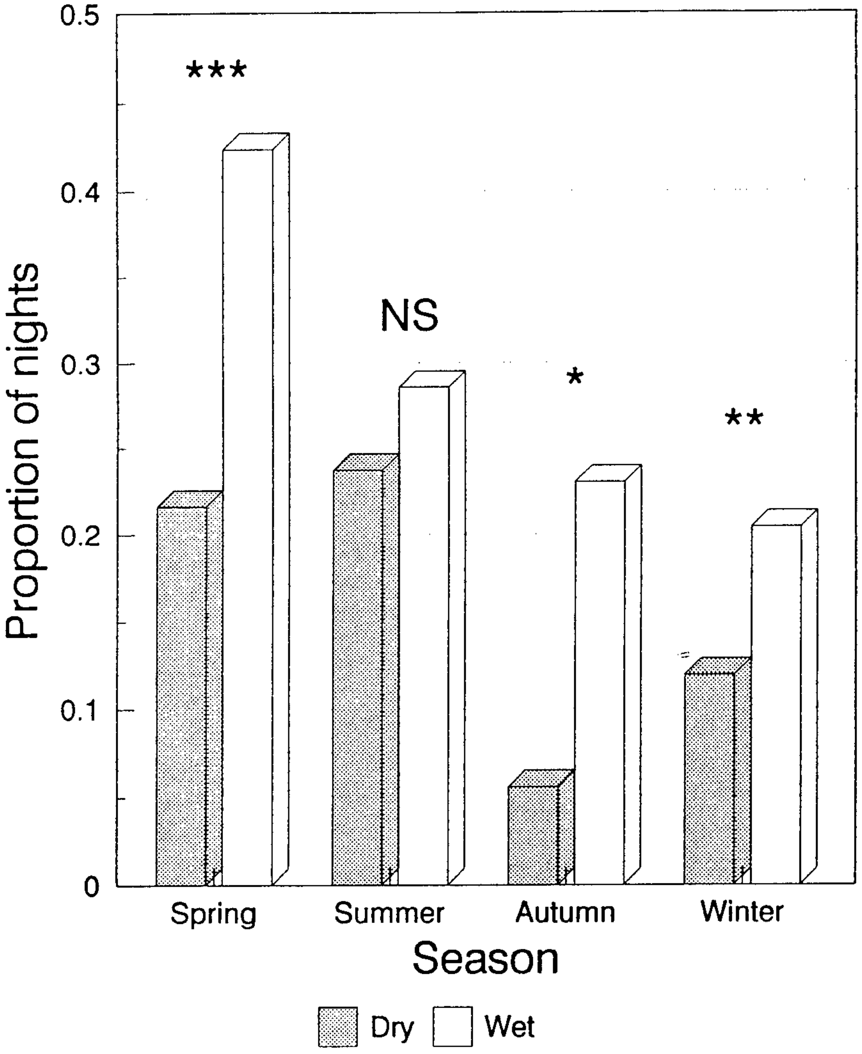


NS = Not sig. * = P<0.05 ** = P<0.01

Figure 5

Effect of rainfall on wader numbers

at night at RAF Kinloss



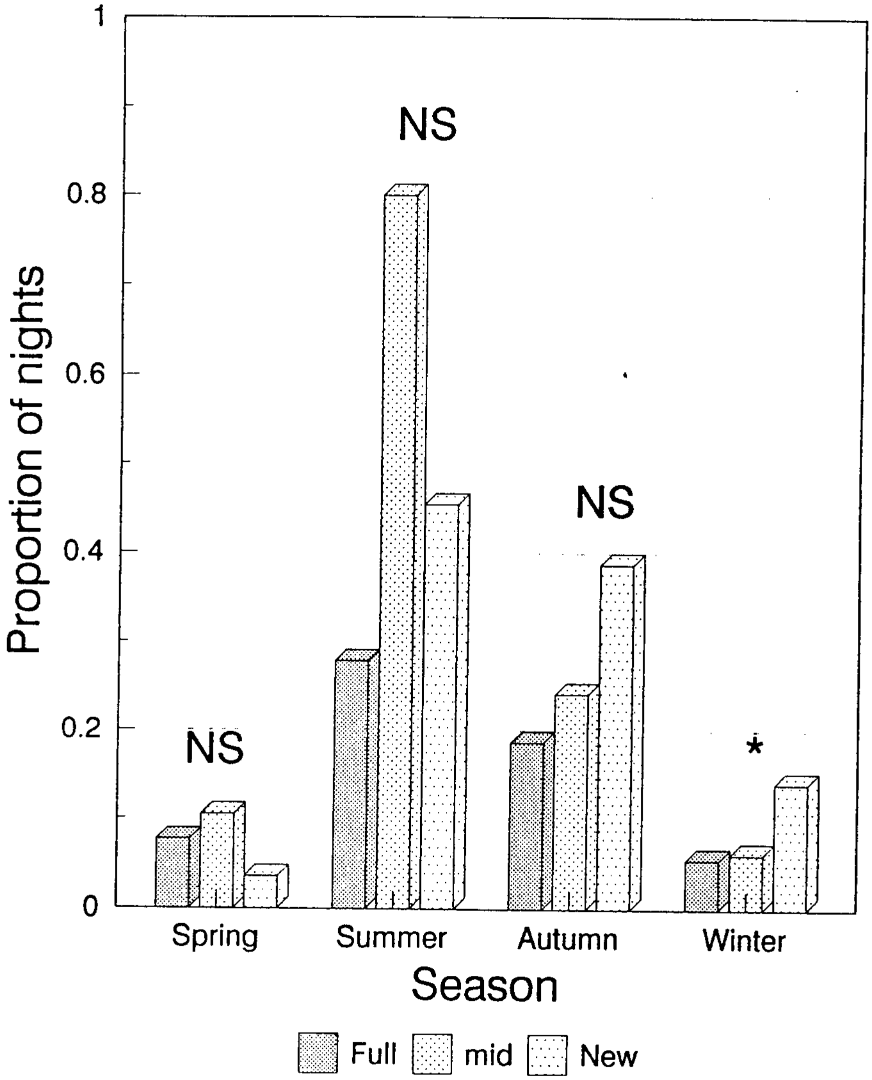
NS = Not sig. * = P<0.05

** = P<0.01 *** = P<0.001

Figure 6

Effect of moonphase on gull numbers

at night at RAF Kinloss



NS = Not sig. * = P<0.05

Figure 7

Effect of moonphase on wader numbers
at night at RAF Kinloss

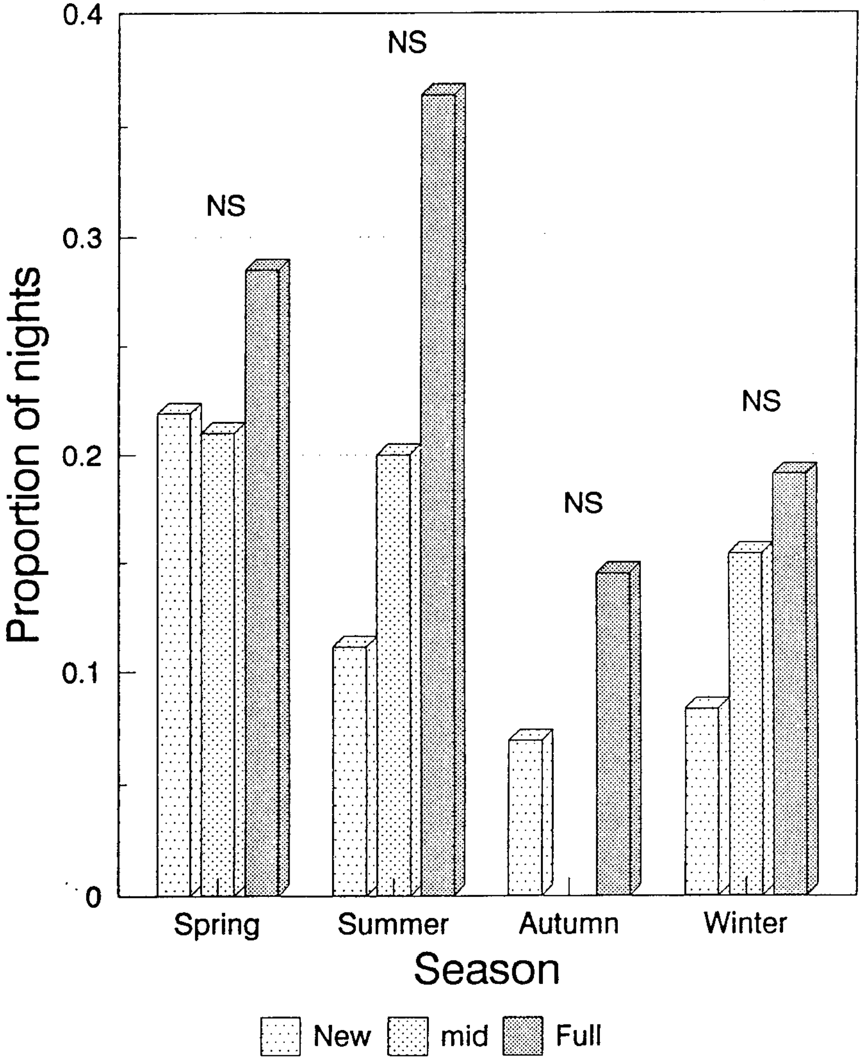


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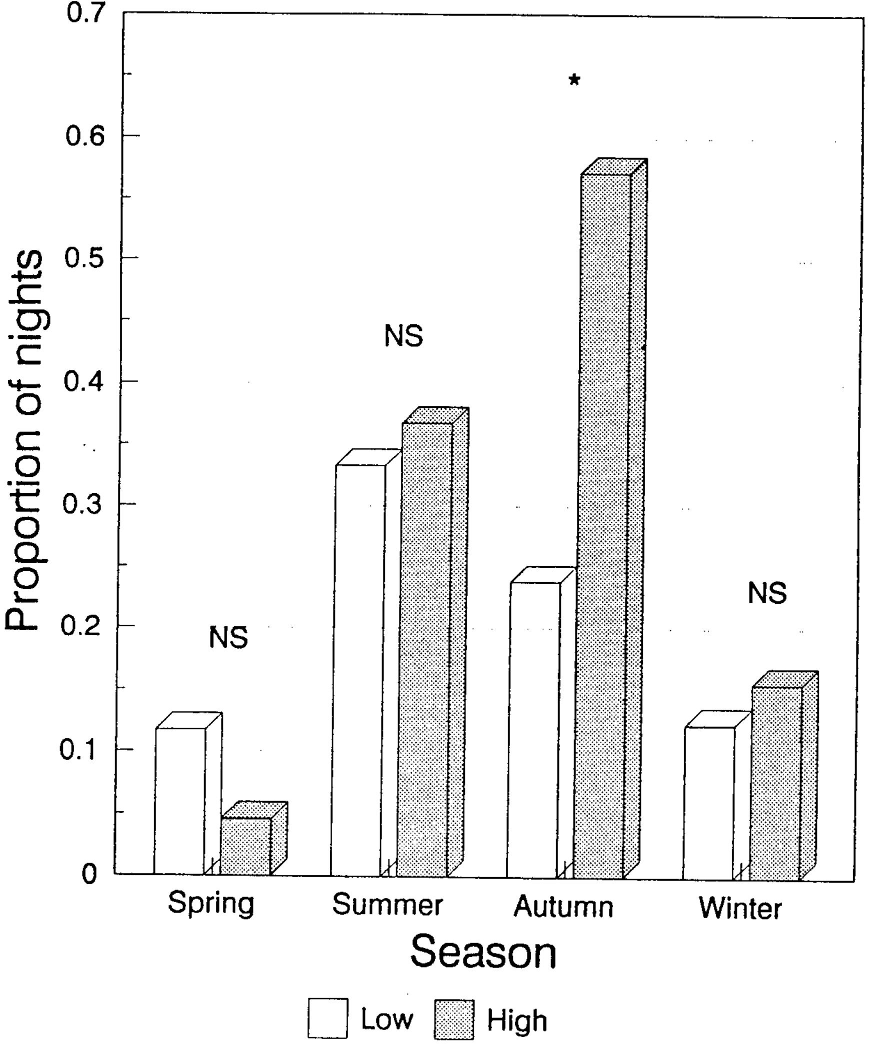
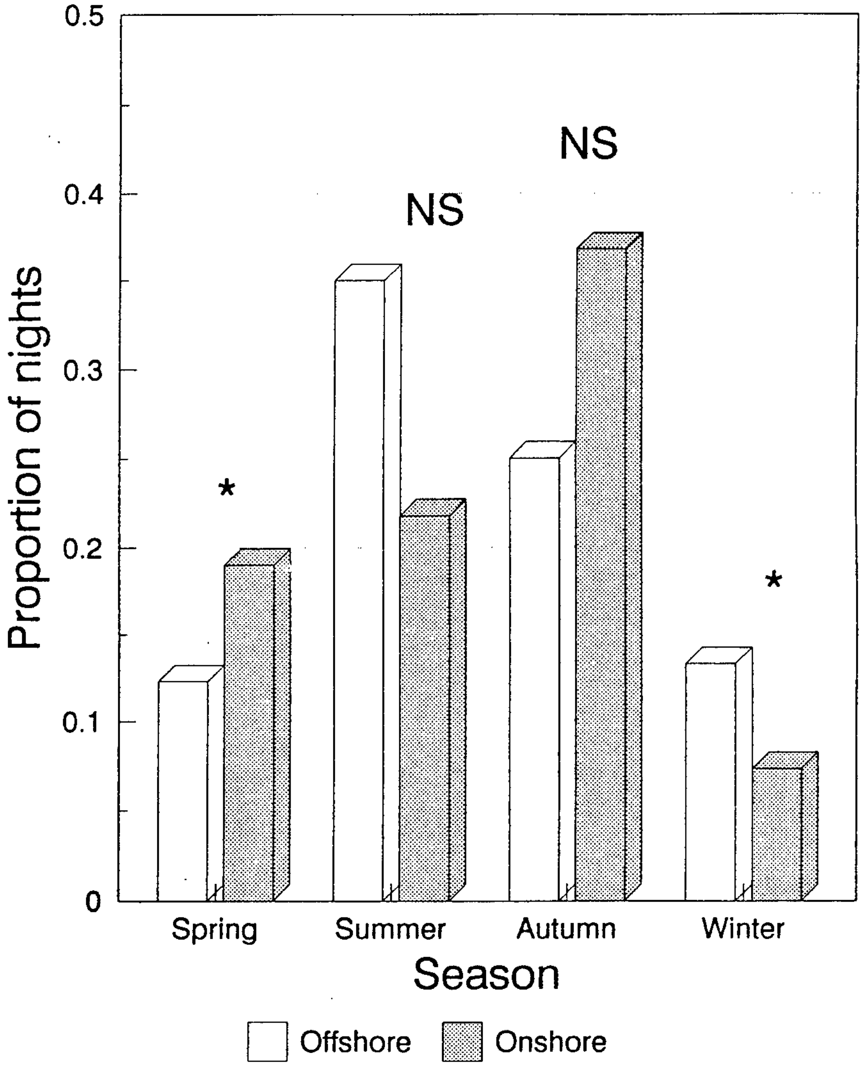
Figure 8

Effect of tide on gull numbers at night at RAF Kinloss



NS = Not sig. * = P<0.05

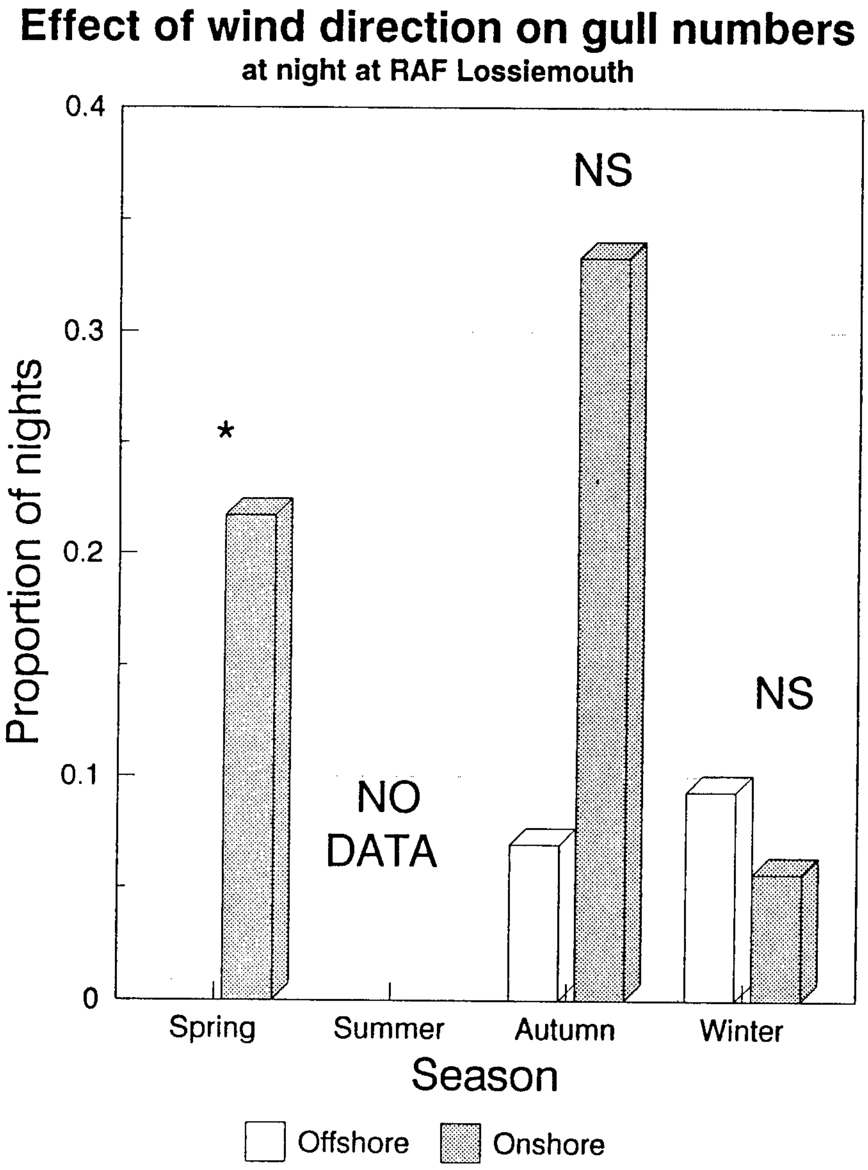
Figure 9



Effect of wind direction on gull numbers
at night at RAF Kinloss

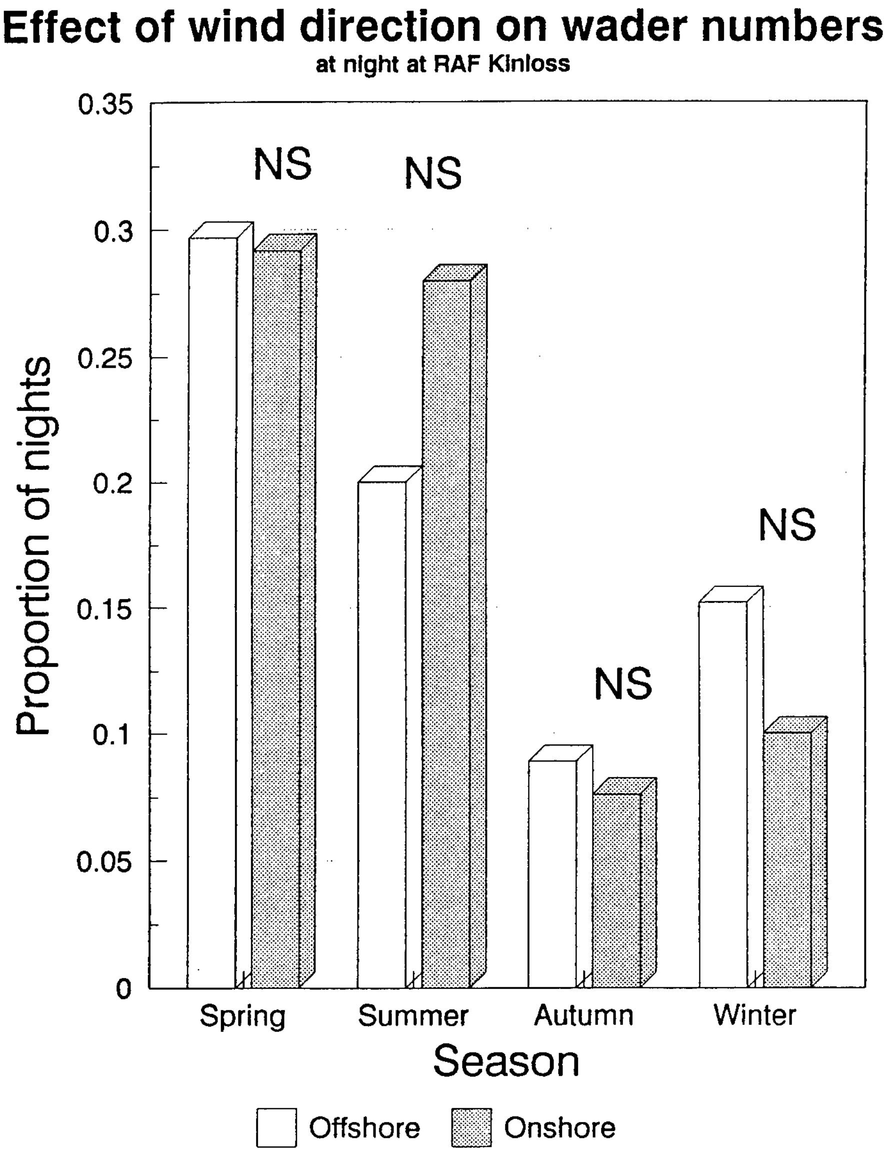
NS = Not sig. * = P<0.05

Figure 10



NS = Not sig. * = P<0.05

Figure 11



NS = Not sig.

ADF616433

BSCE 20/34
Helsinki 1990

IMPROVING THE BIRDSTRIKE WARNING SYSTEM IN CENTRAL EUROPE

by

J. Becker
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SUMMARY

The Bird Movements and Low-Level Working Group shall develop preventive measures to minimize the bird hazard to low flying aircraft. Whereas civil aviation is focussed to the birdstrike problem at, or in the vicinity of aerodromes, military aviation needs birdstrike warnings covering larger areas. The Belgian, Danish, Dutch and German observation and warning procedures have shown that an improvement of the system is only possible if calibrated radar observations of bird movements are performed continuously, and birdstrike warnings are transmitted without delay and loss of information.

1. Introduction

According to the recommendations of BSCE 18, Copenhagen, the Bird Movement Working Group shall develop preventive measures to minimize the bird hazard to low flying aircraft. The progress report of the first two meetings "Bird Hazard at Low Level" was presented at BSCE 19, Madrid, and BSCE agreed on the new title "Bird Movement Low Level Working Group" considering the importance of the additional purpose. The participants emphasized that the procedures of birdstrike warnings/BIRDTAM are mainly significant for military aircraft flying at low level. Therefore the military participants of BSCE 19 agreed to further contact on this subject beside the regular meetings of BSCE. In the meantime 2 meetings were held at the German Military Geophysical Office, Traben-Trarbach/FRG and one meeting at HQ RAF Germany, Mönchengladbach/FRG with the purpose of improving the birdstrike warning system in Central Europe.

2. International regulations for birdstrike warnings

The Air Navigation Commission of ICAO, at the 20th meeting of its 111th Session held on 25 March 1986, considered a proposal for amendments to Annexes 14 and 15 concerning bird hazard reduction. The proposed amendments should introduce new procedures for the assessment and reduction of bird hazards at, or in the vicinity of an aerodrome. The Air Navigation Commission considered a requirement for the introduction of a specific message relating to bird concentrations, possibly a form of NOTAM or "BIRDTAM". 53 States did not indicate position on this term. 7 states registered disagreement, 2 states indicated qualified agreement, and another state foresaw no difficulty in the introduction of such a message. The result reflects the specific position of Civil Aviation focussed to the birdstrike problem at, or in the vicinity of aerodromes. In these small areas the temporary birdstrike risk can be better indicated by local ATC-procedures than by NOTAM/BIRDTAM. The specific problems of Military Aviation are not considered by ICAO.

The NATO countries agreed on the usefulness and importance of birdstrike warnings covering larger areas outside the aerodromes/airfields. The format is laid down within the NATO by the standardization agreement STANAG 3879 FS-Birdstrike Risk/Warning Procedures (Europe). Until 1988 the STANAG had been ratified by 10 countries. During the Flight Safety Working Party (July 1989) France and Spain promised the ratification, whereas UK will only agree to the STANAG for the area of continental Europe. USAFE and CFE do not have the capability to generate birdstrike warnings and are reliant upon host nations for such services. Portugal did not ratify the STANAG, but has notified a national agency for the communication of bird intensity data. Countries having ratified the STANAG are not obliged to implement bird observations and to issue warnings. Birdstrike warnings are no forecasts but based on real oberservations of bird migration mostly by radar, but also visually by pilots or ground staff. Visual detection as well as the identification of bird echoes on the radar screen, and the determination of the bird intensity are difficult if standardized procedures and calibrated data are missing.

3. Effectiveness of the Bird Observation System

The existing observation system of bird movements is insufficient. Only 4 countries (Belgium, Denmark, Netherlands, and West Germany) observe regularly migratory movements of birds by radar, and these observations are not calibrated due to different equipments and techniques of identification. The general situation was explained in BSCE 19/WP6. In the meantime the following results must be emphasized:

In the Netherlands the electronic counting system ROBIN (see BSCE 19/WP40) is taken into operational use. This system extracts bird echoes at highest possible resolution from the raw radar video. Using the latest computer technology, specially developed filter algorithms and pattern analysis a synthetic bird migration image is produced and transmitted by telephone to a high resolution computer screen at the user's desk. Digitized raw data, statistical data on individual echoes and accumulations of more than one antenna resolution can be requested as well. After evalution by an expert of the Air Staff bird warning messages are issued. Due to the positive experience with the system RNAF has spent money for a second equipment.

In Belgium the electronic counting system BOSS (see BSCE18/WP16) is implemented at Belga Radar. The registration of bird intensities is independent of air traffic control purposes. In spring 1989 birdstrike warnings could be issued only till 15 march due to operational reasons. The intensities reported were often higher than the dutch ones, but on very busy migration days the results of both systems were similar. Belgium intends to establish a observation network based on military and civil radar stations covering the whole country with respect to bird movements, but the calibration of the different radar data seems to be a hard work.

In Denmark the electronic counting system FAUST (see BSCE8/WP8-2) is still in use. In spring 1989 bird intensities were missing for many weeks due to technical reasons. The intensities reported did not always correspond to the Belgian and Dutch messages due to technical and ornithological reasons, for in Denmark not only long term migratory movements but also local migratory patterns are recorded by radar.

In the Federal Republic of Germany all attempts to establish electronic counting procedures at the air defense stations have been without success. The photographic registration system is still in use (see BSCE18/WP5). In spring 1989 the bird intensities reported were generally lower than the intensities determined by electronic counting in the neighbouring countries. On main migration days in fall 1989, the bird intensities reported by a radar station in Schleswig-Holstein corresponded very well to the Danish and Dutch intensities; but differences of one step of the intensity scale between neighbouring radar stations are frequent. Radar stations in central and southern Germany mostly reported bird intensities below 5. The reason may be that in hilly areas bird migration runs partly below the lowest radar beam.

Further attempts were made to include several ATC-airfield radars in the German observation network. Though concrete instructions are still missing many bird observation messages were sent to GMGO from GAF- and RAFG- airfields in 1989. The main problem of these observations is the fact that ATC-radars operate within a smaller range than air defense radar stations, and record mostly bird movements at lower altitude. Therefore the bird intensities reported do not correspond to each other. The shortage of radar equipment and personnel makes thorough investigations with respect to bird intensities impossible, and to make matters worse, most ATC Radars have only synthetic videos, and a large amount of bird echoes gets lost during video processing.

4. Effectiveness of the Birdtam-System

Birdtam/Birdstrike Warnings are regularly distributed by Belgium, Denmark. The Netherlands, and West Germany. Except Germany all warnings are based directly on radar observations. In Germany the GMGO Forecast Center changes the observation message (by radar or visual) into warnings considering different keys in relation to type of observation, bird intensity and season. Therefore the number and the content of observation messages do not correspont.exactly to the BIRDTAM. Nevertheless gaps between different

BIRDTAM-areas are frequently existing due to an insufficient detection of migratory movements. During heavy bird migration in these gaps the birdstrike risk is similar to the risk indicated in BIRDTAM-areas. Improvements of the Birdtam-system are therefore depending on the quality of the observation network. All German BIRDTAM are distributed to foreign countries by telex (BFSTA/AFTN), and directly to CFE, RAFG and USAFE-bases in Germany. In these airforces standing procedures must provide that further distribution to the Flying Units is possible without any delay. The birdstrike hazard caused by large-scale bird movements can only be avoided respectively reduced if radar observations are carried out regularly, and the delay between the time of observation an the receipt of the warning by the pilots will be shortened.

5. Improvements recommended by the subgroup "Bird Hazard at Low Level"

A significant improvement of the warning procedures is only possible if calibrated radar observations of bird movements are performed continuously. Money spent for this task would improve considerably the flight safety without extending the present restrictions.

The appropriate authorities should pursue the aim of calibrated electronic assessment of radar data concerning the low level bird hazard and should evaluate the capability of currently deployed radar systems as well as the future or projected radar systems to fulfil the aim of electronic assessment of such radar data.

Neighbouring radar stations should compare the data of strong bird migration counted electronically or determined by photographic pictures for calibration and standardisation of bird intensities.

The ATC personnel of military airfields should be encouraged to test the feasibility of their radar for the observation of bird movements even though a general guidance is still missing.

The appropriate authorities should investigate the possibility of contributing to a dedicated multi-national system for the detection, reporting and dissemination of birdstrike hazard warnings.

BIRDTAM/Birdstrike Warnings are transmitted via ATC and Wx-networks. National air staffs should consider/reconsider, how the warnings can be obtained without delay and loss of information.

AD F616434

BSCE 20 / WP 35
Helsinki 1990

The Convair accident in the Skagerak 1989
- A presentation of the identification work on feather remains found in the wreckage.

Per-Göran Bentz & Tim G. Brom

SUMMARY

A Norwegian registered Convair aircraft crashed into the sea north of Denmark in 1989. Fifty-five people were killed. This paper describes the results of the chemical tests and the identification work which were carried out on the feather remains found in the wreckage. The findings do not support the theory that a bird strike caused the accident.

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INTRODUCTION

A chartered Convair aircraft LN-PAA, owned by the Norwegian company Partnair, crashed in the Skagerak on 8 September 1989 at 4.37 pm. This twin-engined propeller aircraft was cruising at 22 000 feet on its route from Oslo to Hamburg, when it suddenly lost height and crashed into the sea. In all, 55 people were killed.

The aircraft, which disintegrated, was localized on the sea-bed 5 nautical miles north of Skagen on the northernmost point of Jutland, Denmark (in Tannis Bay). The parts of the wreckage, which were found on a soft mud bottom at a depth of about 90 m, were spread over more than 50 km^2. More than 500 parts have been found and more parts are still being retrieved in nets by fishermen. The remains have been transported to Oslo, where the Aviation Accident Investigation Board has its headquarters. Of the 55 people that were killed in the accident, four have still not been found.

MATERIAL AND METHODS

When the parts of the aircraft were examined in detail by the Investigation Board, bird remains were found. One feather was stuck to the deformed altitude decoder and another was found on the internal framework of the cargo door. The altitude decoder with the feather and the feather from the cargo door were examined by the Aviation Bird Office at the Zoological Museum and by the Institute of Forensic Medicine, both at the University of Oslo. Light-microscopical comparison with reference material and chemical tests of the feather surfaces were carried out. The two feathers, which are shown in Fig. 1, were later sent to the Institute of Taxonomic Zoology at the University of Amsterdam for further examination. This examination consisted of light-microscopical (LM) and scanning-electron-microscopical (SEM) studies of the feathers and a direct comparison with feather material in the bird skin collection of the Zoological Museum in Amsterdam.

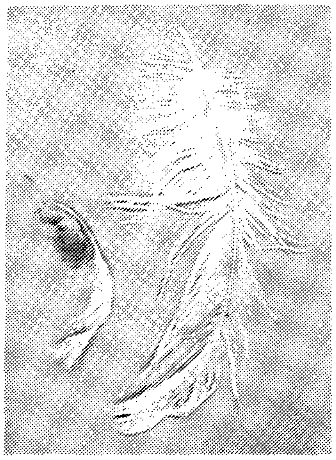

Figure 1. The two feathers found in the wreckage. *Left:* The feather from the cargo door. *Right:* The feather found in the altitude decoder.

RESULTS

Chemical tests of the feathers and the altitude decoder

Chemical tests were carried out in order to find blood or bloodstained material on the surface of the feathers or on the altitude decoder.

- Feather no. 1 (the feather on the altitude decoder) was tested with a benzidin reagent. The reaction was negative, i.e. no traces of blood were found on the feather.
- The altitude decoder was also tested with the benzidin reagent. No certain positive reaction was observed, i.e. some of the tested areas on the decoder gave a very weak and slow, bluish-coloured response, which could not be recorded as an unambiguous positive reaction.
- The benzidin test was carried out on feather no. 2 (the feather from the cargo door). This test gave a delayed, atypical colour-reaction. In addition, the outermost part of the feather was exposed to Ouchterlony´s test for anti-human serum. This test gave a negative reaction.

Conclusion of the chemical tests: No blood or bloodstained material was found on the feathers or on the altitude decoder. This indicates that the feathers might have been shed by the bird(s) in connection with active moult rather than by violent impact.

Identification of the feathers

Feather no. 1 was a white body-feather with a greyish base. The feather, which was not glossy, was complete, including an afterfeather, and its total length was 44 mm. The shaft was broad at the base and curved ventrally, and it was most likely a breast-feather. The afterfeather, which was without shaft, closely resembled type "e" of Ziswiler (1962). This type is found in the families Podicipedidae (grebes), Ardeidae (herons and bitterns), Rallidae (rails, crakes and coots), Haematopodidae (oystercatchers), Charadriidae (plovers and lapwings), Laridae (gulls) and Alcidae (auks).

The microscopic study of feather no. 1 gave the following results:
Pennaceous part: Flexules were present on the pennaceous barbules (Fig. 2) at the tips of the barbs (thus in the open pennaceous area) and graded into barbicels on the pennulum; denticules were absent, ungules present.

Figure 2. Feather no. 1: Flexules on barbules from a pennaceous barb in the tip third of feather (SEM, 760x).

According to Brom & Visser (1989) this leads to one of the following families: Diomedeidae (albatrosses), Procellariidae (fulmars, petrels and shearwaters), Hydrobatidae (storm-petrels), Pelecanoididae (diving petrels), Pelecanidae (pelicans), Sulidae (gannets), Phoenicopteridae (flamingoes), Gruidae (cranes), Rallidae, Haematopodidae, Charadriidae, Scolopacidae (sandpipers and allies), Recurvirostridae (stilts and avocets), Stercorariidae (skuas), Laridae and Alcidae.

Downy part: Downy barbules were short (total length< 3 mm) and lacked distinct or pigmented nodes. Their bases were without villi; prongs were placed on the pennulum in groups of 2 or 4, were shorter than internodes and confined to distal halves of barbules (Figs. 3 & 4). According to Brom (1986) this limits the number of families to which the bird could have belonged to: Gaviidae (divers), Podicipedidae and Alcidae.

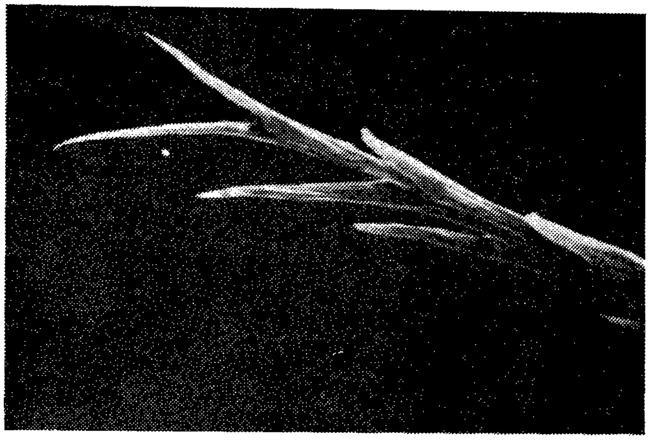

Figure 3. Feather no. 1: Tip of basal barbule from a downy barb of the feather (SEM, 2060x).

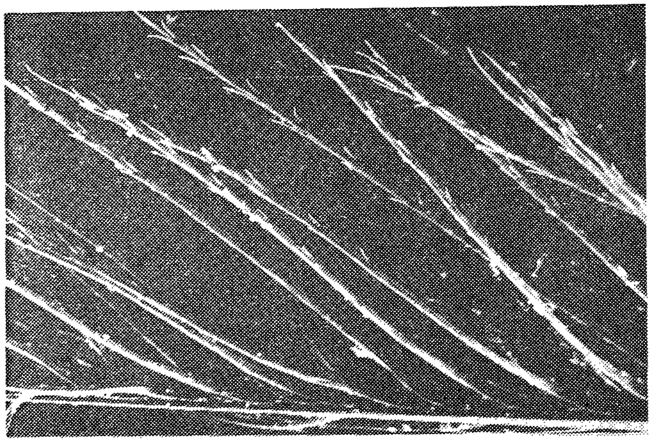

Figure 4. Feather no. 1: Prongs at the tips of barbules mid on a barb of the afterfeather (SEM, 770x).

The diagnosis of the identification according to what has been mentioned above strongly indicates that feather no. 1 originates from one of the alcids, as only in this family (Alcidae) such a combination of these three characteristics is found.

Feather no. 2 was a dirty-white, non-glossy feather. It had no afterfeather and was most likely an under wing-covert. It was complete and its length was 99 mm. The shaft was curved laterally (left). Feathers of this type are only found in Sulidae, Anatidae (swans, geese and ducks), Haematopodidae and Laridae.

Pennaceous part: The distal barbules had large and curved hamuli (Fig. 5). The pennula were rather short. No flexules, denticules or ungules were present. The feather structure was most similar to that found in the gull family (Laridae).

Figure 5. Feather no. 2: Large and curved hamuli on the distal barbules from the basal part of a pennaceous barb (SEM, 760x).

Downy part: The bases of downy barbs were of a pennaceous structure. Sparse downy barbules were found with weakly developed four-lobed nodes proximally (Figs. 6 & 7). The bases were without villi. The structures observed point towards the family Laridae.

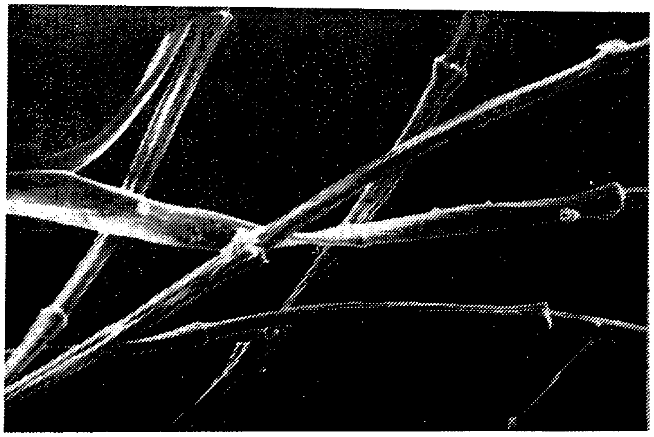

Figure 6. Feather no. 2: Weakly developed four-lobed nodes proximally on the downy barbules mid on a basal barb (SEM, 1020x).

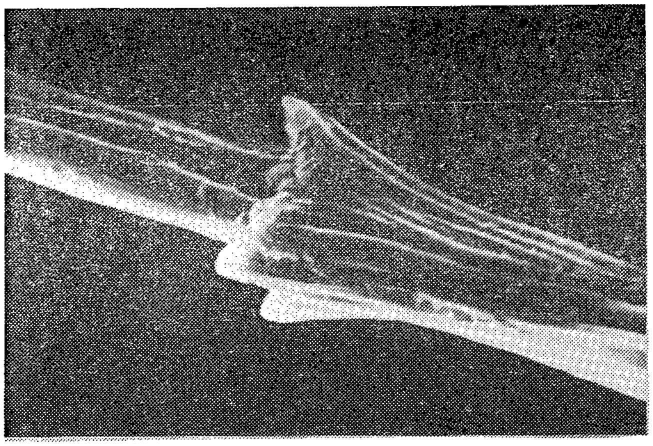

Figure 7. Feather no. 2: Four-lobed node in the basal third of a downy barbule mid on a basal barb (SEM, 5040x).

The diagnosis of feather no. 2 is: Laridae. On the basis of comparison with reference material in bird skin collections it appeared that the feather belonged to one of the larger gull species, i.e. Great Black-backed Gull *Larus marinus*, Lesser Black-backed Gull *L. fuscus*, Herring Gull *L. argentatus* or Common Gull *L. canus*.

Conclusion of the feather identification work: The characters of both feathers match those of the Charadriiformes, but do not lead to one and the same species. Although both have the same colour, the feathers come from two different species. The small one (feather no. 1 on the altitude decoder) is from one of the alcid species, probably from a Guillemot *Uria aalge*. The larger (feather no. 2 from the cargo door) is most probably from one of the bigger gull species *Larus sp.*

CONCLUSIONS

The two feathers from the Convair wreckage were complete (i.e. no fracture of calamus or rachis) and no blood was found on them. Thus they were most probably shed during active moult. The feathers originate from two different bird species; one Alcidae species and one Laridae species. The alcid feather is most probably from a Guillemot, while the gull feather comes from one of the larger species.

Alcids do not fly at altitudes of 22 000 feet, and can therefore be excluded as a bird strike species in connection with this accident. The feather might have been shed by one of the guillemots which regularly moult in the Skagerak in August - September (Cramp 1985).

Gulls are sometimes known to fly at very high altitudes, but 22 000 feet is very high even for a large gull. The weather conditions at the time of the accident, rainfall and very strong (60-70 knots) WSW winds, most certainly exclude even the gull from the list of possible causes of the Convair crash in the Skagerak. Gulls moult during the time of the year in which the accident took place.

The two feathers found on the wreckage have probably become attached to aircraft parts after the accident took place, and thus have no connection with the cause of the accident.

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ADF616435

BSCE 20/WP 36
Helsinki 21-25 may 1990

THE APPLICATION OF RADAR FOR BIRD STRIKE PREVENTION

Compiled for the Bird Strike Committee Europe
(radar working group)
by

L.S. Buurma[1]

and

B. Bruderer[2]

The following pages of the "radarbooklet" (from a total of 75 pages, 37 figures and photo's, one colormap) may serve as an introduction for those readers who were not present in Helsinki or did not receive a copy yet. The first edition is still available through the first author. He also appreciates to receive all comments that may help to produce a next edition.

The Hague, - may 1990 - first edition

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PREFACE

During the periodical meetings of Bird Strike Committee Europe it was felt necessary to have a booklet on the application of radar for bird strike reduction. Neither another textbook on radar, nor a pure biological story about bird movements, but a collection of empirical experiences that could serve as a reference for discussions. This booklet is an attempt to fulfil this wish.

Readers will quickly find out that the first part (up to the color plate at page 27) does not deal with radar. The booklet starts with a identification of the "en route" bird strike problem on the basis of bird strike statistics, because the bird strikes themselves offer the best clue to understanding the real nature of the problem. The next subject is a short biological treatment of bird movements, partly based on radar ornithological studies.

The radar part of the booklet is mainly a collage of short introductions and illustrations. Each chapter deserves much more detail, but we prefer to refer to more detailed publications. However, improvements and additions, especially on new developments, are most desirable for future editions.

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F-104 Starfighter after collision with an eiderduck (Sommateria mollisima, 4 lbs) at 4000 ft. Leakage of fuel let the aircraft enflame during landing.

1. INTRODUCTION

1.1. Aims

Radar has proven to be a powerful tool for detection and quantification of the flying activity of birds. When applied correctly, it can help aircraft to avoid regions and air layers with high bird densities. Reducing the number of collisions between aircraft and birds seriously improves flight safety. High costs and even fatal accidents are at stake.

The aim of this booklet is to stimulate the operational use of radar for bird strike reduction. Although several European air forces practice radar warning for bird movements within their operational procedures, many others do not or profess their belief in so-called BIRTAMS (BIRd information To Air Men) only verbally. Civil operational use is nearly absent. Nevertheless there seems to be a continuous need for information about the flight activity of birds, simply because aircraft and birds collide again and again.

Within Bird Strike Committee Europe (BSCE) it is felt necessary to produce a brochure on these matters. The development of measures to separate aircraft and birds needs cooperation between truly different diciplines. The right procedures can only be achieved by combining information on three different topics: the operations of aircraft, the movements of birds, and radar techniques. However, it is clear that even with the best data, processed in an optimal way, it never will be possible to exclude bird strikes completely. A certain risk always has to be taken when flying.

One could ask whether there still is a need for a booklet introducing basic aspects of "radar ornithology" after the clear and comprehensive text-book under this title by Eastwood (1967). Apart from the size and unavailability of this book there were other reasons to review a number of aspects.

First, after the boom of radar ornithological publications in the Sixties the attention for methodological aspects faded away. Those who continued to extract more information on bird migration by means of radar discovered important limitations. Where these were not taken into consideration they seriously biased conclusions. In particular, the proper quantification and assessment of the altitudes of bird migration suffered from over- enthusiasm during the early years.

The second reason for writing the booklet is our concern about how seldom the available useful knowledge has been applied to flight safety problems. It is considered as the first task of the Radar Working Group of BSCE to bring together practical experience. In order to do so, a second main task is to stimulate research on spatial and behavioural aspects of bird movements. The lack of correct quantitative descriptions of these purely biological matters have often appeared to be the bottleneck. The third reason for publishing the brochure is the development of new radars and video processing techniques. While modern radars become less suitable for direct recording of bird movements, recent developments in computer technology offer new and fascinating possibilities. However, the capacity of extracting information on birds directly from the raw video signal should be a formal part of the system design.

1.2. Overview

We will start with a general survey of the bird strike problem, followed by some research results on the distribution of flying birds in time and space. By comparing these data we evaluate the risks of bird strikes and arrive at certain priorities with respect of technical and methodological means to detect or predict bird movements (chapter 2). Chapter 3 and 4 deal with general aspects of the radar techniques and with the types of equipment used succesfully in ornithological research. In chapter 5 we decribe and discuss different types of applications of radar to operational warnings about bird movements. In chapter 6 current and potential research in radar ornithology is discussed with respect to desirability for flight safety. Illustrations are primarily taken from the research work of the two authors in the areas of the Alps and the Dutch lowlands.

1.3. Acknowledgements

The publication of this booklet has been made possible thanks to reproduction facilities of the Royal Netherlands Air Force. The RNLAF also provided most of the radar pictures and the photo's. The color map with bird migration patterns was made available by the Schweizerische Vogelwarte. The authors are much indepted to Dr R.P.Larkin for comprehensive comments and suggestions.

2. GENERAL SURVEY OF THE PROBLEM

The question of when and where avoidance of birds is practical can be answered in two ways. A first approach is bird strike statistics, using the bad experiences of the past. The problem is that statistical data may be biased for varying reasons. Their usefulness is often reduced by poor reporting. Further, new types of aircraft and altered flight performances might invalidate earlier conclusions. The second approach is by properly analyzing the flying activity of birds and aircraft in three dimensions. From the combination of both data sets theoretically we should be able to predict exactly the hazardous situations. However, the main shortcoming is our knowledge about the spatial distribution of birds. Therefore we start our analysis with the first approach. In chapter 2.2. we continue with some general ornithological information on bird movements partly based on radar studies.

2.1. Bird strikes

2.1.1. How to define a bird strike

Given enough reports certain patterns in the distribution of bird strikes in time and space show up. However, before drawing any firm conclusion, one should realize that not all types of collisions are equally well reported. Serious accidents, of course, cannot be overlooked. But the number of heavily damaged aircraft is relatively small. So, one also wants to include in the analysis incidents with no or only slight damage. Whether or not such bird strikes are, or even can be, documented is partly a matter of attention of the crew and partly dependent on which part of the aircraft was struck. Further, the rate at which identifiable bird remains are found affect the chance of a certain bird strike to be discovered and properly classified.

Bird strikes above the runway are more likely to be reported than bird strikes "en route". Ground personnel may observe collisions directly which were not noticed by the air crew. Bird remains found along the runway, and for that reason considered as corpi delicti, selectively enlarge the proportion of bird strikes belonging to the category "local". The relative overestimation of these cases may even become an absolute one when also slip stream victims are included. These are birds smashed against the ground in the turbulent air behind big airliners without hitting the aircraft itself . Another type of bias is the fact that big and white birds will be seen or found easier than dark and small ones.

We define a bird strike simply as a physical collision between an aircraft and a bird or flock of birds, thus neither including slipstream victims and near-misses nor defining a certain damage and/or risk level.

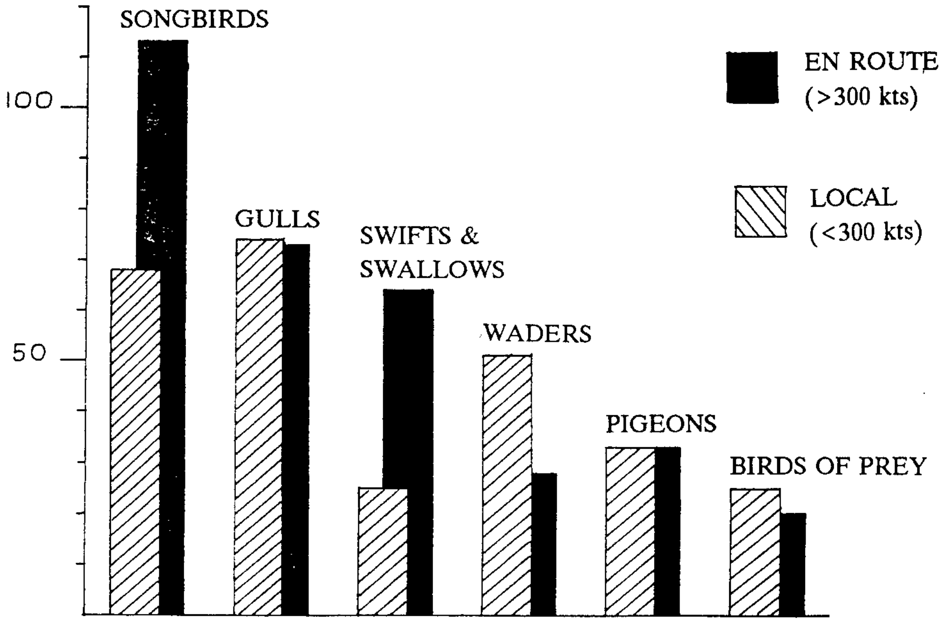


figure 1 Number of bird strikes for RNLAF jet fighters(1977- 1983) per bird category. Flight phases were ranked as "local" (<300 kts) or "en route" (>300 kts) (see fig 15).*

One could object that including all minor bird strikes without damage provokes an enormous reporting effect. We reject this argument when it is induced by the consideration: who reports most bravely ends up highest at the (black) list of ratio's. Honest collection and analysis of data is a conditio sine qua non. Furthermore, comparison of military bird strike statistics from several countries indicates a fairly fixed ratio of damaging to non-damaging cases given a good reporting standard.

2.1.2. Species and damage

All species that spend much time in the air may become victims of aircraft. Jet fighters during low level training missions provide the most bias-free sample. They usually fly at high speeds therefore minimizing evasive manouvres by the birds. Further, they cover large distances over a wide spectrum of landscapes causing their bird victims not to be a typical airfield population. Figure 1 shows that certain species are more involved in "local" strikes (lapwing, a common wader in Holland) while others collided mostly with aircraft "en route" (swifts and swallows). Sorting out the bird strikes with respect of season proves that "en route" bird strikes often include migrating birds, while bird strikes at airfield reach a peak when unexperienced young birds arrive there from the surroundings. This peak is over before most birds leave the area indicating that the birds quickly learn to avoid the danger. Further analysis per species gives results that nicely can be explained in ornithological terms (Buurma, Dekker & Brom 1986), which in turn indicates that aircraft can be seen as devices correctly sampling the air space with respect of birds.

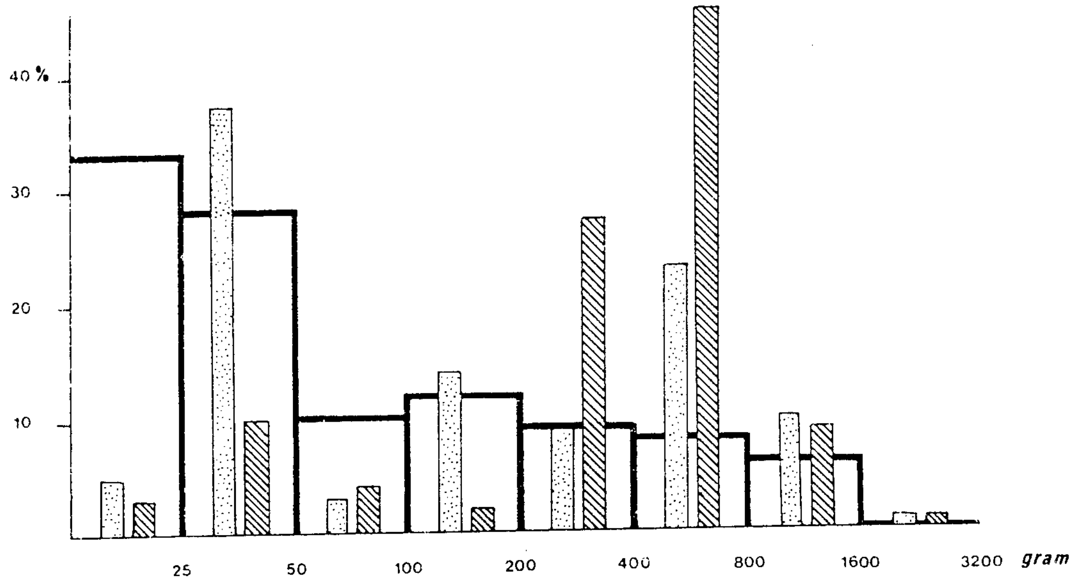


figure 2 Weight distribution of birds breeding in The Netherlands (white columns) and of those involved in collisions with RNLAF jet fighters during the period 1964-1976 (shaded bars) and the period 1977-1982 (dotted bars). Weights in 8 weight classes. Breeding bird totals for all species and 11 million pairs.

For risk assessment and airworthiness standards the weight of the birds concerned is more important than their type. Figure 2 illustrates the weight distribution of Dutch breeding birds compared with all birds involved in collisions with Dutch fighter aircraft (Buurma 1984). Heavier birds are overrepresented. Years with extreme attention to collecting all possible data and analyzing bird remain microscopically (the second period) show bigger proportions of smaller birds. Nevertheless, the smallest birds do not show up, which is explained below.

The damage to aircraft due to bird collision is related to impact speed in the first place because speed quadratically influences impact energy while weight of the bird is only linear related. This is shown in figure 3 for three out of five curves that represent birds weighing over 100 grams. Even birds of moderate weight cause over 60 % of damage when the fighter concerned is on cruising speed. Small birds however do not penetrate the compressed air layer in front of fast flying fighter aircraft. This of course is only valid for the tapered parts of the aircraft. Small birds must be sucked into engines very frequently and perhaps cause delayed and indirect damage. This, however, isn't easy to document.

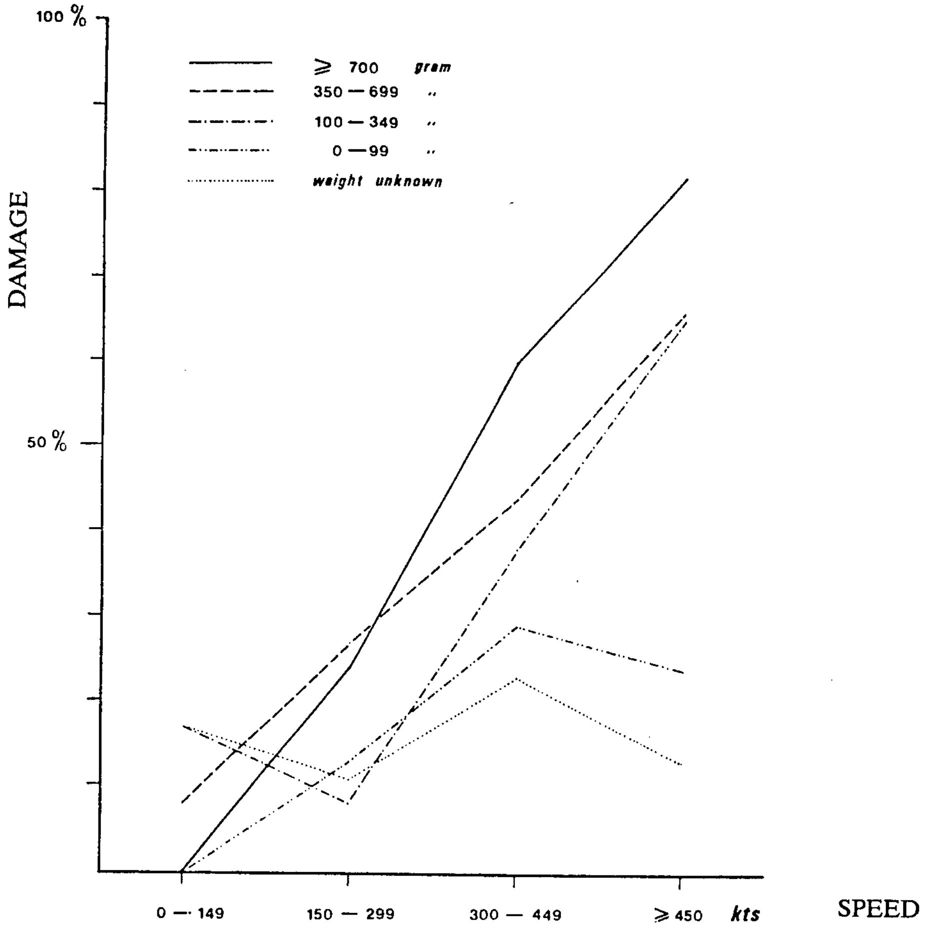


figure 3 Percentage of bird strikes with damage in 5 weight classes of birds against aircraft speeds (RNLAF, period 1977- 1982).

2.1.3. Geographical distribution

As illustrated by figure 4 "en route" bird strikes show a wide spread, better indicating home ranges of the RNLAF jetfighter family than the distribution or flightlines of birds. The only clusters of birds occur in the special low flying areas and shooting ranges where the aircraft increase their bird strike risk by extreme low level flying. By their nature local bird strikes are confined to the direct surroundings of airfields.

figure 4 Geographical distribution of RNLAF bird strikes "en route" (dots) and "local" (squares) for the period 1977-1981. Black dots indicate damage cases, while the black part of the squares indicates the percentage of damage in the "local" bird strikes.

2.1.4. Number of bird strikes over the year

The occurence of birds throughout the year is nicely illustrated by the number of bird strike victims, even if the numbers are fairly small. Clear differences can be found which nicely fit into what is known about the occurence of particular species in farmland (=airfield environment) and the timing of their migratory, dispersal and local flights.

This static information may help to plan certain flying activities of aircraft in order to avoid bird strikes. It becomes even more promising as far as short-term variations of bird presence are concerned: day-to-day variations of the bird strike rate occur, especially within the "en route" category. In certain years the RNLAF experienced clusters of collisions during days with increased migratory activity of birds. Normally, this is of course masked by flight restrictions which prevent a large part of "en route" bird strikes by relatively few cancellations of low level missions.

2.1.5. Frequency of bird strikes with height

We start with the proposition that a proper height distribution can only be expected when we select those flight phases during which the aircraft cover equal distances within each air layer. This is approximately true between 0 and 1500 ft for take-off, final-approach, landing, and, in case of militairy aircraft, touch-and-go and overshoot. In these flight phases the aircraft fly with a more or less fixed angle to the earth surface. There may be some doubt whether the birds are equally sampled in each air layer because low speeds may enlarge the success of evasive actions i.e. especially in the lowest 100 ft. But if the assumptions are reasonable figure 5a illustrates the average altitudinal distribution of birds over the year. It indicates the high density of flying birds within the lowest 100 feet. Because during the flight phases low-level-en-route and high-altitude- cruise certain standard flight levels are practisized figure 5b largely reflects the the heights of those standard flight levels rather than the heights of the birds. Civil aircraft have usually only a "local" problem; the total height distribution from bird strikes suffered by UK airliners nicely fits into the military selection of "local" bird strikes (fig 5a).

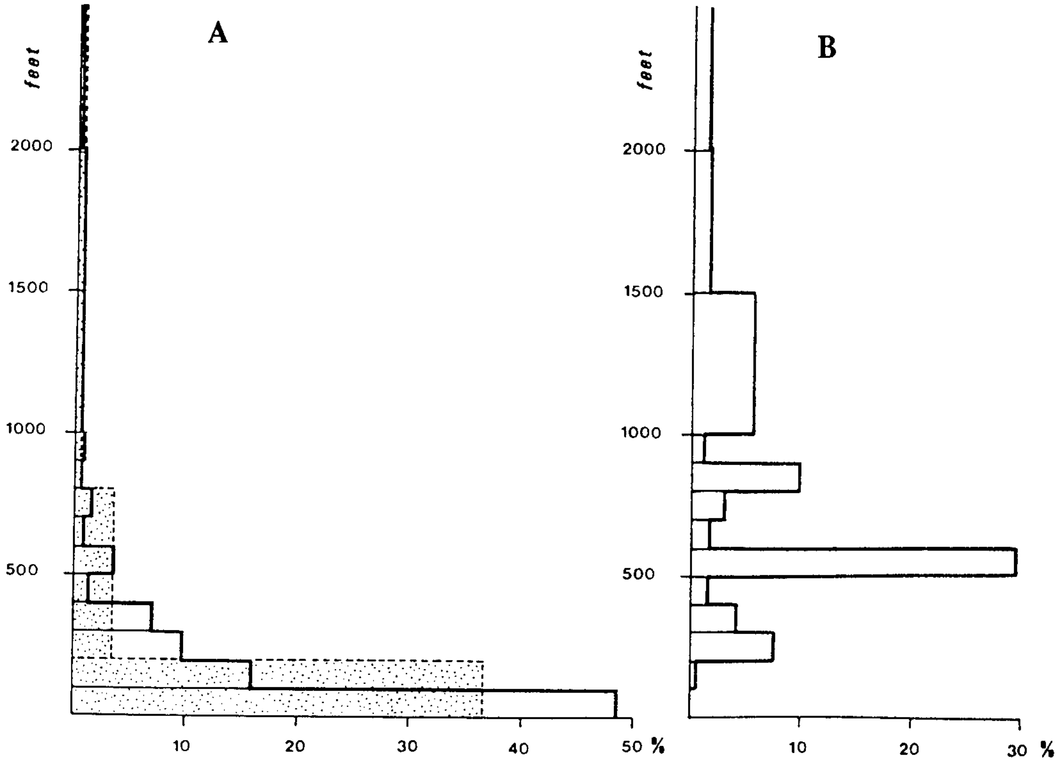


figure 5 Height distribution of RNLAF bird strikes in 100 ft air layers. A: bird strikes during take-off, final approach, landing, touch-and-go and overshoot (n=294). Dashed distribution: civil aviation. B: bird strikes during low level and high altitude cruise (n=466).

2.2. Distribution of flying birds in time and space

Most birds are able to fly, and use this ability for different purposes: when searching for food, in courtship displays, in roosting flights, dispersal and migration. Referring only to potentially hazardous flights in the open air space, this chapter aims at a description of the different types of flight in order to identify the times and locations of highest risk.

2.2.1. Local movements

Thanks to the low radar coverage above flat country radarfilms from Holland (Buurma 1977, 1987) show patterns of intens local bird movement. By day a dense tangle of bird activity can often be observed just outside the region where the radar screen is saturated by ground echoes. These very low flying birds are not easily discernable on the scope of long range radars. Furthermore, moving target suppression facilities of radars working at small scale often eliminate most birds. Outside this zone, i.e. better visible to the radar operator, the following types of higher local bird movements can be observed.

Bird activity in thermals This common type of bird flight shows up regularly in rising air currents around noon and in summer. The movements are often a combination of insect feeding, searching for food patches, display and also migration. The birds concerned are often large soaring birds like buzzards, dynamic gliders as swifts and several other species. These movements produce a serious part of all bird strikes. Extreme examples of this dangerous flying activity may be found in warm and dry regions. In India military flying has been forbidden between 10.00 and. 14.00 hrs because of the risk of colliding with vultures and kites. Another nice example of a bird strike prevention measure is the issuing bird plagued zones in Israel which in fact indicate the narrow routes of those migrants that primarily use thermals (Leshem 1988).

Feeding and roosting flights Depending on the distance to cover, certain foraging flights can be clearly visible by radar. A nice example is the "air-lift" from the Dutch Waddensea towards a huge garbage dump 65 km. inland (figure 6). Each morning some 15,000 Herring Gulls move en masse inland. At noon the first well-fed birds start to return to their normal quarters in small flocks, causing one long line of echoes at the radar screen. This situation appeared so hazardous that the RNLAF had to initiate a re-routing of NATO linkroute 10A. Other feeding flights, also from roosts, are the well known Starling exoduses. Because of the synchronisation of their departure into waves they produce expanding ringlike echoes. During winter in Holland these rings sometimes can be followed up to 50 km. from the roost (fig. 7). In general non-migratory bird activity over land shows distinct peaks around sunrise and sunset. Ducks, waders and gulls often dominate echoes around these times.

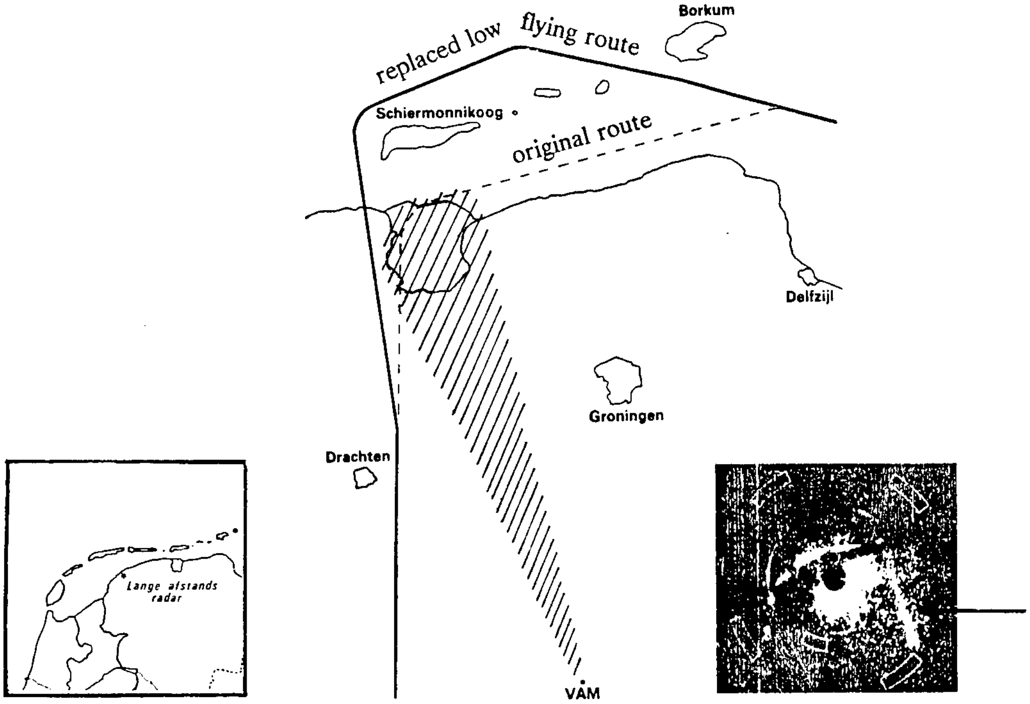
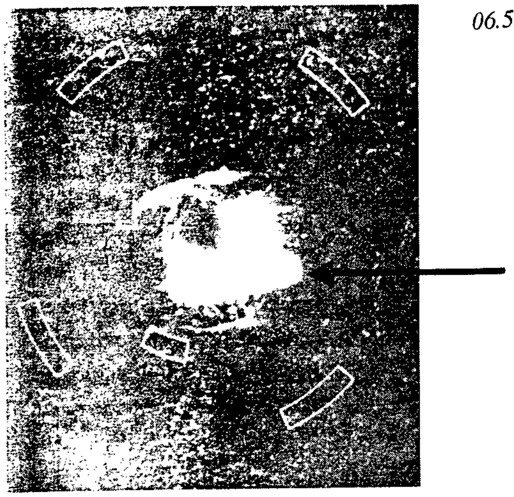


figure 6 Former (dashed) and new routing of NATO link route 10A.
Insert left: map of the northern half of The Netherlands with location and bird range of the radar. Insert right: radar picture (single antenna rotation) with line of echoes from the giant garbage dump (VAM) towards the Waddensea.

Tidal movements In the coastal zone, and especially in the bird- rich Waddensea, tidal flights are very apparent and continue during the night. The birds act like commuters between the tidal flats and the high tide refugia along the borders of the Waddensea.

2.2.2. Migration

Global pattern and seasonal variation Migratory movements of birds occur wherever seasonal changes in climate lead to periodic food shortage. In the temperate regions this is usually the case during the winter period, while in the subtropic areas many birds are short of food during the period of draught; in the tropics food supply may be continuous. In any case migration is pronounced in the transitional phases between "rich" and "poor" seasons. The worldwide seasonality of migration depends on the different type of climates (fig 8 and 9). It is complicated by the historic and the irregular shape of the different climatic belts, and especially by the varying behaviour of different bird species. To reduce it down to a few lines is extremely difficult and (as simplifications are) always wrong to a certain extent. Thus figure 9 gives only a rough impression of the main times of migration in the different parts of the world.



06.53 hr

07.03 hr

07.08 hr

figure 7 Expanding ring echoes caused by starlings (Sturnus vulgaris) leaving their roost in successive waves.

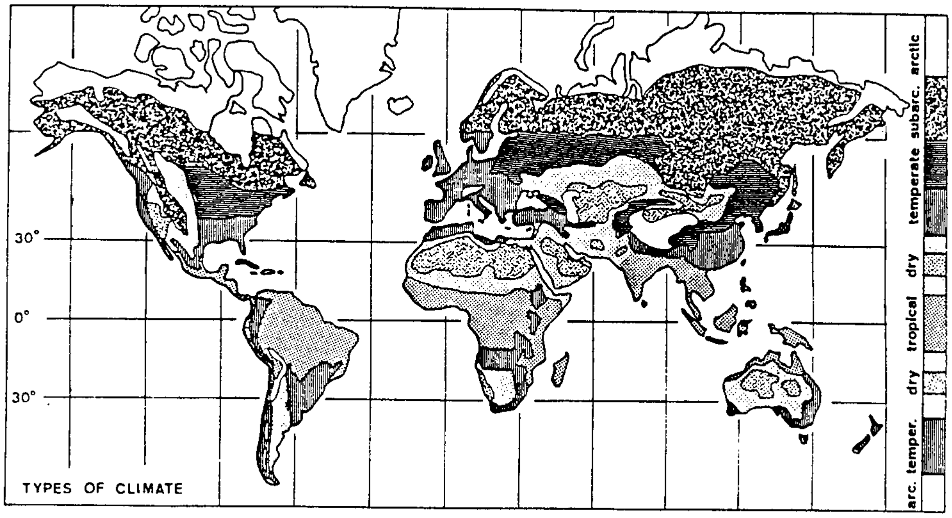


figure 8 Different climatic belts with seasonally changing food supply are the ultimate cause of bird migration.

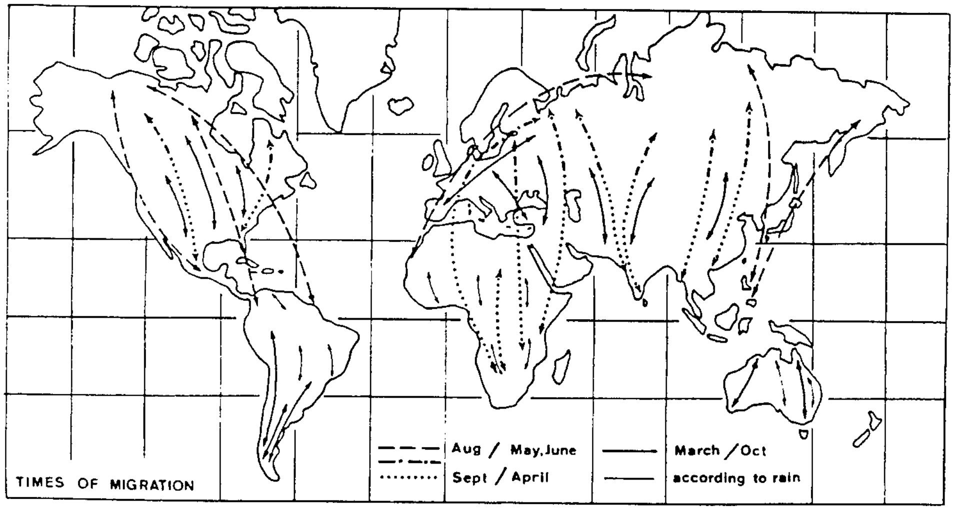


figure 9 The transitional phases between rich and poor seasons are the times of peak migration.

Diurnal cycle Short distance migrants are able to undertake their migratory flights within the course of their normal activity; most of their migration takes place in the first hours of daylight. Somewhat later in the day, when the warming effect of the sun causes thermals, large soaring birds enjoy their best time of migration. At the same time of day flocks of pigeons or rooks may be on the wing as well as swallows and martins, using suitable places for flight-hunting. During the afternoon migratory activity is reduced (figure 10). Most long distance migrants (except soaring birds and flight hunters) take off for their extended flights around dusk. The maximum intensity of night migration is usually reached towards midnight. Nocturnal migrants may continue their flight until dawn and even during the following day when at daybreak they find themselves over the ocean or other inhospitable areas. Diurnal migration usually consists of flocked birds (except birds of prey), while nocturnal migrants are more or less spaced: in passerines the nearest neighbour distances are usually larger than 50 m (figure 10).

Day to day variation and weather Migratory intensity varies day- to-day. In temperate regions this variation is mainly due to weather. Bad weather (precipitation, fog) suppresses the migratory activity of many species. If poor weather persists for several days, the number of birds physiologically ready for migration increases. A change to favourable waether may release waves of migrants. On the other hand, the number of birds ready to migrate declines when good conditions for migration persists during several days.
Peak migration usually occurs when a high-pressure area lies to the right and/or a low-pressure area to the left of the main vector of migration (figure 11). This synoptical situation is characterized by warm southerly winds in spring and by cold northerly winds in autumn. In statistical sense 50-70% of the variation in migratory intensity, as seen by radar, can be explained by correlation with combined weather factors.

2.2.3. The spatial distribution of migrants

Broad-front and concentrated bird movements Migration over areas without pronounced topographical features may consist of a flow of birds progressing on a broad-front. Its dimensions depend on the width of the breeding or assembling areas of the birds concerned. However, topographical features, such as coastlines, mountains or valleys deflect this stream to some extent and lead to local or regional concentrations. Strongest "leading-line- effects" occur by day in the lowest air layers (Buurma & Van Gasteren 1989). Because this is the part of the migratory process most easily detected by the field ornithologist there is a strong tendency to exaggerate the amount of clear routes in bird migration maps. A better approximation of the geographical shape of migratory flyways is presented in the colormap (pag 27).

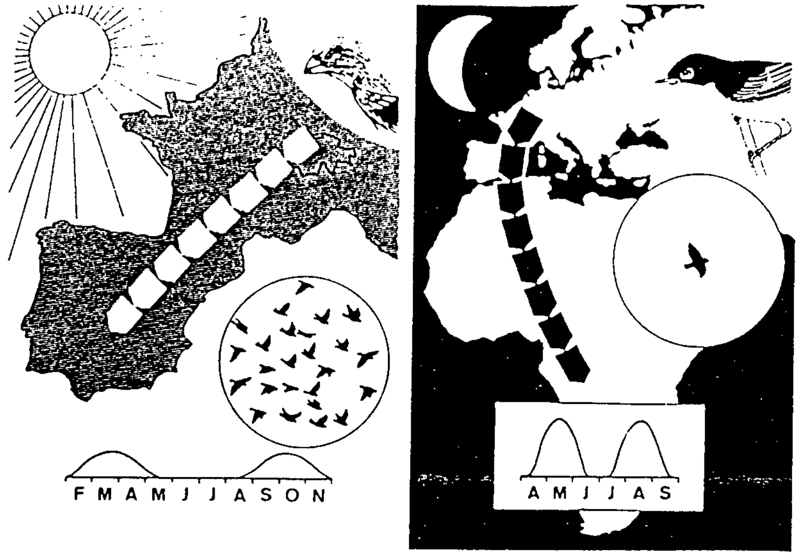
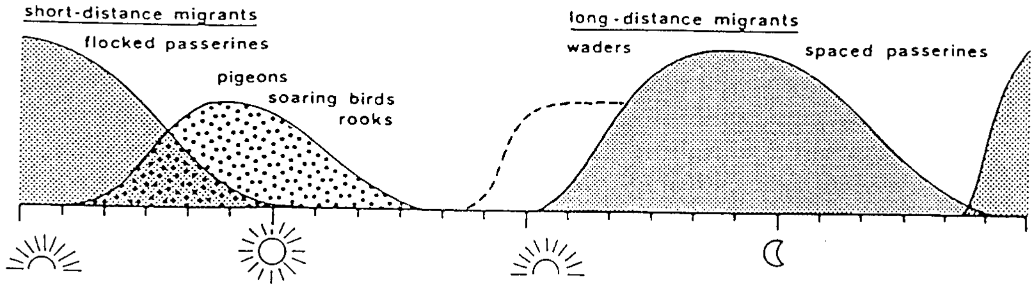


figure 10

Diurnal migration consists of: a) granivorous short-distance migrants (as finches, rooks, pigeons) migrating in flocks during the first hours of day-light, early in spring and late in autumn, b) soaring birds (as raptors and storks) migrating around noon, c) flight-hunters (as swallows, martins and swifts) and d) species perfoming long single flights like waders and geese.

Nocturnal migration consists of: a) insectivorous long-distance migrants (as warblers, flycatchers, some thrushes) migrating in loose formations or singly, late in spring and early in autumn, b) waders and most waterfowl, often already departing 1-2 hours before sunset in clear flocks that remain dense during the night.



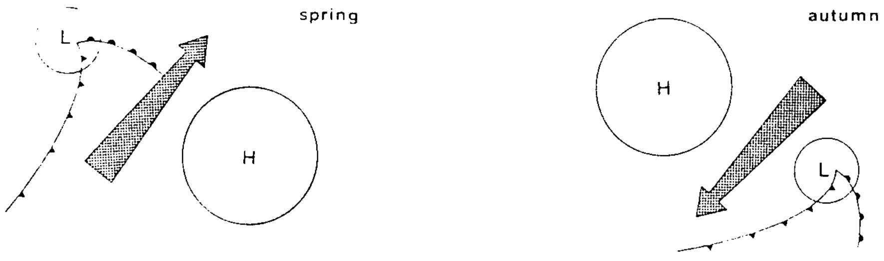


figure 11 Peak migration in relation to the simplified synoptical weather map.

The height of bird flights The overall average altitude distribution of migration above the European mainland shows highest concentrations of birds below 500 m. AGL. Above the Swiss lowlands this lowest flight level contains a mean percentage of about 60% of the day migrants and about 40% of the night migrants (fig. 12, Bruderer 1971). In eastern Holland, where the countryside is really flat, the proportion of extreem low level migration is even higher (fig. 13, Buurma, Lensink & Linnartz 1986). The birds concerned seem to seek for a compromise between flying low for contact with vegetation and conspecifics, and headwind avoidance, and rising for overview. Only about 10% of the birds fly at levels above 2000 m ASL. Highest flying birds are observed at altitudes of about 5000 m ASL. Above the Alps the upper limit of migration is slightly increased (5500 m ASL). Above the ocean, large deserts or very high mountains mean levels of migration are lifted up and highest migrants may be found at altitudes of 8000 m ASL (occasionally even higher).

In disturbed weather the altitude of migration decreases. Close to a pronounced frontal system, nearly all the birds may be concentrated within the lowest 500 m (fig. 14A). In fine weather flight levels are generally higher than in the overall mean distribution. Highest densities of birds may be found at levels up to 2500 m above flat country in central Europe. The height is primarily determined by the distribution of winds: during the first hours of the night birds seem to search for favourable flight levels. During the following part of the night they concentrate at altitudes with strongest tailwinds or weakest side- or headwinds.

The reason for the high proportion of october migrants migrating below 100 m over Holland (fig 13), and also over the northern parts of W. Germany, could be an adaptation to the frequently occurring head and side winds in that region. In flat and smooth countryside the drag of the air flow by the earth surface is less strong and more limited in height than in hilly countryside. Therefore, birds avoiding headwinds should fly extreem low. As a result, the "understream" of migrants is often badly detectable by radar.

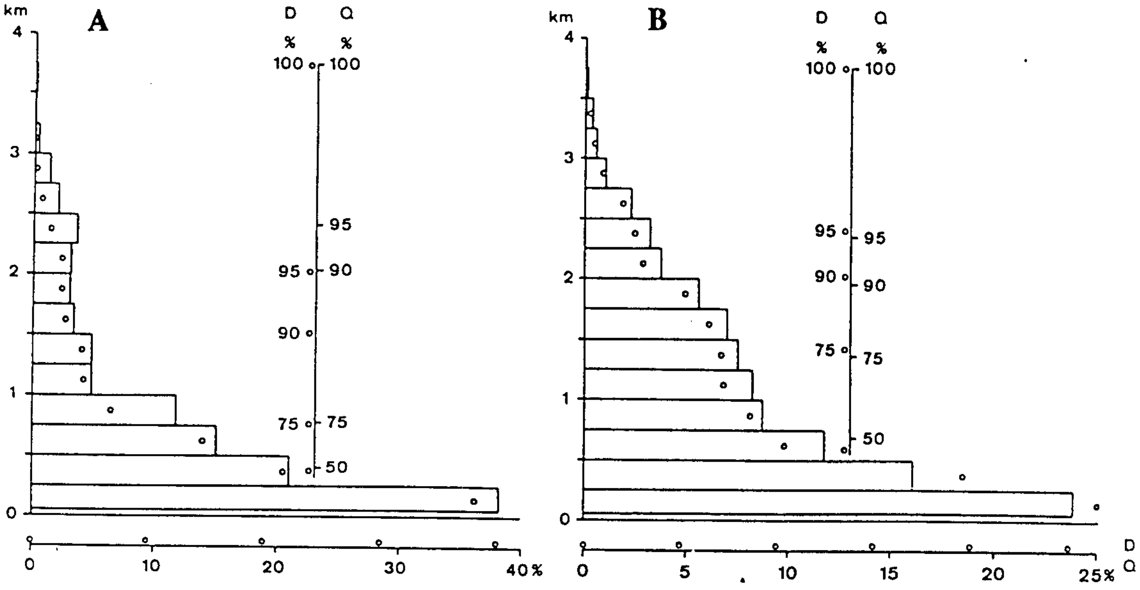


figure 12 Mean height distribution of migrating birds above the Swiss lowlands (A: by day, B: at night). D is the density of migration (birds per volume, indicated with circles), Q is the frequency or traffic rate (birds crossing a line per unit time, indicated with columns). Usually the frequency is higher than the density (as a result of the preference for tail winds, especially at high levels).

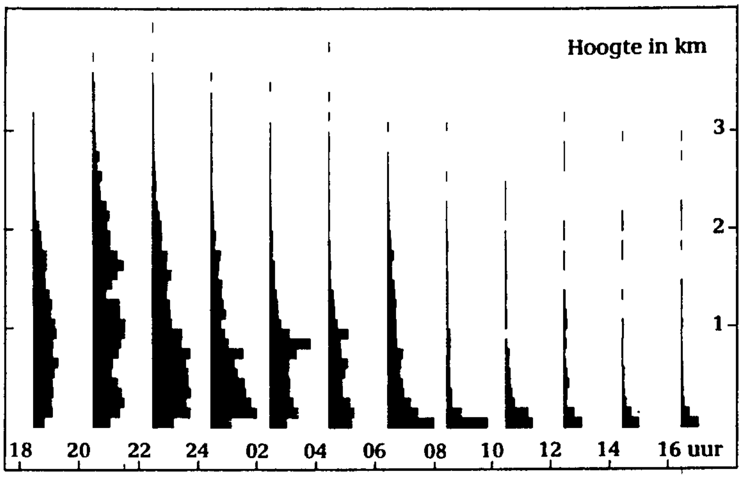


figure 13 Altitudes of bird echoes around the clock as detected by the pencil beam of an X-band Flycatcher radar scanning in a vertical plane perpendicular to the main migration stream over Eastern Holland. The samples were taken hourly from 9 till 18 oct 1985 and were averaged in two hour classes.

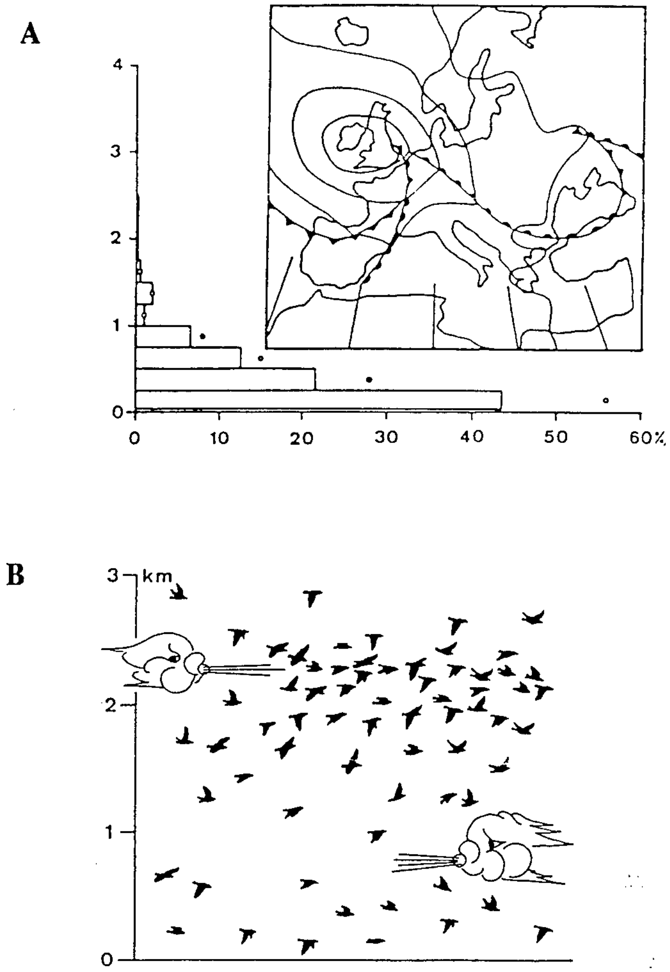


figure 14 A: migration at low levels in the neighbourhood of frontal systems. B: in fine weather birds search for the best tail wind and avoid strong head winds.

2.3. Evaluation of bird strike risks

Aircraft speed is the major factor with respect to aircraft destruction during a bird strike. Further, the altitudinal distribution is the most important factor with respect to the chance to suffer a bird strike. The combined effect of these factors causes the evident dichotomy in fig. 15. Herein all Dutch military bird strikes have been sorted according to aircraft speed. We firstly recognize the group of bird strikes ocurring during start and landing. These low-speed flight phases constitute only a minor part of the total flying time, but the high number of local birds on the wing or scared from the ground causes a substantial amount of incidents. The opposite is true for the second group. While on average bird numbers at heigher flight levels are relatively low, the time that jet fighters spend on cruising there at high speeds constitutes the major part of the flight duration. As a result a similar amount of bird strikes was found. The relative lack of collisions at intermediate speeds mainly results from the flight envelope of the aircraft. According to fig 15 by far the highest proportion of damaging bird strikes occurs within the en route group. Low level training missions are therefore a major concern.

2.4. Reduction of bird strike risk

One may think of the following flight restrictions under bird- rich conditions:

a. no flying below a given altitude
b. flying elsewhere
c. reducing speed
d. measures near air bases

a. *Altitude restrictions* From the descriptions above it may be concluded that flight restrictions with respect to altitude should be considered first. It is however a difficult task to determine the right minimum flight level for aircraft. Depending on prevailing wind conditions the ceiling of bird activity may justify minimum flight levels of 1000, 2000, 3000 or 4000 ft, as often imposed by the German Air Force. However, this should be based on correct altitude measurements by means of radar. Such measurements are seldom performed, usually only within special ornithological studies. Operational use occurs, as far as we know, only very incidentally. As will be seen in the next chapters several suggestions for specially built radar-bird- detectors have been published.

Several West European countries not having the appropriate radars or the knowledge and/or procedures for joint use of operational equipment, confine themselves with disseminating bird warnings without altitudinal information. Usually a flight restriction of 2000 ft minimum flying height is imposed but this reduces drastically, if not completely, the value of low level training.

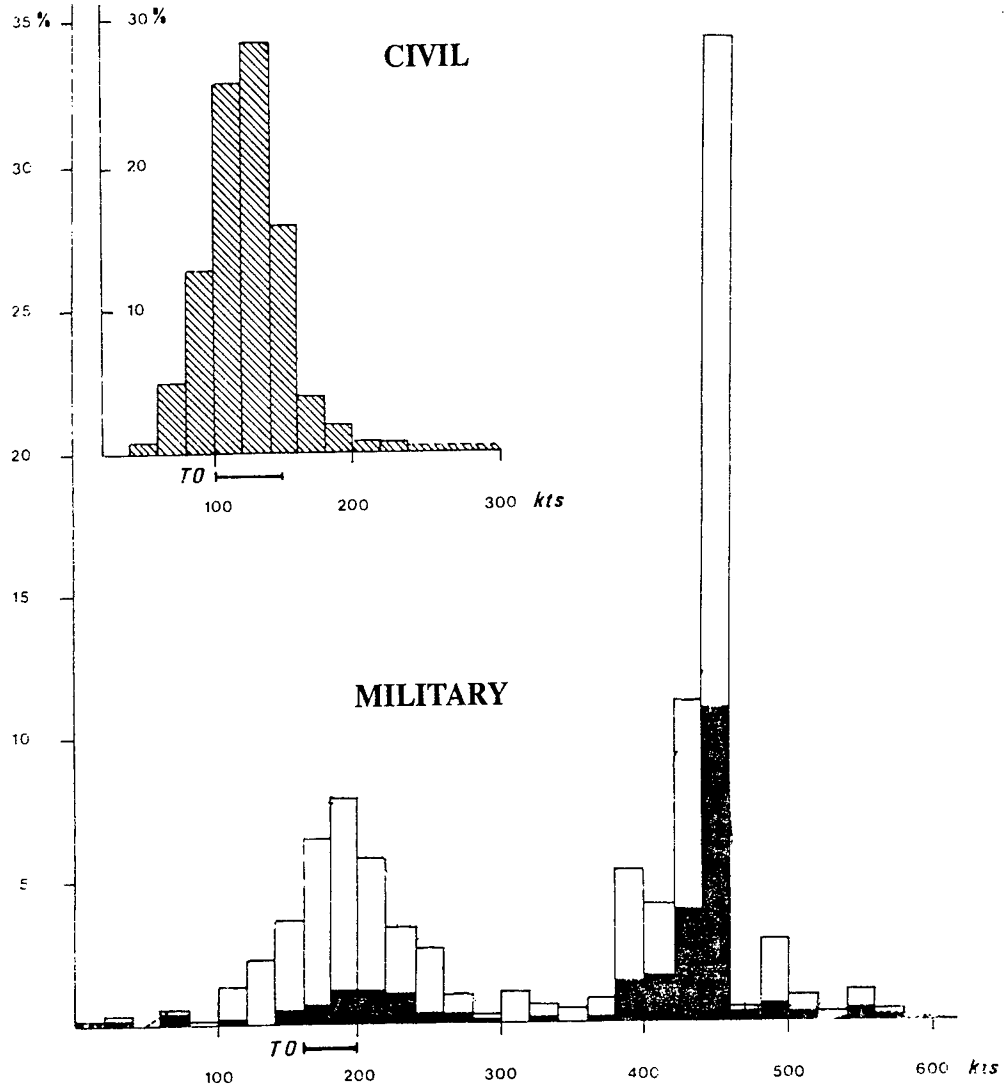


figure 15 Percentual distribution of RNLAF bird strikes over aircraft speeds (1977-1982). White parts of columns without damage, black parts with damage, total 100%. Percentual distribution of civil bird strikes taken from Thorpe 1983.

b. *Geographical flight restrictions* High level bird migration therefore may urge to reschedule flight plans. A shift towards completely other low flying areas may be a solution for large countries. The USAF operates a model helping to select the safest low flying routes and areas. However, in Europe alternatives are not available to the same extent. Germany disseminates listings of bird densities per "georef". This format has recently been adopted by NATO members.

c. *Speed restrictions* This third option may help in two ways. First, it drastically reduces impact forces. Second, it gives the birds a better chance for succesfull evasive manouvres. One should keep in mind that a collision at 320 kts with a 4-pound bird equals a collision at 450 kts with a bird of 2 pounds. Birds over 2 pounds are 50 times more numerous than those weighing 4 pounds or more. Thus, lowering the speed by 100 kts in this example lowers the damage treshold by 50 times, all else being equal.

d. *Measures near air bases* As shown by the insert of figure 15 civil bird strikes vs aircraft speed resembles the distribution of local military ones. Both sets of data show a grouping around take-off speed, indicating the effect of the high bird densities in the lowest air layer and on the airfields. Bird strike prevention in the sense of air traffic control should in this case concentrate upon the horizontal distribution of birds at and nearby airfields, not so much on altitudes. Already 25 years ago Schaefer (1969) explained that ground radars should be used to detect birds, even when sitting on runways. Recently the possibilities for joint use of this type of equipment have increased and some firms even advertise the potential.

Prevention of bird strikes "en route", such as implemented in military low level operations with jet fighters, is also an option for "small air traffic" including sport flying and helicopter operations. Here one should try to profit from existing military bird warnings. Also low flights over bird sanctuaries and bird concentration areas mapped in the Aeronautical Information Publications should be avoided.

In summary The chance of suffering a bird strike will never be zero as long as man continues to fly. When the number of birds in the air would always and everywhere be the same, even no reduction would be attainable at all by means of avoidance plans. Fortunately, however, the presence of flying birds fluctuates to a very large extent. This makes avoidance of bird-dense parts of the air space and periods of intense bird traffic a realistic option. Consequently, the aim should be to optimize the balance between a maximum of flight safety and a minimum of flight restrictions. The more precise the presence of birds in the air can be measured, the more detailed restrictions can be disseminated, and, as a result, the smaller the impacts on operations will be. This emphasizes the need to choose appropiate detection equipment, such as certain radars, and, simultaneously, to organize an optimal "ad hoc" use of the information gathered. When such radarmeasurements are also stored and analysed, general trends and correlations will be found which might be used as parameters in a model to predict bird movements. An operational forecast system would facilitate early adaptations of flight programming. However, predictions by definition introduce uncertainties; it seems unrealistic that a forecast model at the moment would make "ad hoc" registrations superfluous. The ideal situation therefore seems to be a combination of both.

3. GENERAL ASPECTS OF BIRD DETECTION BY RADAR

3.1. Introduction to some radar principles

Radar stands for RAdio Detection And Ranging. The equipment radiates electromagnetic waves, usually formed into pulses (packages of radio energy). By alternating pulse transmission with receiving echo returns the radar is able to range objects. Distances are calculated by using pulse return time and wave propagation speed (constant 3*10 m/sec). The bursts of microwaves are funneled into a beam, enabling the radar to measure angles. The shape of the beam depends upon the shape of the radar's antenna. Finally, certain properties of the echoes offer clues to their identification.

The range at which an object of certain size can be detected is calculated by means of the radar formula and depends on many variables and circumstances. For birds this distance may vary from a few hundred meters in small ship radars up to over 150 km in case of long range surveillance radars.

Scanning the beam through the airspace opens the possibility to build up a two or three dimensional picture of the distribution of those objects reflecting enough energy. Beam shape and scanning procedure determine how we monitor the air space. In the well-known ATC (air traffic control) radars (see cover), which rotate their beam in the horizontal plane, echoes are represented on a PPI (Plan Position Indicator). This circular monitor often includes the projection of a simple geographical reference map. Mixing map and radar video facilitates the interpretation of the live display. After having stored the radar information time- lapse on film or electronically we may get an excellent time- compressed summary of bird movement.

ATC radars have beams wide in the vertical and very narrow in the horizontal plane (fan-beams). They offer a high resolution in geographical sense, but exclude the discrimination of altitudes. Nodding height finders use the vertical type of two-dimensional scanning (cf fig. 16). A third possibility is the so-called pencil beam. Such narrow beams offer high-resolution but a large amount of scanning time is needed in order to build up a three- dimensional picture. The most simple application of pencil beams described in this booklet is mere ranging: when fixed vertically it can be used to assess the altitude distribution of birds in airspace. Its most complicated use is as a tracking beam, fixating a target during its flight and describing its three dimensional flight path.

The radar types most frequently used as bird detectors are pulse radars, which usually are classified in three or four families, according to frequency band (and therefore wavelength): table 1. They usually represent classes of equipment differing in power, size, range and resolution.

A

band	L	S	(C)	X
wave length (cm)	23	10	(5)	3
frequency (MHz)	390 - 1550	1550 - 5200		5200 - 10900
radar types	* air traffic control	* air traffic control * airport surveill. navigation		* precision approach * tracking * ship

B

wave length	N/D	counting range nM	subsaturation density (/nM2)	min.det. height ft	source
23 cm	N	20-30	0.4-1.0	600	Nisbet 1963
	D	15-25	1-2	?	Geil et al 1974
10 cm	N	30-40	ca 35	300	Buurma 1986
	D	30-40	ca 10	300	id
	N	10-20	20-25	var	Gauthreaux 1977
	D	10-20	6-8	var	id
3 cm	N	1-2	250	75	Buurma &
	D	1-2	150	75	Van Gasteren 1989

table 1 A: The old-fashion classification of radars according to wavelength. B: Diurnal (D) and nocturnal (N) "subsaturation" densities of bird echoes on the PPI of search radars and minimum detection height. Ornithologists watching over the shoulder of the radar operator might find this bird resolution in the raw video of older radars. The synthetic video of many modern radars will produce fewer bird echoes while raw video often is not available anymore. These partical experiences do not reflect theoretical possibilities which may be exploited by modern electronic (bird) echo extraction.

Instead of simply using the echo returns, pulse doppler radars also measure the frequency modulation caused by the speed of the targets relative to the radar (radial velocity). This provides the possibility to separate moving targets from stationary objects, even though the echoes of the moving targets are very weak compared to the clutter. Radar detection of low flying birds within an obstacle rich environment is only possible when the Doppler effect is exploited. But certain limitations with respect to targets with very low speeds (song birds!), as well as the fact that only radial velocity is the selection criterion, have both serious draw-backs.

The Doppler effect is also the basis of Continuous Wave (CW) radars. Instead of rapidly switching between transmitting strong pulses and receiving weak echoes CW radars "speak" and "listen" simultaneously. In its simplest form they "hear" speeds of moving targets but do not measure distances. By applying FM and other principles CW radars can also range objects. However, multiple target detection is done easiest with pulsed radars.

3.2. Detection chance and the quantification of bird echo densities

3.2.1. The radarformula and maximum range

The maximum distance at which an object is detectable can be derived by using the radar formula:

$$R_{max} = \sqrt[4]{\frac{P\,G^2\lambda^2\sigma}{64\,\pi^3 P_{min}}}$$

Maximum range (R max) is positively correlated with transmitter power (P) and antenna gain (G, the multiplier factor due to concentration of microwave energy by the antenna; G is squared because both transmitted and received energy is concentrated), the wavelength (λ- lambda) and the echoing area (σ- sigma -, also called radar cross section) of the target. The maximum range is negatively correlated with the minimum receiver power (Pmin) required to produce a detectable signal. P, as effective power, includes the Pulse Repetition Frequency (PRF). When this PRF is chosen high, the interval time between two pulses is short. This short interval limits the maximum distance at which a target can be detected, but will never limit the maximum distance of small targets like birds. In practice we need the effective range of the radar for birds instead of the theoretical maximum range.

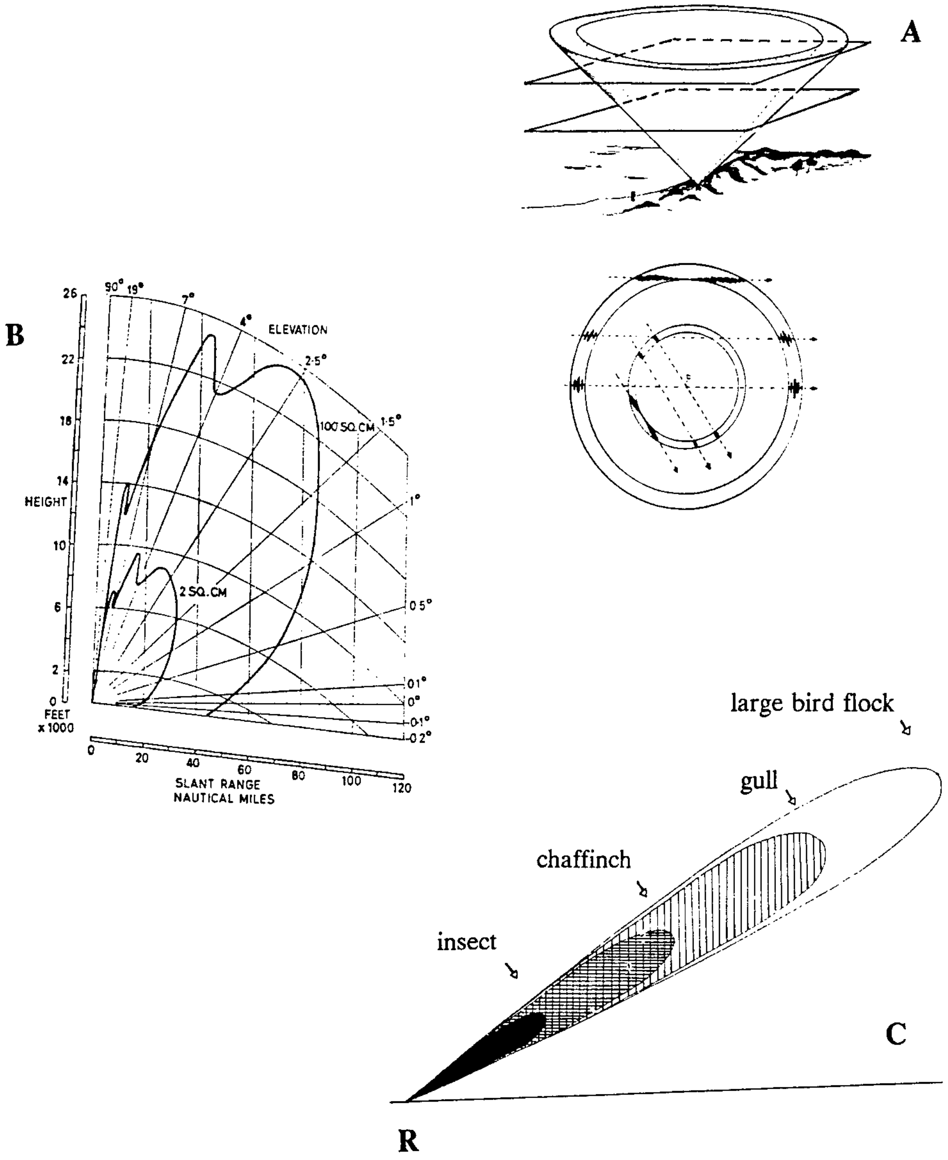


figure 16
A: conical scan of a pencil beam (upper part) and two horizontal sections (lower part) providing ringlike detection.
B: Radar performance diagram (after Eastwood 1967).
C: Relative bird ranges of a pencil beam.

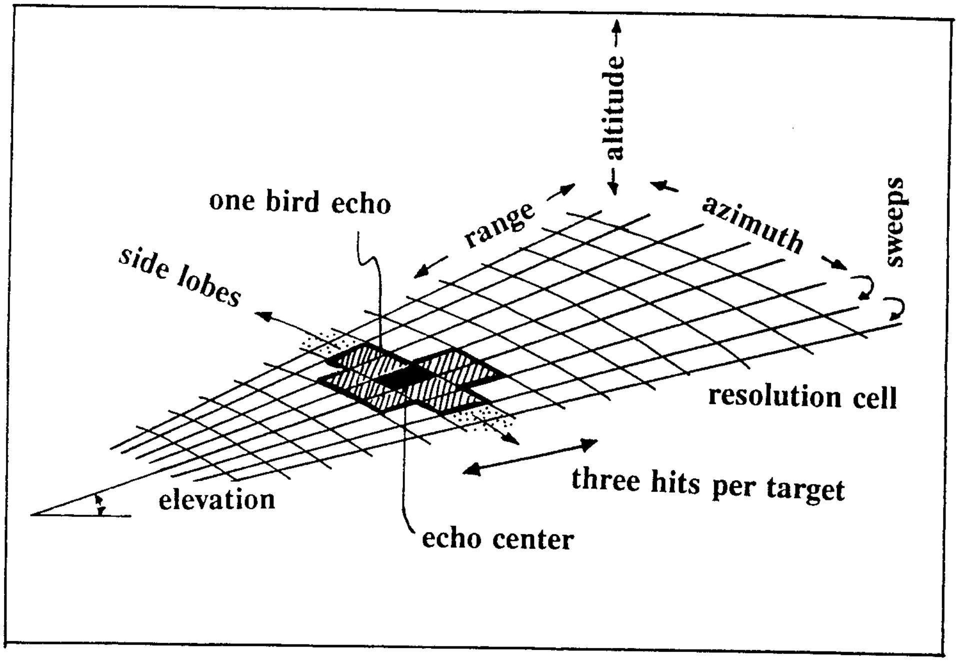


figure 17 Terms for the description of resolution and echo properties.

The pulse power of the radar, the echoing area of the target and the spreading of the electro-magnetic energy are the crucial factors limiting range. The strength of the returning echo decreases with the 4th power of the distance radar target. In other words: to double range we need a radar with 16 times more power. But also: accepting a little bit less range means a lot less power required. And if one bird has a radar cross section which is half of another's, it can be detected up to 84 % of their maximum detection range.

3.2.2. Range and resolution

Usually radars work at such large scale that they enable us neither to count birds within groups nor to recognize the shape of the flock. Even the density of flocks may be obscured when the screen of an air traffic control radar is saturated with bird echoes. The smallest volume of air that can be meaningfully measured with a radar is called "resolution cell" (fig. 17). The resolution of a pulse radar depends theoretically on pulse length and beam shape. These values are not chosen independently, and of course relate to the type of application of the radar.

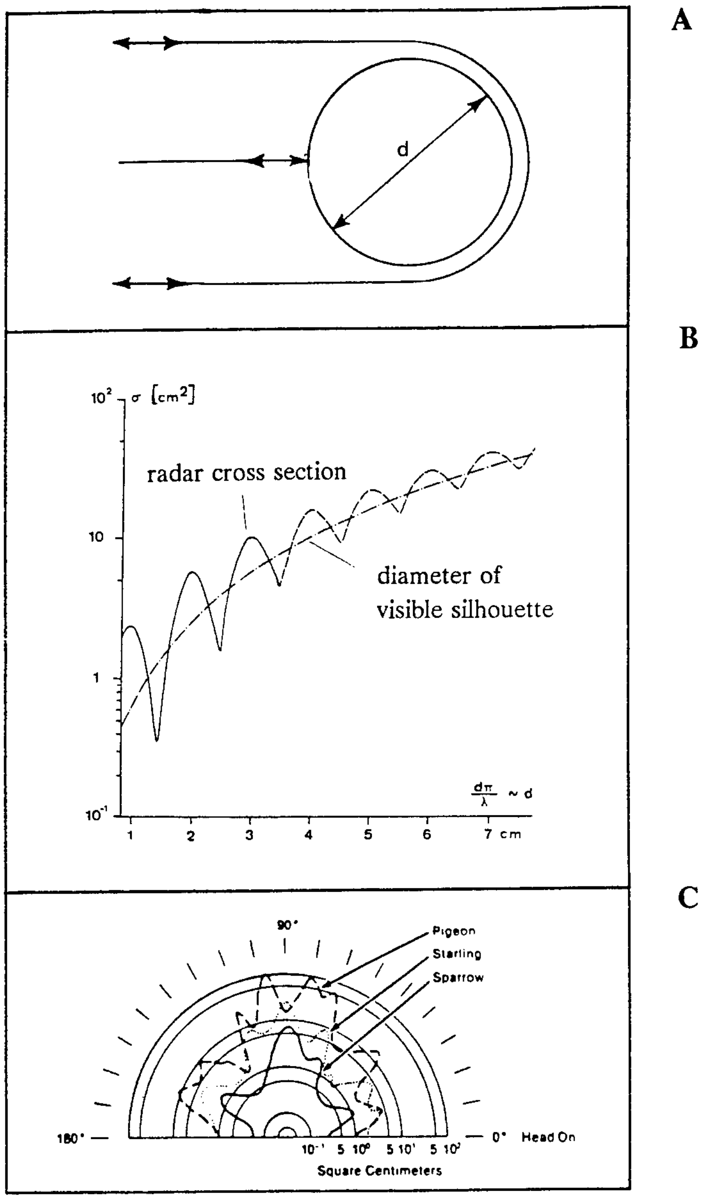


figure 18 A: Extreme simplified model to describe the relation between fluctuations in echo strength and wingbeat pattern. Directly reflected energy is supposed to interfere with energy curving around the target. Different path lengths of both energy components result in phase shifts. Because the circumference of the bird fluctuates with wing muscle contractions also the path length does so, causing the phase shift to vary.

B: Radar cross-section (σ) of targets depending on the ratio circumference - wavelength (λ). For 3 cm radars this ratio correspnds roughly with the bird diameter in cm. As a result of the interference bird diameter and amount of reflected radar energy are by far not lineary related. When the circumference of the target is a full number of wavelengths, then the echyo is strong. When the circumference is a half wavelenght shorter or longer the echo is weak. In larger targets the silhouette for radar waves and visible light shows closer correspondence.

C: Radar cross-section polar diagrams of three bird species. Observing wavelength is 3.5 cm. Linear polarization parallel with the body axis. Approximate target weights: pigeon (Columba livia) 300 g; starling (Sturnus vulgaris) 80 g; house sparrow (Passer domesticus) 27 g (from Edward & Houghton 1955).

As can be seen in the radar formula, a long detection range can be realised easiest with long wavelength. But long waves are more difficult to funnel into a narrow beam and necessitate large antennas. Moreover, the greater the distance to cover, the slower the beam should scan. If the pulse has to travel a long distance (low pulse repetition frequency), then apart from the divergence of the beam, the increment of scan also reduce angular resolution. High resolution in range is difficult to achieve in combination with large scale operation. An extra difficulty is that a high amount of energy necessary for long distance ranging is difficult to squeeze into a very short pulse. Nevertheless, several modern (military) search radars have been equipped with pulse compress modes reducing pulse length by a factor 60, thereby enlarging range resolution.

3.2.3. radar cross section

The radar cross section is defined as "the (fictional) shadowing area of the target intercepting that amount of power which, when scattered in all directions, produces an echo equal to that of the target. The electromagnetic waves are reflected by objects having different electric and magnetic properties than the surrounding medium. The water in blood and muscles of the bird body are most reflective while bones and feathers seem to contribute only little to the echo.

The average intensity of a bird echo roughly equals the echo of a sphere of water with the same weight as that of the bird. This echo strength is half of that of a metal sphere of the same size, which offers a possibility of calibrating the radar equipment.
In the case of big targets (compared to the wave length of the radar) the reflected energy is more or less proportional to the shadowing area of the target; the known optical principles are valid. When target size is in the same order of magnitude as the wave length the echo strength does not correlate in a simple way with target surface.

Figure 18A gives a model explaining the interference of electromagnetic energy partially curving around and partially reflected directly by the sphere with a circumpherence in the same order of magnitude as the wavelength. The two energy components, travelling different distances become out of phase. The resulting echo strength may vary up to a factor 16 when the circumference of target and wavelength are more or less the same and the circumference varies by half of the wave length. Figure 18B indicates how the ratio of both results in varying radar cross sections (cm2).

Clearly a bird's body is a more complicated target than a sphere. A spheroid or a "cigar like" body may be slightly better approximation. In the case of the "spheroid-bird" the echoing area is larger in side view than in head-on or tail-on view. As explained above small differences in silhouette size may result in larger differences in echoing areas. A graphical representation of these echoing areas as "seen" under all angles with the bird's body axis is called a "polar diagram". Fig 18C gives an example. It shows

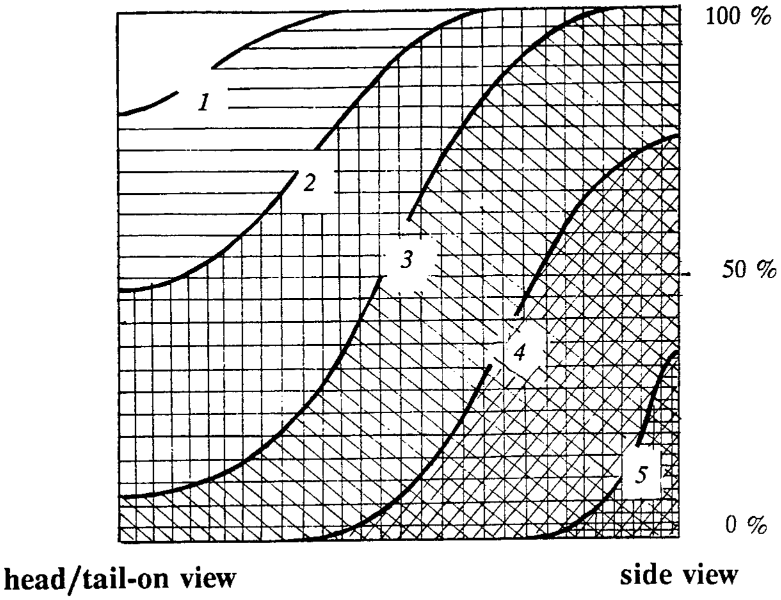


figure 19 Echo density during broad front migration at night at the PPI of a 3 cm search radar in relation to distance (1 nearby - 5 far away) and aspect (birds seen in head/tail on view - side view). Maximum density taken as 100 %.

enormous fluctuations and may give the impression that dealing quantitatively with detection probabilities is very complicated. We cannot deny this, indeed, but when processing a radar picture with hundreds or thousands of bird echoes an average bird size is taken into account. Small individual differences in size, wingbeat phase and flight direction smooth the average polar diagram of the whole cohort. As a result we will find a smooth curve representing the head/tail view - side view ratio of detection chance in statistical terms (figure 19, derived from Buurma & Van Gasteren 1989). We can use such empirical curves to correct our measurents. It is clear that we need information on the heading of the birds in relation to the angle at which we see them within the sampling window on the radar screen.

Contractions of the flight muscles influence the diameter of the bird body. This results in remarkably strong variation of received echo strength. When a tracking radar follows a single bird, its Automatic Gain Control (AGC) compensates for these fluctuations in order to get a constant signal. When we record these AGC power variations we get valuable information on the wing beat pattern (see 4.5).

3.2.4. Radar horizon

In order to detect an object above the horizon at a distance of 50 km it must be 100 m above the surface. At 100 km an object must have a height of 300 m! Loss of visibility behind the horizon does not increase linearly. Radar waves normally slightly curve behind the visual horizon but radar detection at long distances is anyway limited in the same manner as visual observation. The height/range relation is therefore graphically incorporated in the conventional Vertical Performance Diagram.

In the fictitious example of figure 20 we included the bird range of the three classes of pulse radars of table 1. Inability to detect low-flying targets behind the radar horizon is a problem, especially of long range radars. Because these radars also have the largest bird detection range, they miss many birds. Moreover, if the lowest air layers contain most flying activity, as is usually the case in the European low lands, the bird density on

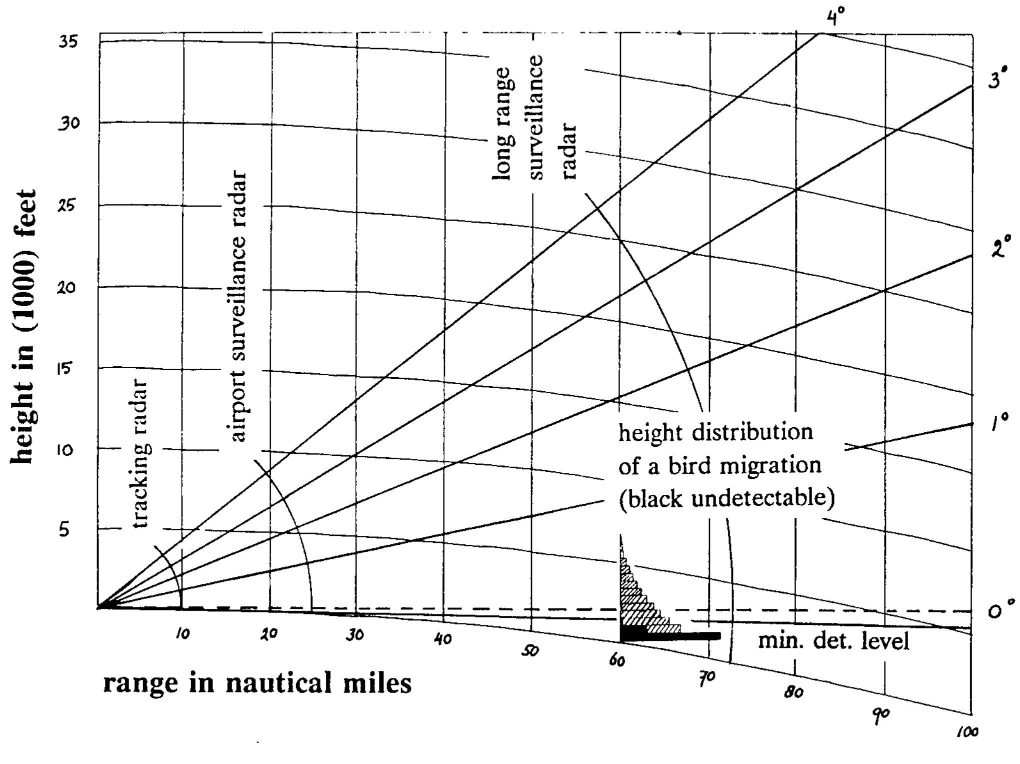


figure 20 Vertical coverage in relation to distance for three important classes of search radars depending on the width and elevation of the radarbeam.

a PPI of long range surveillance radars soon diminishes to very low values when going from center to periphery. Because at short distance echoes of objects on the ground saturate the radar display, the effective region for proper bird detection becomes very limited. Low level bird migration (say below 50 or 100 m) may be totally "overlooked", and therefore radar is usually described as complementary to the visual bird observer who will start to miss small birds at 50 m, even when they pass overhead.
As a result of the horizon effect, the thinning rate of bird echo density with range in long range radars often is not primarily caused by the decrease of sensitivity but rather by the altitudinal distribution of the birds. Therefore, samples of the bird flying activity taken by long range radars are always biased with respect to height. Provided the radar beam propagates along straight lines we can turn this in our advantage by calculating the intersected portion of the air space at several distances. Comparing the bird echo densities offers a indication of the altitudinal distribution of birds. Calibration of such indices by means of small radars and/or visual observers is needed.

A special problem with respect to 3-D measurements by means of radar is the so-called anomalous propagation (fig.21). The radar beam may be reflected against or funneled by discontinuities in air density, such as inversion layers. As a result the radar looks behind the radar horizon and the PPI is spoilt with extended fields of groundclutter. This may totally disturb an index of bird migration intensity because many more bird echoes may be received, provided they can be separated from the ground clutter. The solution to this problem is to check always whether the clutter pattern is normal and, if not, to cease measuring. Fortunately, the frequency of "anaprop" is not prohibitive. Furthermore, the phenomenon is predictable to a certain extent and is usually easy to recognize.

3.2.5. Polarization, STC, FTC and other circuits

So far, we dealt with physical effects in (bird) detection by an unfiltered radar signal. This unfiltered signal is not always sufficiently clear for operational use. Often the amount of unwanted echoes, including "bird clutter", can be so predominant that aircraft detection and tracking becomes impossible. Therefore, several techniques and filter processes have been developed to suppress unwanted echoes. We have to know their influence upon bird detection chance, especially when the radar is simultaneously being used for other purposes. The most important techniques are discussed below.

Polarization: Electromagnetic radiation is normally polarized in either the horizontal or the vertical plane. Both are said to be linearly polarized. Often radars can also be switched to circular polarization. The effect is a reduction of the reflectivity of sphere-like bodies, such as rain drops. Small birds being more or less spherical water bodies will give weaker echoes too. The reduction of recorded bird echoes is said to vary between 11 to 54 %, depending on radar and range. Small song birds are more affected by circular polarization than bigger birds. Dutch electronic counting results were corrected with a factor 1.6. Vertical and horizontal polarization also differ slightly ; the chance of bird detection being somewhat better in case of horizontal polarization (1/2 unit in 0-8 scale).

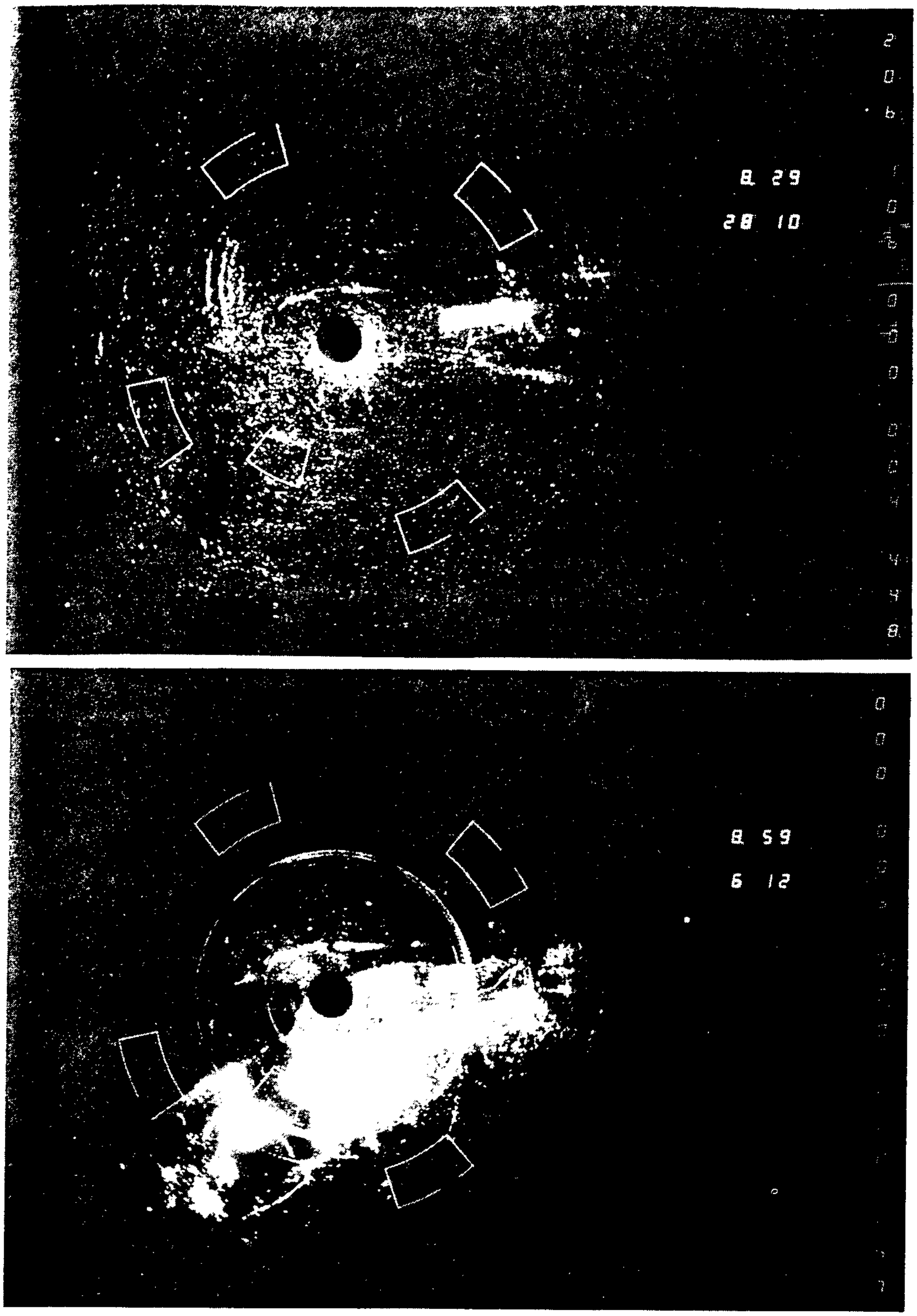


figure 21 Time exposure photos of the PPI of the S-band radar in the NW of The Netherlands (one antenna rotation, range set at 73 nM). A: Most echoes from birds. B: Massive groundclutter indicates the distribution of land (saturated with echoes) and sea (no echoes). Echoes of object on the ground were created due to energy ducted along the earth surface (anomalous propagation). Ring echoes are side lobe echoes of very strong ground echoes. The five sectors are electronic counting areas (KIEVIT system, see 5.1.). Time, date and echo counts in LED displays (right).

receiver type and noise figure: Usually video voltages within the receiver are directly proportional to the echo signal amplitudes (linear receivers). But sometimes a logarithmic or other specialized type of receiver may transform the received signals. The presented echo intensity variation should be interpreted accordingly.

Sensitivity Time Control (STC): Close to the radar, aircraft guidance may become impossible because their echoes are hidden through mass occurrence of echoes from undesired targets such as birds. STC circuitry counteracts this by reducing the gain of the IF amplifier by an amount inversely related to range. As a result the number of bird echoes may be markedly reduced, in large search radars up to distances of 20 - 30 nM. STC circuits can and should be switched off in order to detect birds.

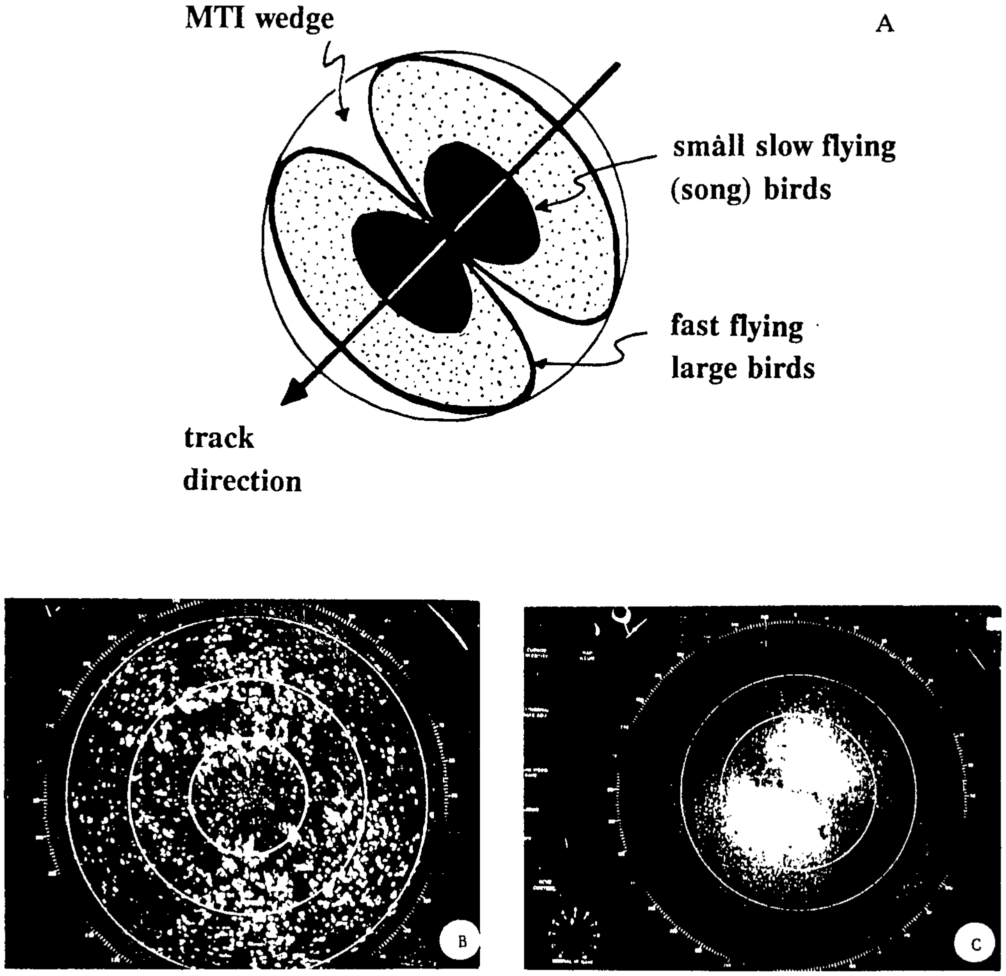
Fast Time Constant (FTC): In contrast to aircraft and birds, large targets, such as rain showers, produce echoes of much longer duration than that of a single pulse. FTC circuitry starts to suppress such echo returns after a given amount of time. As a result only the leading edge of showers appear on the radar screen, while point echoes should remain in tact. However, bird echo's can also disappear, especially in radars with low resolution and when bird echoes occur in high densities. Preferably, FTC should be switched off. Comparable to FTC but more complex are so-called Pulse Length Discriminators (PLD's). Depending on their characteristics they may reduce the number of bird echoes according to their length in range. PLD filters may also select echoes smaller than a certain size, as was the case with an adjustable PLD in the electronic counting device KIEVIT.

Instantaneous Automatic Gain Control (IAGC) and Constant False Alarm Rate (CFAR): The gain of the IF amplifier can at any instant be related inversely to the average power received during several pulse durations prior to that instant. As a result large areas of clutter are suppressed while point echo's should remain largerly unaffected. This is what IAGC and the more sophisticated CFAR circuits do. As was the case with FTC and PLD, again high densities of bird echoes may become suppressed and therefore application of these circuits should be avoided.

3.2.6. Moving Target Indicators

Elimination of stationary targets (ground clutter) is one of the most obvious needs in radar design and under many circumstances crucial to the detection of birds. Radar detection of birds in mountainous regions is virtually impossible without special circuitry. But even in flat country, echoes from objects on the ground can cause clutter up to ca. 25 nM under normal conditions when the lower side of the radar beam is directed to the horizon. This implies that low and medium powered radars with maximum bird ranges of less than 25 nM can only resolve low flying birds when equipped with Moving Target Indicator (MTI).

figure 22 The undetectability of birds flying more or less perpendicular to the radar beam when using MTI (moving target indecator circuitry). A: a sketch of the so-called MTI-wedges, B: a weak MTI effect during the day when bird migrate in flocks and produce strong dot echoes. Direction of movement according to the MTI wedges is SSW-ward. C: more clear MTI effect in the mass of weak echoes of nocturnal migrants flying singly to the SSW. Both photos taken from Gauthreaux 1980.



MTI's extract Doppler frequency shifted echoes by means of one or more delay-line cancelers, with or without positive feedback. The delay-line canceler acts as a filter to eliminate the DC component of fixed targets and to pass the AC components of moving targets. The video portion of the receiver is divided into two channels. One is a normal video channel. In the other the video signal experiences a time delay equal to one pulse repetition period. The output from the two channels are subtracted from one another. The fixed targets with unchanging amplitudes from pulse to pulse are canceled on subtraction. However, the amplitudes of the moving target echoes are not constant from pulse to pulse and subtraction results in an uncanceled residue. Nowadays spectral techniques are replacing the described delay-line cancelers. For a description of the priciples and many types of MTI's see the radar text books.

The diversity of MTI's results in very different rates of suppression of bird echoes. The most obvious effect is the cancellation of birds observed perpendicular to their flight path, where they move at radial velocity zero. During broad front migration this results in so-called MTI-wedges, sectors without bird echoes at the PPI (fig. 22). The azimuthal size of these bird echo free sectors differs depending on a) power output and sensitivity of the radar, b) the shape of the "velocity response curve" of each particular MTI, c) the range d) the size distribution of bird targets and e) their ground speeds. Another very unlucky aspect of MTI's is their limited dynamic range. The range of signal amplitudes which an MTI canceler can process is not as wide as the range of echo amplitudes that a radar may receive. As a result birds flying over an area from which strong ground echoes are being received are less likely to be detected than the same birds flying over an area with no ground echoes, even though the ground clutter may be completely suppressed by the MTI.

In conclusion: the rate of suppression of bird echoes by MTI's varies in time and space and with different types of equipment and their setting. In other words, careful selection of sampling areas at the ppi and calibration of measurements should be given high priority. If clutter free areas are available through horizon screening and nevertheless low altitude coverage, the use of MTI should be avoided.

3.3. Recording technics

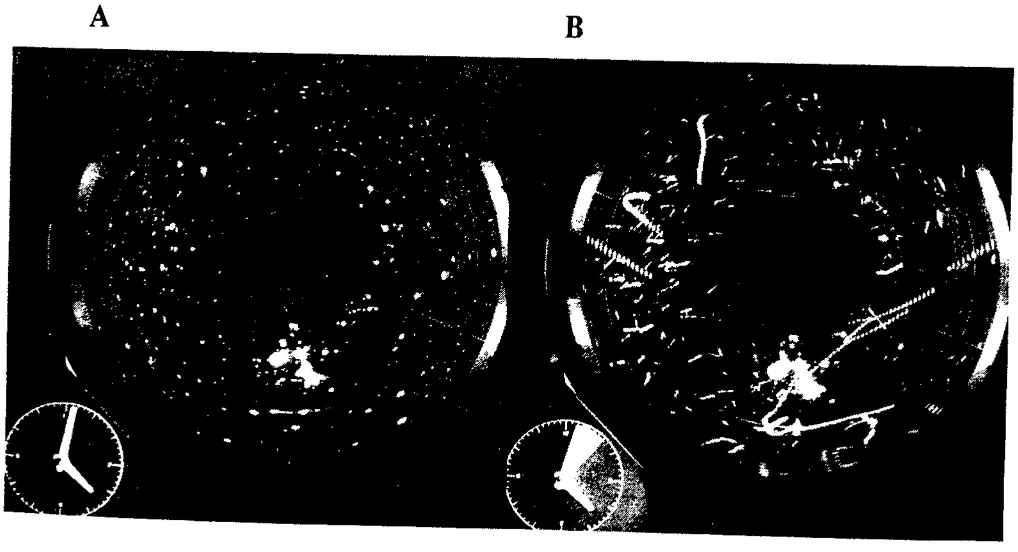
The movements of birds are difficult to follow directly on the PPI because of the large scale on which radars work (even short range radars) and because of the weakness of afterglow tails. Therefore, data have to be stored for serious analysis. Because of the electronic nature of radar equipment electronic storage seems to be the obvious approach. This however is usually a costly and complicated affair. Therefore much of the ornithological and operational work applied photographical means.

3.3.1. Photographical methods.

Two methods are frequently used: time exposure photographing and time lapse filming. For instantaneous assessment of bird migration intensity often polaroid photos are taken. A cheap method for long term studies is periodically taking time photos with a 16 mm or even an 8 mm filmcamera.

Time exposure photos of 2 to 15 minutes indicate speed and direction. Photos of the PPI taken during one revolution of the antenna yield a valuable impression of the echo density in the space covered by one sweep of the beam. The single echoes appear as dots (fig. 23A). Depending on scale and bird speeds the echoes of several antenna rotations build up shorter or longer streaks (fig. 23B). Direction suffers a 180 degrees

figure 23 Time exposure photos of one full rotation of the radar antenna (A) and the accumulation of echoes within one picture when exposed five minutes (B).



ambiguity. This has been prevented by adding one short extra exposure to each time photo after a short closure of the shutter. The point echo added to the streak indicates track direction. The obvious disadvantage of time exposure photos is the quick saturation of the image while the radar still displays single echoes (fig. 24).

Time lapse filming is a better, but more expensive technique. Radar films vividly illustrate the process of bird movements. An indication of how spectacular such films may be is provided by the series of photos in figure 25. The cognitive powers of the human eye and brains provide extreme quick pattern analysis. However, proper elaboration of the film recordings in order to reach scientifically satisfying results is very difficult. Selective extraction of the easily recognisable heavy and quick echoes may cause severe bias. Eye fitting average track directions of cohorts may obscure non-random directional variation. Weak but consistent bird cohorts or reversed movements can easily be overlooked.

A general disadvantage of photographical recording is the loss of information and addition of variation due to limitations of this extra medium: reduction of resolution, bias through a non-linear relation between brightness of echoes and sensitivity, blurring and backgound illumination of the whole picture by bright echo fields from rain, causing weak echoes to merge into the noise.

3.3.2. Electronical methods.

A first step towards more stable storage is using video instead of film. The newest CCD video cameras offer reasonable resolution and, at least theoretically, open the possibility of electronic assessment.

A more sophisticated possibility is the use of the synthetic digital radar information available at modern radar stations. This information extracted for operational purpose however, usually reduces or even excludes bird echoes. The best but also the most expensive option is to convert the analogue raw video into digital data. It enables collection and analysis of basic radar information, but also provides the possibility of extracting bird echoes at the source and/or performing pattern analysis (see chapter 5).

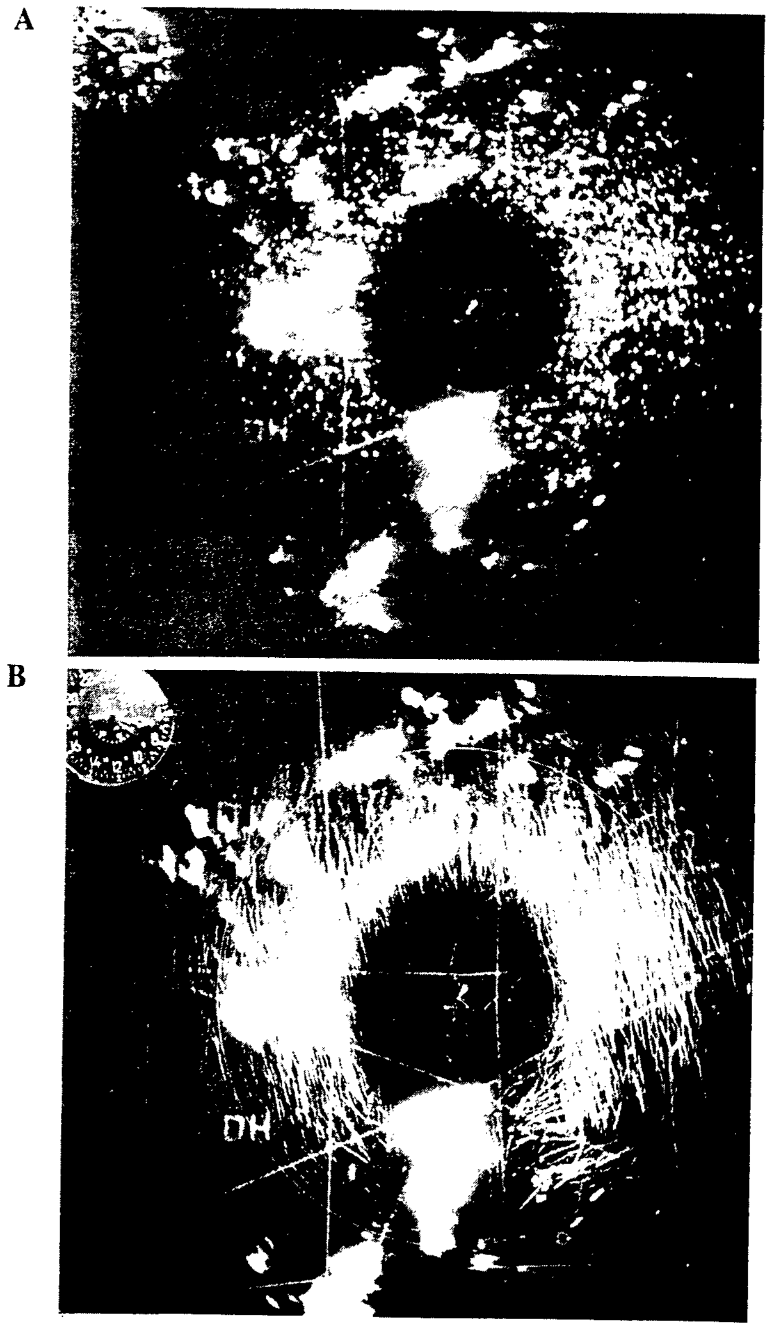


figure 24 Time exposure photos of the former L-band radar in the NW of The Netherlands showing bird echoes (point echoes), a few rain showers (small echo fields) and the normal amount of groundechoes around the station in the centre (A, one antenna rotation). The accumulation of all images of 10 minutes of antenna rotation causes bird echoes to grow into short streaks indicating direction and speed. A few much faster echoes from aircraft produce stipple lines to (or from) Amsterdam airport.

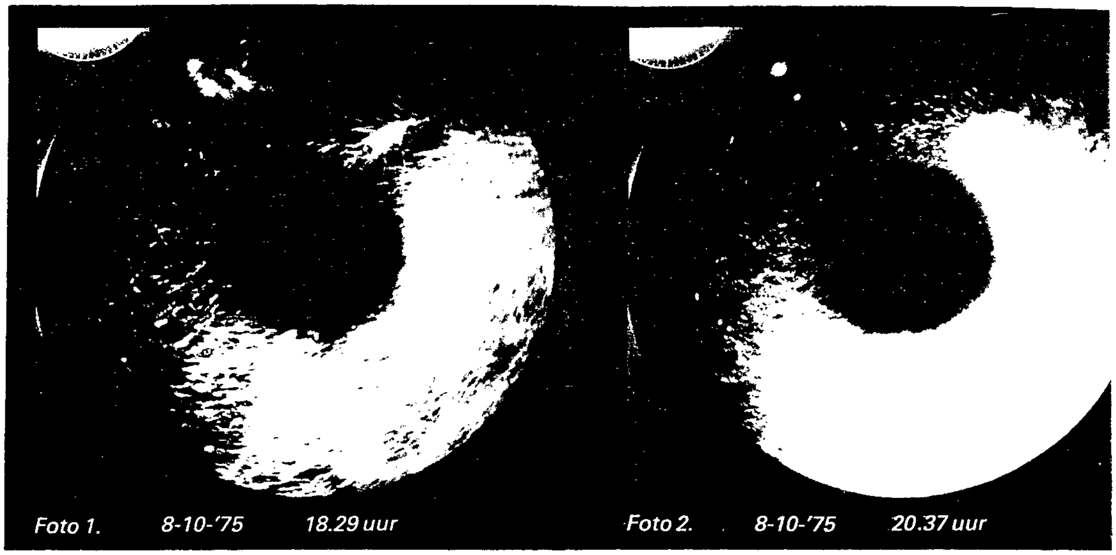


Foto 1. 8-10-'75 18.29 uur

Foto 2. 8-10-'75 20.37 uur

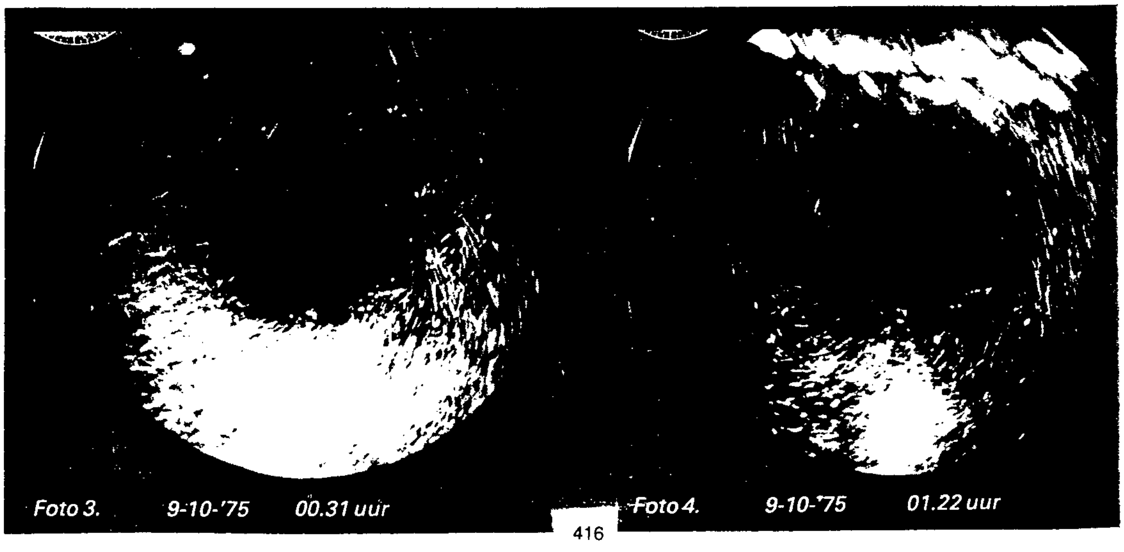
figure 25 Photo series illustrating the process of bird migration over the North Sea as seen by the former L-band radar
near Den Helder in the NW of The Netherlands.

(1) Departure of nocturnal migration towards WSW. Because the echoes start above the Waddensea islands and above the mainland, we may conclude that they were produced by landbirds. The time of the year and the massality of the movement makes thrushes the most probable species.

(2) Two hours later the migration is really massive. Saturation of the PPI is extra strong because of the change in flock behaviour at dusk. At sunset the birds flew in dense flocks, but in the darkness the birds are spacing out.

(3) Shortly after midnight the intensity of westward migration has weakened. In the upper part of the screen fast bird echoes appear. They indicate migrants that left southern Norway at dusk.

(4) One hour later the southward migration is clearly visible. The birds fly with the wind as can be deduced from the movement of the front of rain showers. The bird echoes are very long as a result of the high ground speeds.



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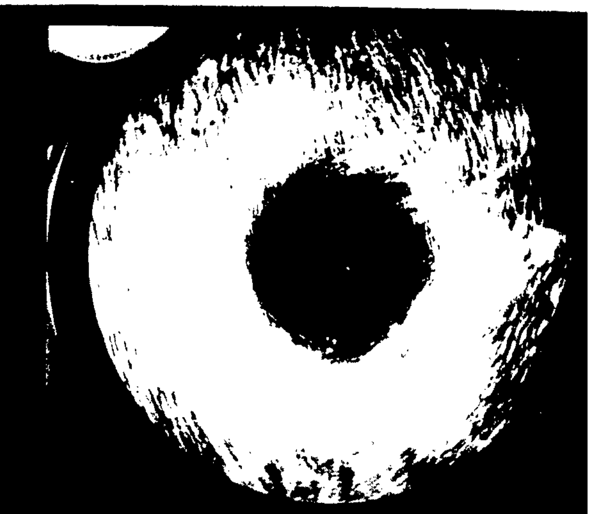

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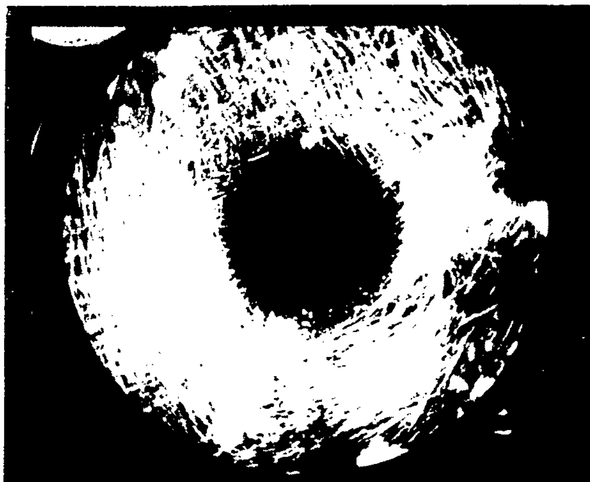
(5) Behind the rain front a huge mass of nocturnal migrants is approaching Holland. While the westward migration has ceased, the Norwegians have to proceed because the birds can not land at sea.

(6) This big arrival from the north continues far into the following day. The direction of the stream has shited to the SE. The echoes became stronger because the birds reordered into groups at dawn.

(7) At noon there is still very heavy migration over sea. Perpendicular to the flight directions of the Norwegian birds there is WSW day-time migration over land as well as over sea, as during the night before.

(8) Several days later there is W-WNW movement of very big bird echoes coming from the low parts of The Netherlands. Lapwings (Vanellus vanellus) is a good candidate to explain this type of migration. Reflections of obstacles on the ground indicate more or less the topography of The Netherlands. The centre of the PPI was artificially kept echo free..



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4. TYPES OF RADAR AND THEIR SUITABILITY FOR BIRD OBSERVATION

In this chapter we will shortly describe some examples of ornithological work for each type of radar that we consider of interest for bird strike prevention. Only studies that contributed to our understanding of the quantification problem have been included. Apart from giving some references we aim at emphasizing particular advantages and shortcomings of the different classes of radar. Radar pictures with a few results rather than extended text are chosen to support our conclusions.

4.1. Fan-beam search radars

Fan-beam search radars map the movements of air and sea traffic on PPI's. They have beams wide in the vertical and narrow in the horizontal plane. While scanning along the horizon, the beam covers a large part of the air space but discrimination between targets on the same spot at different altitudes is impossible. This third dimension of air traffic control can only be performed by additional equipment such as nodding height finders or, near airports, by precision approach radars.

Fan-beam search radars were the first and most important tools that evoked the new discipline "radar ornithology". Spectacular sequences of bird migration waves around the clock and over the seasons can be visualized by time-lapse filming. This representation of the process of bird migration is so impressive that, unfortunately, many people judged bird migration studies with simpler means to be superfluous. Fan-beam search radar still can be considered as the type of radar to be chosen for getting a general overview of migration and a rough indication of relative intensities in large areas. However, its inability to provide altitudinal information on bird movements as well as the qualitative rather than quantitative nature of its data must be emphasized.

4.1.1. Air Traffic Control (ATC) radars

These high-powered long range surveillance radars, often connected into networks, guide the flights of civil airliners outside the control zones of airports, where short or medium range airport surveillance radars (4.1.2.) take over their task. Modern civil ATC radars will usually not provide any significant bird information, because their operationally used video signals (mostly synthetic) have been cleaned up for undesired echoes. Certain video extractors may provide a figure indicating the amount of removed clutter including bird echoes, but to what extent this figures has any value to indicate bird densities remains very uncertain.

Military ATC or air defense radars are usually better suited for bird detection. Depending on their task, they should register even fairly small targets that do not respond to the radar by transmitting IFF (Identification Friend or Foe) signals. Moreover, they usually are designed to provide higher resolution.

Military ATC radars have already been used for ornithological purposes since the Fifties. Well known is the work of the British school of radar ornithologist "founded" by Lack. Also researchers in Denmark, Sweden and the USA produced papers based on military long range surveillance radars, mostly fan-beamed. Nice pictures could be taken from the PPI of the Dutch L-band radar near Den Helder (figures 24 and 25).

The radar registrations from Holland are well suited for demonstrating possibilities and restrictions. The flatness of the country provides the best low coverage one could think of. The ground clutter pattern is very regular, normally a circle with radius 20 nM around the radar. Birds can be observed far beyond 50 nM, but the filming was limited within this distance. Therefore a "donut" like annulus of 30 nM depth is available for bird detection. When fixed echoes are removed via MTI, only a central area of 10 nM radius cannot be used. Because of the wave length of 23 cm the difference in detection chance between birds observed head- or tail-on and those seen.from the side is fairly small. The latter echoes exceed the noise level at longer distances. Due to the combined effect of low resolution and long wave length, saturation of the ppi by bird echoes can occur easily, especially at night. Solitary songbirds cannot be detected but when several individuals simultanously occupy one resolution cell a weak echo is received. This is clear from the daytime pictures wherein the echo of a flock of finches cannot be told from that of a single goose, apart from typical differences in speed. During the night many songbirds fly singly and remain invisible but chance may bring them within one resolution cell. As a result a very diffuse bird echo pattern emerges on the PPI. Sometimes, it resembles weather echoes and mostly it does not provide reliable directional information.

The biological significance of observations with this type of radar primarily concerns the recognition of large scale patterns of migration. The short series of time exposure photos (figure 25) may illustrate this. According to departure areas, timing and speeds several so-called cohorts (Alerstam & Ulfstrand 1972) can be identified as "songbirds", "waders", "geese", "gulls" and others. Systematic recordings offer the possibility to describe temporal patterns (circadian and circannual) and the short-term reactions to weather. Migration intensity can be scaled roughly, using the exponentional 0 to 8 values (see 5.1.), but real quantification is difficult. Apart from the saturation problem, also the invisibility of the smallest birds, even on short range, makes it impossible to select a certain sampling spot where all birds above a certain minimum altitude are detected.

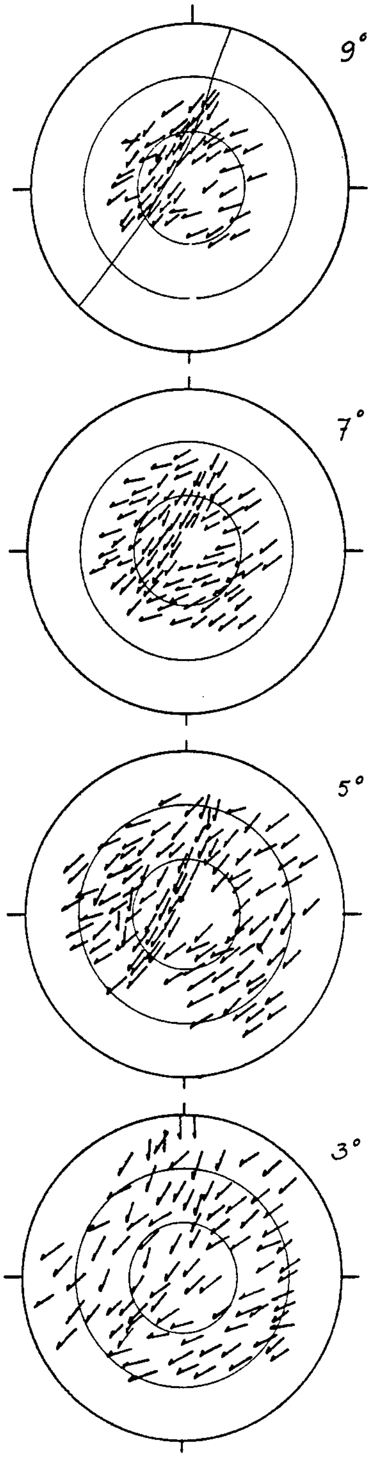


figure 26 Diurnal autumn migration (ca 10.00 hr) around the Dutch west coast, as taken from the PPI of an old airport surveillance radar at the naval base Valkenburg. Range rings were set at 5, 10 and 15 nM. The coastline is indicated in the upper figure. The elevation of the fan beam was set at 3, 5, 7 and 9 degrees, cutting off bird detection from low to high altitude.

4.1.2. Airport Surveillance Radars (ASR)

What is said about ATC radars partly applies also to ASR radars. Although airport radars work at smaller scale, they nevertheless cover such large areas that they are able to monitor large scale bird movements. Especially when several ASR radars are exploited for simultaneous registration of bird migration, geographical patterns can be studied in detail.

While most fan-beam ATC radars operate at 23 cm wavelength, ASR radars use the 10 cm (S) band. This improves the potential detection of solitary flying small songbirds, while the wave length is just long enough to avoid serious insect contamination. This makes ASR radars better for the assessment of bird numbers within a certain volume of air than ATC radars. The smaller scale increases resolution. But the inclusion of smaller birds leads to bigger numbers of echoes. Therefore, also the PPI of ASR radars can become saturated. Gauthreaux (1970) has proposed a procedure to quantify bird migration even in case of mass migration. By stepwise attenuation of the radar sensitivity the bird density will diminish. After calibration of this thinning effect by parallel observations with other means, the real densities are calculated and the drawback of saturated PPI is avoided.

Very detailed and biological reliable migration studies have been performed since the fifties at the airport radar near Zurich in Switzerland (Sutter 1957, Gehring 1963 and Hilgerloh 1981). A good analysis of the quality of ASR radars for bird detection and an extended ornithological study was performed by Richardson (1976) in Canada.

A series of sketches directly taken from the screen of an old GCA radar at Valkenburg naval base along the Dutch west coast is reproduced in figure 26. Tilting the antenna from 0-9 degrees reveals two types of bird movement: ENE-WSW broad-front migration over land as well as over sea and a narrow, concentrated stream of migrants flying parallel to the coast. Different from what most ornithologist think, the migrants following the coast perform this behaviour also at very high altitudes. They seem to use the coast as a guide line.

With respect of biological results the work at Ben Goerion airport near Tel Aviv, Israel (Leshem 1988) is very interesting. This ASR-8 radar is used without any special modification. Figure 27 shows the video normally used by the air traffic controllers. In this radar setting birds of small or medium size, flying singly or in small flocks, do not reflect strong enough to penetrate the filters. Only flocks of heavy migrants like storks, pelicans and bird of prey, soaring from thermal to thermal, produce echoes. The numbers and identity of these birds, and thereby the performance of the radar, were checked by visual observations from a motorized glider. As a result the radar can be used in its normal setting as a calibrated tool for "ad hoc" warnings to the Israeli Air Force. Broad-front migration remains undisclosed in this way, but nowadays other (more sensitive) settings are tested.

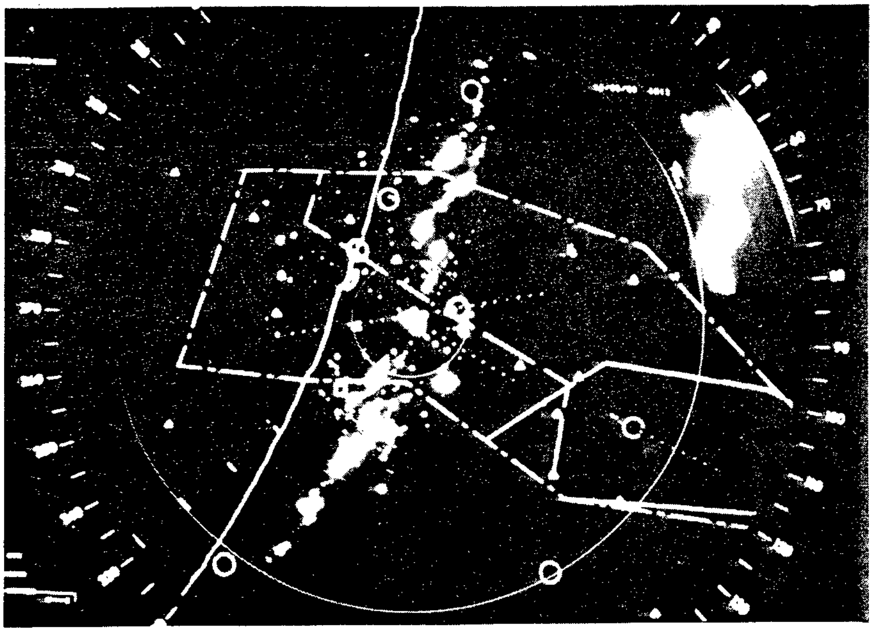


figure 27 Ben Goerion airport surveillance radar (ASR-8) on 28 sept 1986, 11.30 hr. A long line of 82 km of Lesser spotted eagles (Aquila pomarina) are visible as a row of cloudy echoes parallel to the coastline projected into the PPI. It is estimated that the echoes represent ca. 15.000 eagles.

4.1.3. Ship navigation radars

Ship navigation radars are the smallest fan-beam search radars used for bird detection (Williams et al 1972). Because of the big market of recreation vessels, these radars are cheap and easily accessible to ornithologists. However, maximum bird range is small. Songbirds cannot be seen beyond 1 km (if at all) while the detection of flocks of large birds is only possible up to 2-3 km at the most. Therefore such radars can not cover the full altitude range of bird migration. By replacing the fan beam antenna by a narrow pencil beam range can be enlarged.

The application of ship navigation radars is mostly scientific. The disadvantage of very limited range is more or less compensated by good resolution and the easy use in the field. Recently, the Danish field ornithologists Brinch Pedersen and Poulsen used a modern Furuno ship radar to study nocturnal bird movements around a windturbine. Modern types, like the Furuno, have memory functions enabling the operator to see simultaneously the latest and several earlier plots of each target. This enormously facilitates recognition and understanding of the bird movements in real time.

Gauthreaux has included a ship radar into his mobile field laboratory, which was set up for, amongst others, the study of birds colliding with electric power lines. He combined several remote sensing technics and profitted from the sometimes complementory nature of these.

Figure 28 gives an impression of the PPI of the search beam of the Flycatcher tracking radar. This component of the Dutch X-band military radar can be considered as a small-range fan-beam search radar like the ship navigation radar. However, because of the much higher power bird detection can be done at somewhat larger scale (rings indicate 5 and 10 km range). The row of echoes in the NW indicates the metal poles of an electric power line. The echo field from the center to the SW is a fairly open area wherein all single trees, farms and many smaller objects reflect radar energy. The reason for the clean PPI in all other directions is that the radar could be placed at a location surrounded by low homogeneous woods, obscuring the horizon over 270 degrees. Birds could be detected (and tracked!) down to an altitude of only 20 meters at a distance of 2-3 kilometer. Single trushes were detectable in side view up to 7 km.

figure 28 PPI of the search beam of the Flycatcher tracking radar. Explanation in the text.

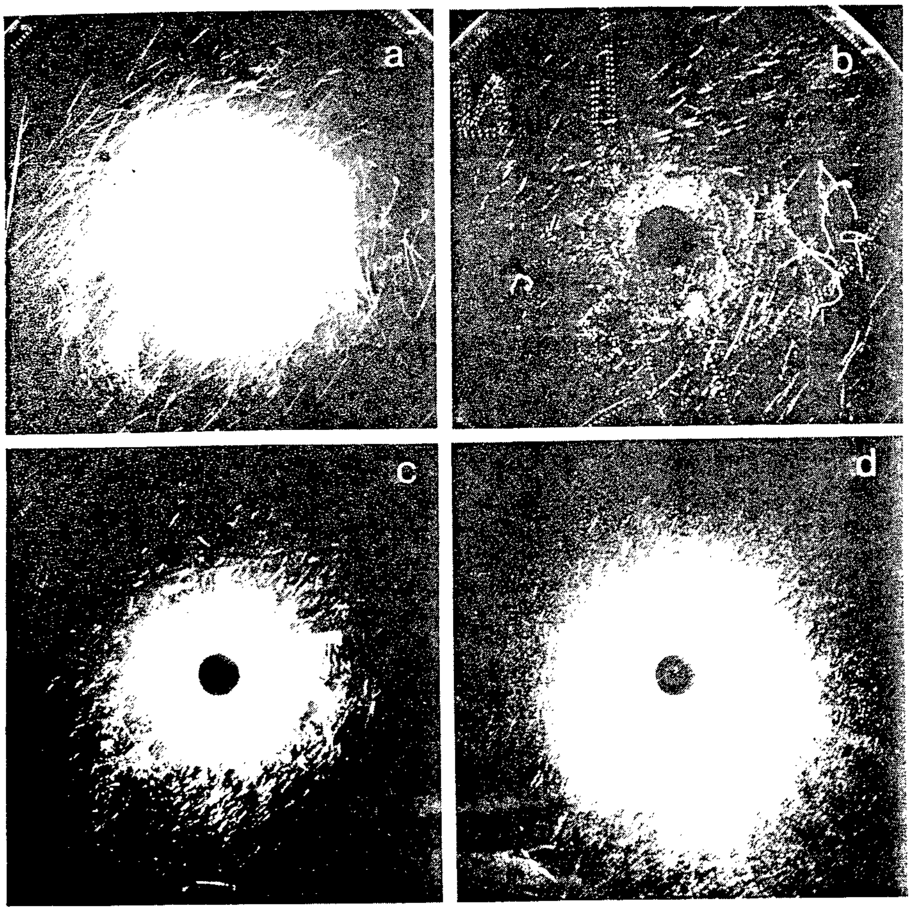


figure 29 The filtering of unwanted echoes as visualized at the PPI of the stacked beam long range surveillance radar in the NW of The Netherlands. Explanation in the text.

4.2. Pencil beam search radars

4.2.1. Long distance (stacked beam) radars

Pencil beam antennas produce beams which are narrow in azimuth as well as in elevation. The aperture of long range radars is usually around one degree. In stacked beam radars the radar energy is divided over several wavetubes. Each radiates from a slightly different position in the focal area of the big antenna and produces it own radar beam. The beams together fill a vertical detection plane which is rotated in the horizontal, resulting in a three dimensional coverage. For bird detection only the lowest two beams are interesting. Combining the information of both beams gives a limited idea of the heigth distribution of the birds.

The S-band stacked beam radar in The Netherlands (see figure 24) offers fascinating facilities for bird detection. The raw video of this radar may be densily packed with bird echoes as a result of the perfect low level detection in very bird-rich and very flat country side. For normal operations (the guidance of aircraft), the video should therefore be cleaned. Figure 29A is a 10 min time-exposure polaroid photo of the raw video showing many bird streaks. Picture B is taken nearly at the same time and gives only that part of the video which is extracted for operational use (again acumulated over 10 minutes). Here aircraft echoes dominate the picture. North of the radar strong also echoes from ships remained visible. Those signals that were trapped by the video extractor can also be shown, albeit in reduced quality: figure 29C. The availability of this "unwanted echoes video" was accidental and proves the possibility of a dedicated bird echo extractor. A-C were day-time pictures, 29D illustrates the unwanted echoes filtered out of the signal during a night with heavy bird migration.

4.2.2. Medium distance (weather-) radars

This category of radars is not often used for bird detection. Most weather radars are fairly low powered because of the low resolution needed for detecting rain showers. Both affect the quality for radar ornithology. However, very good results were achieved with the weather surveillance radars (WSR) in the US by Gauthreaux.

4.2.3. Short distance radars

A high resolution pencil beam radar with a corresponding short range, which is nevertheless long enough to reach the highest flying birds, is ideal for bird studies as well as for future bird strike prevention (see 5.3.2.).

figure 30 Radar study along the Dutch west coast by means of the two search pencil beams of a L4/5 tracking radar. Explanation in the text.

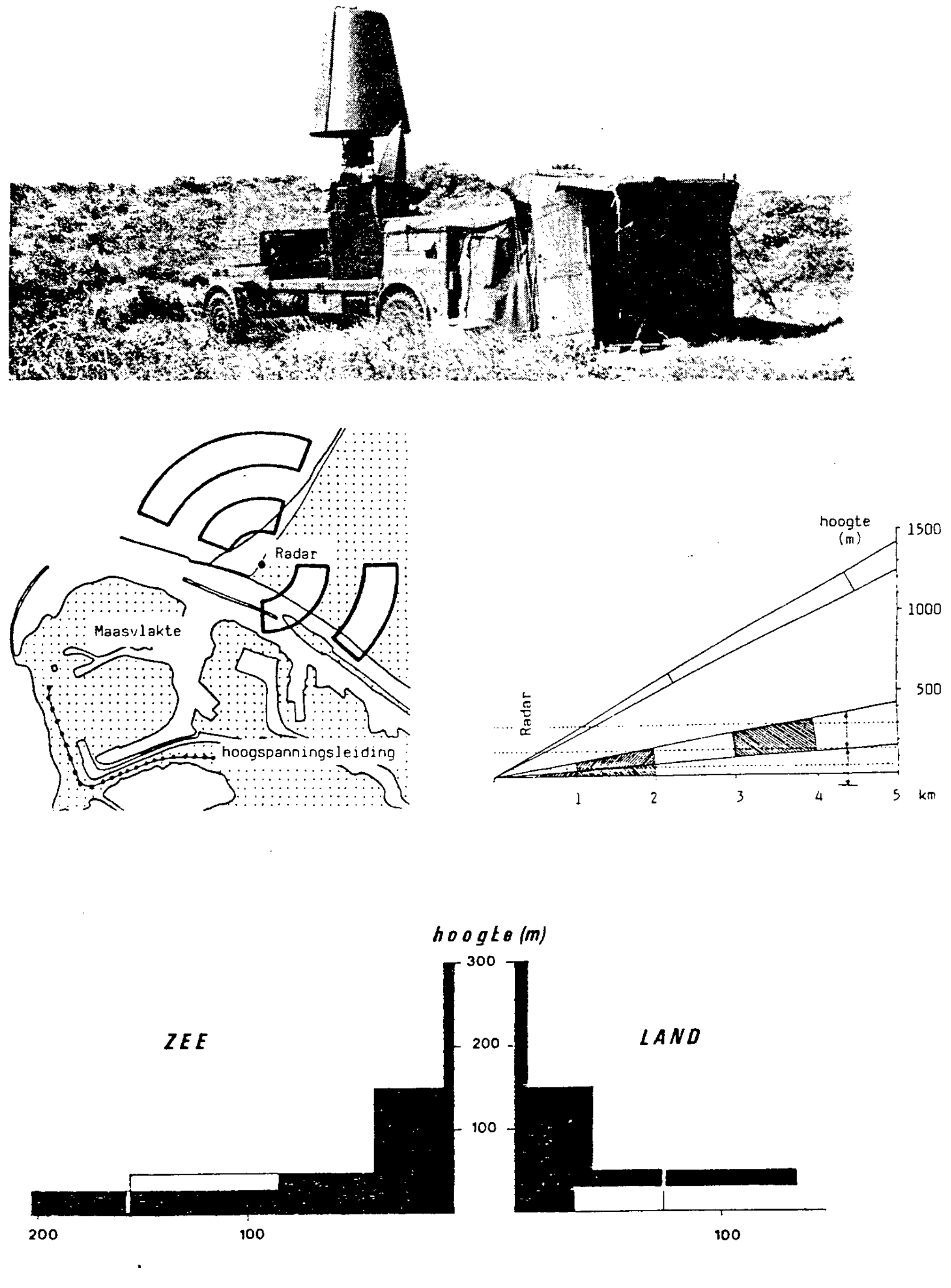


Figure 30 presents a collage of work done in The Netherlands with the two pencil search beams of L4/5 (tracking) radar (A). The mobile system was put on top of the dunes along the Dutch west coast near Hook of Holland. The project aimed at assessing autumn bird movements during day and night at different height levels. The lowest air layers got special emphasis because of the concentrated diurnal migration parallel to the coast and the question whether this well-known movements also occur at such low levels during the night. One reason for the study was the completion of a nearby electric power line perpendicular to the coastline and to the bird stream (Buurma & Van Gasteren 1989). The two radar beams scanned in the horizontal plane under different elevation angles (C). Bird movements were filmed time- lapse hourly. Figure 30 B and C show the sampling areas chosen in the horizontal and vertical plane respectively. The results of one night (6 november) were averaged with respect of the altitude distribution of bird density (per km3) above sea and land: figure 30D. This night of intense migration shows that the birds seem to avoid the lowest meters over land but that they don't do so above sea.

4.3. Nodding height-finders

4.3.1. Height surveillance radars

These old-fashion radars complement the fan-beamed search radars by providing altitude information. In fact they are fan- beam radars of which the antenna is rotated 90 degrees around a horizontal axis. The beam, narrow in the vertical plane, is scanned up and down and the signal is displayed at a so-called Range Height Indicator (RHI). Figure 31 gives an impression of this type of presentation, although it came from a nodding pencil beam.

Riemens (1971) evaluated a large nodding height-finder (S-band) in The Netherlands, that belonged to the same radar park as the L-band long range surveillance radar, shown at the cover. He took time-exposure photos simultaneously at both stations (figure 32). The nodding height finder was used as a search radar giving a very narrow beam in the vertical plane. The results showed very meager correlation, which seems to be primarily a matter of skewed altitude distribution during daytime migration. The SSW flying bird at the L-band radar are missing at the S-band radar, probably because they flew low above the sea.

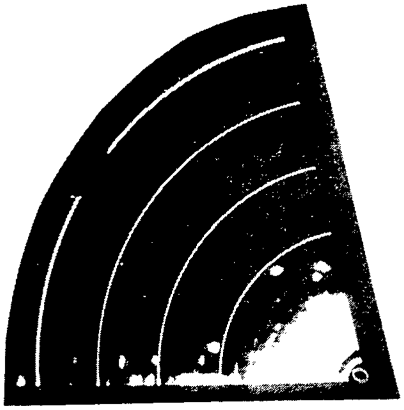
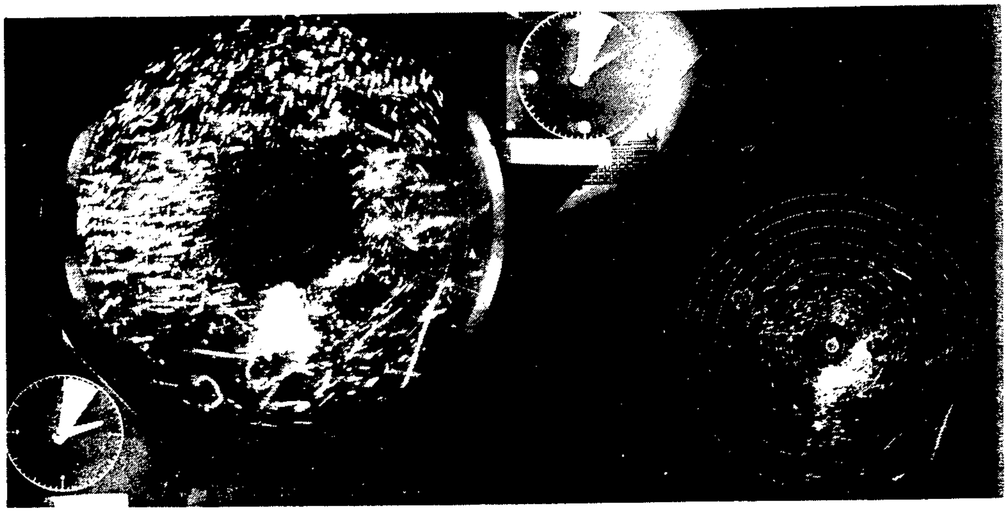


figure 31 Vertical scan of the tracking beam of the Flycatcher. Rang rings at each km indicate a maximum detection at nearly 5 km altitude. Figure 13 showed results. Dot echoes came from birds. The first km is saturated with a mixture of noise, side lobes and insect echoes. Reflections of trees etc. are visible at the bottom.

figure 32 Time exposure photos taken simultaneously from the PPI of the L-band fan beam radar near Den Helder, The Netherlands (left), and a S-band nodding height finder at the same spot (right). Both radars were scanning in the horizontal plane.



4.3.2. Precision Approach Radars (PAR)

PAR's help landing aircraft to follow their flight path as precise as possible in the vertical plane. Mostly these radars, operating in X or C-band, have their antenna fixed in one direction. Birds passing through the scanning plane produce clear echoes, directly giving altitude information. When there are no details on flight direction and speed of the birds, it is difficult to quantify the movement. PAR's are not often used because they offer not much flexibility for ornithological use.

4.4. Tracking radars

The ultimate radar system for scientific studies on bird migration is the (military) tracking radar, especially when optimally attuned, adapted and instrumented for bird observation. For a classic study see Bruderer 1971. The tracking capacity offers the possibility of studying the flight path of individual birds. But most tracking beams offer also the (potential) possibility of being used as a scanner. During tracking fluctuations of the automatic gain control voltage appear to reflect the wing beat signature of the bird(s) tracked, enabling the researcher to identify species(groups). Bloch et al (1981) give a good overview of potential results. Figures 33 and 34 illustrate some details of the Swiss studies with Superfledermaus X-band tracking radar.

As was judged by Richardson (tabel 2) tracking radars score high in the quality of the results. This does not necessarily mean that they are very suitable for operational use in bird strike prevention. Tracking birds one by one does not easily support the needed quantitative measurements. But as explained in 5.3.2. the use of a fairly short-range tracking beam as a flexible volume scanner come close to the ideal dedicated bird radar. Tracking radar studies can support the further development of such a system.

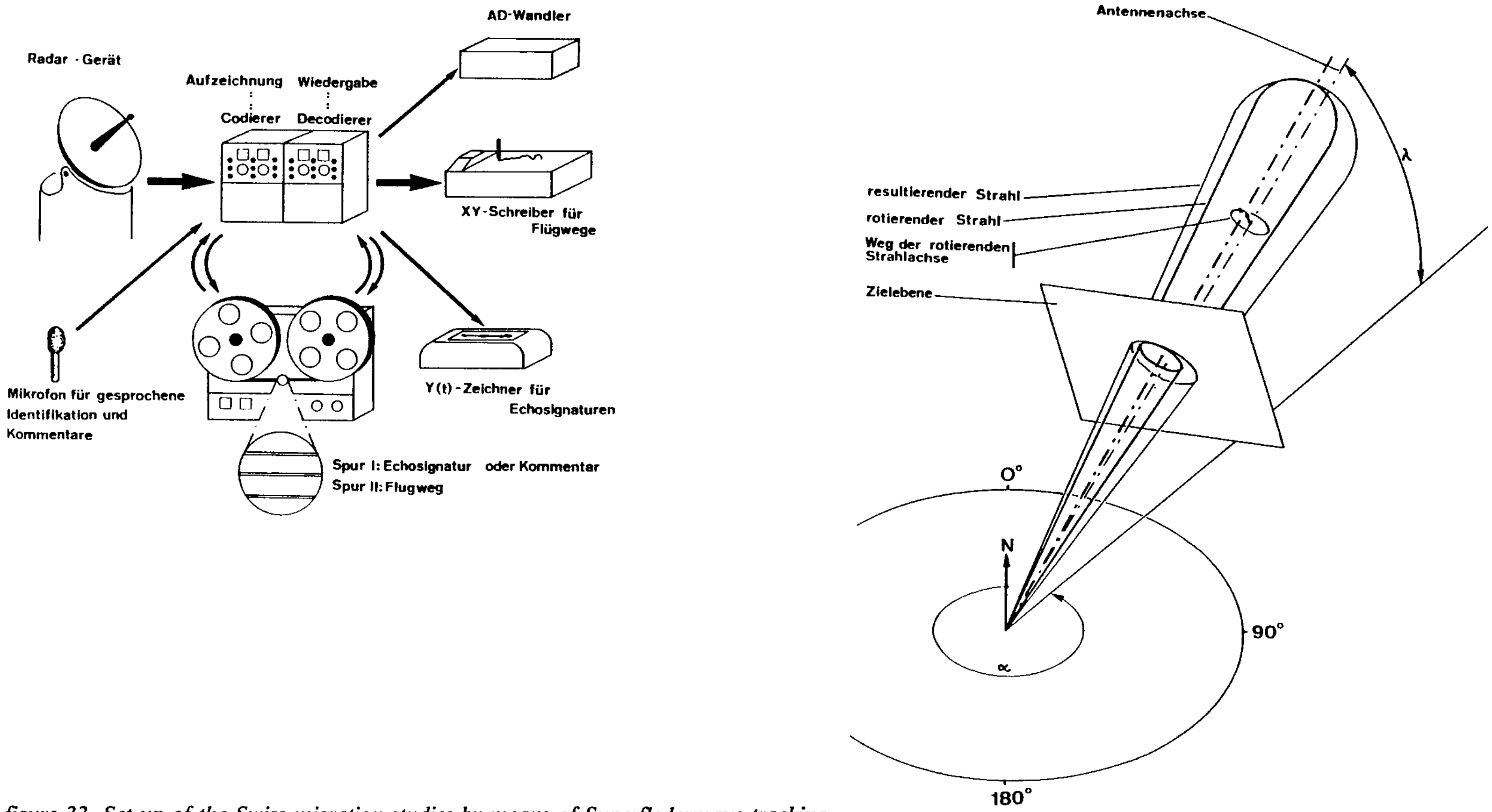


figure 33 Set-up of the Swiss migration studies by means of Superfledermaus tracking radar. Fig A illustrates the transfer of flight path data and AGC signatures from the radar via a coding device to a tape recorder, a X/Y-plotter, an Y(time) plotter and a A/D converter. Spoken text can be added. Fig B explains the rotational scan of the radar beam while tracking. The effective widened beam has an energy dip in its central axis, enabling the circuitry to fixate a target.

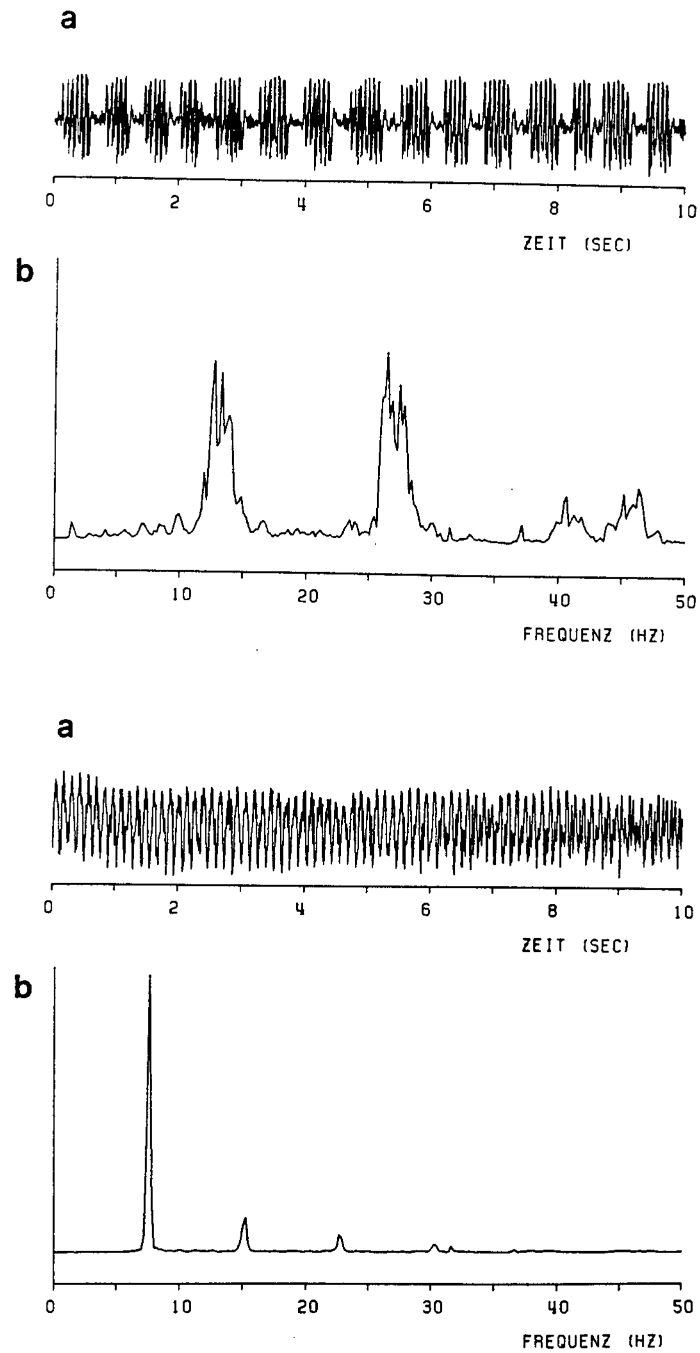


figure 34 Wing-beat patterns (AGC signals) of a passerine bird (upper figure) and a non-passerine species (lower figure). The a) parts give the pure signals, while b) represents the occurrence of each frequency within both signals. Passerine birds alternate short burst of wingflapping with short gliding phases.

Table 2 --Characteristics and applications (emphasizing bird studies) of various radar types. ++ = very suitable, + = suitable, ± = some capability (often difficult), - = unsuitable.

Radar type	Typical characteristics						Parameters measurable[5]									
					Beam width[4]											
	Band	kW Peak Power	Range[2]	Pulse Duration[3]	Horizont.	Vertical	Chronology	Routes	# Flocks	# Birds	Bearing	Distance	Height	Course/Speed	Grouping	Signature
A. FAN-BEAM SEARCH																
Ship navigation	X-S	25	S	SM	2°	20°	+	±	+	+	++	++	-	++	±	-
Airport surveil.	S	400	SM	M	1½	20	++	±	++	±	++	++	-	++	-	-
Air route; military	S,L	5,000	ML	ML	1	10	++	++	++	-	++	+	-[6]	+	-	-
B. PENCIL-BEAM SEARCH																
Weather surveil.	C,S	500	ML	ML	2	2	++	++	±	+	++	++	±	++	-	-
Mod. Ship/Airborne[7]	X	25	S	SM	2	2	+	±	-	+	++	++	+	+	±	±
Tracking (search mode)[8]	X-	40-	SM	SM	1-2	1-2	±	±	±	±	++	++	+	+	±	-
	S	5,000	ML	M	½-1	½-1	±	+	±	±	++	++	+	+	-	-
C. HEIGHT FINDERS																
Precision approach	X,C	150	S	SM	5	1	±	-	±	±	±	++	++	-	±	-
Surveillance	C,S	4,000	ML	M	3	1	±	±	±	-	±	+	+	-	-	±
D. VERTICAL BEAM	X	25	S[9]	SM	2	2	+	-	-	+	-	-	++	-	±	±
E. TRACKING[8]	X-	40-	SM	SM	1-2	1-2	-	-	-	-	++	++	++	++	+	++
	S	5,000	ML	M	½-1	½-1	-	±	-	-	++	++	++	++	+	++

[2] Usable range for biological targets; S=short (<5 km), M=Medium (5-30 km), L=Long (>30 km).

[3] Short (<½ μsec), Medium (½-2 μsec) or Long (>2 μsec); corresponding range resolutions are <75 m, 75-300 m and >300 m.

[4] Corresponding resolutions (in km) = Range (km) x sine (Beamwidth).

[5] Parameters 1-4 concern multiple targets; 5-10 concern individual targets.

[6] Roughly measurable on multiple-beam (3 dimensional) radars.

[7] Ship navigation or aircraft weather radar with dish antenna (see Graber & Hassler 1962; Schaefer 1976).

[8] Upper and lower lines give characteristics of low and high power trackers, respectively.

[9] Range is measured vertically in this case.

table 2 Summary of characteristics and suitability for bird studies of different classes of radar according to Richardson (1979).

5. Operational use

5.1. Military systems at work

5.1.1. Observations based on polaroid time-photos

Germany, Norway, France and Belgium still succesfully apply this technique which was proposed by Gunn in Canada and has been introduced in Europe during the early sixties after a persistent BSCE/NATO campaign. As described in chapter 3.3.1. and illustrated in many photos throughout this booklet, birds appear as well recognisable streaks. By comparing the polaroid photo with a standard reference series the technician is able to estimate the bird activity nearly "ad hoc". Bird densities are expressed according to a exponential zero to eight scale. Also certain geographical information as well as rough estimates of top altitudes of bird activity can be derived from the bird echo patterns. The method is reliable and cheap provided the radar and photo equipment is set correctly and the operator has the knowledge and skill to interpret the results.

As described in chapter 3 the common difficulty in all use of radar is calibration of the quantities of bird echo returns. One cannot register more than the radar "sees", while one can loose part of the information available. Most regrettably, this usually happens in case of the photographic method. The attentuation method of Gauthreaux may ameliorate the difficulties. But not all radars offer stepwise attenuation and not all users can execute careful calibration studies. However, comparison of bird density measurements at one radar station over the seasons will provide at least a good idea of the relative variation. It depends on the amount of safety a user wishes to achieve were to put the flight restriction treshold.

5.1.2. FAUST (Denmark)

This is the first operational warning system with electronically determined echo densities. It was developed for the Danish Air Force in 1971 by Clausen, partly based on ideas from Holland (see Tengeler 1972). For several years it served as an example for the radar working group of BSCE. It was revised and is still in use. Just like the other more or less comparable systems, it does need a skilled radar observer. Separation of bird echoes and clutter is imperfect and the system does not give height information.

5.1.3. KIEVIT (The Netherlands)

Since 1978 the RNLAF has operated an electronic counting system called KIEVIT (Kast met Integrale Vogeltrek Intensiteits Tellers) at its stacked beam radar in the NW of Holland. Only the lowest two beams are used because only they detect large numbers of birds.

The system determines bird echo intensity within 5 movable windows (figure 21) provided the radar works in Pulse Compression mode (range resolution 30 m.). The raw video signal is quantified by means of two seperate thresholds, a distance dependent low bird threshold and a 16 dB higher clutter threshold. Herewith two digital video signals are produced, resp. called "bird video" and "clutter video". The clutter video selects all strong echoes which are directly fed into a clutter counter. The video first is counted by a "bruto bird counter" and confines all energy not exceeding the clutter video. The bird video also passes a combined pulse length discriminator and an "isolation filter" to eliminate weak echoes from rain and ground objects. All echoes with a certain minimal distance to their neighbours (in range) and having a certain maximum pulse length do pass the filter and are counted by the "netto bird counter". The two filters may have different settings and are usually adjusted either to the heavier, widely spaced, diurnal echoes or to the denser but weaker nocturnal echoes.

Quantification implies the calculation of the percentage occupied resolution cells within each window after subtraction of the number of clutter cells plus the difference between bruto and netto bird cells. The figures are converted to the well-known 0-8 exponential scale for bird migration warnings. The two lowest radar beams are sampled seperately per window giving a rough height indication. Furthermore, the location of the 5 adjustable windows offers the possibility to discriminate roughly between different types of bird migration over Holland and the adjacent parts of the North Sea.

The system also includes a SRT-radar screen, photographical recording facilities and a output plug delivering formatted output of counts.

KIEVIT is still in use as a back-up system. It has proven to be able to select bird echoes under most circumstances. If this is not the case the bruto bird counters indicate the potential mistake. However, due to the filter process many birds may eliminate each other when the echo density is too high. Therefore, the system still needs an experienced person to evaluate the figures (not necessarily seeing the screen), although it was intended to work automatically.

5.1.4. ROBIN (The Netherlands)

ROBIN stands for Radar Observation of Bird INtensity. It is the acronym for the new Dutch system that recently replaced KIEVIT. ROBIN consists of two cooperating systems: a registration system and a presentation system, which can be separated geographically. The registration system has to be located near the radar; the presentation system can theoretically be set up anywhere.

The communication between both systems takes place via a serial line (a modem connection): commands are sent from the presentation system to the registration system; the recorded and processed images are returned to the presentation system (figure 35).

The presentation system is a standard workstation with a high resolution screen and ample data storage capacity. The system is controlled by a hierarchical menu structure in which selections can be made using a mouse.

Numeric parameters can be entered via the keyboard in various windows linked to the menus. Text and graphic output also occurs in windows.

The adjustable parameters include among others the time of acquisition, the resolution in distance and azimuth and the choice of different filters. The size and location of the acquisition area are indicated by the mouse on the map displayed on the screen. The image, compressed to allow for minimal transmission time is converted by the workstation (after decompression) from polar to cartesian coordinates.

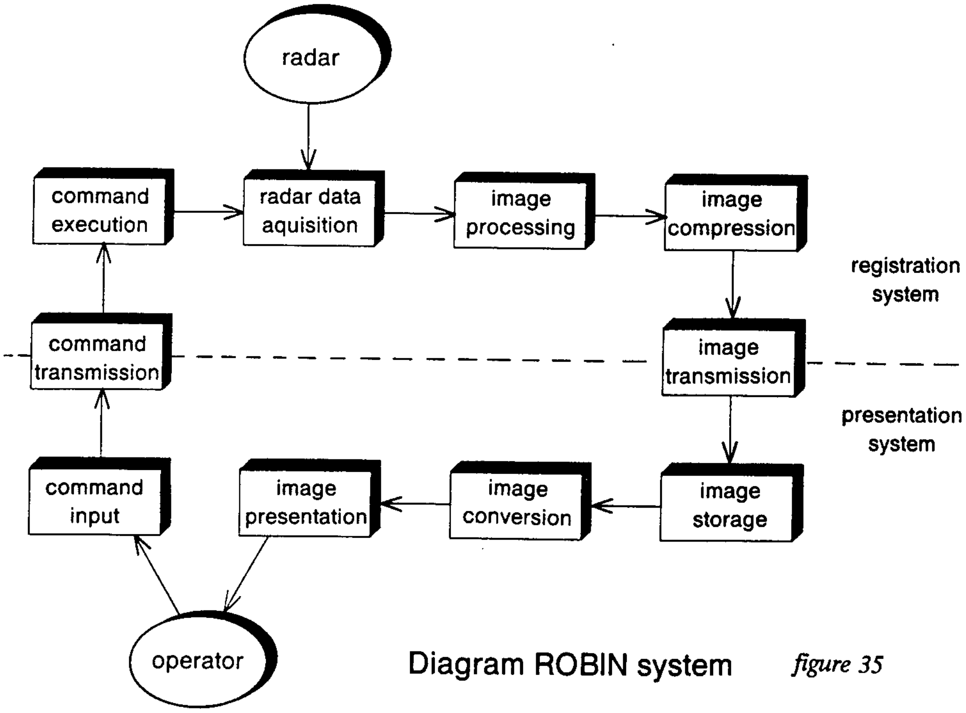


Diagram ROBIN system *figure 35*

The registration system takes care of the data acquisition and image processing without further intervention being necessary. The radar signals are recorded and processed without affecting the radas's primary operational task (Air Traffic Control, object detection etc.).

The system includes the data acquisition hardware, combined with commercial VME-bus processor modules on which software programmes for image processing, datacommunication and data acquisition control are executed. The architecture is strongly directed at het flexible implementation of signal processing algorithms in software.

The image processing aims at supporting the user in making quick, accurate and reproducible interpretations of radar images. The image processing can be divided into the following stages:

- compensation of less desired characteristics of the radar as sensor such as beam form and distance dependency;
- filtering of disturbing radar reflections (towers, etc.) and noise;
- improvement of images for visual assessment by removing insignificant details and assigning colours to different sources of echoes;
- determination of quantitative characteristics for bird migration like bird density and flight direction;
- compression of images for transport and storage;
- transformation of polar radar images for presentation on a raster oriented computer screen.

The most important aspect is to distinguish between birds or groups of birds and other reflections, such as rain showers. The criteria used are:

- size and strength of echoes;
- spatial distribution of reflections;
- movement in direction and speed.

Reflections linked to the ground can be eliminated by their correspondence in place in consecutive images.

Rain can vary in the radar image from massive echoes to finely distributed speckles. Classification as rain can be made if these characteristics occur over a connected and sufficiently wide area.

The contour of the area found in this way is depicted by the thick line in figure 36B. Potential bird echoes are identified by limits on size, strength and mutual distances. Several migrational directions may be identified in one image; further selection is possible after linking echoes in consecutive images and by grouping displacement vectors.

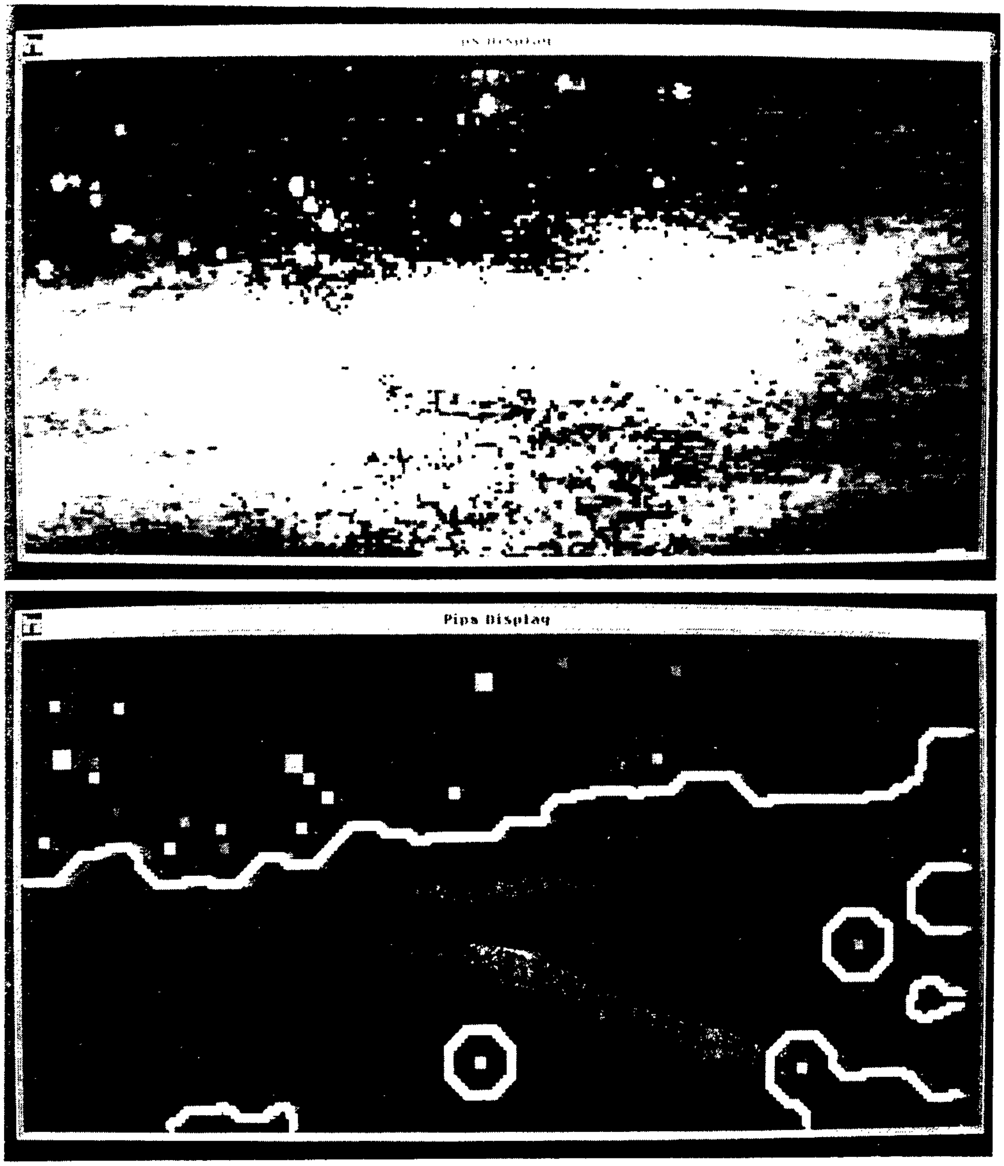


figure 36 Bird and rain echo recognition by pattern analysis within ROBIN (lower figure). The raw video signal from a window selected at the PPI was first processed into digital information (upper figure). Bird echoes are the dot-echoes consisting of several pixels. Rain consists of large fields of smaller echoes and single pixels.

5.1.5. BOSS (Belgium)

In modern phased array radars for air traffic control many "temporal" pencil beams in fixed or rotating arrays "fire" in random sequences one by one in different directions. They build up a three-dimensional picture of echoing objects. Many functions are implemented in software. Although the programming is not adjusted for optimal bird detection a smart programmer could reprogram for bird sampling. As a consequence the radar is out of normal operations for a few seconds or minutes.

During "bird scanning" the Bird Observation System Semmerzake is sampling the Belgian air space air three dimensionally like a stacked beam surveillance radar. All echo returns are extracted in the way typical for this radar. The plots are presented and counted within height classes of 2000 ft (Dupont 1986). Judging to the maximum reported echo densities the resolution and bird sensitivity is meager. It should be reminded that the system is not specifically extracting bird echoes according to their properties right from the raw video, as is done by ROBIN. Nevertheless, BOSS provides an index of real bird activity. Calibration with other (radar) sensors should reveal its value. More refined altitude information, especially within the lowest 2000 ft is highly desirable.

5.2. Civil systems in work

A few attempts have been made to apply bird warnings, obtained by radar, in civil aviation. Because the prime interest is in the prevention of local bird strikes, long range bird surveillance is not very helpful for air carriers, which quickly ascend above the heigths where the birds fly. Hunt (1974, 1975) developed a system for Winnipeg International Airport (Canada) where heavy goose migration poses a real threat also for civil aviation. His electronic counting system on the ASR radar rings a bell when bird echo densities exceed a certain threshold. There are no recent reports on the functioning of this system.

Like in the military some radar operators undoubtly warn the air traffic control tower or pilots when they discover big bird echoes in the (potential) flight path of aircraft in their local control zone. But such voluntary initiatives fully depend on the potentials of equipment and procedures and the knowledge of the operator. The crucial question is of course: how to quantify the danger. Clearly, civil aviation is awaiting a more refined and, above all, an highly reliable sensor of bird activity directly above and around the runways.

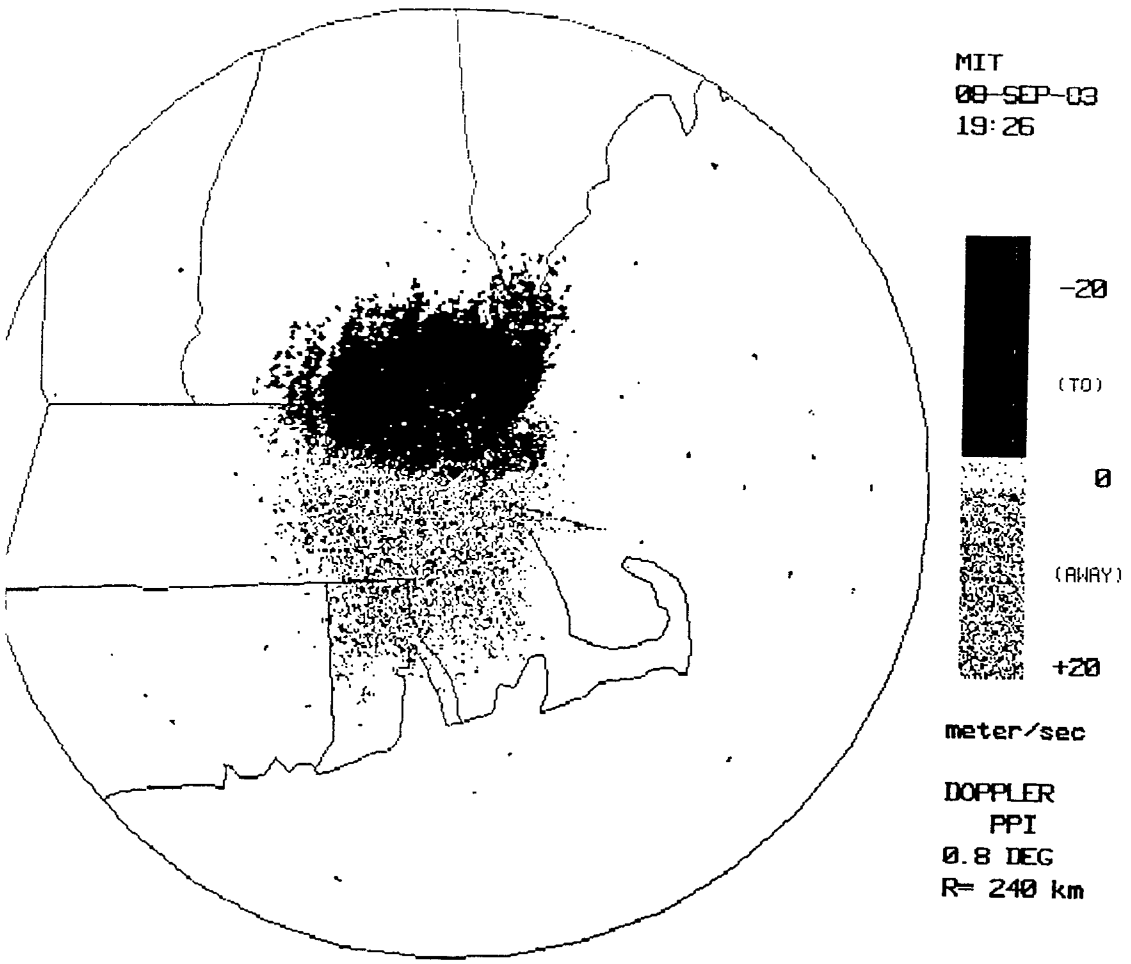


figure 37 Image of the PPI of a doppler radar. Explanation in text.

5.3. Systems proposed

5.3.1. NEXRAD software

The National Weather Service in the US may soon (1990) start spending more than a billion dollar on a radar network to improve its forecasting. The service plans to set up 135 NEXRAD (NEXt generation RADar) units (2.5 million dollar each) at airports and weather stations to cover the whole country. Larkin & Quine (1988, 1989) study the possibility of implementing bird recognition algorithms in the large S-band pulsed Doppler radars. The radars will be equiped with a narrow beam and great power (1 megawatt) and sensitivity (90 dB dynamic range). Apart from the Radar Data Acquisition Subsystem it includes a Radar Products Generation Subsystem and a Principal User Processor Subsystem. Digital NEXRAD weather data are automatically processed by large computer programs but periods without severe weather will offer considerable processing time to run special bird programs. It is expected that actual bird information will be available every 5-15 minutes.

The great sensitivity of the radar indicates that the curvature of the earth will be the limiting factor for bird detection. Calculations show that a single Herring gull would theoretically be visible as a faint target at a distance of 450 km (but, of course, never will fly high enough to ascend above the radar horizon). Songbird echoes during migration often extend out to beyond 100 km. Another limitation for scientific purpose is the low resolving capacity of the system.

The researchers expect to be able to devise algorithms allowing NEXRAD to automatically distinguish echo patterns of weather and birds according to:
1) speed of the birds (the Doppler radar directly provides speed information - see figure 37), 2) their appropiate migratory directions, 3) the timing of their flying activities, 4) their relation to topography and 5) certain echo characteristics.

The plans are to let NEXRAD radars to report bird hazards with reference to large geographical areas and to estimate the degree of hazard in different altitude strata over these regions. The USAF has the resposibility for communicating future warnings from such summaries to pilots in the air and before take off.

5.3.2. Towards a dedicated birdradar

During the 19th meeting of BSCE in Madrid (1988) the radar specialist agreed upon the rough characteristics of a "ideal" bird sensor. The plenary meeting accepted a recommendation alone the lines defined within the radar working group. This is an important step forward because the diversity of methods and types of equipment is very large, as is examplified in this booklet.

- Avoiding insect contamination requires a wave length of 5-10 cm (C or S band). Polarization should be horizontal. It should be a coherent radar, with two MTI's: separating slow and fast flying objects (birds 1-40 m/s) and rejecting ground clutter (-1 to +1 m/s). About 1500 Hz PRF would give about 10 RPM sweep rate with 25 pulses per target.

- The display should contain about 512x512 square pixels with 16 colors or more. The principal display is PPI with radar cross section color-coded. Altitude should easily be determined on the display when needed. All information from the display and pertinent housekeeping information should be available on a connector designed for computer-compatible output.

- A research version with several extra options such as manual scanning, mobility, dual polarization (hor/vert) and full doppler capability, may be desired.

An important rationale behind the above described bird radar is that it should be small enough in range to perform the three dimensional task correctly. The beams of long-range-radars cannot be shaped refined enough, and, more important, must be directed with very small elevation angles. This raises a serious problem of anomalous propagation, frequently disturbing the altitudinal coverage. Furthermore, small dedicated bird radars offer much better possibilities of international standardization of bird warnings. As a result, they will substantially promote international coordination within warning systems and procedures, which, in turn, will favour credibility.

The most important properties of a radar system, specifically assembled for bird detection, are the following:

- It should be able to detect a single herring gull (100 cm2 radar cross section) at 10 km. Thus, the system belongs to the family of (fairly) small-range-radars, like the military tracking radars discussed in 4.2.3. and 4.4.

- No full-time crew should be required. The display would be added to other instruments, available to existing personnel. Because of permanent monitoring a very high "mean time between failure" is a must.

- The system should be designed to monitor the air space three- dimensionally with a resolution in range, azimuth and elevation of 160 m at 10 km. This means that a pencil beam of 1 (max 2) degree aperture is needed, which, at C-band, requires a antenna of 2-3 m across. Volume scanning at 1 degree increments and 5 scans per elevation would cover the important air layers.

6. RESEARCH

Developments in radar and computer technology proceed very fast. In fact, several approaches described in this booklet,may seem fairly obsolete. However, biologist have very limited access to new equipment which is extreme expensive and has an operational task not allowing deviating settings. Even flight safety considerations do not open all doors as one would presume. As a result, most insight into the spatial and behavioural aspects of bird migration was gathered with low budgets, relative simple means and, in case of radar, old fashion equipment. And even nowadays a lot of progress in scientific terms can be made older methods. Fundamental biological knowledge still is a limiting factor with respect of designing warningssystem and procedures.

However, operational implementation of electronic counting systems requires a sophisticated approach because modern radars don't allow simple co-use as they did in the past. Furthermore, a simple index of bird migration intensity is not enough to meet the latest requirements for operational inclusion. At least a three dimensional dataset should be provided. And further details on the species composition with respect of bird weights are also highly desirable. The information provided to the pilots and disseminated internationally should be calibrated. Thus, future applied research should concentrate upon quantitative assessment of bird numbers aloft. Automatic recognition of bird echoes by means of pattern analysis algorithms is a first step. Further improvements can be expected neural network technology. This will make echo extraction faster and less critical. Learning the neural network recognizing bird echoes by offereing examples is another potential advantage. Artificial intelligence may help to recognize temporal patterns in the process of day to day bird activity. However, all these challenges of the future should not let us forget that most decision makers don't have the slightest idea of what is going on high up in the air. Therefore, simple means should be applied when ever possible and be paralled by process of permanent education.

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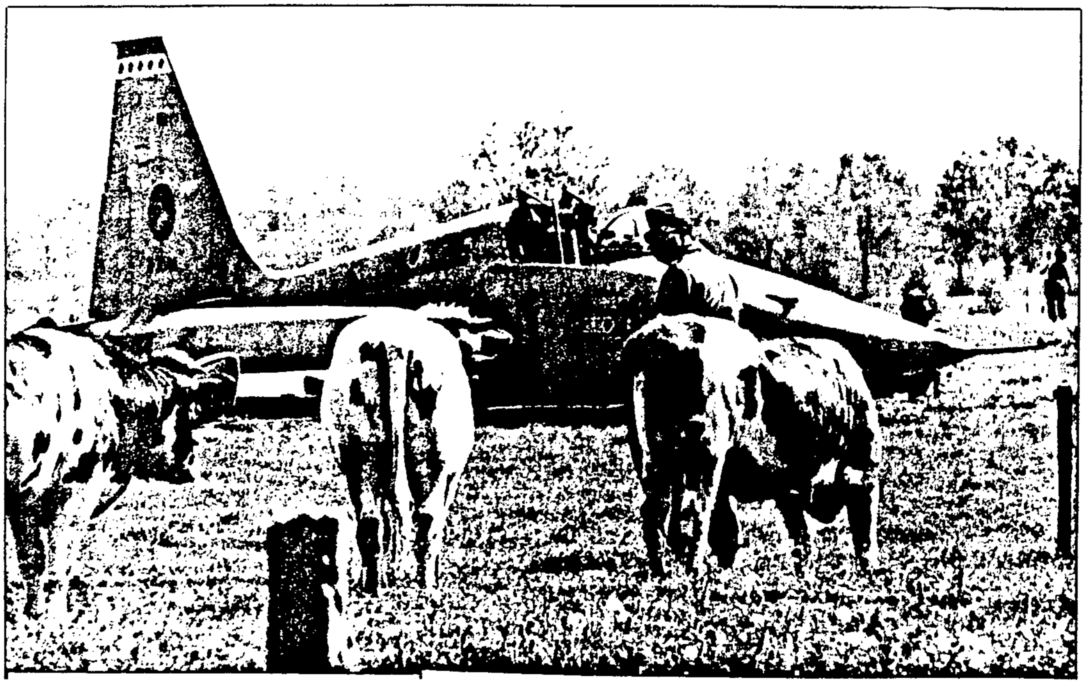

BSCE 20 / WP 37

Helsinki 21-25 May 1990

SCARING AWAY BIRDS BY LASER BEAM

- laser rifle
- automatic laser scanning

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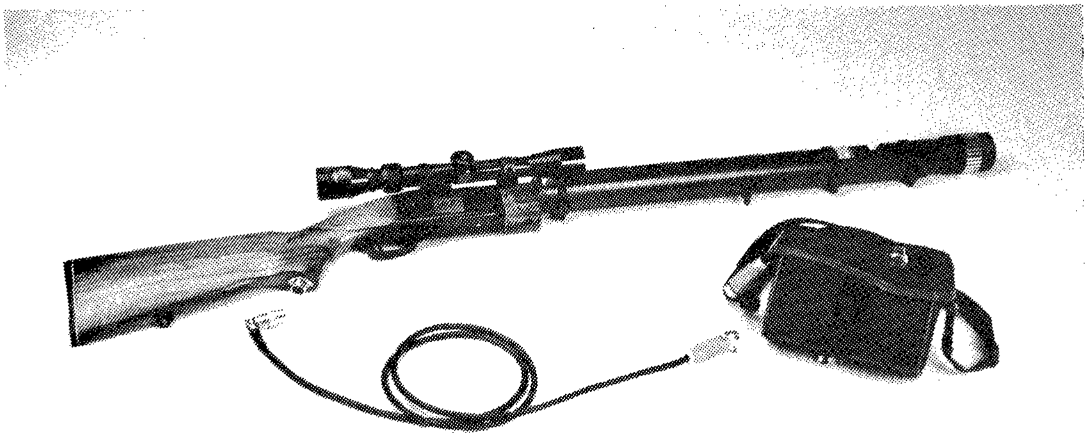
Summary :

Since December 1987 we have carried out tests in various locations using a laser rifle to scare away birds. Results have been very encouraging. This article gives details of all the trials to date and proposes a further development, a system of automatic scanning.

A - LASER RIFLE



1. EQUIPMENT USED

Fig 1

The laser rifle which we have used through out our trials is portable and fitted with a helium neon laser tube which emits a red laser beam. The main advantages born out by our tests are its ease of use, its silence, its small size and lightners, and its very high aiming accuracy (approaching 100 micro radians). The rifle weighs 4,3 kg and the power pack 2,8 kg. Its range is up to 2 km, and the whole appliance confirms in every respect to the norms laid down by the international standard CEI 825 governing radiation safety of laser products (equipment classification ; requirements; user's guide). The rifle falls into class 3A of this standard.

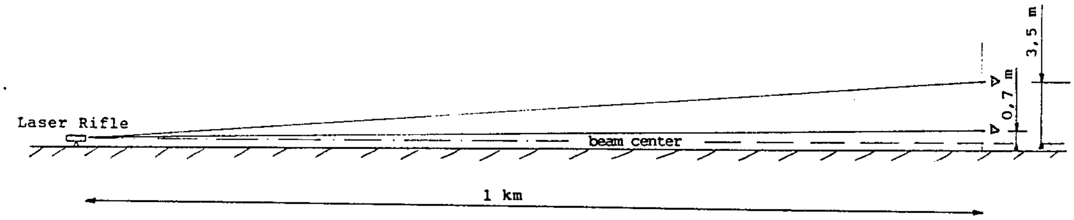
2. USE

a) Aiming directly into the eye of the bird

To use the laser rifle one has to line up on the birds visually first and then shoulder the rifle in the conventional way. There after one can aim at the birds the telescope sight. Simply pulling the trigger emits the laser beam whose red spot is clearly visible in the telescope sight. It is then easy to direct that spot toward the eye of the bird one wants to scare away. When the laser beam veacher the eye, there is a flash as at reflects in the eye which is clearly visible by the person giving the rifle and standing immediatly next to him. This is called the bulls' eye effect.

b) Proximity aim

If for any reason it is not possible to aim directly into the eye of the bird, one can still scare it away by aiming in its proximity. Fig 2 Experiments with animals "in situ" showed this very clearly, and we also carried out tests on the human eye : with an observer placed 1 km from the laser rifle he could perceive the beam up to 70 cm from its axis, and the actual source of the laser light up to 3,5 m from its axis. This perception of the laser beam within the immediate proximity of its geometric linear projection is significant, as it disturbs the animals environment and increases its stress.



Source perception: From 0,7 m to 3,5 m of the beam center

Laser beam perception: From beam center to 0,7 m

3. RESULTS

Over distances varying from 100 m to 1500 m successful results were obtained with following species : carrion crow, jackdaw, maypie, common buzzard, black kite, kestrel, duck, sheldrake, cormorant, grey heron, egret, pink flamings, lapwing, black-headed gull, herring gull, common gull, and others... We obtained exceptionally good results (= 100 %) with lapwings.

All these trials were carried out in real life conditions both within and outside airports.

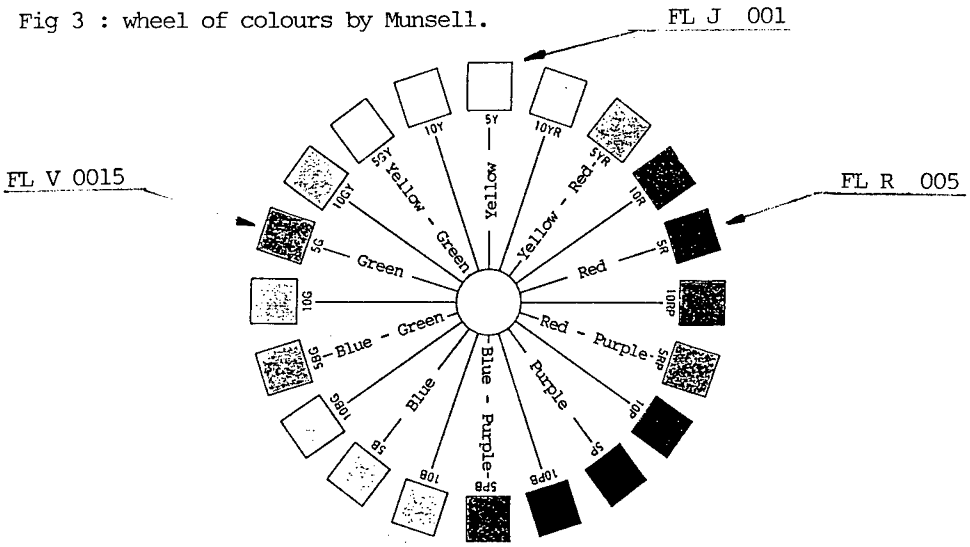
4. IMPROVEMENTS

During the tests we noted that the red laser was not 100 % effective on two species : starlings and sparrows. However, recent progress in laser beam generators has enabled us to replace the red He Ne laser with a green He Ne laser with the same dimensions. We can therefore now also supply a laser rifle emitting coherent green light.

The wavelength of green being closer to the center of the visible spectrum than red. See Fig 3.

We have high hopes of successfuly scaring away those birds which cannot perceive disturbances close to the edges of the visible spectrum.

Fig 3 : wheel of colours by Munsell.



5. OFFICIAL TESTS

The French Civil Aviation autorities have ordered several production models of the FL R 005 laser rifle which emits coherent red light.

6. AVAILABILITY OF THE LASER RIFLES

We are offering three types of rifle as standard production models :

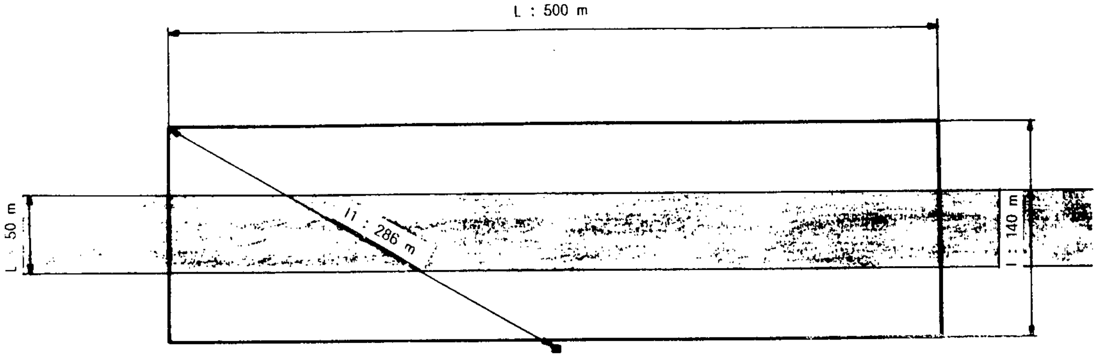
He Ne laser rifle FL R 005 emitting red,	F.O.B price : USD 7 200
He Ne laser rifle FL V 0015 emitting green	F.O.B price : USD 10 400
He Ne laser rifle model FL J 001 emitting yellow	F.O.B price : USD 9 500

B. AUTOMATIC LASER SCANNING

The rifle described in the paragraphs above is highly effective for pin-point targeting or for actual bird perches. However, one of its disadvantages is that it requires an operator. For this reason we have designed a laser appliance with an automatic sweep scanning action

TECHNICAL DESCRIPTION GENERAL

The proposed system is capable of sweeping a landing area or any surfaced airport area 500 m by 140 m. See Fig 4



S = 500 x 140 = 70 000 m2

Fig 4

A 3 km landing strip would therefore require 6 appliances placed immediatly alongside the area to be cleared. The projected laser "spot" light is made up of 9 adjustable laser beams emitted by 9 laser sources.

The system consits of six elements (Fig 5) :

- the mounting frame holding the laser tubes
- the control box for the laser emission
- the motorised swivel mount (2 axes)
- The control box for the swivel mount
- the portable programming console
- the control software

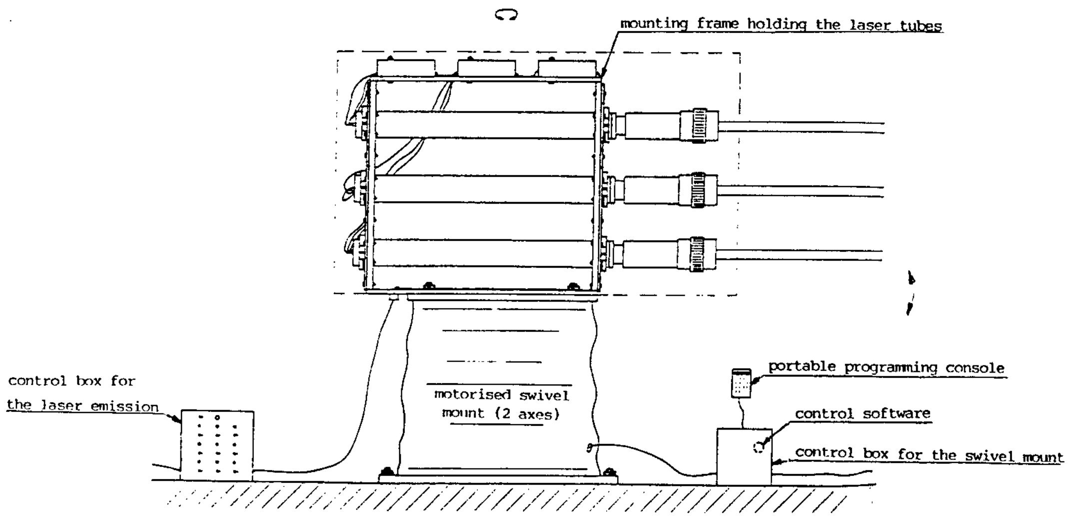


Fig 5

Some of these elements can be spaced tens of meters apart. The overall height of the appliance is between 0,7 m and 1 m. It is designed to operate in rain or spray within a range of temperatures from - 20° to 70°C ; and it conforms on all points to the requirements of standard NFC 43 - 801 regarding radiation safety of laser equipment.

a) The mounting frame holding the laser tubes

This holds 9 He Ne laser heads with attenuators, each emitting a beam of red, green or yellow light. Each head has a telescope enabling variable angles of divergence for each shaft or light. The angle of each head can be moved in relation to the median position by appropriate mechanical devices.

b) The control box for the laser emissions

There is a main circuit breaker fitted on the inside, together with a main control switch governed by a key, in keeping with the requirements of standard NFC 43 - 801 ; a push button is fitted on the outside. Each of the nine laser power supplies is fed by an independent electrical circuit which can be activated separately. A laser emision warning light is filled to each of the nine power supply circuits. All electrical or mechanical controls for the functionning of the lasers are placed in such a way that access to them does not involve any exposure to laser radiation.

c) The motorised swivel mount (2 axes)

Externally this consists on a pedestal with a 400 mm base taperning to 300 mm, an upper mounting plate (for the mounting frame holding the laser tubes) and a bellows type protective covering between the base and the mounting plate. The swiveling movement of the mount can be controlled at variable speeds in a horizontal sweep up to 180°, and at variable vertical inclinations over a range of 50°. The accuracy of the positioning is in the order of 1/5 degree. The maximum speed of the swiveling movement is 10° per second. The mass of the swivel mount is 20 kg and its carrying load 25 kg.

d) The control box for the swivel mount

This countains the power supplies for the various devices used to control the motorised swivel mount. The computer is fitted with 2 serial interface standards RS 232 or RS 422.
Remove control by telephone is possible as an accesory, using two linked modems.

e) The portable porgamming console

This uses one of the serial lines available from the computer. It has an alphanumeric, membrane keyboard and an LCD display for 64 characters. The keyboard is custom designed to make optimally the functions of the control programme for the swivel mount. The dimensions are approximately 200 x 110 x 50 mm and the mass is 700 g.

f) The control software

This is menu-driven software enabling the operator to choose functions, for example :

- linear sweep, point to point
- manual mode, by increment
- continuous circular pattern
- continuous square pattern
- user programmable pattern
- preprogrammed sequence stored in EPROM

Each sweep can be regulated to predetermined limits in terms of angle ($\theta 1$ and $\theta 2$) and angular velocity ($\theta 1'$ and $\theta 2'$). This programming makes it possible to avoid laser beams reflecting off surfaces such as the paraboles of lights and so on. At all times a basic functions checks for any malfunction of the swivel mount. An additional control enables any breakdown of equipment to be tested and diagnosed automatically.

Note : The whole of this appliance is protected by a patent registred by us.

g) Guide price

Purchase of a complete system for automatic laser scanning would come to nearly 174 000 USD per unit for the first models. Once in strandardised production this equipment will cost 122 000 USD per unit. These prices also depend on the colour of laser beam required which, it will be recalled, is available in red or green or yellow.

C. CONCLUSION

Our tests have shown that birds can be scared away effectively by using laser beams, and this has been confirmed.

We can supply laser rifles emitting a red, green or yellow laser beam for pin-point targeting.

The automatic system would however provide greatest efficiency since the area covered by the sweeping action is large, the cost is reasonable, and no staff is required.

ADF616437

20TH BSCE HELSINKI - WORKING PAPER N° 38

STATIC BLADES UNDER LOAD FOREIGN OBJECTS DAMAGES TESTING PROGRAM

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ABSTRACT

To analyse the gun and projectiles main influences on Foreign Object Damages tests done on High ByPass Ratio engines French certification authorities have asked CEPr to find a test mounting able to support the study. CEPr has chosen to simulate the projectile impact on a static blade placed in similar mechanical conditions as those encountered on engines.

As the main study has been delayed due to surprising first results, other studies were proposed and performed with this special mounting : in particular CEPr was interested in using it for propeller composite blade development. The mounting has helped CEPr to prepare TRANSALL FOD qualification tests.

Today, the initial study is still on work, but the research is mainly aimed to the definition of a realistic «false bird».

INTRODUCTION

In the foreign object damages field, French certification authorities and CEPr main concern has always been the tests representativity. In fact it is essential to be sure that the tests being done are conform to the regulations and that they effectively cover almost all dangerous bird strike cases encountered by the engine.

Five years ago, the problem of the bird type was raised without any technical arguments to help CEPr to make a decision [1]. In parallel, certification authorities wanted to know the effects of gun acceleration and bird conserving on the final result as they suspected that those parameters might have some influence on it.

Therefore, CEPr has launched a research program in collaboration with STPA (Service Technique des Programmes Aéronautiques) to try to answer partly or completely to those questions.

CEPr knowledges are mainly based on our HBPR engine testing experience : we have tried to take this experience in account, in order to be able to do comparative analysis between the test mounting we were preparing and the real bird strikes encountered by all kind of engines.

STATIC BLADES UNDER LOAD MOUNTING

The chosen mounting principle is based on the bird impact velocity triangle analysis (figure 1) : a bird sent against a rotating fan blade at a given velocity will have a relative velocity in the blade reference system which can be easily calculated if you know the fan rotational speed and the blade impact radius.

The chosen mounting principle consists in doing the bird shot in the blade reference system (figure 2) : the projectile velocity is then the relative one in the further galilean reference. Blade pitch angle and projectile velocity impact angle on the fan front are kept similar to the real ones.

Then the main problem to solve was the mechanical behaviour simulation. The fan rotation main effect is the centrifugal force acting on the blade which induces a metal centrifugal stiffness : to simulate it we have put the aimed blades under controlled loads. Only three blades are used in order to ensure a compromise between a good test representativity on the second blade and a low test cost.

Another problem was the dynamical behaviour, and mainly the embedding effects related for example to the shroud or the blade tip: CEPr has put a flexible movement clearance at the tip of the blade to avoid strong embedding effects.

The blade support built by CEPr is shown figure 3. Figure 4 give a detailled scheme of the chosen solution.

GUN PARAMETERS STUDY

After a blade support reception campaign, the first campaign main aims were to study the gun parameters effects on the final deformation set : none of the previous aims were reached at the end of the campaign, due to simulation problems encountered during the first tests. Then the campaign has been transformed in shooting adjustments research (figure 5).

As a matter of fact, the first shots adjustment conditions were in accordance with the aimed relative velocity corresponding to normal HBPR bird strike on blade tip at take-off conditions : the deformation set obtained was too large.

This result was related to a too severe bird impact as only one blade was knocked : the main explanation was to be found in the angle between the projectile main axis and the relative velocity (no angle in the static simulation contrary to the real case as shown in figures 1 and 2).

No real solution has been found during the campaign and in fact a change of modelization was necessary to bring the simulated results near again. Therefore two main research axis are presently studied :

1 - an impacting angle increase to improve the bird repartition on several blades,

2 - a bird velocity decrease to minimize the permanent deformation set.

In parallel, we have to find a coherent rotational speed.

With this new adjustment parameters, a second campaign will start soon to check if the results are more sensible. If they indeed are, we will continue the program by analysing the influence at the same initial velocity of :

- gun diameter,
- gun length,
- gun air quality.

This last campaign will give us very interesting results on the test repeatability in terms of blades permanent deformation set.

PROJECTILE STUDY

Included in the initial study aims, the projectile study was part of the first campaign done to analyse the gun parameters. We have sent three types of medium birds :

- sea gull (5 shots)

- chicken (10 shots)
- homogeneous synthetic bird (called «false bird» : 5 shots)

We have found that considering the mean permanent deformation set obtained, the sea gull was the less severe bird, followed by the chicken. The homogeneous «false bird» was really the most severe projectile, probably because it was the most homogeneous one.

If the differences between the real birds and the false one were significant, the differences between chickens and gulls are too small to conclude definitely. The trend observed is confirmed by the rotating tests : however, the chickens are freshly killed in contrary to the gulls which are delivered each two or three months from south of France and therefore must be freezed an defreezed before shooting, which might change their global behaviour. .

Results obtained were considered as very encouraging and during the third campaign, we will try to characterize the defreezing influence on real birds and the gun acceleration effects on the three bird types.

Finally, the poor results obtained with our homogeneous «false bird» have convinced CEPr that an effort has to be made in this direction in order to define a cheap standard projectile, which will resist to acceleration effects inside the gun and will not be degraded by defreezing operations : CEPr tries to develop an axisymetrical «false bird» composed of three density types respectively replacing feather, meat and bones in respect with their repartition in a real bird.

PROPELLER BLADE QUALIFICATION

As the previous test campaign was a failure and considering that we had no experience on propeller foreign object damages testing, we have tried to see if the static blade under load mounting could be use for preliminary testing: CEPr need was mainly the definition of the stone projectile.

Extension to bird strike tests were done to compare the results obtained with rotating tests ones : they fit good and were also comparable to the manufacturers observations made on real impacts in its overhaul workshop.

CEPr has tried to explain the differences between the good results encountered with propeller blade and the bad ones obtained during HBPR blades testing. Two kinds of explanation are put forward to understand the encountered differences :

- only one blade is knocked in real propeller FOD tests. Therefore the argumentation put forward to explain the HBPR simulation failure is no more true for propeller blades : whatever the angle of the bird will be, the blade (rotating or static) divides it into two parts only.
- axial loads are also less important for propeller mounting,
- centrifugal effects on the impacting bird can be neglected when considering

a propeller strike : it is no more possible when studying an HBPR strike.

As explained in [2], the results were so satisfactory that this method is today put forward to qualify propeller blades and also propfan [3].

CONCLUSIONS

CEPr has developed a special mounting to study the gun geometry and projectile type influences on the final results of FOD testing : the results observed on HBPR engines blades were not satisfactory and indicate that the chosen mounting, although sophisticated, is inadequate to characterize the blade behaviour during a bird strike. The results transposition is also a real problem which is not simple to solve, as both the projectile behaviour and the blade response are not the same.

At the opposite, the mounting was proved to be very useful for propeller qualification and CEPr thinks that a complete propfan qualification process should include such tests.

Finally CEPr has tried to define the «false bird» main characteristics : the definition of such a projectile, the qualification to each kind of bird strike tests and the agreement from civil aviation authorities is a difficult and very long process we have just begun. Next shooting campaign on static blades will include a first approach of a two density «false bird».

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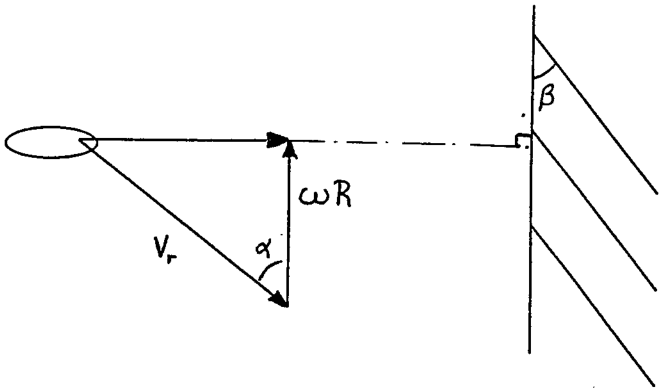

Figure 1 : REAL BIRD IMPACT VELOCITY TRIANGLE

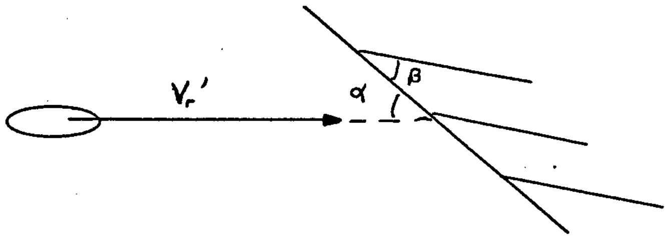

Figure 2 : SIMULATED BIRD IMPACT VELOCITY TRIANGLE

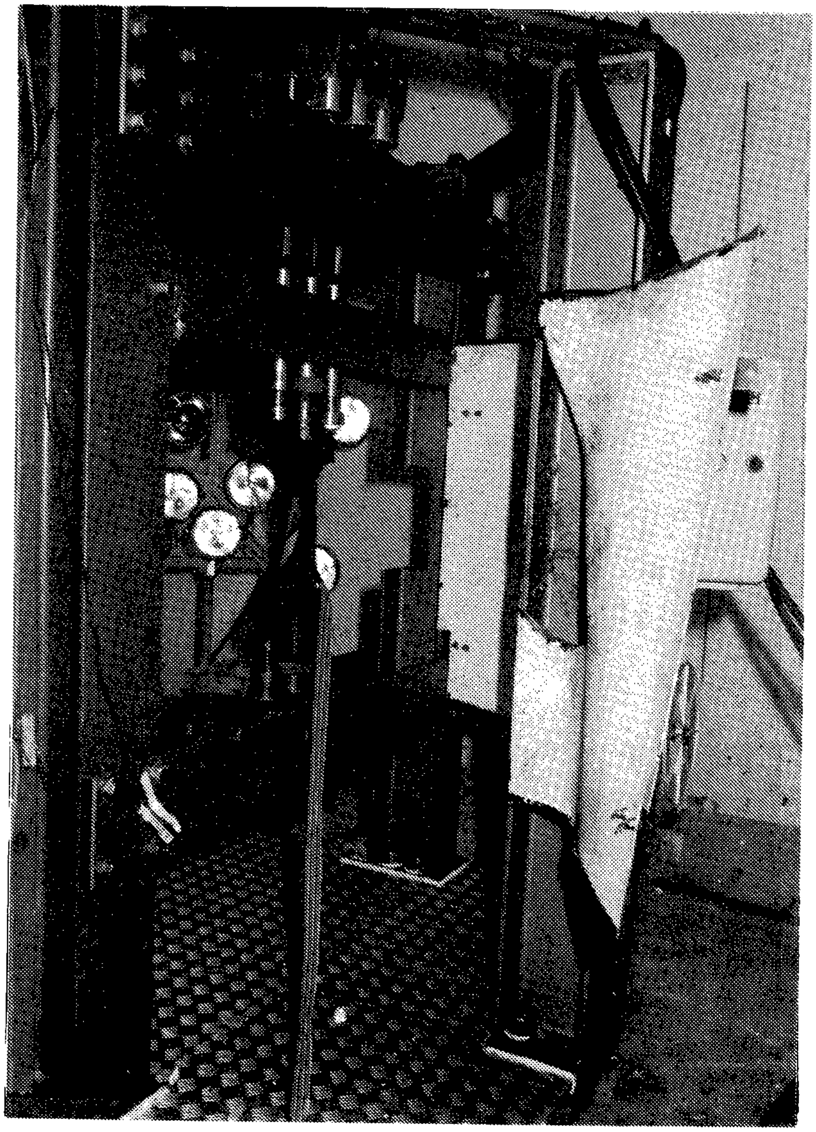

Figure 3 : BLADE SUPPORT
(Photo CEPr 88-1856)

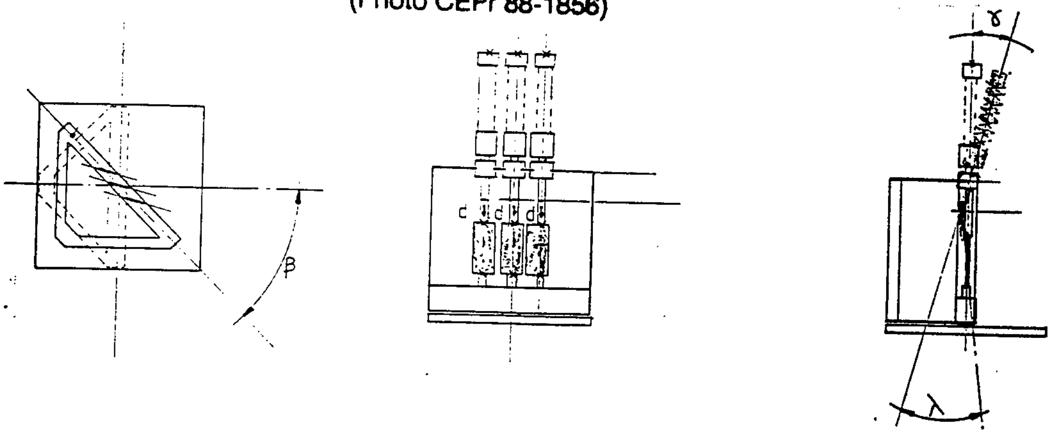

Figure 4 : BLADE SUPPORT PRINCIPLE

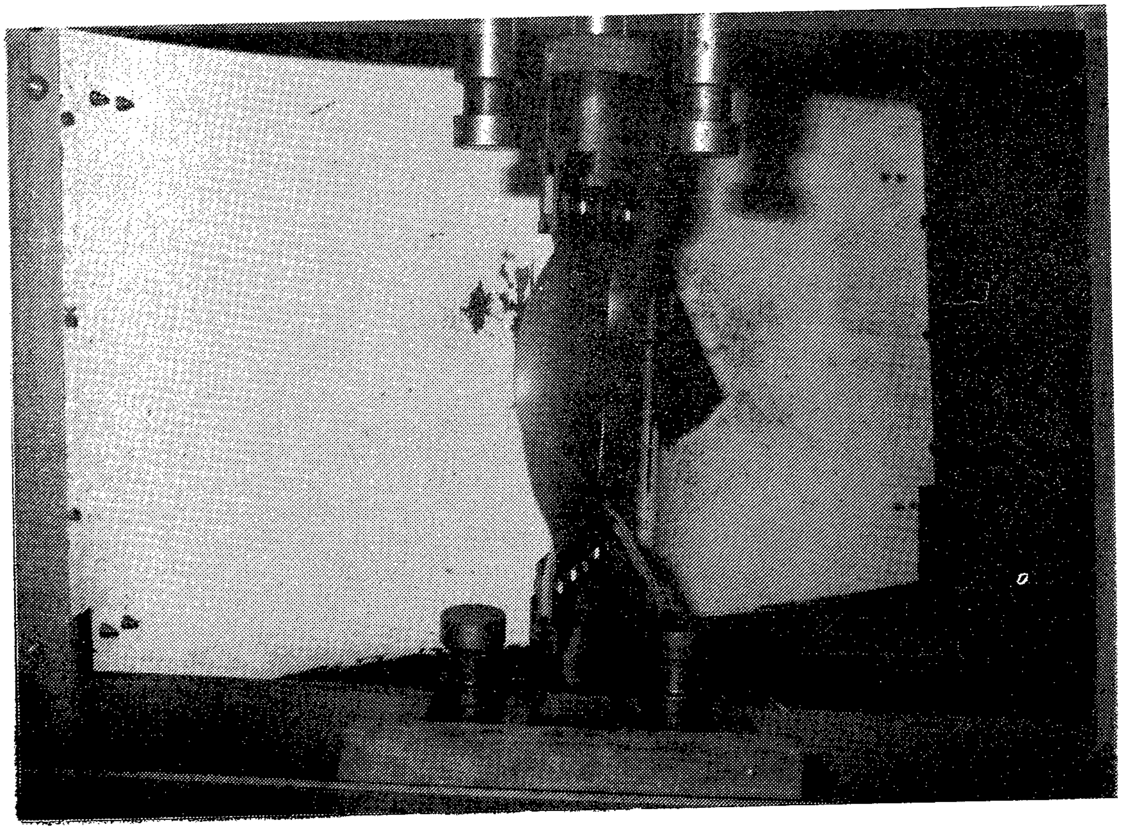

Figure 5 : SHOT RESULT EXEMPLE

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20TH BSCE HELSINKI - WORKING PAPER N° 39

PROPELLER FOREIGN OBJECTS DAMAGES TESTING

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ABSTRACT

CEPr has proceeded in 1987 and 1988 at new TRANSALL composite propeller foreign object damages (FOD) qualification in its H0 test rig.

Those tests were performed under the JAR-E and FAR 33 regulations spirit : therefore new testing techniques were developed by CEPr to achieve tests objectives.

All the tests being done have given a lot of informations on the difficulties, FOD testing teams might encounter during a propfan or propeller qualification.

Test campaign conclusions indicate clearly that some arrangements must be introduce in the qualification process of such engines in order to find a compromise between test cost and engine reliability.

INTRODUCTION AND HISTORY

For now seven years, CEPr has been involved in propeller foreign object damages (FOD) testing. This new part of the general FOD testing activity is directly related to the high speed propeller concept, call PROPFAN, and the composite material use for old propeller replacement on existing turboprop engines.

After a first campaign performed on a four composite blades BASTAN propeller, CEPr has been involved in the new composite TRANSALL blade qualification in 1987.

In the same period, CEPr has worked a lot on the Unducted Fan GE36 qualification and on what should be changed in both its tests methods and tests installations to ensure a full FOD campaign success [1].

The BASTAN campaign has previously shown the FOD testing in real take-off conditions extreme difficulty for propeller type engines. Due to a lack of time, CEPr was forced to shot the birds in the propeller plane in order to guarantee a successful shot probability as high as possible. (see figures 1 and 2) : it was then obviously necessary to change the propeller blade pitch to recover similar conditions as the aimed ones (take-off conditions).

After the campaign, a complete test analysis has been done : the chosen shooting technology was criticized by CEPr itself for three main reasons :

1 - the missing shot rate was relatively high.

2 - the shots were not repetitive, mainly in term of impact location and impact velocity (see figures 2 and 3),

3 - the propeller mechanical behaviour during the strike was not the same : in particular, it has not been possible to analyse a failed shot completely (10% blade losses during a heavy bird test) and to explain what would have happen in a real take-off or cruise bird strike.

Therefore, new technological studies were done to develop a FOD test rig able of projectiles shooting parallel to the propeller axis.

The choice of such a technology was mainly based on the fact that the only existing FOD engine qualification requirements were the JAR-E and FAR 33 requirements : French qualification authorities have therefore taken those regulations as a base for the demonstrations to be done. In fact, the regulations do not force a bird projectile trajectory parallel to the engine axis, but the common use has always led to such a constraint and authorities are considering this fact as a jurisprudence.

The chosen test rig was the H0 CEPr propeller test rig which allows :

1 - a similar mounting as the aircraft one, which is important in terms of mechanichal global behaviour of the whole propulsive system (see figures 4 and 5),

2 - a real take-off simulations in terms of engine rating and propeller blade pitch,

3 - stresses analysis on one chosen blade.

Four different foreign objects were to be sent at the chosen blade :

- stones
- hailstones (50 mm diameter)
- medium bird (sea gull 0.7 kg)
- heavy bird (sea gull 1.4 kg)

Due to global qualification cost constraints, only six metallic and six composite blades were given for almost 40 shots to perform during the all campaign.

This implies that CEPr test rig development major objective was mainly written in term of missing shots tolerable rate : CEPr choices were mainly based on those missing rates per projectiles :

- stones : 75%
- hailstones : 50%
- birds : 0%

The engine thrust was considered as a qualification parameter.

CEPr FOD TESTING TECHNOLOGY IMPROVEMENTS

To achieve its ambitious objectives, CEPr FOD testing team has mainly worked on the shooting automaton.

Gun, high speed movies and video cameras and their afferent management system were not changed : only little improvements were put to increase the film quality and projectile speed measurement. However, a very long and detailled calibration campaign has been done for each pieces of the test rig in order to know the different FOD parameter uncertainty as best as possible (gun pressure, detonator explosion time, installation electrical repeatability, gun air quality, etc ...).

In parallel, theoretical studies were launched : they led us to the conclusion that a blade aimer system (BAS) was obviously the only solution of our problem : coupled to a little FOD managing system improvement, a BAS would allow us to choose the blade to be knocked against and would also be self learning capable if a lot of shots were not successful.

Blade aimer system

Blade aimer system original idea is a World War I aircraft machine gun firing system derivative : this old system allows to shoot the machine gun through the propeller without damaging the blades by synchronisation with the propeller rotating velocity. BAS principle is just the opposite : firing all the time in the propeller blade.

BAS implies a very good knowledge of the different time spent by the projectile and the aimed blade between the shooting authorization and the impact.

To ensure the time spent by the blade between the shooting authorization and the impact, BAS is mainly based on a stroboscopic video system whose frequency is related to the propeller rotational speed. View of the aimed blade is taken by the stroboscopic system and the test engineer can choose the blade to be knocked against by acting on a shooting time delay. In order to increase accuracy, the minimum time step possible was the micro-second (in accordance with the automaton internal clock frequency). This delay is automaticaly taken in account by the automaton during the firing sequence. (figure 6)

Through this visualisation concept, BAS allows also a very good survey of the impacted blade after shot during the five minutes engine stabilisation.

Gun calibration

The time spent by the projectile between the firing authorization and the impact is put in the automaton as a time delay constant : it is a result issued from the calibrations campaign and which might be corrected if some engine influence appears.

This constant is in fact the most important parameter to characterize : therefore it has been necessary to improve our uncertainty analysis during the calibrations : as a consequence, the reutilization of old calibration shots was almost impossible.

New calibrations shots at given firing conditions were done in order to measure all the different times which characterize the projectile trajectory :

- time between shooting authorization and detonator explosion,

- time spent by the projectile inside the gun after the detonator explosion,

- time spent by the projectile to cover the distance gun propeller plane.

The second parameter is mainly related to gun air pressure and final bird velocity. Each parameter was measured and its uncertainty was calculated : then influence coefficients between the different uncertainty were calculated and analysed. They were also compared to the different adjustment parameters such as shooting delay, air pressure, bird mass, projectile carrier mass, etc ...

Knowing the major uncertainty causes, some methods improvements have been develop to reduce them. At least, the bird velocity uncertainty has been reduced at nearly 1% at 50 m/s (between 2 and 3% before).

Although each calibration campaign was seriously done, the propeller effects were not simulated : as their influence was badly known, CEPr was rapidly convinced that at the beginning of each projectile shooting campaign, some shots would be non successful and therefore, the first shots were always considered as «calibration shots». CEPr objective was to reduce those adjustment shots under 5 shots for stone projectile and under 2 shots for birds.

QUALIFICATION METHODOLOGY

As no existing regulations might be applied, French military qualification authorities have chosen the JAR-E regulations as a discussion base : however it was most important to check if the damages encountered during the qualification tests were comparable to those seen by AIR FORCE and NAVY on their bases or by RATIER in its overhaul workshops.

In parallel with the TRANSALL qualification, two kinds of comparisons have been developed :

1 - shots on static blades under load [2] were performed in order to establish the differences between composite and metallic blades in same conditions,

2 - shots on rotating metallic blades were previously done and results (deformation set) compared to the real damages seen in repair workshops.

With all those results, CEPr and RATIER have tried to predict what kind of behaviour the composite blade would have during rotating FOD tests. In fact, the analysis of results has shown that :

- shooting parallel to the propeller axis was the most representative solution,
- results observed on metallic blades were entirely similar to those encountered during real bird strikes.

The choice of take-off conditions and the calibrated projectiles was confirmed by the conclusions of both comparative tests. It has been therefore decided to keep the JAR-E regulations for the TRANSALL propeller qualification, but to restrict the projectile number to one per shot, which was the most reasonable number in terms of impacting bird density as our theoretical studies have shown us.

CAMPAIGN MAIN RESULTS

CEPr is not realy qualified to present in detail the results obtained during the TRANSALL qualification campaign : however, important facts were seen and will be recorded here.

The composite blade behaviour has been judged better than the old metallic one, mainly in term of deformation permanent set and material health. In particular, the nickel base metallic protection against erosion put on the blade leading edge was not damaged and the glue used was very satisfactory. No composite delamination has been observed : this result is very good considering that more than 30 birds have been shot on 4 blades often at similar impact location. As a matter of fact, no composite blade has been changed during the all campaign.

A surprising result is the fact that the impact location can sometimes avoid the leading edge of the blade, which is always the case for HBPR engines : this confirms our theoretical studies [3].

MAIN PROBLEM RAISED

As said before, the uncertainties calculated and observed on the different FOD test installation parameters have been studied in order to analyse more precisely the impact time dispersion. The different calculations hypothesis led us to think that the impact time repartition can be describe as a gaussian function [3]. Subsequently, the relative distance between the blades and the bird at a given time is also a gaussian function.

Comparing this result to the one obtained in an High Bypass Ratio (HBPR) engine qualification [3], CEPr has confirmed during the tests that only one part of the bird mass was really impacting the blade : as a matter of fact, in an HBPR engines bird strike test, the whole mass of the bird takes part in the shock, almost equaly distributed on several blades.

As during some shots, we have been capable to analyse how the bird was cut by the blade, we have experimentaly found that the «acting mass» implied in the impact is almost a gaussian curve as well (figure 7).

Then the main problem raised after a shot was perform was :

IS THE TEST BEING DONE THE MOST SEVERE ONE ?

In other words, is a one shot qualification test really reliable ?

CEPr experience leads to the conclusion that you can guarantee for a one bird shot, the projectile would not miss the blade : little installation improvements at low investment costs are sufficient. However, it is more difficult to control and reduce the FOD main parameter uncertainty : a noticeable reduction implies most of the time a subsequent change of technology and therefore a complete installation renovation at high investment costs (for example, just try to imagine what should be done to control and to make repetitive a real bird trajectory between the gun exhaust and the blade).

Due to the lack of time (qualification date to be respected), CEPr has not tried to improve more its FOD testing system : we have defined what seemed to be the worse impact (in term of blade radius) and we have perform 10 shots at similar conditions, in order to have a consequent data base and to be sure that approximatly half of the bird mass has one time knocked against the blade.

As said above, the results of those shots have confirmed the gaussian repartition.

Not only the mass effects can differ, but also the impact location : as for HBPR engine you are always sure that most of the shot will be on the leading edge, for the propeller blade, the impact can be on the pressure face or on the suction face depending on the bird or propeller rotating velocity. This fact backs up the uncertainty related to the severity of the bird impact.

CONCLUSION

Facing the propeller FOD qualification, CEPr has developed new shooting installations and new testing methods which are very satisfactory.

It seems however that the choice of JAR-E regulations will lead to some practical difficulties related to the uncertainty of the FOD installations main parameters. In fact, as for HBPR engines there is no need to define how a bird is impacting a fan blade, for a propeller a new parameter is necessary to describe the strike severity : we call it «acting mass». Unfortunatly this parameter is difficult to characterize through real strike statistics analysis and therefore has to be imposed by the reglementations.

To reduce the cost of propeller FOD qualification tests, the use of static blades under load seems to be a sensible solution, mainly in terms of costs : however, it does not replace the complete engine test which can be done only on a rotating turboprop equiped with its propeller and all its equipments.

The question of the shots number necessary to meet the imposed «acting mass» is then also a regulation decision to make, considering the test installation capacities and the engine performances.

The very encouraging results, we have on static blades under load campaign show that a mix of the two testing methods is necessary : the static blade campaign will ensure, that the blade can resist to all kind of bird strike and the rotating propeller FOD test will show that the all propulsive system can support a foreign object strike.

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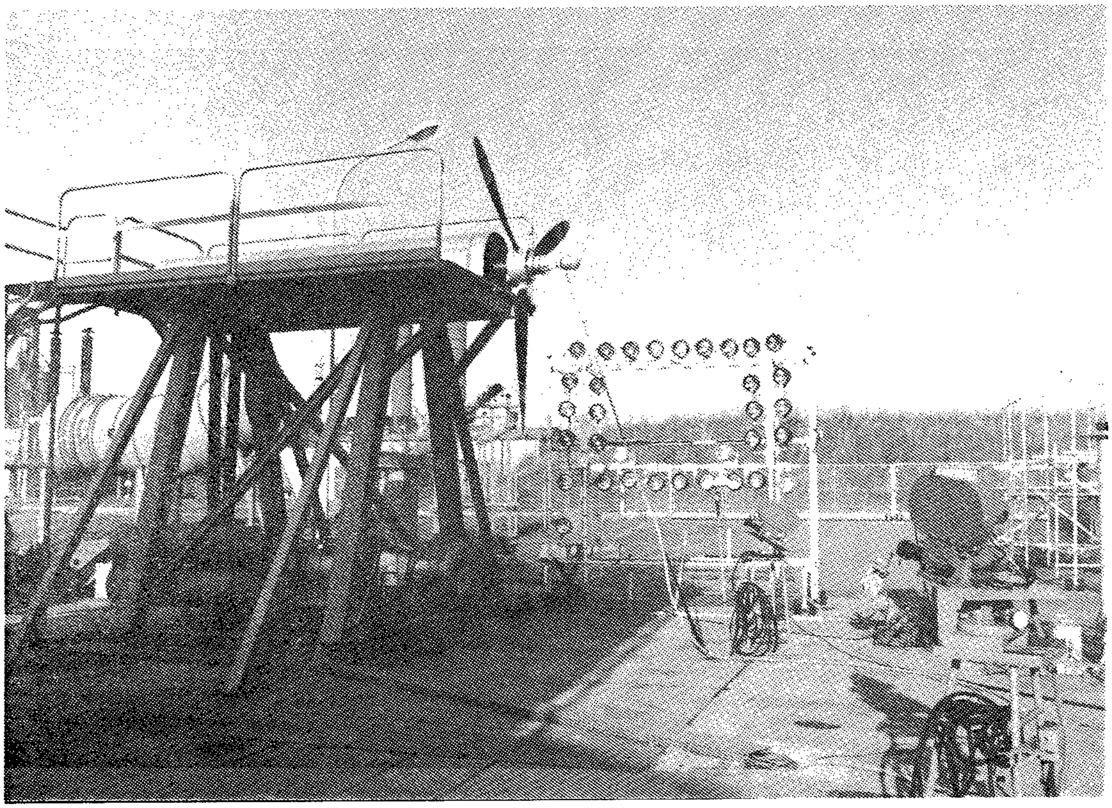

Figure 1 : BASTAN FOD TESTING INSTALLATIONS
(Photo CEPr 85-211)

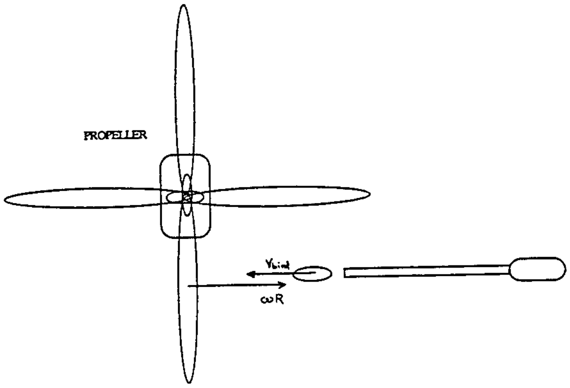

Figure 2 : BASTAN FOD TESTING INSTALLATION SCHEME

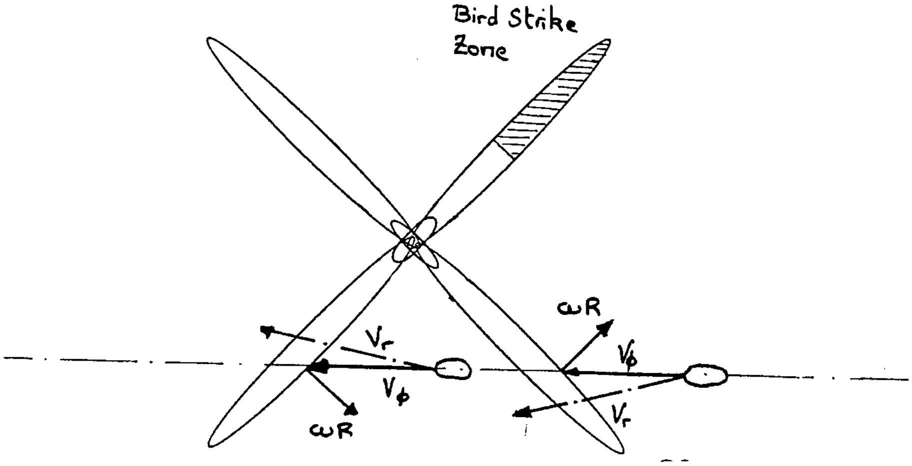

Figure 3 : BASTAN FOD TESTING PRINCIPLE

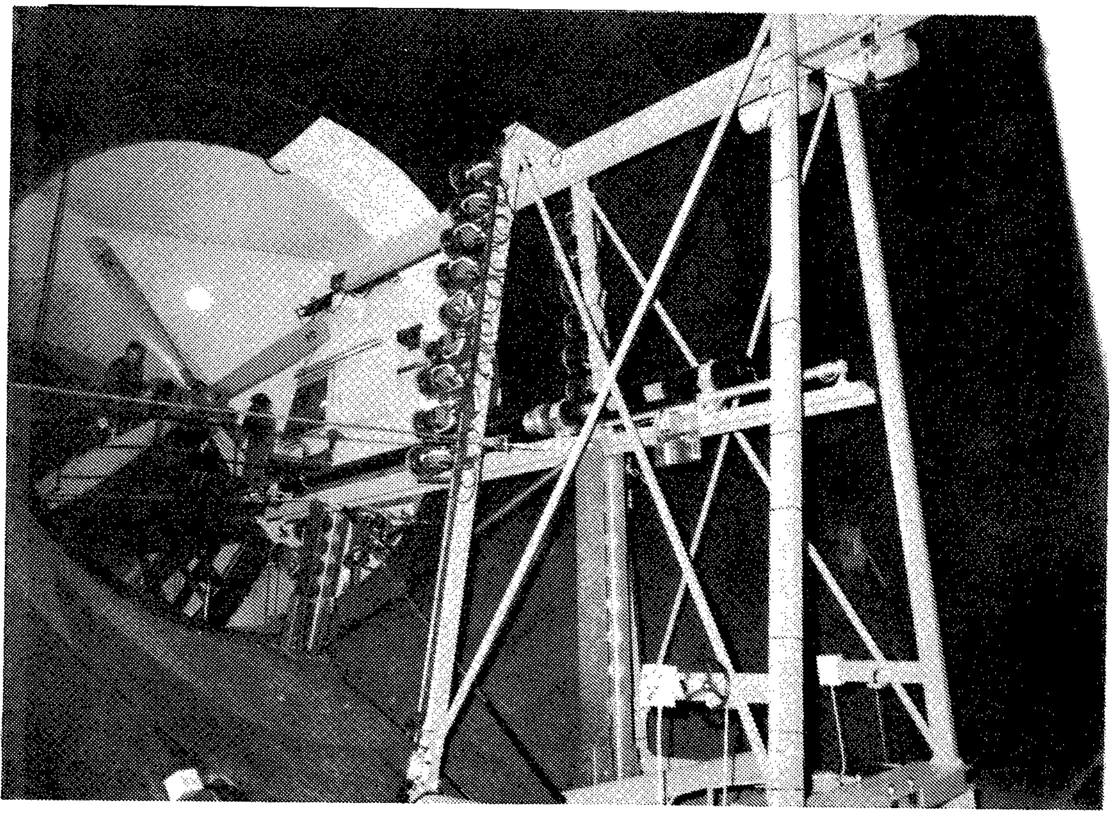

Figure 4 : TRANSALL FOD TESTING INSTALLATION
(Photo CEPr 87-5566)

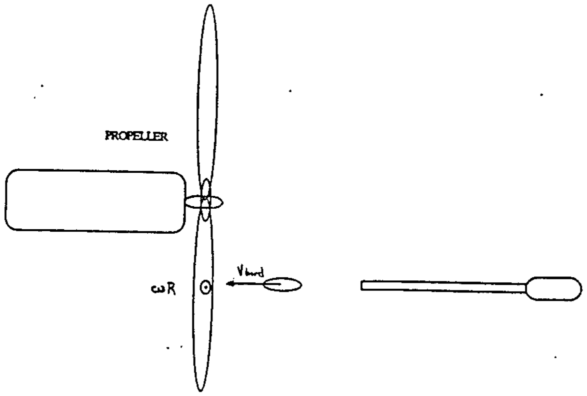

Figure 5 : TRANSALL FOD TESTING INSTALLATION SCHEME

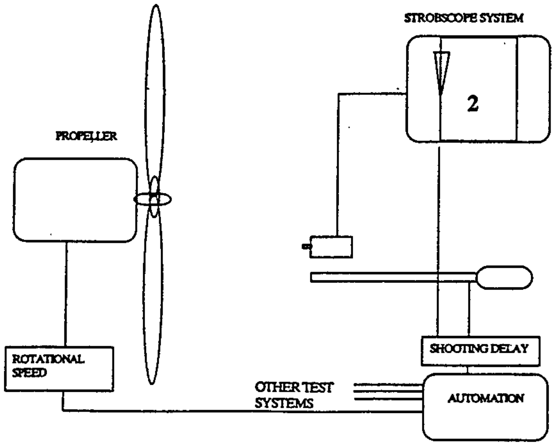

Figure 6 : BAS SCHEME

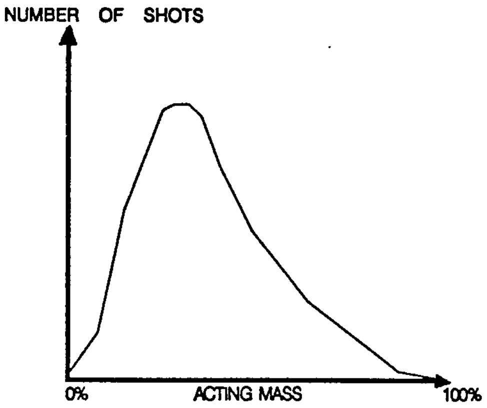

Figure 7 : ACTING MASS REPARTITION

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BSCE 20 / WP 40

20TH BSCE HELSINKI - WORKING PAPER N° 40

PROPFAN BIRD INGESTION TESTING

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ABSTRACT

To face the UDF GE 36 qualification and to understand the results obtained during the TRANSALL composite propeller blade Foreign Object Damages qualification, CEPr has developed a simple modelization of bird impact on turboengines blades, which take the tests installation parameters uncertainty in account.

Preliminary tested in comparison with our experimental results obtained both on High ByPass Ratio engines and propeller, the model is a good description on what can happen and what is the probability of it to happen.

Some results obtained on propeller or propfan models are surprising and have direct consequences on the FOD qualification methods or processes to be used for engines certification.

INTRODUCTION

At the beginning of the theoretical studies realized by CEPr to analyse the TRANSALL foreign object damages (FOD) qualification feasibility, the main questions raised were :

- what might happen during such a bird strike ?
- what kind of differences might we encounter by using High Bypass ratio (HBPR) FOD technology ?

As TRANSALL FOD qualification tests second aim was also to prepare both the test installations and the regulations to the UDF GE 36 qualification, CEPr has tried during its preliminary studies to identify the main differences between four kinds of engines :

- HBPR engines (like CFM 56 or V2500)
- Propeller engines (like TRANSALL or BASTAN propeller)
- Unducted fan (like UDF GE 36)
- Ducted fan engines (like the German CRISP FAN)

As CEPr has decided to study only the first bird impact on the first fan, the last engine category can be joined to the HBPR engines one.

The study was reduced to a simple model development and CEPr aim was to confront the results obtained on HBPR engines to those found during the different CFM56 qualification campaigns. After this, CEPr has tried to define what a propfan would be and what kind of results propfan FOD tests might give.

CEPr has also tried to understand what the uncertainty effects might be on the final results : this explained that the model is both a description of the tests installation and of the engine to be tested. This has been always a major preoccupation, even in HBPR engine FOD testing, to know wether our technology was sufficient or need more improvements : as our technology allows us to cover all the existing cases, only the precision and therefore the quality of the test is now a problem.

MODEL DESCRIPTION

The model being used is divided in two main systems simulated by characteristic numbers :

- the first system is representative of the technology level, the reliability and repetability of our shooting installations. We will find there the installation parameter and their uncertainty such as :
  - * shooting authorization time,
  - * shooting delay,

* time spent by the projectile in the gun after detonator explosion,
* gun pressure,
* gun diameter,
* fan-gun distance,
* projectile velocity,
* projectile characteristics (length, diameter, density, etc ...),
* etc..

The first two parameters are representative of the automaton subsystem, the three following ones of the gun subsystem, the distance of the test mounting and the last two ones of the chosen projectile subsystem.

- the second system is representative of the engine type. CEPr has chosen to reduce the engine at its propeller or first fan and therefore the parameters used in the engine system description were :

* fan or propeller number of blades,
* blade characteristics as a function of blade radius,
* critical radius,
* fan or propeller rotational speed,
* fan or propeller propulsive torque,
* etc ...

When we have tried to understand how to ensure an impact on the second fan, this one was described with the same parameters.

All parameters are described by a gaussian law (mean value, standard deviation) Assuming that they are independent, the results will also obey a gaussian law. This description of parameter uncertainty is conform to French Bureau National de Metrologie recomandations.

The final result given by the model is the bird impact location when it occurs. A probability analysis allows us to transform this result in :

- missing shot rate or impact probability,

- «acting mass» repartition, which is the mass really impacting the blades.

As CEPr wanted to keep the model as simple as possible, many physical aspects of the shots have been simplified or sometimes not considered :

- we have neglected the aerodynamical effects on the projectile during its flight and in the fan volume.

- we have neglected the mechanichal effects of the impacting projectile on the blade and the consequences in terms of rotational speed and vibrations.

- the projectile is described as a sphere or a cylinder and moves along a straight line.

CEPr in fact has studied in an other program the influence of those parameters : this program, the FODES program (Foreign Object Damages Expert System), is in fact the program which is directly preparing the shots and therefore which must take the secondary effects in account to have a successful shot. In our preliminary study, the secondary effects do not really interfere with the row results and they can be neglected.

MAIN RESULTS

CEPr study has been divided into two periods : first the impact probability study and comparison with HBPR engines previous experimental results and secondly the uncertainty influence study.

First impact and knocked blade number study

Three engines models were chosen to describe the different engine types considered in the study : they are described in figure 1. Each time, we have studied the bird strike at 90% of the blade radius, which is most of the time the most critical location.

To qualify the model, CEPr has begun its study by HBPR engines in order to compare the results and the real bird strikes experience we had. Figure 2 shows the row results given by the model. Those results were very satisfactory as the knocked blades number was similar to reality : the differences found between the damaged blade number found in real bird strike and the knocked blade number found by the model is in fact easily explained :

1 - by the weak mass impacting the first and the last blade,

2 - by the chosen bird modelization (an ellipsoid model would have given better results than a cylinder one).

We can note on picture 2 that the «certification zone» defined as the zone were authorities might choose the qualification parameters, both in terms of engine rotational speed and bird velocity, is completely inside the 0% missing shots rate zone : this is a particularity of the HBPR engines which make FOD tests relatively easy.

Finally, we can see that the impact location will always be on the leading edge and on the pressure side. The model was coherent with the results found during previous HBPR FOD qualification test campaigns.

As results were good for HBPR engines we have applied the model to propeller engines. Figure 3 indicates the row results scheme obtained. One major difference appears : the «certification zone» is completely outside the 0% missing shots rate zone. Something therefore must be done to adjust the different reference times to avoid high missing shots rate : this result has led CEPr to define precisely the Blade Aimer System [1].

Considering the impact location, CEPr has found that it was possible for an impacting bird to avoid the leading edge and knocking only the pressure or the suction face : this has been confirmed by experimental results for the pressure face impact possibility during the TRANSALL propeller FOD qualification [1].

As the model was excellent in its prediction for TRANSALL propeller testing, we have tried to see what kind of results we might expect for propfan engines. For time reason, the study has been restricted to the first fan impact.

The row results obtained are given in figure 4. We can see there that the propfan has a complete different behaviour compared to HBPR engines or propeller : in particular, the «certification zone» is partly inside the 0% missing shots rate. This means that the tests technology used for HBPR engines is not sufficient to guarantee a 0% missing shot rate and therefore the propeller testing technology with the use of a Blade Aimer System is necessary, even if this BAS is less sophisticated than the ones developed for propeller testing.

We found here that a propfan is between the two types of engines : its global behaviour will therefore in fact be also in between and we will have to face for Propfan FOD testing the same troubles as the one encountered for propeller FOD testing.

Uncertainty influence

The second part of the study was much more focused on the test severity and quality. The major parameters are then :

- the «acting mass», which is the total mass impacting the blade,

- the impact location.

In fact those two parameters are completely related and the results found on the first give clear ideas on the second parameter behaviour.

On HBPR engine, as the whole bird is impacting several blades, all the bird mass impacts the propulsor and the parameter to be considered is then the maximum acting mass per blade. Uncertainty becomes a problem to deal with only when you try to avoid double impact on the same blade.

For propeller and propfan, the impact location (in the blade reference system as shown in figure 5) becomes uncertain, due to the main adjustment parameters uncertainty : our model shows us that at given conditions (mean value and standard deviation), the «acting mass» is also described by a gaussian function as a result of the adjustment parameter mathematical independence.

We have studied the influence coefficients of the installation adjustment parameters on the final result. The results obtained showed that :

- the distance between the gun and the first fan has a major influence : increasing this parameter increases subsequently the total uncertainty. This result is backed up by taking in account in a more sophisticated model the trajectory effects due to aerodynamical environment : we have therefore considered that the trend shown by the model was in reality much more important and this has led us to reduce the gun-fan distance for the TRANSALL propeller qualification.

- the bird velocity is acting in the opposite way : the uncertainty is very bad at low velocity shots and tends to decrease at high velocity. This trends can be backed up in a more sophisticated model by the fact that intended velocity uncertainty increases when final bird velocity aimed decreases (Gun modelization results). This has been a real problem to solve for the TRANSALL propeller FOD campaign.
- the engine rotational speed tends also to increase the uncertainty : the main consequence is an increase of the acting mass uncertainty for propfan engines.

STUDY FIRST GENERAL CONCLUSIONS

CEPr is still going on with the study : however some general conclusions are now clear and let us think, propfan FOD testing for qualification purposes will not be as so simple as HBPR engines ones and will probably similar to the propeller FOD qualification process.

If the certification authorities choice is to maintain the actual philosophy (shooting several birds at an engine in real take-off conditions), two problems are to be solved :

1 - we have to find the right engine and gun mounting for UDF Propfan or Propeller to allow the engine to be at the right conditions (mainly for the blade pitch and the aerodynamical effects) without disturbing the engines global performances : this solution was chosen for TRANSALL propeller FOD qualification because the engine mounting was still existing.

2 - we also have to be sure during a multi-bird shot that all the birds are impacting the fan or the engine and that the global impact is representative of a real severe bird strike.

On TRANSALL propeller, CEPr study has concluded that only one bird was needed. This was a result of a bird density analysis : we have assume that the JAR-E bird number requirements is related to a bird flock density and we have calculated the equivalent HBPR area (in term of aerodynamical blockage) and deduced the bird number. However, to ensure that the worst cases have been covered, CEPr has performed 10 shots at similar conditions : this induces a very high testing cost both in term of tested material and direct test costs.

Doing the same thing for propfan will lead to 1 to 3 birds shots depending on the fan diameter, blade chord and pitch angle. Therefore, the number of shots necessary to ensure that the most damaging cases have been covered is obviously higher and so the testing costs.

It is then clear that new FOD qualification processes have to be find in order to replace or reduce direct shots parallel to the engine axis at take-off conditions. Some solutions trends can be presented very here quickly : none of them is really satisfactory and the final solution might perhaps be a mix of all.

1 - developing the static blade under load tests techniques : presently used to define the critical zones, this testing techniques could be used to analyse the deformation set induced all along the propeller blade to be certified. Once the deformation set are obtained, the blades are mounted on the propulsive system to check the thrust and the dynamical integrity. This method induces a good understanding of what might differ between real bird strikes and simulated strikes. Comparative test on existing engines are obviously a necessity.

2 - single shot testing on rotating fans : this solution is obviously reducing the global number of shots, but cost reduction is relatively low compared to the volley shot solution. The problem of the relations between reality (multiple impacts) and the qualification test is still present and will therefore induce as well comparative tests on existing engines.

CONCLUSION

The CEPr study has led to conclude that the propfan testing technology choice is mainly depending on the regulations rules and demonstration processes which will be use for such engines.

Between the propeller type and HBPR engines types, propfan FOD behaviour comes up more to the first type, considering that the missing shots rate is different from zero and that only one blade can be knocked.

Therefore, it seems very important to work more on propeller statistics in order to analyse the regulations main parameters such as the bird number, the impact locations, etc...

The regulation choice is then a very long process based on specialist discussions to find a compromise between qualification reliability (certification tests have covered the worst FOD cases) and testing costs, taking also in account the bird menace evoluion and the impact of new technologies.

Bibliography

[1] PROPELLER FOREIGN OBJECT DAMAGES TESTING
JP DEVAUX WP** BSCE 20

	HBPR	PROPFAN	PROPELLER
Rotational Speed	5000 rpm	1500 rpm	1000 rpm
Blade Number	36	8	4
Chord length	0.15 m	0.20 m	0.40 m
Blade Take Off pitch	25°	#35°	#30°
Fan diameter	1.5 m	1.6 m	2.0 m
Critical radius	90%	90%	90%

Figure 1 : ENGINES TYPES CHARACTERISTICS

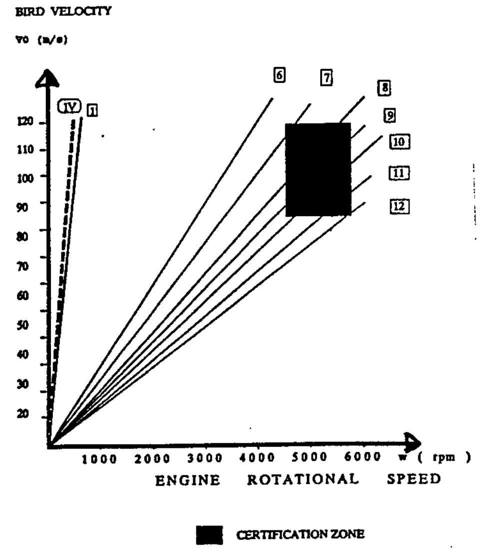

Figure 2 : HBPR KNOCKED BLADES MODEL RESULTS

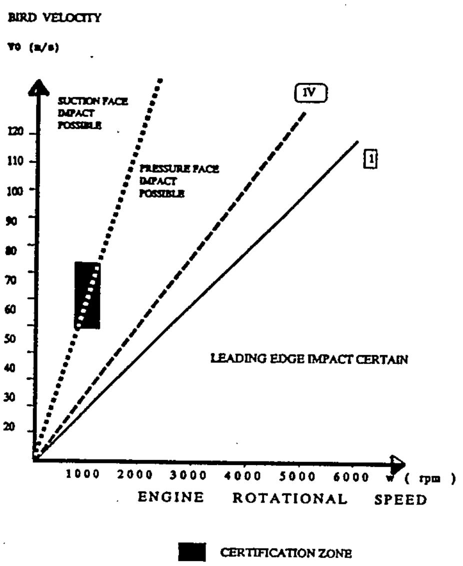

Figure 3 : PROPELLER KNOCKED BLADES MODEL RESULTS

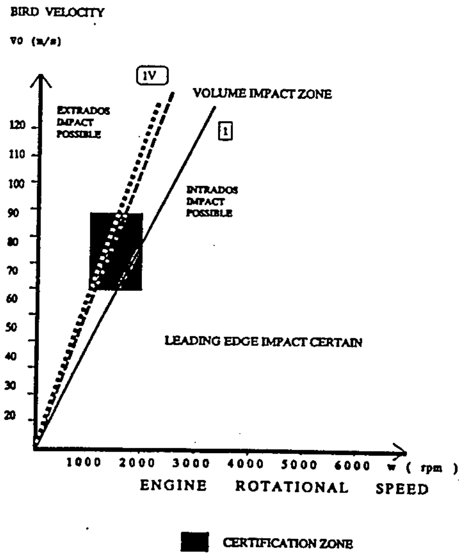

Figure 4 : PROPFAN KNOCKED BLADES MODEL RESULTS

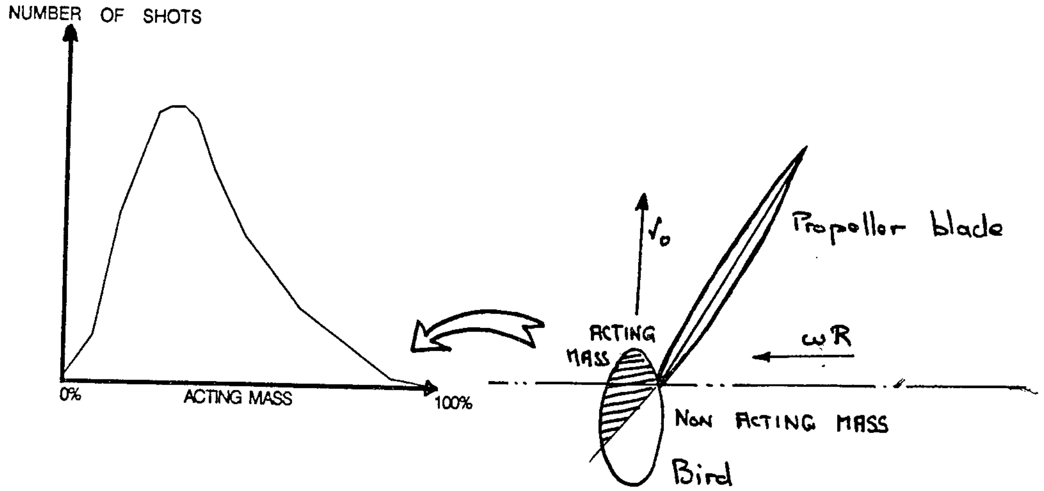

Figure 5 : ACTING MASS REPARTITION

BSCE 20 / WP 41
Helsinki 1990

GEESE AND AIR TRAFFIC IN THE NETHERLANDS

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In winter large numbers of geese stay in the Netherlands. The total number may approximate to 1 million. So, the Netherlands has great international importance for the management of migrating and wintering geese. The availability of sufficient information about the distributions and movements of geese in breeding areas, migration areas and wintering grounds is important to conduct an adequate management. Counts of geese receive special attention in the Netherlands. The system used to count the geese not only provides an overall picture of the Netherlands, it also gives a good idea of developments in specific areas and in movements of geese. Movements of geese occur primarily between the breeding areas and the wintering grounds in spring and autumn. But the geese also move a lot in winter. Changes in weather conditions may cause large numbers of geese to move in the Netherlands and Europe. These movements occur partly during the day and partly during the night. An important category of movements are the flights between roosts and forage areas. To obtain more information about the movements of geese, the network of enumerators will have to be enlarged internationally. Perhaps technical tools, such as radar, may also supply much additional information.

1 THE IMPORTANCE OF THE NETHERLANDS TO GEESE

On a map of Europe the Netherlands covers only a small area. However, in spite of its small size it is of great importance to goose management in Europe. In winter large numbers of geese stay in the Netherlands. The total number may approximate to 1 million. The geese that in summer are hard to find in their vast breeding areas occur in winter sometimes in concentrations of tens of thousands of birds in the Netherlands for the conditions are exceptionally favourable for them. Due to the Gulf Stream the winters are generally mild and snow usually melts within a week or so, and as a result the geese have almost always access to the grass they live on. The landscape is flat and open, crossed by rivers and rich in lakes, an ideal combination of forage areas and safe roosts for geese.

In recent years the number of geese wintering in the Netherlands has strongly increased. Figure 1 shows the total increase and the increase per species. White-fronted goose is the species that winters in the largest numbers in the Netherlands. This species comes from the region between the Kanin peninsula and the Ural mountains. Between half December and the end of February almost the entire population breeding in this region is in the Netherlands. The development of the number of White-fronted geese wintering in the Netherlands is shown in Figure 2; their number has gradually increased. Another species, Bean goose, shows a different development (see Figure 3). The number of Bean geese wintering in the Netherlands varies widely per season. In hard winters the number of wintering Bean geese is large. In mild winters the majority of Bean geese remains in East Germany and Poland. The Netherlands is also important as a wintering ground for Pink-footed goose, Barnacle goose, Brent goose and Greylag goose. The total population of Pink-footed geese that breeds at Spitsbergen, about 25,000 birds, winters in the Netherlands. The number of Barnacle geese wintering in the Netherlands amounts to about 100,000, which is almost the entire breeding population of the islands of Vaygach and Novaya Zemlya in the Barents Sea (see Figure 4). Of the Dark-bellied Brent geese breeding on the Taymyr peninsula (see Figure 5) about 35% assemble in the Dutch wadden area in spring. Greylag goose is the only species that naturally breeds in the Netherlands.

An important breeding area is the Oostvaardersplassen, a marshland area that recently developed in the new polders in the centre of the Netherlands. About 200 Greylag geese breed here. It is also important as a moulting ground for Greylag geese. The number of moulting geese may run to 50,000.

These data show that the Netherlands has great international responsibility for the management of migrating and wintering geese. That is why the Dutch government conducts a policy which aims to protect and maintain the populations of geese, with due regard for the interests of agriculture and shooting.

Since geese often forage on farmland, agricultural interests should be considered as well. As a result of goose grazing much damage is done to arable lands and pastures. Goose grazing damage is reimbursed in full by the Game Fund, which passes the reimbursements on to the Ministry of Agriculture, Nature Management and Fisheries. Figure 6 shows that the reimbursements paid have strongly risen. Especially arable land damage peaks in hard winters because then arable crops are more prone to damage and there are more geese in the Netherlands.

2 DUTCH GOVERNMENT POLICY WITH REGARD TO GEESE

The increase in the number of geese and in the damage caused by geese has prompted the Minister of Agriculture, Nature Management and Fisheries to reconsider the national goose policy and to adjust it where necessary. This has resulted in a memorandum, which is soon to be presented to Parliament. The memorandum focuses on the protection of populations of geese and the damage problems.

The Memorandum on Geese [Ganzennota] fits in with the framework of the Nature Policy Plan, a first version of which was published in May 1989. The Nature Policy Plan describes the policy of the national government with regard to nature protection in the next decades. The policy for the first period of eight years (the so-called planning period) is described in detail. Part of the planning period policy is the development of plans for the protection of so-called priority species; the Memorandum on Geese is to be seen as one of these plans.

The Memorandum on Geese focuses particularly on the more vulnerable species, such as Brent goose, Barnacle goose and Pink-footed goose. The vulnerability of these species is connected with their highly varying breeding success (Brent goose and Barnacle goose) and the relatively small size of the population (Pink-footed goose). The latter reason also goes for the Bean goose subspecies fabalis. The policy aims at giving structural shelter to vulnerable species. This means that in some areas land will be acquired to create reserve areas and that management agreements will be concluded with farmers to tolerate geese and to adjust land management to the presence of geese. Especially in the coastal area efforts are to be made to make sufficient space available for Brent goose. Moreover, with regard to the wintering grounds of vulnerable species arrangements are to be made with the local hunters to refrain from shooting during the period when the geese are staying there. The most important goose areas are also offered physical planning protection. The main objective is to secure the quiet and openness in these areas.

The policy aims at receiving the geese wherever possible in natural areas and on less damage-prone land. Scaring geese away from damage-prone crops (for instance, plots sown with damage-prone arable crops, and in the late spring cultivated pastures) to less damage-prone land (for instance, pasture plots, green cover crop plots and natural areas).

There will be no changes in the present possibilities of shooting geese. This means that White-fronted geese, Bean geese and Greylag geese can be shot in the period from 1 September to 31 January inclusive between a half hour before sunrise and 10 a.m. The use of living decoy geese in shooting is prohibited. The present large-scale shooting proves to have no negative effect on the populations, because they are still increasing. In the 1988/1989 season a total of about 50,000 geese were shot in the Netherlands, almost 7,000 of them Greylag geese, about 5,000 Bean geese and about 38,000 White-fronted geese.

Important in the government policy is the encouragement of co-operation between farmers, hunters and conservationists in the regional management of geese. This co-operation should be reflected in the development of regional goose management plans. The national government will encourage such plans through contacts with local farmers´ organizations, hunters´ organizations and conservationists and through the distribution of information material.

A few years ago a study was completed of the damage caused by White-fronted geese to pastures. One of the recommendations was to work out how dairy farming could take goose grazing into account. Several experiments are going to be carried out on dairy farms as well as on arable farms. In addition, a research will be shortly started into the effect of goose grazing on the development of arable crops and the possibilities of restricting the damage to arable crops. The research will also focus on the possibility of receiving the geese on green manure crops. The research will take 4½ years, and part of it will be carried out by the Research Institute for Nature Management.

The last but certainly not the least objective mentioned in the Memorandum on Geese is international co-operation. This co-operation is important, especially with regard to migrating species such as geese. At present attempts are made to realize an Agreement and Management Plan for the West Palearctic Waterfowl. The Dutch Ministry of Agriculture, Nature Management and Fisheries contributes considerably to the realization of this Agreement and Management Plan.

The availability of sufficient information about the distributions and movements of geese in breeding areas, migration areas and wintering grounds is important to conduct an adequate management. In the following the collection of information in the Netherlands will be described at some length.

3 COUNTS OF GEESE

Characteristic of bird counts in the Netherlands is that the major part of the work is done by volunteers. Between 1978 and 1983 an army of 5,000 volunteers counted the birds in the Netherlands throughout the year and charted them on a map. The results are found in the Dutch Bird Atlas [Vogelatlas van Nederland]. For each species a map was included showing its distribution in the Netherlands in the various months.

Counts of geese receive special attention. During the winter-time the numbers of geese in all potential goose areas are counted by volunteers. The counts are coordinated by a working group on geese, composed of seven members each specialized in a certain species of geese. Each year the working group publishes a report on the developments in the populations of geese.

The system used to count the geese not only provides an overall picture of the Netherlands, it also gives a good idea of developments in specific areas and in movements of geese. This is where we have the link with air traffic: movements of geese may involve dangers for in particular low-flying aircraft.

4 MOVEMENTS OF GEESE

Movements of geese occur primarily between the breeding areas and the wintering grounds in spring and autumn. Meanwhile it has been found that in winter, too, they move a lot. Depending on, for example, weather conditions and food supply the geese fly now to one area and now to another. The geese use a network of suitable areas, between which they migrate. This network includes areas within the Netherlands, but also areas (sometimes far) outside the Netherlands. An example is given in Figure 7.

In winter the weather conditions have a considerable influence on distributions of geese. Generally the distribution area of the geese moves parallel to the snow-line. Changes in weather conditions may cause large numbers of geese to move in the Netherlands and Europe. These movements occur partly during the day and partly during the night.

An important category of movements are the flights between roosts and forage areas. These flight movements are illustrated by an example. The example concerns the Lower Rhine area on the border between Western Germany and the Netherlands. Originally, mainly Bean geese occur in this area, in hard winters several tens of thousands. The area has one big roost, the Bijland lake which developed as a result of an excavation (see Figure 8), and some smaller roosts. Furthermore there are vast forage areas, mainly on cultivated land. In the morning the geese fly from their roosts in all quarters and spread over a large area to forage. Later in the day they fly back and forth between their roosts and forage areas to drink and to bathe. At sunset the geese fly to the roosts to spend the night there. They generally cover distances between 1 and 7.5 km. In recent years, however, Bean geese are frequently spotted flying from the Bijland lake to a forage area at a distance of about 50 kilometres. Possibly this is due to an explosive growth of the number of White-fronted geese wintering in the Lower Rhine area. In the first part of the 1970s there were several hundreds, now more than 60,000 of them. This development may have led to a shortage of food, because of which the Bean geese (it is known that they in general cover larger distances than White-fronted geese) move to farther forage areas.

Another form of movements in the Lower Rhine area is related to differences in shooting regimes. In the German province Nordrhein-Westfalen shooting has been prohibited, whereas in the Dutch border area White-fronted geese and Bean geese can be shot up to 31 January inclusive. As a result, up to 31 January the geese are mainly foraging in the German part of the area and as from 1 February they come in large numbers to the Netherlands.

5 FUTURE OBSERVATIONS

There is insufficient insight into the movements on a larger scale. It is not impossible that the White-fronted geese and Bean geese from the Lower Rhine area visit areas in, for example, Hungary at certain periods in the year. It is also possible that the increase in the number of White-fronted geese in the Netherlands is related to the decrease in the number of White-fronted geese on the Hungarian pusztas. If we want to have more information, the network of enumerators will have to be enlarged internationally. Perhaps technical tools, such as radar, may also supply much additional information. Moreover, by radar nocturnal flights can be detected, which may supply information useful to both the management of geese and the safety of air traffic crossing a flight of geese.

FIGURE 1. Annual peak counts of geese in the Netherlands (x 1000; the figures for 88/89 are provisional).

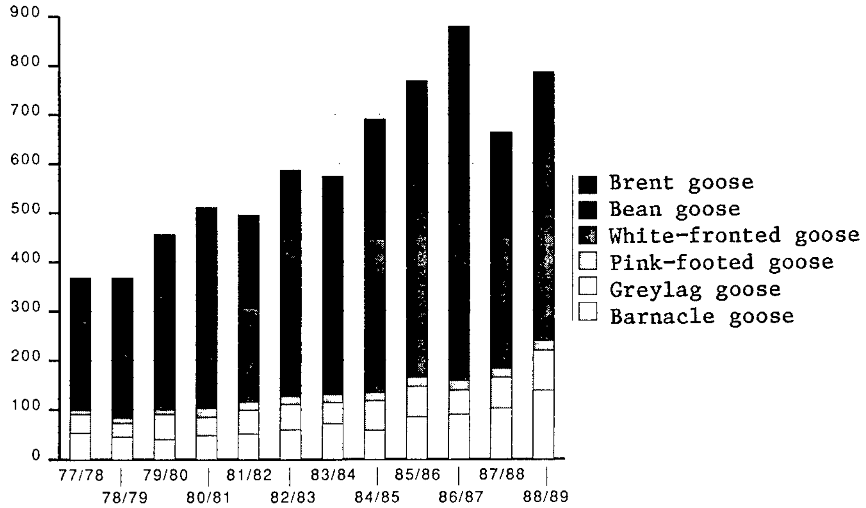


FIGURE 2. Annual peak counts of White-fronted geese in the Netherlands (x 1000; the figures for 88/89 are provisional).

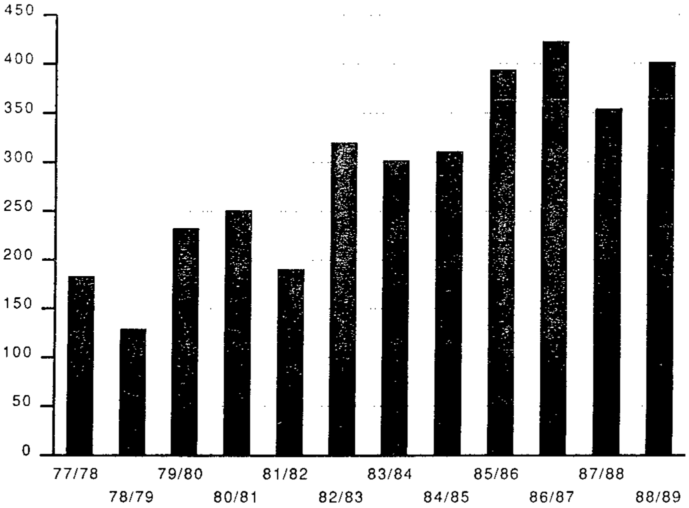


FIGURE 3. Annual peak counts of Bean geese in the Netherlands (x 1000; the figures for 88/89 are provisional).

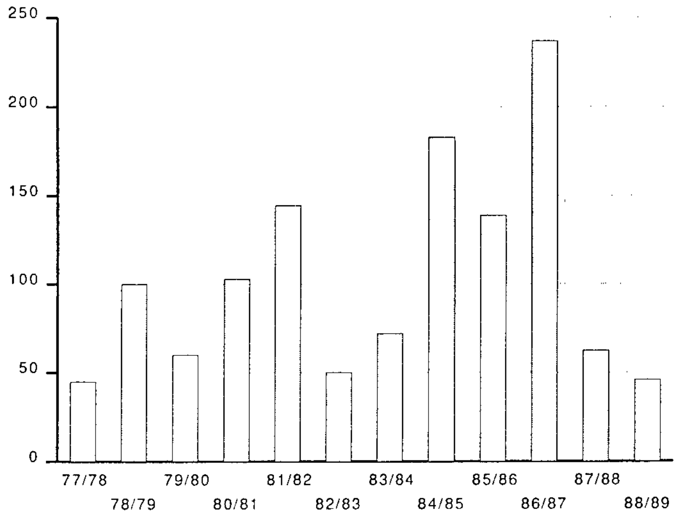


FIGURE 4. Breeding areas, migration route and wintering grounds of Barnacle geese, migrating and wintering in the Netherlands (after Wetlands en watervogels, 1989).

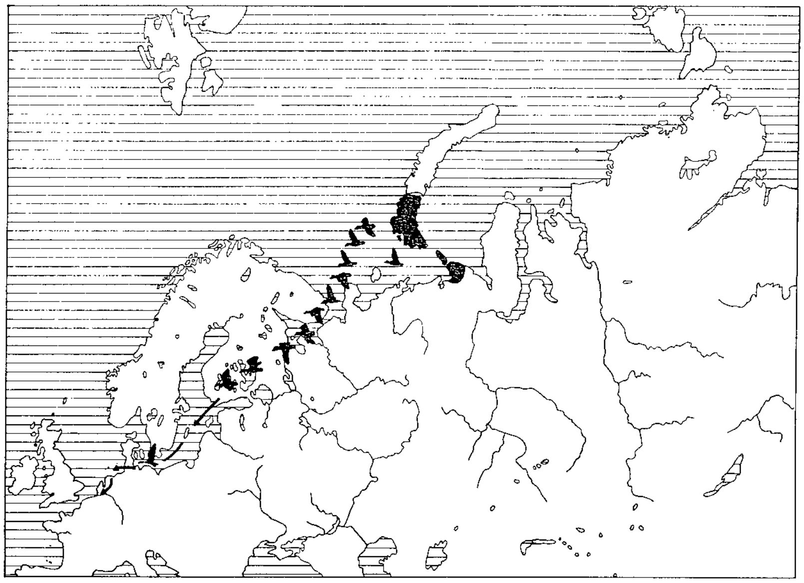


FIGURE 5. Breeding areas, migration route and wintering grounds of Brent geese, migrating and wintering in the Netherlands (after Wetlands en watervogels, 1989).

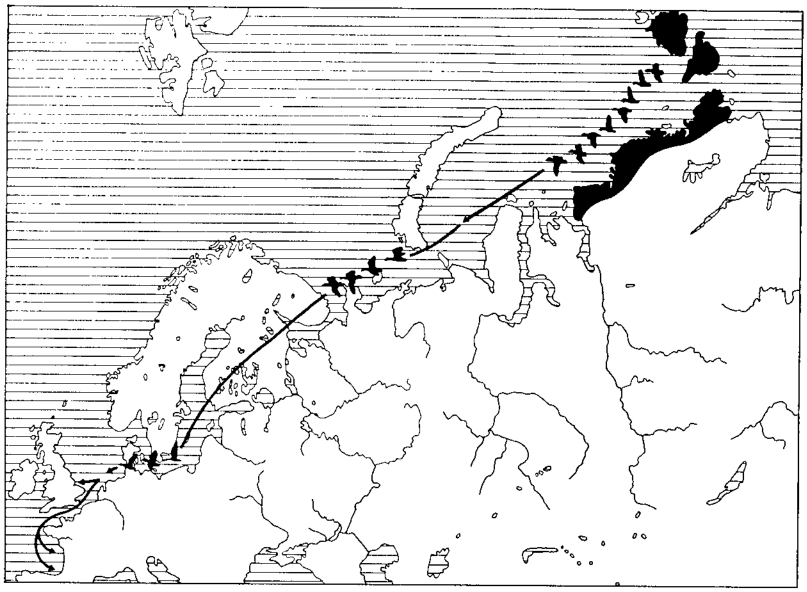


FIGURE 6. Amounds paid by the Game Fund to compensate goose-damage (in DFL.).

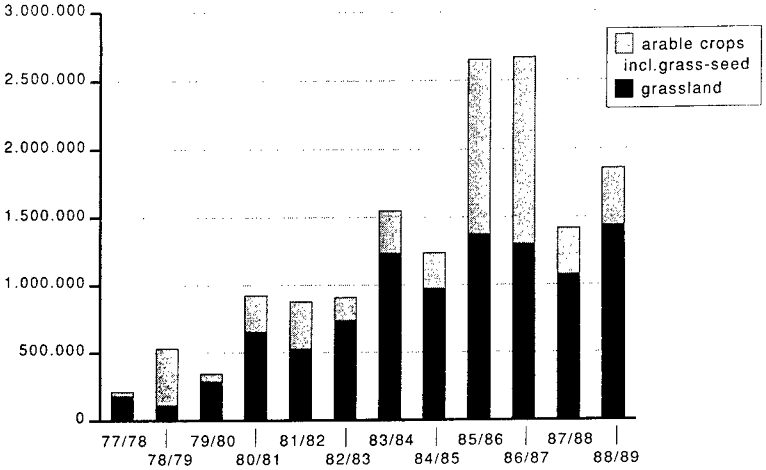


FIGURE 7. Staging areas of Bean geese in the Netherlands. Main concentrations areas are given in black (after De Levende Natuur, 1987/5).

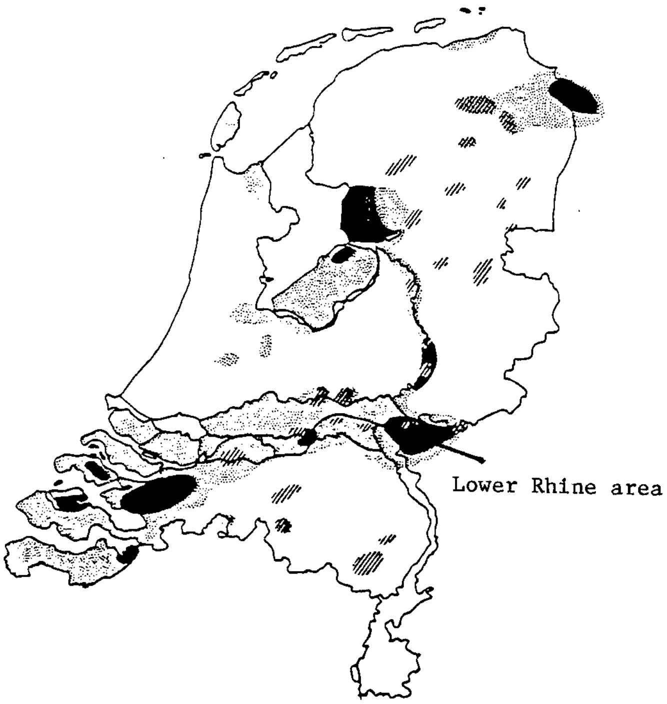
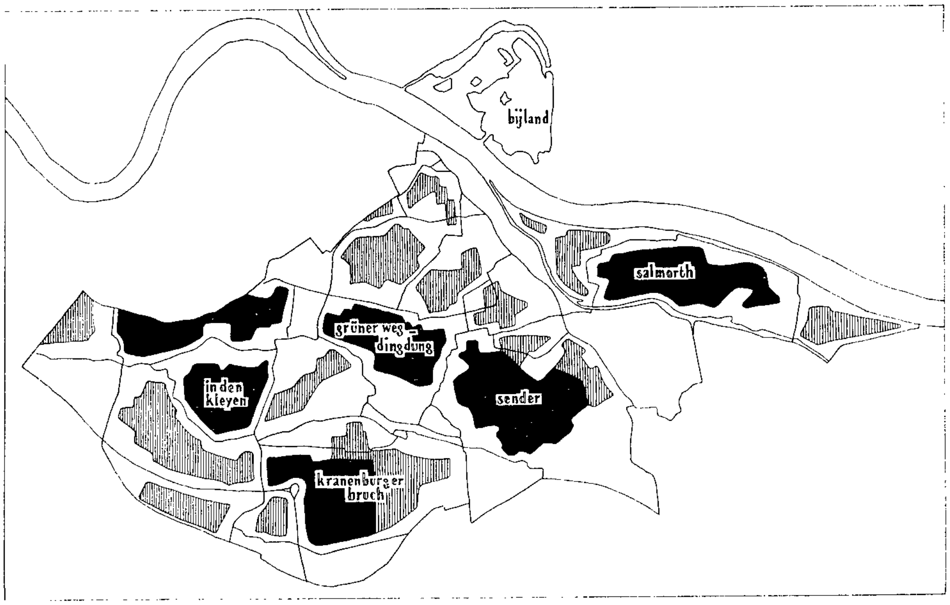


FIGURE 8. Staging areas of geese in the Lower Rhine area. Very important forage areas are given in black (after Beiträge zur Avifauna des Rheinlandes, 1986; Die Vögel der Düffel im Kreise Kleve).



AD-F616 441

THE U.S. NAVY'S BIRD AIRCRAFT STRIKE HAZARD (BASH) PROBLEM 1985-1989

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Reported Bird Strikes in the Navy

Each year the Navy suffers significant aircraft damage due to collisions with birds (bird strikes). The Naval Safety Center has recorded 6,365 strikes (an average of 707 annually) (figure 1) since 1981 when the Department of Defense standardized accident reports in military. Even though the number of reported strikes is high, the actual number is strikes is far higher. A 1989 study of the BASH problem at Naval Air Station Point Mugu showed that only 33% of bird strikes are reported. Therefore, Naval aircraft have probably taken close to 20,000 strikes (2,000 annually) since 1981.

A bird strike itself is not the problem though. Loss of aircraft, money and time is the problem. Since the inception of the BASH program, two aircraft have been lost to birds: an A-4 crashed north of Mayport, Florida in 1984 and an AV-8 crashed near Yuma, Arizona in 1986. Over $30 million have been lost due to bird since 1981 at an annual average of $2 million (figure 2). In these days of shrinking budgets, $2 million is a significant sum. We have been very fortunate that there have been no fatalities, USAF has not been so lucky.

Who Is Taking All These Bird Strikes?

Bird strikes occur on most of our Naval Air Stations (figure 3) and to almost every aircraft in the Navy's inventory (figure 4). Naval Air Station Cecil Field, Florida, has the distinction of having the most total strikes (152) and the Hermes, an experimental aircraft (E006), having the greatest strike rate 3766 strikes/100,000 hours). Of those aircraft types being flown over 500,000 annually, the Orion (P-3) had the greatest strike rate (72 strikes/100,000). The overall Navy bird strike rate was 33.4/100,000 hours.

Mission and type effect the susceptibility of an aircraft to a bird strike. Fifty percent (50%) of all the bird strikes were taken by patrol (25%) and attack (25%) aircraft (figure 5).

When Birds and Aircraft Meet

There are three ways to break down the encounter of a bird with an aircraft; (1) by altitude, (2) phase of the aircraft's flight, and (3) by time (season and hours). By examining these three categories, we can get a good idea about where bird strikes occur and which will lead to a method of reducing the bird strike problem at a given installation.

Birds can be encountered at nearly all flight levels. The highest strike ever recorded was to a vulture at 37,000 feet. However, most birds fly much closer to ground level; over 95% of all strikes are reported below 3,000 above ground level (AGL) (figure 6). In fact, 80% of all strikes taken by Navy aircraft occurs below 1,000 feet AGL. Therefore, it is not surprising that most of the known location strikes occur within the airdrome environment (figure 7). This is due to one reason, most bird activity occurs below 1,000 feet. The higher an aviator goes, the less likely a bird strike incident becomes. Therefore, aviators should consider altitudes whenever crossing know bird concentration areas, particularly during migration periods.

Bird strikes occur around the clock and throughout the year, but are most likely during certain periods. Migration seasons (April-May and September-October) are when there are the most birds in the air and when Naval aircraft take the most bird strikes (figure 8). There most dangerous time of the year to fly is during Fall after the breeding season.

How Can the BASH Problem Be Reduced

I have read the phrase "Beyond Command Capability" on many bird strike reports. This is a popular method to deny the problem. While there is not a fool-proof method to eliminate all bird strikes, there are ways to reduce chances of a bird strike that are both low cost and low effort.

A look at where the bird strikes occur will give a place to start in our efforts to reduce the number of bird strikes. Figure 7 shows that most strikes are over the airfield. Mr. Thomas Walker and C. Willard Bennett assisted four Naval Air Stations in developing a bird strike program during 1983. These four bases reported 57-78% fewer bird strikes in 1984 than in 1983. Bird strike reduction is possible through a variety of methods. The most common method is to convince aviators not to take off with birds on or near the runway and to identify and avoid landfills or other potential attractions to birds.

Habitat manipulations should be closely coordinated with the natural resources specialists. Habitat manipulation includes changes in grass height and other land management practices, removal of nesting or roosting sites, and improving drainage to reduce water sources. Bird dispersal is possible using pyrotechnics, distress calls, shooting, Avitrol, and hazing with vehicles. Each program is different. The objective of a comprehensive BASH program is to use as many techniques as necessary to reduce the hazard. A review of the Air Force's experiences indicates that repeat visits by trained professionals are required to keep the programs dynamic and responsive to changing conditions and populations.

Who Can Help?

As with any problem, it is necessary to consult with someone who is knowledgeable about it. The four places available to installations for help in combating your BASH problems are the Naval Facilities Engineering Command (NAVFAC)'s Natural Resources Branch for assistance in habitat manipulation, NAVFAC's pest management branch, the Naval Safety Center, and the U.S. Air Force BASH Team.

Naval aircraft take a considerable amount of damage from birds each year and endanger the lives of our aviators. The chance of serious loss of life and dollars can be reduced by instituting a BASH program at local installations. The authors would like to thank Mr. William Broyles, Naval Safety Center for providing the raw data for this manuscript.

BIRD STRIKES BY YEAR

1981-1989

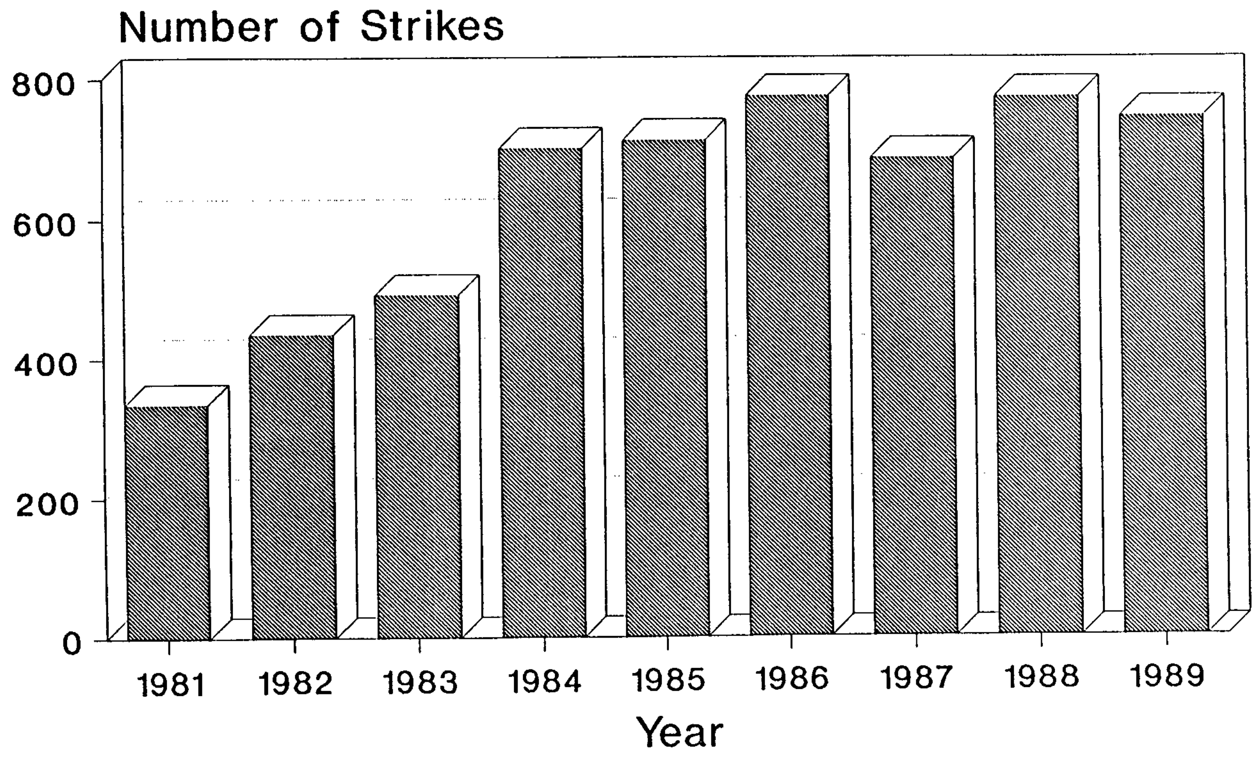

Figure 1

COST TO THE NAVY

1985-1989

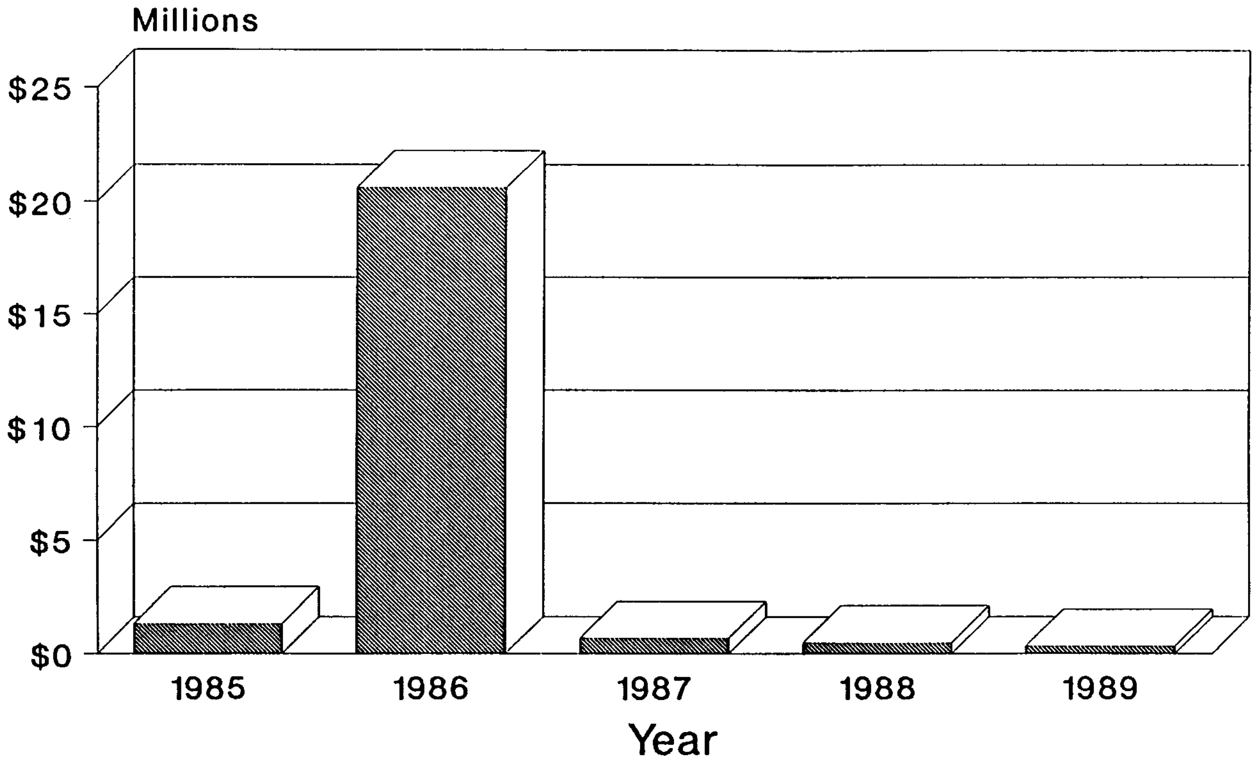

Figure 2

BIRD STRIKES BY NAVAL AIR STATION
1985-1989

Base Location	Total Strikes
Cecil	152
Moffett	150
Corpus Christi	126
Whidbey Island	121
Oceana	120
Jacksonville	110
Chase	109
Brunswick	101
Mayport	100
Norfolk	86

FIGURE 3

AIRCRAFT STRIKE RATE 1985-1989

100,000 FLIGHT HOURS MINIMUM

Type Aircraft	Number of Strikes	Flying Hours	Strikes/ 100,000hrs
T-44	157	199089	94.5
P-3	894	1237880	72.2
AV-8	112	159839	70.1
C-9	144	230123	62.6
A-6	382	708826	53.9
C-130	118	305000	38.7
F/A-18	223	644842	34.6
A-4/TA-4	295	855597	34.5
SH-60	76	227030	33.5
T-2	138	424817	32.5

FIGURE 4

BIRD STRIKE BY AIRCRAFT TYPE

1985-1989

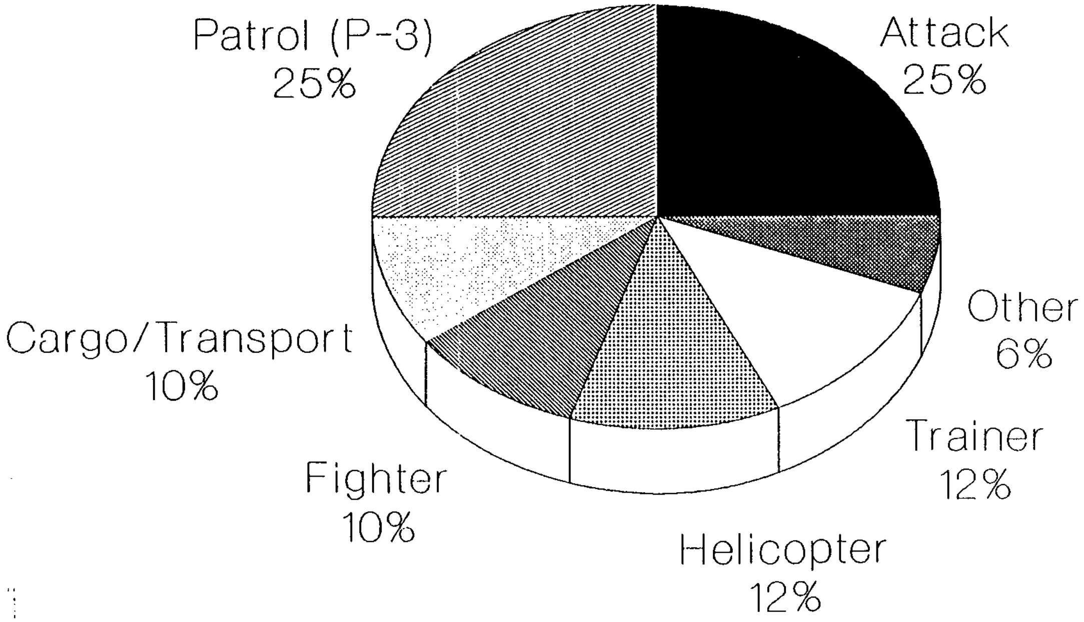

Figure 5

BIRD STRIKES BY ALTITUDE

1985-1989

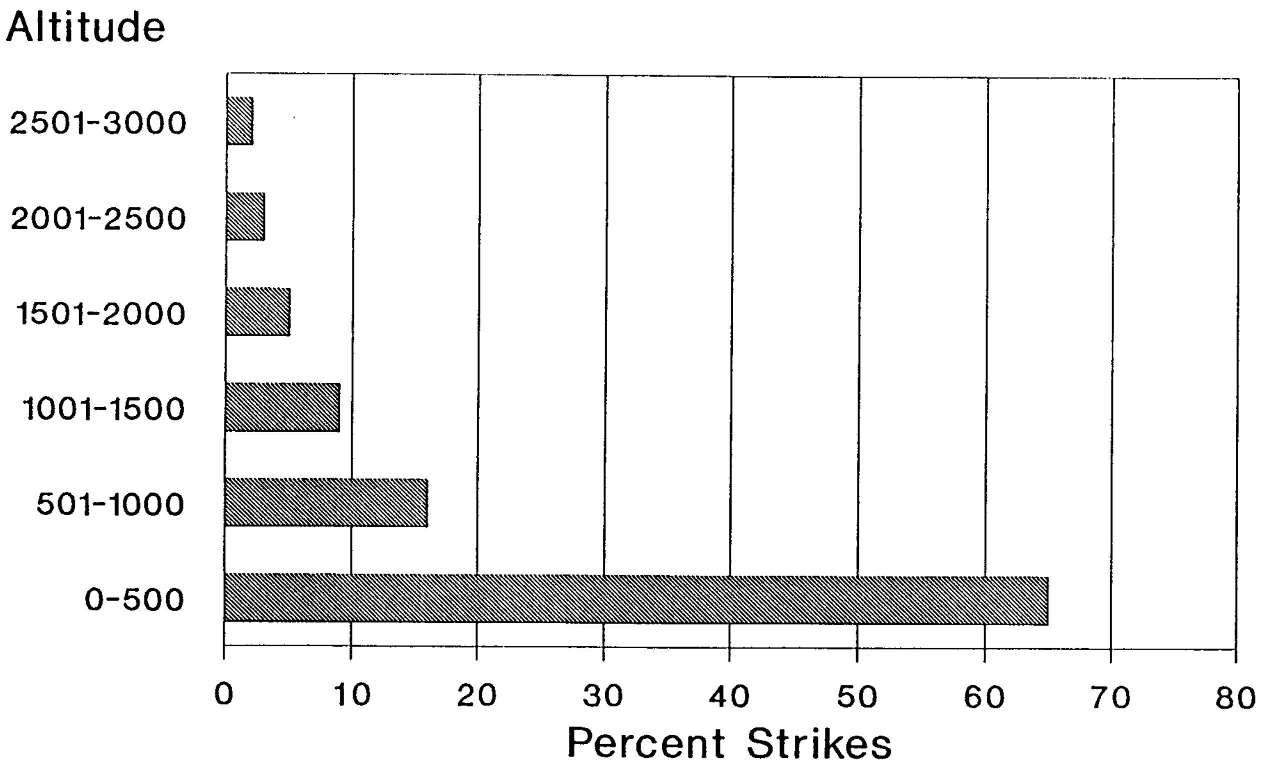

Figure 6

BIRD STRIKES BY PHASE OF FLIGHT
1985-1989

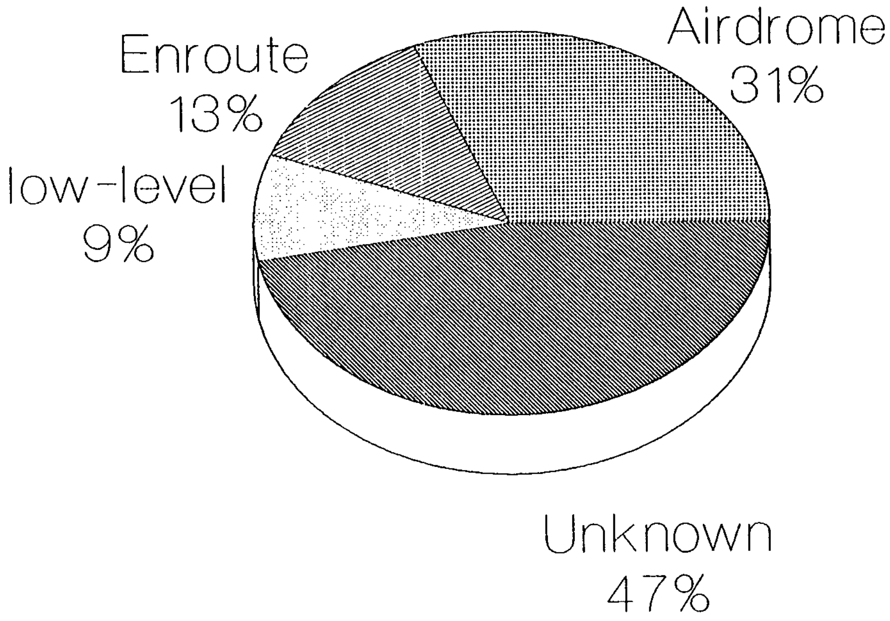

Figure 7

BIRD STRIKES BY MONTH

1985-1989

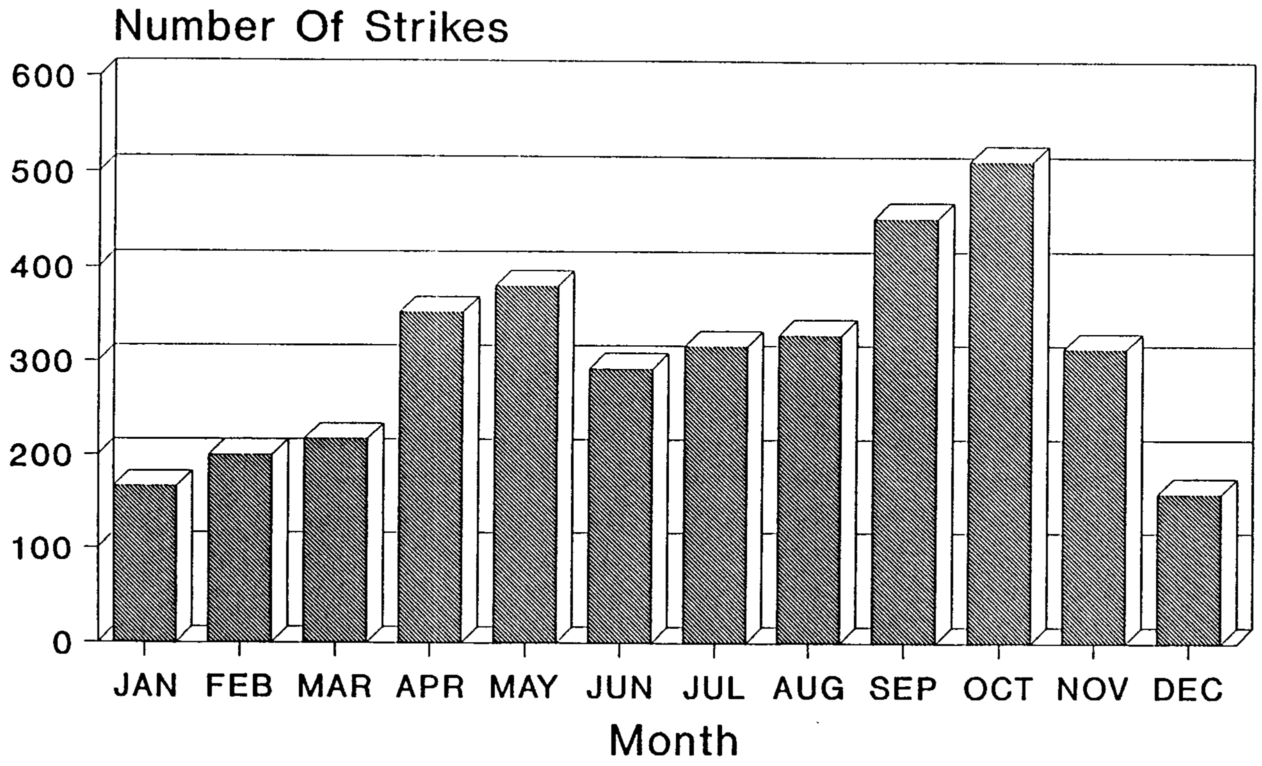

Figure 8

AD F616442

Bird Strikes to U.S. Air Force Aircraft
1988-1989

Maj Ronald L. Merritt
Bird Aircraft Strike Hazard (BASH) Team
HQ USAF/LEEV, Bolling AFB DC

Each year the U.S. Air Force suffers significant aircraft damage due to bird strikes. From 1988 to 1989, 6,444 strikes have been reported to the Bird Aircraft Strike Hazard (BASH) Team. During this period, two aircraft were destroyed resulting in no fatalities and an average annual cost of over 20 million dollars. The following are summaries of the two Class A mishaps in the past two years.

-- In January 1989, an F-16C struck a Turkey Vulture during a high speed, low-level mission. The bird penetrated the canopy forcing the pilot to eject. The aircraft was destroyed with cost estimates exceeding $10,000,000.

-- In January 1989, an F-16C ingested several starlings during takeoff. The pilot initiated an unsuccessful high speed abort resulting the loss of the aircraft. The pilot escaped uninjured. The estimated cost exceeds $10,000,000.

These examples are but a few of the devastating effects birds had on our aircraft in recent years. The severity of many of these strikes is due to encounters on high-speed, low-level missions. The Air Force's increased emphasis on realistic low-level mission profiles places our aircrews in prime avian habitat. High airspeed and high bird densities often result in significant damage or destruction of aircraft. Mission planning and airspace development to avoid birds requires more emphasis as our low-level activity increases. Several major commands have initiated aggressive bird strike reduction programs to combat these problems. Despite the large losses reported during 1987, the strike rate was 69.9 per 100,000 hours, a 10% reduction from the previous year. This reduction may have been the result of improvements in base-level BASH programs and a heightened awareness of BASH reduction strategies. The strike rate for the 1988 to 1989 period climbed to 115 per 100,000 hours. This may reflect an actual increase in strikes, or it may be the result of a vigorous campaign to improve reporting. The BASH Team now provides instruction on the BASH Reduction Program at the Flight Safety Officer School, University of Southern California, Norton AFB, California. This new effort has generated new emphasis and enthusiasm in the BASH program.

The following summary of bird strike data reported throughout the Air Force in the past two years is offered to illustrate the impact birds had on our aircraft. While thorough statistical analysis is not yet available on these data, general trends can be used to concentrate BASH reduction efforts for each mission profile.

Aircraft Involved in Bird Strikes

Virtually every aircraft in the USAF inventory reported bird strikes during from 1987 to 1989. Figure 1 shows the percentage of strikes by aircraft type. Cargo and fighter/attack aircraft reported the most strikes. Bird strikes to cargo aircraft are increasing each year as their low-level missions increase. Bird strike rates per 100,000 flying hours ranked by rate are reported by aircraft type in Table 1.

Fig 1

TABLE 1
Bird Strike Rate By Aircraft
(RANKED BY STRIKE RATE)
1987-1989

ACFT	STRIKES	RATE
E-4	28	516.2
B-1	200	331.6
KC-10	372	281.0
B-52	592	196.9
KC-135	886	143.9
C-130	1205	142.1
A-10	898	140.6
F-111	347	136.7
OA-37	60	102.9
C-5	182	98.8
T-38	856	84.5
C-9	72	83.4
T-37	659	74.8
F-16	733	70.6
C-141	462	56.0
F-15	256	41.8

Impact Location

Distribution of bird strikes to various aircraft components is basically random and related to the frontal surface area. Table 2 shows the percentage of total bird strikes by impact location.

Fig 2

TABLE 2
Bird Strikes By Impact Location

Impact Location	Percent of Total
Engine/Cowling	20.5
Windshield/Canopy	19.2
Wings	18.4
Radome/Nose	17.4
Fuselage	10.4
Multiple Locations	8.7
External Tanks/Pods/Gear	1.5
Other	4.0

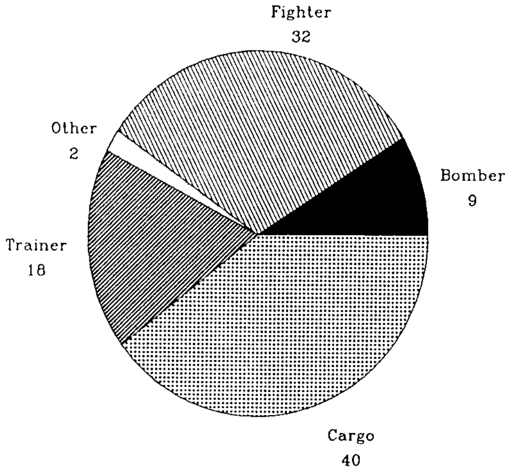

Figure 1. Strikes by Aircraft type

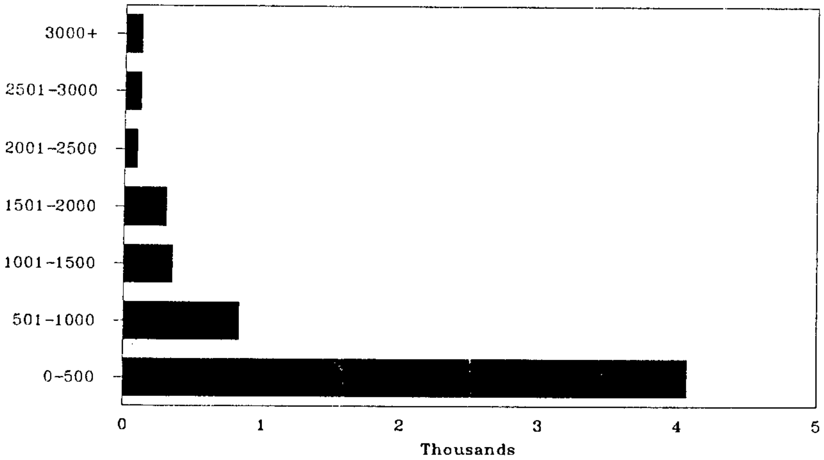

Figure 2. Strikes by Altitude

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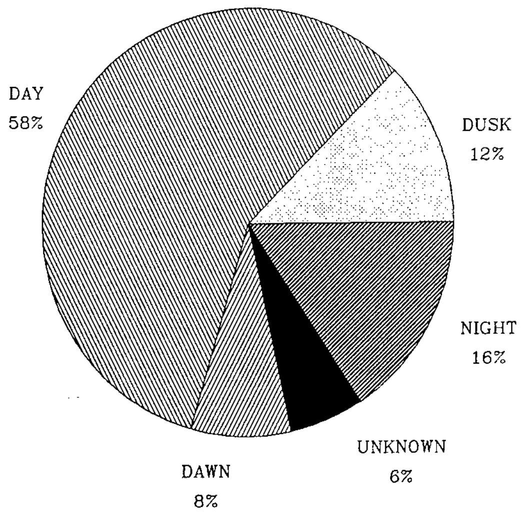

Figure ~~3~~ 4. Strikes by Time of Day

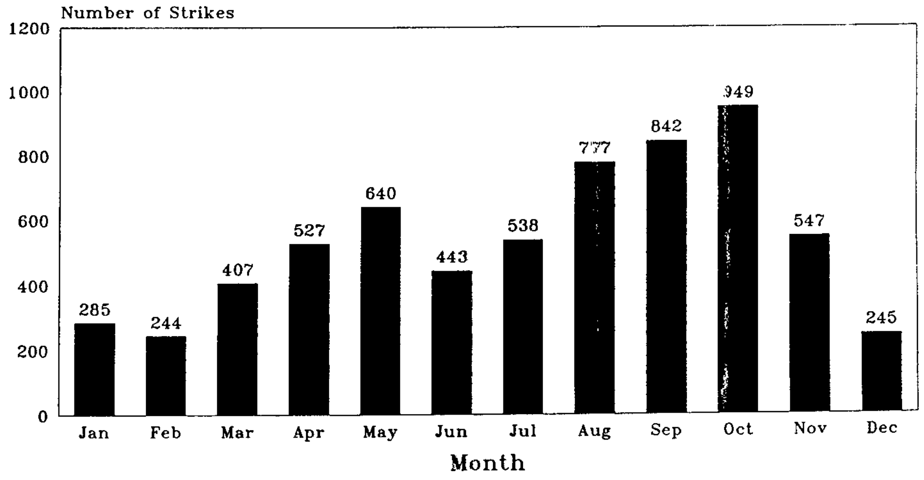

Figure ~~4~~ 5. Strikes by Month

Engines and canopies again topped the list. We also anticipate further problems with canopy strikes and penetrations as the Air Force's low-level role increases. For example, the current F-15 canopy is only capable of withstanding a 4 pound bird at 180 knots. The F-15E, Strike Eagle, is encountering birds more frequently than it did in its air to air mission.

BIRD STRIKES BY ALTITUDE

Birds can be encountered at nearly all flight levels. The highest strike ever recorded was to a vulture at 37,000 feet. However, most birds fly much closer to ground level and over 95 percent of all strikes are reported below 3,000 feet AGL. Figure 2 shows bird strikes by altitude. Strike rates rise significantly as altitude decreases. This is partly due to where we fly, but mostly because birds are commonly active close to the ground. Any gain in altitude represents a substantially reduced threat of a bird strike. Pilots should consider higher altitudes whenever crossing known bird concentration areas, particularly during migratory periods.

TIMES WHEN BIRD STRIKES OCCUR

Bird strikes occur around the clock and throughout the year, but are most likely during certain periods. Figure 3 shows distribution of bird strikes by time of day. Most strikes are reported during daylight hours when we do most of our flying. Despite the low numbers, dawn and dusk are particularly hazardous times since many birds are most active at these times. Several bases have limited operations during these periods and have reduced their strike rate as a result. Most nighttime strikes are reported during migratory movements of birds during the spring and fall.

Figure 4 indicates bird strikes by month. Strike rates peak during the spring and fall migratory periods. These rates are perennially highest during September and October as birds move south. Bird populations are highest at this time following the summer breeding cycle.

Bird Strike By Phase Of Flight

Birds can be, and have been, struck in all phases of flight. Approximately half of the reported strikes occurred in the airfield environment (Figure 5). Fortunately, most of these strikes were not as severe as in previous years. A substantial improvement in airfield grounds maintenance procedures and bird dispersal techniques in the past several years have resulted in improved flight safety in the airfield vicinity.

While only one quarter of reported strikes occurred in the low-level and range environments, the vast majority of damage and all five fatalities resulted here. Reduction of bird strikes in this environment can only be accomplished by careful airspace planning, development, and scheduling to avoid potential bird hazards. The Air Force is focusing efforts on reducing the low-level bird hazard in the future. The BASH

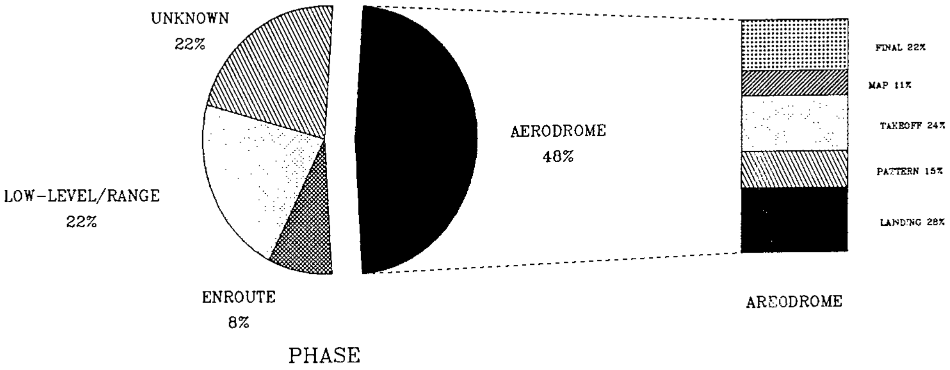

Figure 5. Strikes by Phase of Flight

Team is currently working on several major projects to address these hazards. Expansion of the Bird Avoidance Model (BAM) to include all high-risk bird species and all theaters of operation is being researched. The current model includes populations and movement data for waterfowl and some species of raptors (birds of prey) for the continental United States. Units using the current model reported up to 70 percent reductions in strikes to these birds.

Another area currently under research is the use of radars, particularly the Next Generation Weather Radar (NEXRAD), to help observe birds. NEXRAD is a tri-agency program of the Department of Commerce, Transportation, and Defense, with the Department of Commerce as lead agency. Under NEXRAD, a network of state-of-the-art doppler weather radars will provide improved detection of severe weather events in the CONUS and parts of Europe and the Pacific. Preliminary results indicate that this doppler weather radar can detect bird movements and provide altitude data. This information may provide aircrews with bird hazard warnings for mission planning and possibly enroute avoidance. The BASH Team is sponsoring the development of a bird recognition algorithm for possible inclusion in this system. We are continuing to explore new radar technology that may provide real-time bird detection in the airfield environment.

With these systems operating, we anticipate a future reduction of the severe bird strike hazard in the low altitude flight environment.

BIRDS IDENTIFIED IN STRIKES.

A variety of bird species have been identified following impact with our aircraft. Post strike bird remains are sent to the BASH Team for identification. Most of these remains are then forwarded to Ms. Roxie Laybourne for microscopic analysis. Recent analysis of bird species and weights suggests that we are encountering more larger birds than previously estimated. Table 3 lists the birds most commonly identified.

TABLE 3
SPECIES IDENTIFIED IN BIRD STRIKES

SPECIES	%
Gulls	29.5
Hawks	21.2
Vultures	11.4
Doves	10.9
Ducks	7.2
Egrets	5.5
Starlings	4.8
Larks	3.7
Geese	3.3
Herons	1.3

SUMMARY

The Air Force suffers tremendous losses to bird strikes each year. 1987 was the most costly year in terms of aircraft damage and lost lives. Recent incidents have created an increase in interest in BASH reduction efforts. Much needs to be done to reduce the hazards in all operating environments, but especially away from the airfield. The BASH Team considers development of complete bird population and movement data, and issuance of bird hazard advisories in our low-level and operating areas among its top priorities for future reductions of bird strike hazards. Armed with this information, we anticipate safer flying conditions and a substantial savings of resources throughout the Air Force.

AD F616 443

BSCE 20 / WP 44

BIRDWEIGHT DISTRIBUTION OF LOW-LEVEL BIRDSTRIKES

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Background

Over 20 percent of all U.S. Air Force (USAF) birdstrikes occur during low-altitude, high speed training flights. These low-level birdstrikes are usually the most damaging in terms of aircraft damage and loss of aircrews. Since 1980, the USAF has lost five aircraft and seven aircrewmen during low-level and range training flights. According to the BASH Team records, the total cost of low-level birdstrikes during the last decade is in excess of $250 million.

Estimating birdstrike risk from bird population data known for a block of airspace is the method used by the USAF Bird Avoidance Model (BAM). Since the birdstrike risk is a function of the number of birds in the volume swept by the of the aircraft, the expected birdstrike rate is readily calculated. Birdstrikes can be avoided by changing the altitude, timing or location of a low-level flight. Simply avoiding bird-aircraft conflicts through better planning the route of flight and through flight schedule changes is an easy and cost-effective method of reducing birdstrike risk. However, collecting the bird census data entered into the BAM is time-consuming and not available for some remote areas, which is where low-level missions are flown.

Predicting birdstrikes is important to the development of aircraft components and systems that can withstand the tremendous impact forces. Mishap data typically provides the basis for determining the expected number of birdstrikes for a new aircraft or an old aircraft flying a new mission; e.g., the conversion of the F-15 from an air defense role to close air support. Once the expected number of birdstrikes has been calculated, the probabilty of damage is determined from the strength distribution of the particular component under investigation and the probable birdweight distribution. Berens et al (1989) provide a good review of the model formulation.

If sufficient birdweight data is available for the aircraft type and mission, then a specific birdweight distribution can be developed. The 4-pound birdweight distribution represents approximately 95 percent of all recorded birdstrikes (pre-1970) which were collected during a joint study by the USAF and the Federal Aviation Agency. Subsequent studies using pre-1981 birdstrike data show basically the same distribution (Figure 1). The 4-pound (1.8 kg) bird is usually considered the design standard for the aircraft structures and transparency systems. Although aircraft engines are designed to continue operation after multiple ingestions of smaller birds, the 4-lb bird is the standard for certain aspects of containment design.

Objective

The objective of this study is to reassess the birdweight distribution for low-level birdstrikes. The USAF Bird-Aircraft Strike Hazard (BASH) Team maintains a damaging and non-damaging birdstrike database containing 21,647 birdstrike records from 1975-89. The BASH Team has accumulated records of nearly 4,500 low-level birdstrikes in their database, most occurring after 1982. Of these, over 711 have been positively identified as to bird species involved in the mishap. Additional information about location, altitude, airspeed, and damage is also available for a large number of these birdstrikes. Analysis of these birdstrikes can update our understanding of the bird threat during low-level missions and to what new directions our "birdproofing" efforts should lie.

Methods

The "identified" low-level birdstrikes were used to generate cumulative birdstrike distributions for the low-level mission. The maximum species weight was calculated for each birdstrike from the average weights provided in Brough (1983) and Dunning (1984). When known, subspecies or gender weights were used. Birdstrikes occurring during range operations were not included.

Cumulative distribution frequencies for low-level birdstrikes were developed for different aircraft and mission. Descriptive statistics were also generated for the low-level birdstrike data from 1982-89. B-52 and F-4 aircraft are compared since they (1) have an extensive low-level flight history, (2) have dissimilar missions, and (3) have experienced a large number of birdstrikes throughout their operational range.

Results and Discussion

The cumulative distribution frequency (CDF) of low-level birdstrikes for all aircraft (Figure 2), where the species is positively identified, is skewed toward heavier birdweights than the 4-pound standard typically used to design bird tolerant aircraft systems. The 95 % intercept is approximately 8-pounds (3.6 kg).

A comparison of Figures 3 and 4 for F-4 (including RF-4 aircraft) and B-52 aircraft, which combined account for 50 % of identified low-level birdstrikes, show that the skew is due primarily to the "bomber" mission. This suggests that the 4-pound bird criteria is still reliable for the "fighter" mission but that the "bomber" mission typically hits larger birds. CDFs for other aircraft (A-10, A-7, F-16, F-15 and C-130) show a distribution closer to the F-4; but, they are not shown here since they each based on less than 100 birdstrike reports. Additional analysis is planned to further characterize the birdweight distribution for specific aircraft and locations.

This increased birdweight distribution could be an artifact of the bias to report birdstrikes that involve the more noticeable, large birds over those "wipe offs" that cause no damage. However, the converse situation may be true for the earlier birdweight distributions (See Figure 1) which may include an inordinately large number of small birds even though they may not be a factor on most low-level missions. In general, throughout the daylight hours, most small (<0.5 kg) birds tend to remain relatively close to the ground unless involved in migration activities. Small birds are not usually a factor for low-level operations unless during migration. Larger birds, including gulls, raptors, waterfowl and some shorebirds frequently use higher altitudes to move to feeding areas which often puts them into the path of low-flying aircraft.

The distribution of low-level birdstrikes by month (Table 1) shows the usual increase in birdstrikes during the Spring and Fall seen worldwide for all aircraft and missions. The F-4 aircraft distribution shows a relatively consistent birdstrike rate each month throughout the year, while the B-52 has more significant low-level birdstrike increases during the Spring and Fall bird migrations. This seems logical since generally B-52 low-level routes are longer, flown at slower airspeeds (i.e., the exposure to birds is greater) and are frequently flown at night throughout the year which would include migrating birds of all sizes.

TABLE 1

Monthly Distribution of Low-level Birdstrikes (1982-89)

	F-4	B-52	All	Identified[1]
N	1588	1557	4494	711
Month				
January	5 %	3 %	4 %	5 %
February	5 %	5 %	4 %	5 %
March	6 %	7 %	7 %	10 %
April	9 %	11 %	9 %	11 %
May	9 %	17 %	11 %	10 %
June	9 %	6 %	7 %	6 %
July	9 %	6 %	8 %	7 %
August	10 %	9 %	10 %	7 %
September	8 %	9 %	12 %	9 %
October	15 %	14 %	15 %	13 %
November	9 %	6 %	8 %	10 %
December	6 %	7 %	6 %	5 %

[1] Based on birdstrikes from (1975-89)

Note: Percentages may not add up to 100 percent due to rounding errors.

An inquiry into the time of day that the low-level birdstrikes occur, shows that B-52 birdstrikes are rather evenly distributed throughout the 24 hours and that most birdstrikes occur during the hour following midnight, the time when migrational activity is high. F-4 birdstrikes peak during midday (0900-1600) and from 2000-2100 hours. Over 64 % of the identified F-4 birdstrikes involve Turkey Vultures (Cathartes aura), while B-52s hit a large (>7.5 pounds or 3.4 kg) percentage of migrating birds (geese, and cranes).

As a rule of thumb, aircraft that fly low-level routes spend about one-third of the flight actually engaged in low-level operations. However, in the case of the B-52, the majority of their overall birdstrike history (55.5 %) occurs during low-level training missions. Over half of all low-level birdstrikes occur at or below 500 feet AGL (Table 2).

TABLE 2

Altitudinal Distribution of Low-level Birdstrikes from 1982-89.

Aircraft	F-4	B-52	All	Identified[1]
N[2]	1226	1249	4049	570
Altitude (ft)				
0- 500	68 %	47 %	56 %	52 %
501-1000	15 %	32 %	28 %	34 %
1001-1500	7 %	5 %	7 %	6 %
1501-2000	4 %	10 %	5 %	4 %
2001-2500	1 %	2 %	1 %	2 %
2501-3000	2 %	2 %	2 %	1 %
Above 3000	3 %	3 %	2 %	<1 %

[1] Based on birdstrikes from (1975-89)

[2] Number of birdstrikes where altitude was reported

Note: Percentages do not necessarily add to 100 percent due to rounding errors.

Conclusions

If the new generation of bombers fly the same type of mission as the B-52, it is likely that they will encounter the same type of bird hazard. This is could have significant implications for design criteria for bird tolerant aircraft systems as well as bird avoidance procedures. While the current design criteria provide an adequate margin of safety for fighter aircraft, they may require reassessment for future upgrades. The 4-pound criteria may not be adequate for the bomber mission which flies on routes or at times when larger birds are encountered. Further analyses are planned to more closely scrutinize the tradeoffs between bird avoidance and bird tolerance.

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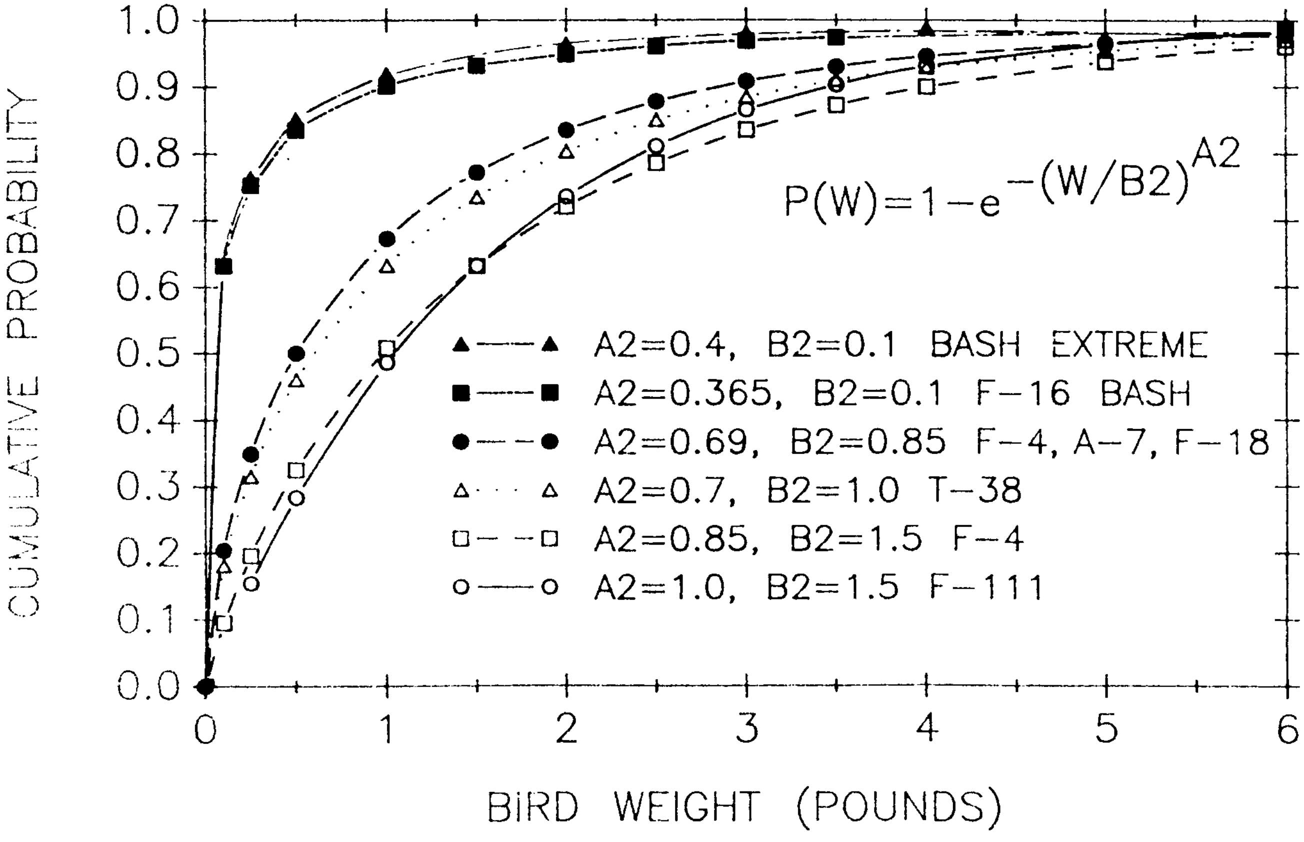
FIGURE 1.



Historic Birdweight Distribution Functions for Various Aircraft.

FIGURE 2

BIRDSTRIKE DISTRIBUTION

ALL AIRCRAFT

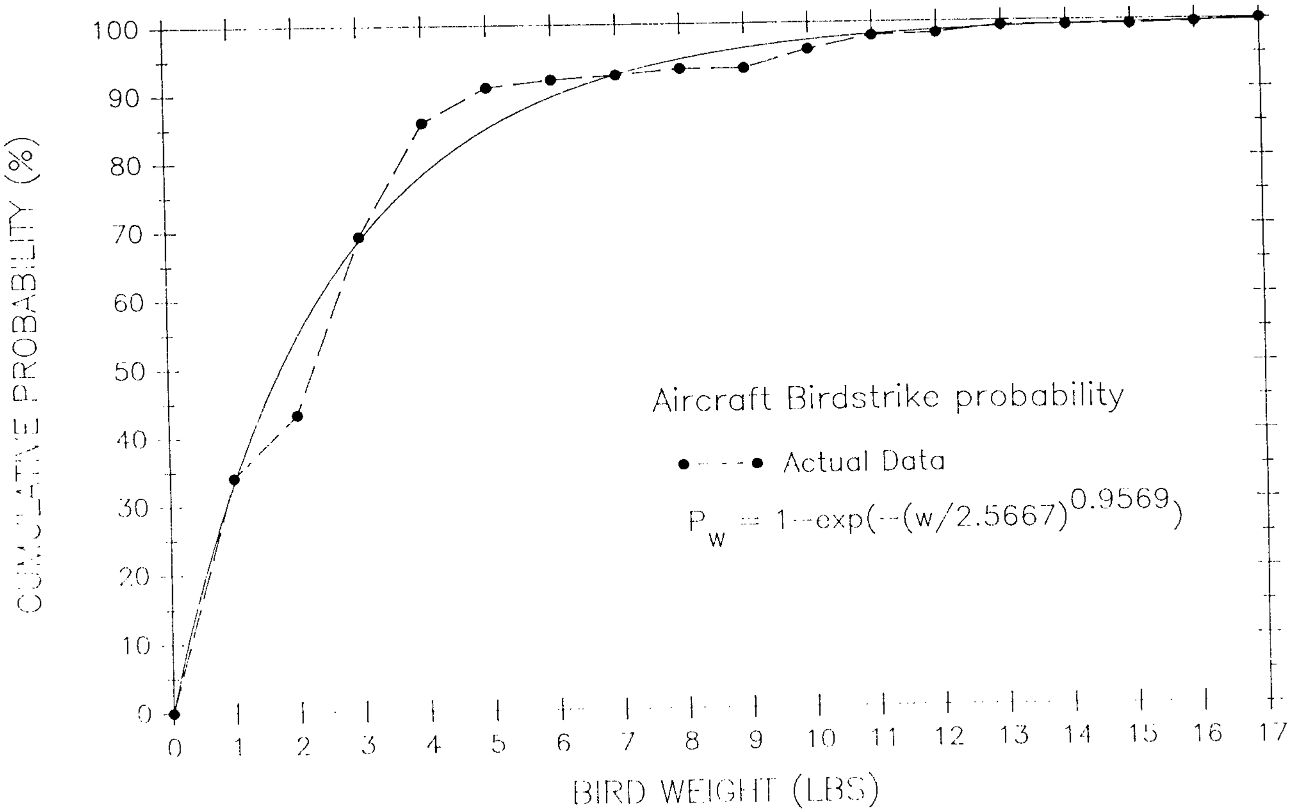


FIGURE 3.
BIRDSTRIKE DISTRIBUTION
F-4 AIRCRAFT

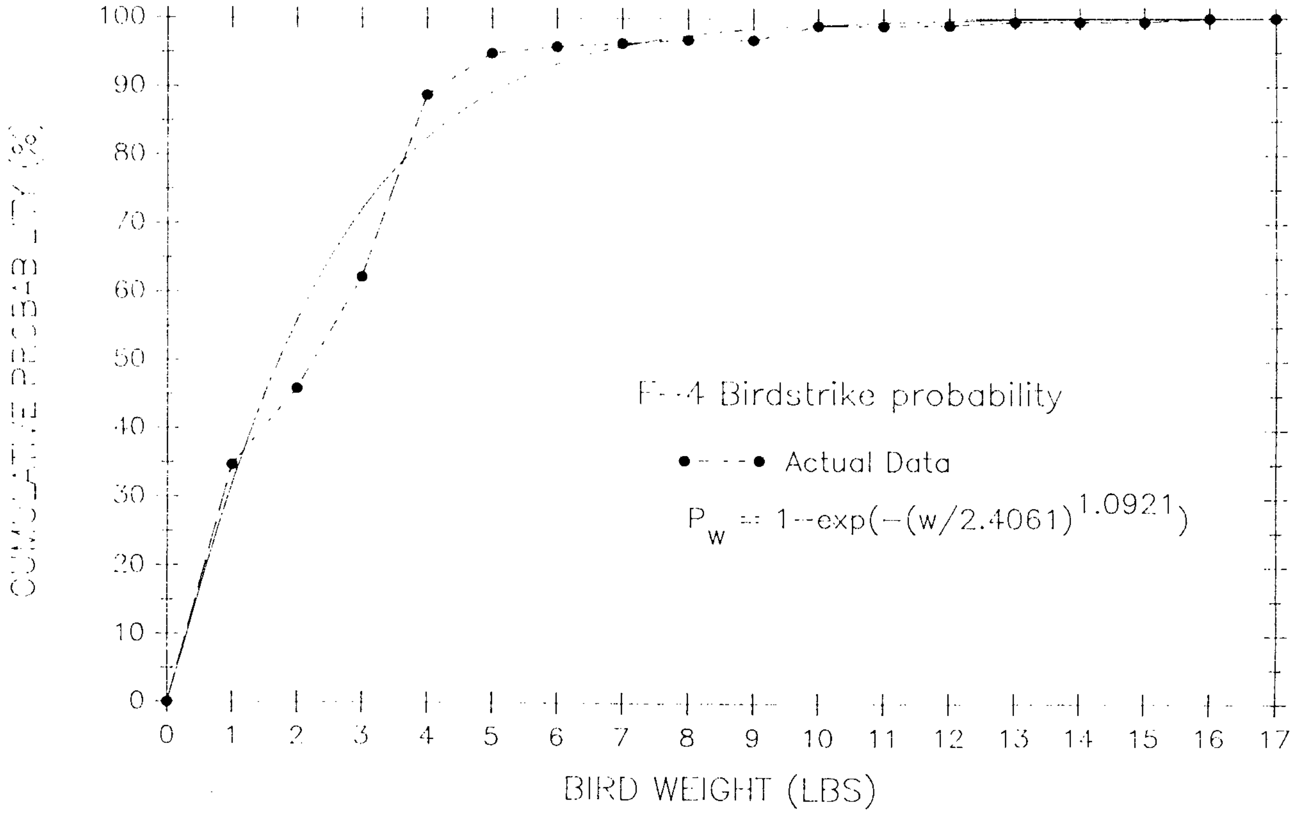
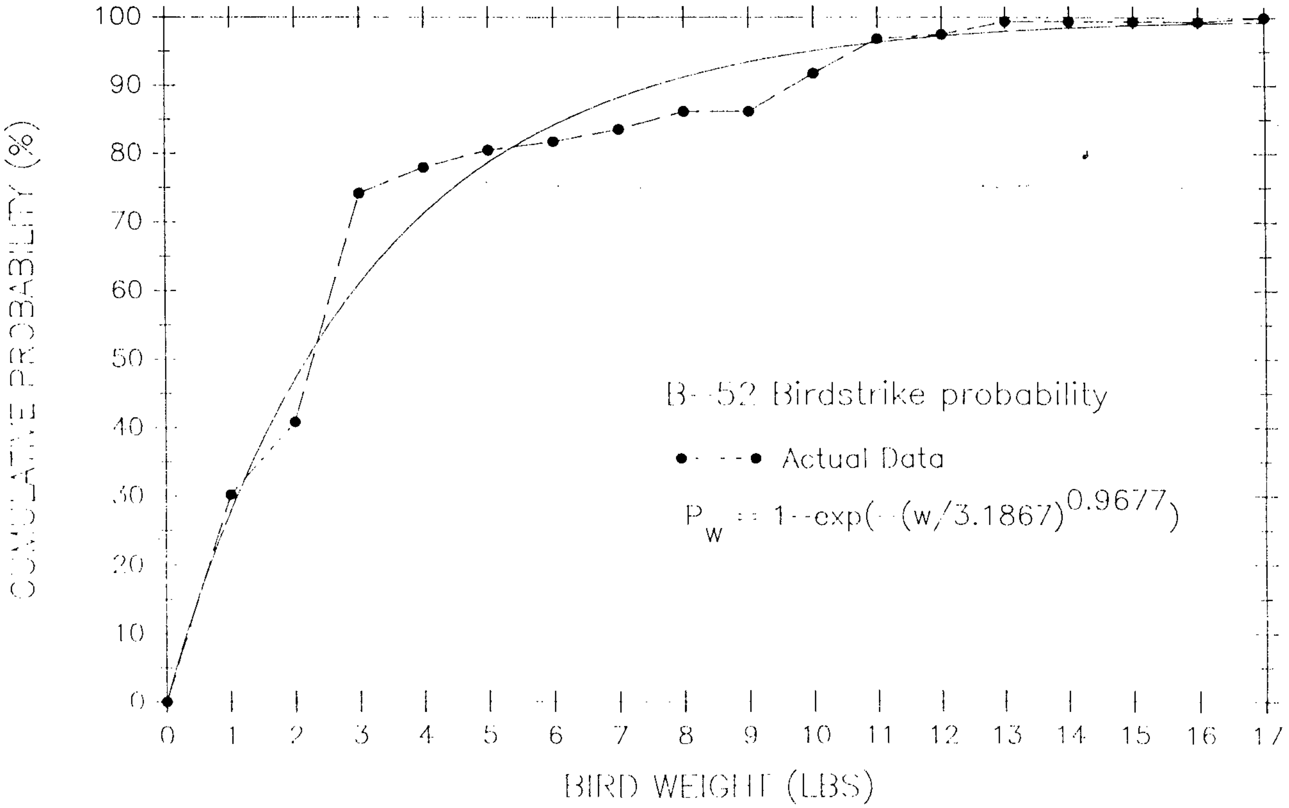


FIGURE 4.

BIRDSTRIKE DISTRIBUTION

B–52 AIRCRAFT



AOF616444

20 th Bird Strike Committee
Europe. Helsinky

21 - 25 May 1990

EXPERIMENTS TAKING PLACE :

TESTS FOR THE FRIGHTENING AWAY OF BIRDS BY MEANS OF A LASER GUN

(Marc Laty - Biologist - STNA/2N - France)

Among the breeds attracted to the apron, certain have turned out to be dangerous for aeronautical activity. The biological requirements of these breeds lead them to search out open spaces vhere there are no visual obstacles over long distances. These birds then frequent the open spaces of the active zones of aerodromes.

As a general rule, and whatever the activity happens to be, the bird or group of birds, are in a state of almost permanent vigilance.

Good eyesight allows the bird to react by flying away when aggressed, when the agressor comes within a certain limit. The distancing of this threshold measure the limit of the bird's safe distance. It depends on the open space in question and for each specimen its physiological state, its activity and how much it is accustomed.

In the case where aggression is detected by sight and which is then followed by avoidind action, set off by its reaction of flying away, the bird's survival depends essentially on the performance of the eye. Consequently, any diminishing of the visual functions can lead to a greater vunerability of the bird.

For certain breeds, looking for food necessitates visual detection. This means that any diminishing of their state of vigilance can also endanger their possibilities of finding food.

Taking these factors in consideration, the following theory has been evolued. Without causing pain, a disturbance by light impacts could affect the eye's performance. It would be detrimental to visual acuteness and to the maintaining of the state of vigilance. This would be considered as an agression to which the bird would react by flying away.

.../...

The corollary, to this theory once prowed, is to use this form of disturbance (from a distance) to drive away the birds which are on te operational zones of the aerodromes.

With this aim, the TECHNICAL SERVICE OF AIR NAVIGATION has undertaken tests to frighten away birds by means of a laser gun.

EXPERIMENTATION

The object of the exercise is to prevent birds from staying in one particular place. For this, the impact of a laser beam is used to provoke the flight of the birds. Being dazzled, the bird can no longer locate the source of disturbance and perhaps, by this means, will free itself of the notion of a limit to its own safe distance.

The following breeds of common birds on French airfields have been used for testing : Lapwing, Black headed Gull, Herring Gull, Carrion Crow, Rook, Jackdaw, Magpie, Homing pigeon, Wood Pigeon, Common Buzzard, Black Kite, Kestrel, Starling.

Duration

As certain breeds are sedentary and others migratory, some for the winter period, others for the summer and some are just passing though, the tests will be carried out for the period of a year from March 1990. The results will be presented at the next meeting of the Bird Strike Committee Europe.

The Experimental process

There are two way for proceeding :

- either to drive about looking for birds to aim at ;
- or to wait, hidden in a look-out near a place where birds stop, which are then fired at once they have landed (in dead trees for birds of prey andcorvidae, on the ground for gulls and lapwing...).

In the more complex of the situations where the operator is working from a vehicle the order of operations is as follows :

1) Sight the birds with the help of binoculars.

2) Drive closer to the birds or group of birds.

.../...

3) Stop the vehicule at such a distance that the birds will not be frightened when the engine is turned off, or by the sight of the operator (this can vary from about a hundred metres to several hundred meters according to the breeds).

4) Aim the laser gun at a bird without firing a beam.

5) Wait about 20 seconds in this position to make sure that the aiming of the gun had no effect on the bird.

6) Fire the laser beam by pressing the trigger. The bird 's eye, having been aimed at through the sights. Taking into consideration the small size of the target (diameter of the eye is less than 10 mm) and of the distance it is often difficult to hit the eye directly. It is easier to hit the breast first, or the flanks or the neck of the bird. Then by keeping a the check through the sights of the progression of the light spot to bring it on the eye itself, making several tries if necessary. For the person who fires the gun, every time the luminous spot passes ower the eye, it is counted as "a laser hit" and is seen as a reflected flash through the sights.

   In the case where the operator is working from a fixed position and is out of sight of the birds, only point number 6 is carried out.

Plotting the experimental parameters

The operator notes down the following information on pre-established cards :

- Date, Time, Place.

- Meteorology : humidity, temperature, pressure, wind (speed and direction) luminosity, sun, rain, fog, visibility.

- Birds : breed, numbers, activity (taking cower, rest, cleaning themselves) feeding (still or moving).

- Firing conditions : distance of the birds from the marksman, position of the sun according to the axis, bird-marksman.

- Results : flying away, semi-flying away, no reaction of flight, by the whole group or only by the bird fired at.

- Number of hits on the eye of the bird fired at.

.../...

Data processing

The tests carried out will be sorted out into two distinct categories :

Firstly : tries with differents breeds in similar experimental conditions.

Secondly : tries with each breed in different experimental conditions.

Analysis of the results

With the aim of determining the receptiveness :

- of different breeds in similar experimental intrinsic and extrinsic conditions ;
- of each of the breeds according to the variation of experimental intrinsic and extrinsic conditions.

Conclusion

Must determine whether or not the laser material used (especially power, wawelength) can be considered as a possible means of scaring birds from the airfields.

A DF 616446

BSCE20/WP47
Helsinki 1990

THE IMPACT OF A LUMBRICIDE TREATMENT ON THE FAUNA OF AIRFIELD GRASSLAND

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SUMMARY

This paper presents data from trials of a lumbricide (worm-killing) chemical to reduce bird numbers on an airfield by reducing the available food supply.

Numbers of feeding birds, worms and other invertebrates were monitored in adjacent 1 ha treated and untreated areas from 1 November 1989 to 2 April 1990.

Data for bird numbers were inconclusive due to low numbers being present on either area for most of the winter. Results for worm numbers showed no significant reduction in the sprayed areas, possibly due to long grass preventing penetration to the soil itself. Soil surface invertebrates showed significant long-term reduction in numbers as a result of spraying. Typical examples of data for the various species groups identified are given.

The potential for the use of lumbricides in airfield bird control is discussed, along with the possible problems which could result from the continued disruption of the grassland ecosystem by chemical treatment. The most profitable use of lumbricides is likely to be for small scale treatment of short grass strips alongside runways and around other installations. Airfield-wide application is not currently recommended. Further work is planned for 1990-91.

1. INTRODUCTION

The data presented in this paper form part of a series of investigations being carried out by the Aviation Bird Unit (ABU) under contract to the UK Civil Aviation Authority into possible new techniques for managing the airfield environment to deter birds.

At present, reduction of bird numbers on airfields is usually achieved by scaring using pyrotechnics and taped distress calls (CAA 1981), and by growing long grass swards to make the grassland areas less attractive to birds (Brough & Bridgman 1980). Both of these techniques are labour intensive if carried out effectively and, as staff costs rise, will become increasingly expensive.

The logical starting point for the study was to concentrate on those species which are recognised as the most hazardous on UK airfields, ie lapwing (*Vanellus vanellus*), golden plover (*Pluvialis apricaria*), black-headed gull (*Larus ridibundus*) and starling (*Sturnus vulgaris*) and to attempt to remove the features which attract them to airfelds. It is generally recognised that food, in the form of grassland invertebrates, and the security afforded by good all round visibility in large open spaces are the two main attractive features of airfields to these species. The removal of some or all of the food supply should, therefore make dispersal by scaring easier since the attractiveness of the airfield would be reduced and birds, once dispersed, would be less likely to return. Other studies have shown that worm numbers can be effectively reduced around runway margins using benomyl (Tomlin & Spencer, 1976) and that bird numbers can be reduced by removing worms using granulated endosulfan (Caithness, 1986). Neither of these chemicals is approved for use as a lumbricidein the UK however. Earthworms (Lumbricidae) are known to form a significant part of the diet of all of the species listed above, the remainder consisting largely of other grassland invertebrates (Cramp & Simmons, 1983, Barnard & Thompson, 1985). A lumbricide chemical approved for use on amenity grassland and sports turf was chosen (Ministry of Agriculture, Fisheries and Food, Health and Safety Executive, 1988), the active ingredient of which (gamma HCH) is also effective against a wide range of insects, spiders and other invertebrate species.

As well as investigating the effectiveness of the lumbricide in terms of reducing bird numbers, consideration must be given to the impact of the chemcial on the grassland ecosystem. Little information is available on how a grassland invertebrate population responds in the long term to the application of what is a relatively persistent pesticide. The desirability of large scale pesticide use needs to be carefully considered in the light of increasing concern about the environment and the public relations implications should not be diregarded. The data gathered from this project will allow the ABU to offer detailed advice to aerodromes contemplating the use of lumbricides as a bird deterrent.

2. METHODS

The study was conducted at British Aerospace's airfield at Salmesbury, Lancashire UK from 1 November 1989 to 2 April 1990.

Three experimental areas, each 200m x 100m in extent were marked out on the airfield and each divided in half to produce three pairs of plots each 100m x 100m. One plot from each pair was selected to be treated with the chemical, otherwise they were managed identically. The chemical was applied in November 1989 at the manufacturers recommended dosage. At the time of application the grass sward was approximately 10cm high. The bird and invertebrate populations present on the plots both before and after treatment were monitored by the following methods.

2.1 **Birds:** The numbers and species of birds present on the three pairs of plots were determined by counting the number of birds feeding on each plot at half-hourly intervals from 0700 to 1100 hrs (the period of maximum feeding activity) daily for two weeks before and after spraying.

2.2 **Worms:** Worm populations were estimated by taking a total of 40 randomly dispersed soil samples (20 from each plot) from each experimental area. The soil samples measured 20cm x 20cm x 10cm deep. Each sample was hand sorted and the worms present measured and counted. Hand sorting is recognised as the most effective technique for removing worms from soil samples, particularly the larger burrowing species (Edwards & Lofty, 1972). One set of samples was taken before spraying, and two further sets at 6 and 30 days after spraying respectively.

2.3 **Soil surface invertebrates:** A series of 25 pitfall traps (plastic cups set into the ground containing a preservative solution into which the invertebrates fall (Southwood, 1978)) was laid out in a grid pattern on each each plot. The traps were approximately 25m apart. Traps were emptied at approximately two-weekly intervals, once before spraying and for a total of 5 months afterwards. All invertebrates trapped were classified into broad taxonomic groupings (Table 3) and in some instances separated arbitrarily by size in order to emphasise those likely to be of importance in the diet of the birds being studied. The number of individuals present in each group was determined, and the treated and untreated areas compared using t-tests.

3. RESULTS

Monitoring of the three pairs of plots before spraying showed some significant differences between the different areas, eg. pair A had a significantly lower worm population than pairs B and C and also held significantly fewer feeding birds (t test $P<.05$). The effect of the chemical treatment was, however, uniform across all three pairs of plots. Data are, therefore, not pooled across the three areas, but are presented for one pair of plots only (area C) for the sake of brevity. A full account will be published elsewhere.

3.1 **Bird numbers and behaviour:** Table 1 gives the data pooled over all bird species for the number of individuals observed feeding on the treated and and untreated plots both before and after spraying. Before spraying significantly more birds fed on the plot which was subsequently treated. After treatment there were still more birds feeding on the treated plot, but the difference was no longer statistically significant.

3.2 **Worm numbers:** Table 2 shows the data for the mean number of earthworms recovered from the 20 turf samples taken from each half of the experimental plot before, 6 days after and 30 days after spraying. The spray had no discernable effect upon worm numbers. The mean number per sample did not differ significantly at any stage of the experiment. There are several possible reasons for the lack of effectiveness against worms which are discussed later.

Table 1. Mean numbers of birds observed feeding on treated and untreated areas before and after application of the treatment. Figures in brackets are standard errors of the means.

a) PRE-TREATMENT (42 observations)

	Plot Ci	**Plot Cii**	**t**	**p**
Mean No. Per observation	24.1 (6.5)	42.3 (7.9)	2.84	0.007

b) POST-TREATMENT (27 observations)

	Plot Ci (unsprayed)	**Plot Cii** (sprayed)	**t**	**P**
Mean No. Per observation	6.9 (1.9)	20.8 (9.1)	1.61	0.12

Table 2. The mean numbers of earthworms present in 20 soil samples taken from each experimental plot before, 6 days after and 30 days after treatment with a lumbricide. Figures in brackets are standard errors.

a) PRE-TREATMENT

	Plot Ci	**Plot Cii**	**t**	**P**
Mean No. per sample	14.5 (2.5)	9.6 (1.6)	1.63	0.11

b) 6 DAYS AFTER TREATMENT

	Plot Ci (unsprayed)	**Plot Cii** (sprayed)	**t**	**P**
Mean No. per sample	14.3 (2.5)	9.0 (1.8)	1.68	0.10

c) 30 DAYS AFTER TREATMENT

	Plot Ci (unsprayed)	**Plot Cii** (sprayed)	**t**	**P**
Mean No. per sample	12.6 (2.2)	9.4 (1.8)	1.15	0.26

Table 3. The groups into which invertebrates were divided from the pitfall trap samples and the species, genera or families which constituted the majority of individuals in each group (where no particular species dominated 'various species' are indicated).

Invertebrate Group	Constituent Taxa
Coleopteran larvae > 5mm length	(Hydrophilidae, Dytiscidae)
Coleopteran larvae < 5mm length	(" ")
Adult coleopterans	(Helophorus sp, Carabidae, Staphalinidae)
Collembolans	(Various species)
Arachnids	(Various species)
Adult Diptera > 3 mm length	(Scathophagidae)
Adult Diptera < 3 mm length	(Nematocera)
Dipteran larvae	(Tipulidae)
Lumbricidae	(Various species)
Homopterans	(Phrophaidae)
Heteropterans	(Various species)
Hymenopterans	(Various species)
Acarina	(Various species)

3.3 **Soil surface invertebrates:** Table 3 lists the groups into which the contents of the pitfall traps were divided, and gives the species, genera or or family which constituted the majority of individuals in each group. Identification was carried out on a pragmatic basis since this study is concerned with invertebrates as the food supply of birds rather than with the effect of chemical treatment on insect species *per se*.

It must be emphasised that pitfall trapping does not give a complete picture of the invertebrate fauna in a grassland. The number of individuals trapped will vary depending on activity levels, and hence temperature, and on the susceptibility of particular species to pitfall trapping (some species may be able to avoid or escape from the traps). The technique is, however, useful for giving a measure of relative abundance of species or groups of species in comparable areas. It is not unreasonable to assume that particular species are equally susceptible to pitfall trapping in two adjacent 1 ha plots and that the effects of temperature on activity levels will be similar. Other studies have shown that the number of beetles caught in pitfall traps is proportional to their total abundance (Baars 1979). Pitfall trapping can, therefore, be used to give a measure of the relative abundance of some species groups in the treated and untreated areas, but gives no indication of total species composition or absolute numbers in the invertebrate population. For this reason data on the actual numbers captured are given for only one species group (coleopteran larvae > 5mm long) in order to illustrate how variation in trapping efficiency ran in parallel in both plots (Fig. 1) presumably due to changes in weather conditions. The remainder of the data are expressed as plots of the t statistic against time. The t test measures the magnitude of the difference between the mean values for the numbers of individuals captured in the two plots relative to the variance of the mean. Since pitfall trapping gives a measure of relative abundance only, the t statistic is a more useful measure of the impact of the chemical treatment on invertebrates relative to those in the untreated areas.

Factors such as variation in temperature, rainfall etc can be assumed to be uniform across the two plots, leaving the t statistic as a measure of the effectiveness of the pesticide treatment alone. Figs. 2, 3, 4, 5 and 6 show the data for coleopteran larvae over 5 mm, adult Coleoptera, Collembola Arachnida and Diptera over 3 mm respectively. These groups have been chosed to show typical patterns in the data and to illustrate some of the potential problems that may result from the use of lumbricide chemicals. Other groups which were trapped in sufficient numbers to allow meaningful analysis show similar patterns to those illustrated.

3.4 **Coleopteran larvae over 5 mm in length (Fig. 1):** There was no difference between the two plots before spraying, and numbers trapped fell in both plots immediately after spray application due to cold weather. Numbers remained very low in the sprayed area for over 50 days before recovery commenced. The recovery coincided with an increase in numbers trapped in the unpsrayed plot which coincided with a mild spell of weather. This indicates that the long term effectiveness of chemical treatments will depend on how weather conditions govern the growth and reproduction, and hence the recovery time, of the invertebrate populations concerned. Fig. 2 shows the value of the t statistic for the data plotted in Fig. 1. Significant differences in population took about 20 days to occur, and the maximum differential occurred after 75 days. 150 days elapsed before the treated population recovered to the level of the untreated one. The times taken to respond to, and recover from, pesticide treatment will not only vary with weather conditions but with the life history and hence reproductive state of the animal concerned. Species which overwinter as larvae, reproducing only in the summer months must rely solely on immigration to restore a population, whilst those able to reproduce all year round may be able to recover more quickly if weather permits.

3.5 **Adult coleopterans (Fig. 3):** Significant differences were detected almost immediately, but it should be noted that there were differences between plots which neared statistical significance before the treatment was applied. As with coleopteran larvae, the maximum effect was not immediate but occurred after 55 days, again coinciding with mild weather. The population had recovered after 140 days.

3.6 **Collembola (Fig. 4):** Although these are too small to feature in the diet of the important bird species, they are prey to many other grassland invertebrates and hence form an important part of the food chain. The maximum impact on collembolans was achieved after 100 days, followed by a rapid recovery. The difference between populations had disappeared after 120 days. This rapid population recovery is achieved by the collembolan's capacity for very rapid reproduction in suitable conditions. The warmer spring weather enabled a rapid population recovery to take place, indicating that chemical treatments applied in summer may have shorter term impacts as populations can recover more quickly.

3.7 **Arachnida (Fig. 5):** There was already a significant difference between the plots before treatment. The application of the chemical increased the size of the difference between plots, and no recovery had taken place by the end of the experimental period at 150 days. Spiders are recognised as one of the major predators in grassland ecosystems (Curry, 1987) and their removal may allow other species to increase their population sizes beyond normal levels (see below).

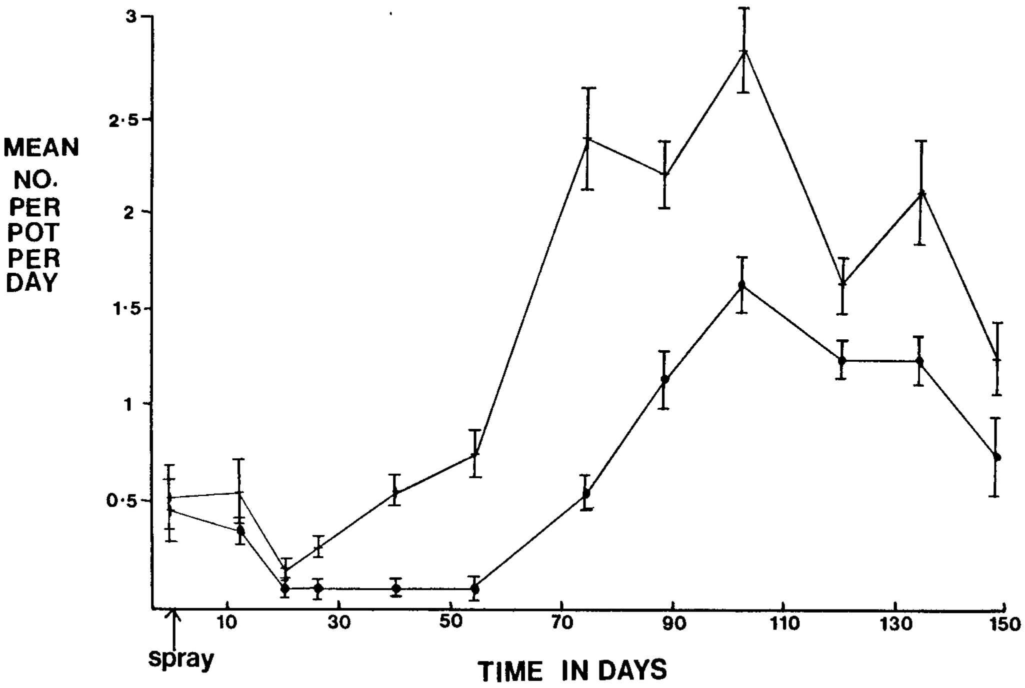

Figure 1. The mean number of coleopteran larvae over 5 mm in length captured per pitfall trap per day for treated (●) and untreated (+) plots. Vertical bars are standard errors of the means. The timescale is from 9 November 1989 to 2 April 1990.

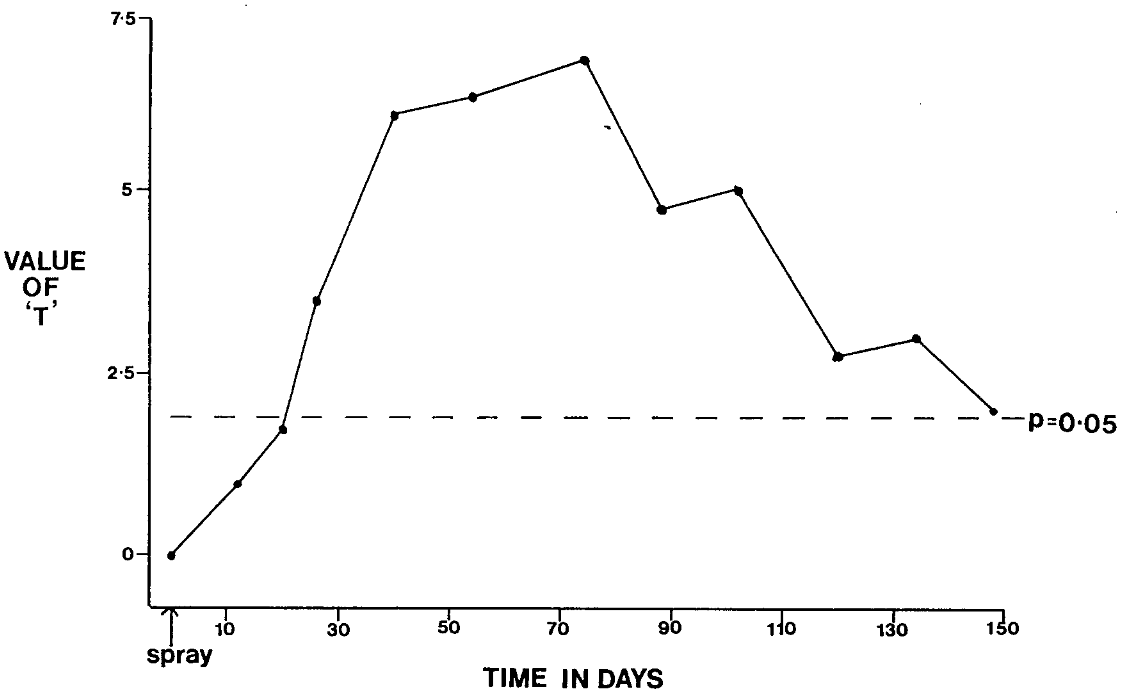

Figure 2. The value of the 't' statistic comparing the mean number of coleopteran larvae over 5 mm in length caught in the treated and untreated plots. The 5% threshold of statistical significance is indicated by the dashed line. Timescale as for figure 1.

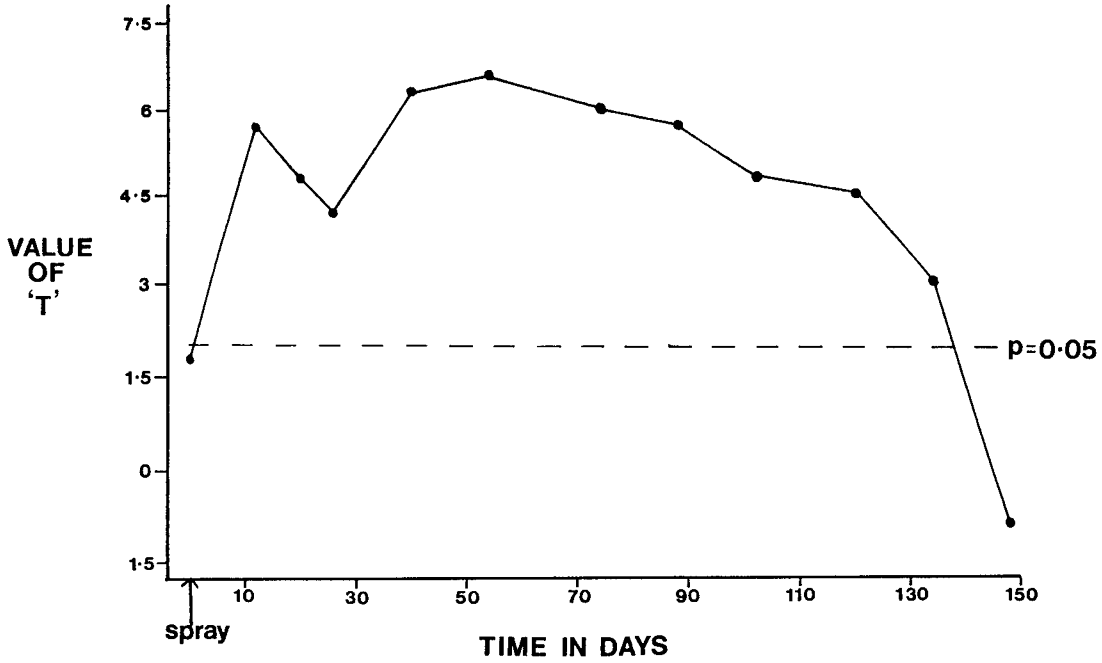

Figure 3. The value of the 't' statistic comparing the mean number of adult Coleoptera caught in the treated and untreated plots. The 5% threshold of statistical significance is indicated by the dashed line. Timescale as for figure 1.

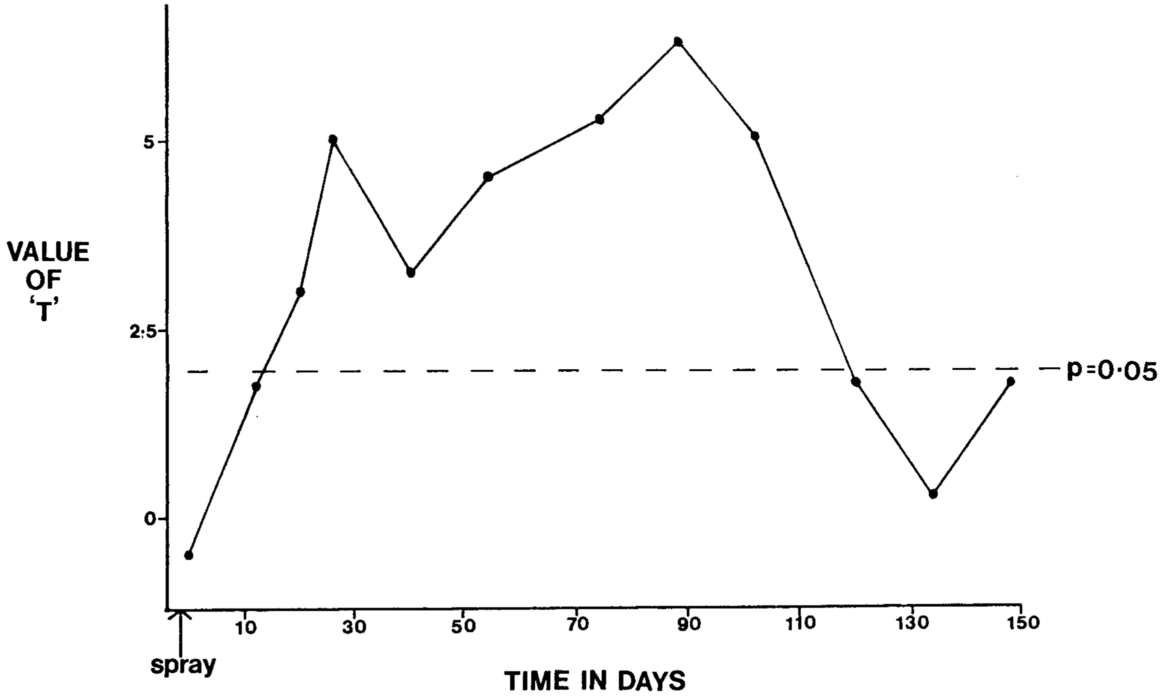

Figure 4. The value of the 't' statistic comparing the mean number of Collembola caught in the treated and untreated plots. The 5% threshold of statistical significance is indicated by the dashed line. Timescale as for figure 1.

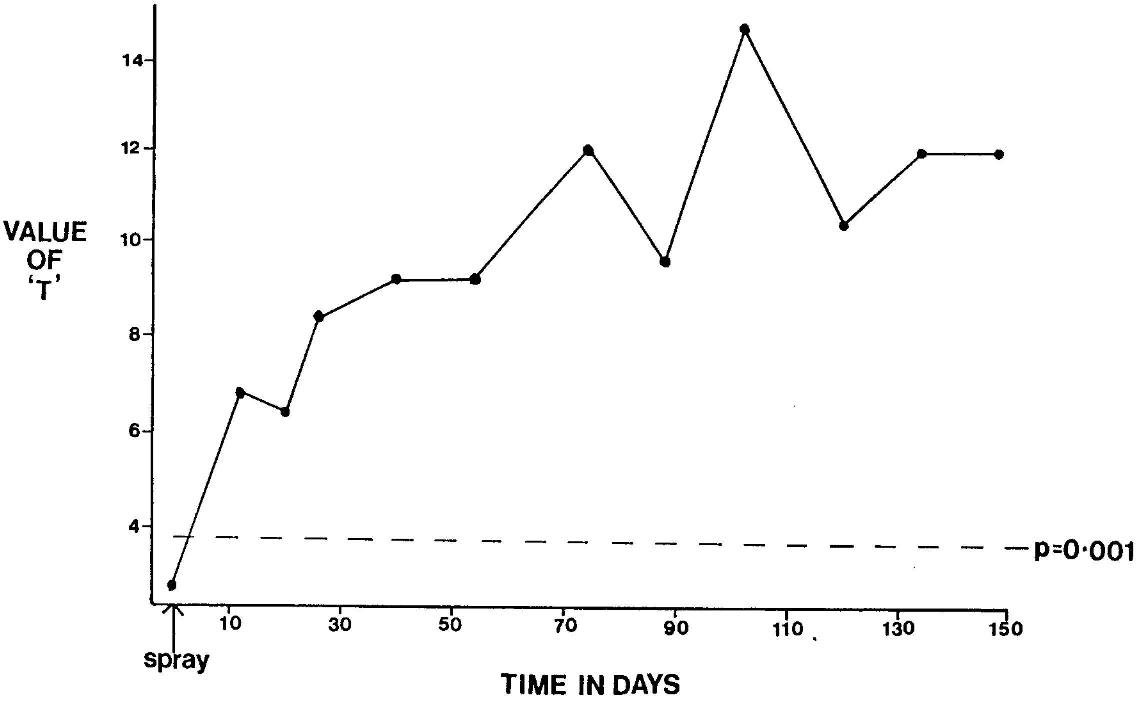

Figure 5. The value of the 't' statistic comparing the mean number of Arachnida caught in the treated and untreated plots. The 0.1% threshold of statistical significance is indicated by the dashed line. Timescale as for figure 1.

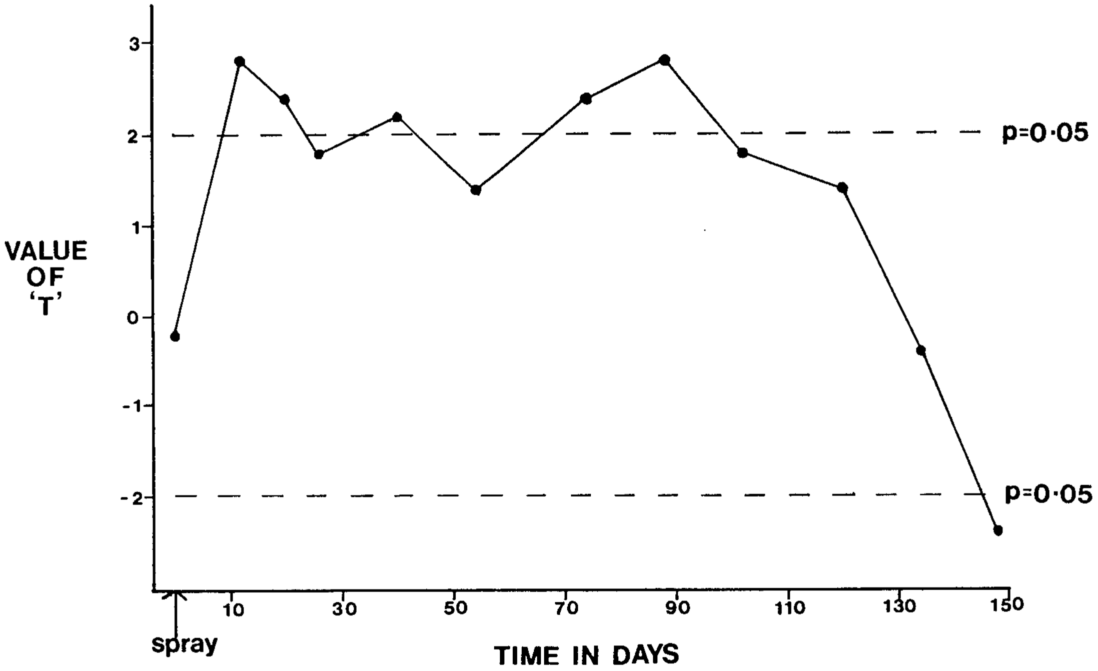

Figure 6. The value of the 't' statistic comparing the mean number of Diptera caught in the treated and untreated plots. The 5% threshold of statistical significance is indicated by the dashed line. Timescale as for figure 1.

3.8 Diptera over 3 mm length (Fig. 6): As with other groups, a significant effect was achieved after about 10 days. The difference remained at around the 5% significance level until about 120 days. At this point a very rapid population recovery took place which resulted in a significant increase in the dipteran population of the treated plot compared to the untreated one after 150 days. This increase is indicated by a negative value of the t statistic in Fig. 6. The population recovery coincided with that of the collembolan population and may have resulted from the emergence of adults from pupae under the soil surface in response to warmer weather or from immigration of winged individuals. The large reduction in the numbers of spiders, said to consume up to 30-50% of emerging dipterans in some situations (Curry, 1987) may have allowed the population in the treated area to overshoot its normal levels.

4. DISCUSSION

4.1 Bird numbers: The data on the birds themselves are inconclusive. Despite the fact that the airfield frequently held in excess of 2000 lapwings, gulls and golden plovers and usually several hundred starlings, the birds moved around the airfield whilst feeding and were on the plots quite infrequently. This fact, combined with the gradual reduction in numbers as birds moved out in response to colder weather resulted in a sparse data set, especially in the midwinter period when the effect of the chemical was at its maximum. The lack of significant differences between the numbers of birds feeding on treated and untreated areas should not, at this stage, be taken as an indication that the candidate lumbricide has no potential as a bird control agent. Further work, during periods of higher bird numbers, is planned for 1990-91.

4.2 Worm numbers: No significant differences were detected betwen the two plots either before or after the application of the lumbricide. There are three possible explanations for this result. Firstly, that the chemical itself was ineffective or improperly applied. This seems unlikely in the light of the highly significant effect on the soil surface invertebrates. Secondly, the sampling technique used may not have been sensitive enough to detect small changes in worm populations relative to the variability in their distribution. This also appears unlikely, as the constant values of mean and standard error for all three samples taken from the unsprayed section indicate that the technique copes with the variability to give a repeatable measure of abundance. The third possible explanation is that the chemical may have failed to penetrate below the soil surface in sufficient quantity to be effective due to the long grass (15-20cms) on the experimental plots. This seems the most likely explanation since the chemical formulation is usually employed on golf greens or other amenity turf which is normally kept short. Caithness (1986) suggests that long grass, with a dense layer of dead material at the soil surface, may prevent the effective penetration of liquid based Lumbricides to the soil. Lumbricides may, therefore, be more effective on short grass areas bordering runways and taxiways where birds often gather to feed on worms, particularly during periods of wet weather when worms are closer to the surface.

4.3 Soil surface invertebrates: The chemical had a profound effect on the numbers of several invertebrate groups likely to form part of the diet of problem bird species on airfields. Those groups trapped in sufficient numbers to allow meaningful analysis showed broadly similar patterns, with significant reduction in numbers after about 10 days, the maximum differential between sprayed and unsprayed areas after 50-70 days and recovery, (except in the case of arachnids) after 100-150 days. These timings should be interpreted with care, however, since pitfall trapping is dependent on the activity levels of the invertebrates and hence on temperature. If, for example, the chemical reduces activity in those individuals it does not kill, or changes their response to variations in temperature, then the maximum effect at 50-70 days could be a measure of differences in activity levels at that time rather than in numbers. The recovery times and time of maximum effect are likely to be shorter in the summer when higher temperatures will result in greater general activity and increased reproduction, allowing recovery of populations by immigration and reproduction to proceed more quickly. Some difficulty is therefore likely to be encountered in targeting what is a broad spectrum and fairly persistent pesticide against invertebrate groups other than worms.

The main problem likely to be encountered if lumbricides are used regularly on airfields is the disruption of the grassland ecosystem. The removal of worms, which are known to contribute to soil structure and fertility (Curry, 1987) may lead to drainage problems and poor grass growth if repeated over a number of years. Increased expense may result if spiking of the turf and the application of fertilizers are subsequently required. The removal of grassland predators such as spiders may result in a superabundance of their prey species later in the year. If this occurs further insecticide applications may be required to control population explosions of some species that would not otherwise have posed a problem, but which could be major bird attractants.

5. CONCLUSION

The ultimate test of any bird control measure is whether it reduces the number of birds, and hence the risk of a birdstrike, on a particular area. This investigation has not been able to prove that the lumbricide was effective in achieving this aim. The data do suggest, however, that the use of this lumbricide will reduce the numbers of a variety of invertebrate species which may form part of the diet of birds on airfields. The fact that the chemical did not appear to penetrate effectively long grass swards and did not reduce worm numbers significantly suggests that its greatest potential is for use on short grass areas bordering runways and around other installations. The limited use of lumbricides in these areas also avoids the potential for large scale disruption of the grassland ecosystem resulting in problems caused by unchecked population increases in certain species which would require further expensive chemical control.

6. ACKNOWLEDGEMENTS

We would like to thank the management and staff at British Aerospace Plc Military Aircraft Division, Samlesbury, for allowing us access to the study site and providing assistance throughout. David Sutton provided advice on pitfall trapping techniques. Dr C. J. Feare, T. Brough, T. P. Milsom and N. Horton commented on the manuscript.

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ADF616447

BSCE 20 / WP 48
Helsinki 1990

THE WAYS IN WHICH FEATHER COLOURS ARE PRODUCED AND THEIR POTENTIAL FOR IDENTIFICATION OF FEATHER REMAINS

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Summary.

Feather colours can be produced in principally two ways.
1. By the deposition of pigments (dyestuffs) in the feathers.
2. By the formation of light-reflecting structures in the feathers.

Pigment colours are the most frequent, giving rise to black, brown, grey, yellow and red colours. Structural colours may have any hue, but are particularly important with green, blue and violets.

There is great variation between species in the appearance of sections of coloured feathers under the electron microscope. Examples of this variation will be given and in relation hereto the potentials of feather colours for the identification of feather remains will be discussed.

1. INTRODUCTION

Ornithologists rely to a very large extent on the great variety of colours and colour patterns when they identify bird species.

It is therefore natural to ask whether we can use the ways in which feather colours are produced when we are to identify tiny feather fragments to species.

The method which gives most information probably is to study ultrathin sections of feather parts with the transmission electron microscope. A number of such studies has appeared since the early 1960'ies, and there now exists a general knowledge of the appearance of the various types of feather colours under the transmission electron microscope.

Neither time for preparation nor space for printing permits a rather complete review. Another relevant fact is that most studies have been performed on bright-coloured feathers of exotic species, the results of which are of little use in practical identification work with European species.

So I shall restrict myself to a very brief review with references to some of the existing literature. Durrer (1986) provides a recent review.

2. APPEARANCE OF COLOURED FEATHER PARTS UNDER THE TRANSMISSION ELCTRON MICROSCOPE.

Feather colours can be produced in principally two different ways. (1) By the deposition of coloured substances, pigments, within the feather keratin, and (2) by the enhancement of reflection of light of a certain portion of the visible spectrum, due to the presence of structures of a particular size, shape and refractive index within the feather keratin.

2.1 Pigmentary colours

By far the two most widespread feather pigments are the melanins and carotenoids.

Melanins. These give rise to the very frequent black, brown, red-brown and yellowish-brown feather colours. They occur as granules, which are easily observed with the electron microscope.

In the black feathers of the Blackbird (*Turdus merula*) the granules are short rods with rounded ends oriented lengthwise in barbules and rami. In transverse sections of barbules the granules appear with a circular outline (diameter approx. 0.2 µm) (E. Sønder, unpubl. study).

Melanins of black and dark brown feathers (eumelanins) vary both with respect to shape and size, but my knowledge of this variation is based only on scattered observations. No systematic survey of these melanins has been carried out to my knowledge.

Granules may be rod-shaped, ellipsoid and (less frequently?) globular. Large variation in size (0.2 - 1 µm) has been observed in the Columbiformes. In species belonging to different passerine families moderate variation in transverse diameter has been noted.

References: Dyck (1971a), Hürter (1980).

Lighter brown melanin granules (phaeomelanins) generally seem to be much more irregular in shape than eumelanins, but my observations are very few. Hübel (1975) has studied them in Coturnix.

Carotenoids. These give rise to, often intense, yellow, orange and red feather colours. Olive green colours arise where a feather is partly yellow, partly black pigmented.

In contrast to melanins carotenoids are diffusely distributed in the feather keratin and do not show up under the electron microscope, at least not with the stains usually applied. However, two other types of structures associated with carotenoids are frequently present.

Aggregations of membranes and tubules may be present in the carotenoid-containing cells (Dyck 1973). I have observed them in woodpeckers and barbets and some passeriform families, while other passeriform families lack them. Variation in this type of structure occurs; thus in woodpeckers aggregations of membranes dominate.

The air-filled medullary cells in the interior of yellow pigmented rami contain a well-developed keratin rod network not present in black and white rami. There is some inter-specific variation in this structure, as can be observed both with the transmission and scanning electron microscope (Dyck 1978).

2.2. Structural colours

Two main types can be distinguished according to whether the colour-producing structures are present in the barbules or in the rami.

In barbules. The shining, metallic, iridescent plumage colours so widespread among birds represent this main type. Physically it is dependent on the interference of light in thin films.

Usually a thin film is represented by a layer of melanin granules parallel to the outer surface of the barbule cell. Important for the production of colour is the very high refractive index of melanin; the hue of the colour is determined primarily by the thickness of the melanin layer, not by the colour of the melanin pigment.

Great variation occurs in the building and arrangement of the layers. Durrer, who has studied these structures extensively, in an overview (1977) distinguishes 23 different types. The melanin granules may be ellipsoid, thin or thick compact rods, rods with the interior hollow, long plates or large discs with hollow interior. There may be one or several layers; they may be close together or separated by keratin layers, etc. To this comes variation in colour, which results from fine adjustments of melanin granule size and spacing of layers (Dyck 1987). Also the modifications of the barbules (twisting etc.) necessary to expose a flattened surface vary between groups of birds (Lucas & Stettenheim 1972) and can conveniently be studied with the scanning electron microscope.

In rami. Non-metallic blue colours as seen f.i. in a Blue Tit (Parus caerulus) belong to this main type. In combination with yellow pigments they produce pure, green colours. Both the violet, blue and green colours of parrots are due to this type of structural colour (Dyck 1976).

Colour production is in the air-filled medullary cells, where a spongy structure consisting of keratin penetrated by air-spaces is present (Dyck 1971a). For the colour to appear vivid a dark background is necessary. This is usually accomplished by part of the ramus containing dark melanin.

Variation in colour results from variation in dimensions of spongy structure and type and distribution of yellow pigments (Dyck 1971a). Variation of structurally coloured rami between different groups of birds is mainly in (1) shape of rami in transverse section (Auber 1957), (2) distribution of dark melanin within rami (Auber 1957) and (3) shape of air-spaces in spongy structure (Dyck 1971b).

2.3 White

Since gulls very frequently are involved in bird-strikes, a few words may be added on white feathers.

A white feather typically results when no pigments or colour-producing structures are present. Reflection of light occurs from the numerous keratin-air interfaces present, both in the medulla of the rami and on the outer surface.

I have found no specializations in the white feathers of the Black-headed Gull (Larus ridibundus) (Dyck 1978) and therefore consider it rather unlikely that structures associated with whiteness can be found which make differentiation of white gull feathers possible. Specializations of wing feathers producing a silvery gloss in terns have, however, been described (Rutschke 1965). The body feathers of the white winter plumage of the Rock Ptarmigan (Lagopus mutus) are modified to increase whiteness (Dyck 1979).

3. DISCUSSION

From the foregoing it will be clear that there is considerable variation in the appearance of coloured feather parts under the transmission electron microscope, and I consider it probable that in many cases it is possible to identify feather fragments as originating from a certain species or a group of closely related species.

It will likewise be clear from the foregoing that the possibilities are different for pigmentary and structural colours. Evidently variation, and thereby potentials for identification, are much greater among the latter. This is unfortunate because structurally coloured feathers are much less frequent among European species than are feathers coloured by pigment. I guess that in the great majority of cases it will be possible to identify a structurally coloured feather fragment of a European species correctly, while for a fragment coloured by pigment the likelihood is considerably less. Some improvement of the situation is provided by the fact that frequently several ways of producing colour are present in a feather, e.g. one type of pigment in the terminal parts of the barbules, another type basally in the barbules and in the rami, and furthermore because frequently feather fragments of different colours are present in a sample.

It is necessary to emphasize strongly, however, that this identification method requires knowledge of the electron microscopical appearance of the feathers of European species, and that this knowledge is generally lacking.

During the past 15-20 years I have made a number of identifications of bird-strike remains, and have never used transmission electron microscopy. In a few cases it would perhaps have been appropriate to do so, but usually I have succeeded to identify the fragments to at least a group of closely related species by using the characteristics of downy barbules according to Brom (1980) and examining skins. When feather fragments of natural elasticity and colour are not present because the sample is sticky, containing blood and remnants of soft tissue, I place the sample in a solution of soap powder with enzymes at room temperature for some days. Then it is usually possible to isolate feather fragments and after cleaning them by rubbing and several ultrasonic treatments and drying, they have normally regained their elasticity and colour.

I suspect that in the major part of difficult cases, where the above 'standard method' does not suffice, other methods will be less time-consuming and perhaps more diagnostic than transmission electron microscopy of colour-related elements. These other methods are e.g. scanning electron microscopy of external surface structures, electrophoresis of feather keratins, and last, but not least, sequence analysis of DNA. The latter method requires 'soft material', e.g. blood or connective tissue. Very little material is required, and f.i. a little feather pulp from a growing feather will do. Whether it can also be applied to dry feathers without living tissue is unknown (P. Arctander, pers. comm.).

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ADF616448

BSCE 20 / WP 49

Bird hazard management at Manchester Airport

Callum S Thomas, *Manchester Airport plc*

Bird strikes are a serious threat to aviation safety. The hazard at each airport is unique and a study of the habits of birds living in the vicinity of the airport is necessary before a control programme can be developed. The habitat of an airfield can be modified to make it unattractive to birds; however, the corner-stone of a control programme remains comprehensive bird detection and dispersal by a small dedicated unit.

Gulls feeding at rubbish dump.

Bird strikes are a serious and expensive threat to aviation safety. Most strikes involving civil aircraft happen on, or close to, an airport, with the result that in many countries, airport companies have a legal responsibility to take reasonable precautions against the hazard posed by birds.

A wide variety of bird control measures have been developed over the years. However, a detailed knowledge of the local bird problem is necessary if their effectiveness is to be maximised. The way in which bird control is organised, and in particular, the relationship between bird control staff and air traffic controllers, is a vital element in determining this success.

The first recorded bird strike (collision between an aircraft and a bird) occurred in 1912 when a gull lodged in the controls of a Wright Flyer off Long Beach, California. The aircraft crashed into the sea and the pilot was killed. Since that time, the hazard posed by birds has increased due to an increase in the number of aircraft flying, increasing speeds, more precise and delicate equipment and, in particular, following the advent of the jet engine.

Today, bird strikes cost the aviation industry tens of millions of pounds every year in engineering bills and operational delays and, in addition, an aircraft crashes, on average, every 18 months as a result of a bird related incident.

An analysis of serious bird strikes reveals that they involve common jet aircraft, normal aircraft activity, common bird types, and normal numbers of birds. For many airports, therefore, a serious bird strike is likely to occur sooner or later. It is not possible, however, to guarantee a reduction in bird strikes. It is equally impossible to guarantee a bird-free environment on the airfield.

The airport company does, however, have a responsibility to take action to control birds. Bird strikes are no longer

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accepted by insurance companies as an act of God, even when they occur at very small airports, and so to avoid litigation, the airport must have a properly documented bird control programme, and staff with sufficient knowledge to defend that programme in an inquiry.

Bird control must be regarded primarily as a method of reducing strikes involving the most hazardous species. However, all birds are potentially hazardous, so a detailed risk assessment should be prepared for each species. In some cases, the costs in economic or environmental terms, or in terms of the disruption which would be caused to normal operations, could outweigh the hazard posed by the birds.

The extent of bird control at different airports ranges from an inspection of the runway before selected aircraft movements, to ensuring that the entire airfield is maintained as a bird-free environment. Each airport has a totally unique problem, and a study of the ecology and behaviour of birds found on the airfield and in the surrounding countryside, is a necessary prerequisite to the development of a bird hazard management programme.

This programme should aim to identify all birds in the vicinity of the airport; assess the hazard posed by each species; identify why they use the airfield and what it is about their behaviour which makes them hazardous; change the habitat of the airfield to make it less attractive; implement a bird dispersal programme; and control birds at sites in the surrounding countryside.

Bird-strike reporting systems are in operation in many countries. The statistics arising from these reports can provide a valuable insight into the bird hazard, however, they can be extremely deceptive if viewed in isolation from data on the behaviour and ecology of the birds. The following analysis of strikes reported through Manchester Airport provides an example of the type of information which can be gleaned from this source.

At least 14 species of birds were involved in 128 strikes reported during 1982-1984. Over 90 per cent of these occurred below 100ft. Lapwings and gulls (particularly black-headed gulls) were the most common cause of bird strikes, accounting for over 70 per cent of those in which the bird was identified.

Many of the remaining strikes involved individual (often small) birds, some of which were never seen on the airfield and were assumed to have been crossing it when killed. The bird hazard management programme at Manchester Airport was designed to deal primarily with gulls and lapwings and, for reasons of brevity, much of the following will deal with these two species alone.

The extent of the hazard posed by a particular type of bird is a function both of its size, and the numbers involved in a single incident (flocking birds are more dangerous than solitary species). On average, a third of lapwing and gull strikes involved more than one bird (usually two or three); however, in an extreme incident 72 black-headed gulls were found dead on the runway following the departure of a Boeing 737.

Year	Aircraft	Location	Bird	Weight (grams)	Deaths
1960	Lockheed Electra	USA	Starling	80	62
1962	Douglas DC3	Pakistan	Vulture	<10 000	1
1962	Vickers Viscount	USA	Swan	<6000	17
1968	Falcon 20	USA	Gulls	<1700	—
1969	Douglas DC3	India	Cranes	<6000	—
1973	Lear 24	USA	Cowbirds	44	7
1973	Falcon 20	UK	Gulls	420	—
1974	Cessna Citation	USA	Gulls	<1700	—
1975	NA265 Sabreliner	USA	Gulls	265	—
1975	DC10	USA	Gulls	<1700	—
1975	HS125	UK	Lapwings	215	6
1976	Lear 24	Italy	Gulls	<1700	—
1976	Falcon 20	USA	Gulls	485	—
1978	B737	Belgium	Woodpigeon	465	—
1978	Convair 580	USA	Sparrowhawk	<1095	—
1981	Lear 23	USA	Loon	3700	[illegible]
1982	Lear 35	France	Gulls	275	—
1983	Lear 25	USA	Starlings	80	—

Table 1. Birdstrike incidents involving crash and loss of life.
Taken from from CAA paper 84019 Analysis of bird strikes reported by European Airlines 1976-80.

Bird strikes occur throughout the year at this airport. However there is a marked seasonal variation in the number of strikes reported each month. The late summer peak in strikes corresponds with the arrival of wintering birds before British breeders have left. Further, a high proportion of the population at this time of year is composed of young birds which appear to be more strike-prone than experienced birds. In part, this distribution is also influenced by a seasonal variation in the number of aircraft movements.

The majority of strikes reported during the spring and summer months involve solitary, small birds. The peak bird strike-rate (number of strikes every 10 000 movements) for lapwing and gull related incidents occurred during the period July to January. Over 95 per cent of reported strikes occurred during daylight hours. Lapwing strikes were reported throughout the day, however, gull strikes tended to be clustered around dawn (over 70 per cent of gull related strikes were recorded within an hour of dawn).

Manchester Airport has only a single runway, yet it is noteworthy that all strikes involving gulls which were reported above 100ft occurred on approach to runway 06, or on departure from runway 24. This reflects a localised bird hazard arising from a gull flightline which passes close to the western boundary of the airport.

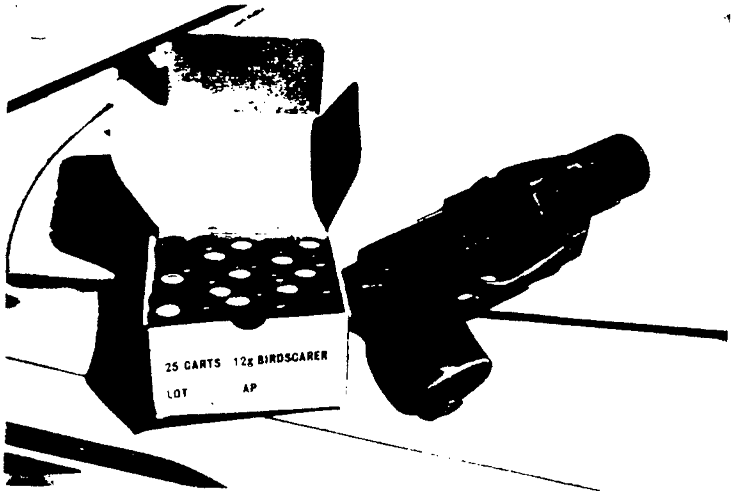
For some species, the weather influences the likelihood of a strike occurring. The proportion of gull strikes which occurred in the rain (28 per cent) was twice that found among lapwings (13 per cent), suggesting a difference in behaviour which makes gulls more hazardous in wet weather.

From the bird strike records alone, therefore, it is possible to detect conditions (time of year, time of day, weather, part of airport) for each species, when strikes are more likely to occur. However, there are many limitations in these data and they provide no indication of why this variation occurs.

Prior to the establishment of a comprehensive bird hazard management programme, lapwings attempted to loaf and feed on Manchester Airport from July until March each year. Numbers would build up to a peak in mid-December, when a flock containing in excess of 500 would habitually use the site. Because these birds are particularly resis-

Species	Number of strikes
Lapwing	34
Black-headed gull	19
Swallow	8
House martin	6
Swift	3
Skylark	3
Golden plover	3
Pigeons	3
Linnet	2
Starling	2
Common gull	1
Herring gull	1
Great black-backed gull	1
Lesser black-backed gull	1
Gull	17
Unidentified	24

Table 2. Bird strikes at Manchester Airport 1982-84.



Very pistol and cartridges.

tant to dispersal, they would spend almost the entire day on the airfield being driven from site to site until air traffic pressures resulted in them being allowed to settle.

It was discovered that intensive bird scaring from dawn to dusk over a period of several weeks was necessary to break their habitual use of the airport. Detailed observations of the time and direction of arrival of flocks was essential to the development of effective dispersal techniques.

The solution to the hazard posed by black-headed gulls was not found on the airfield. These birds arrived at the airport and crossed its approaches while passing between a winter roost 8km away, and feeding sites in the surrounding countryside. The movement of birds out from the roost occurred at dawn when visibility is poor and the airport is very busy, with the result that the opportunities for bird scaring are restricted. The solution was in fact found through action away from the airport.

Broadly speaking, birds come to an airport for one of four reasons, to eat, to sleep (roost), to breed, or to rest (loaf). Different species are here for different reasons and the same species may use the airfield for different reasons at different times of the year. Some birds, because of their behaviour, feature regularly in bird strikes, while others present on the airfield are never hit. Differences of this nature will dictate the way in which control will be achieved. Habitat management involves changing the environment of the airfield to make it less attractive to birds.

Opportunities for feeding may be reduced in a number of ways depending upon the nature of the bird hazard. Many airports maintain grass on the airfield at about 20cm long. Selection of particular varieties of grass, coupled with a complex maintenance programme ensures a tough, bristly growth which will withstand the effects of weather and remain erect.

The long grass makes soil invertebrates inaccessible to feeding birds, and many birds will not stand in it since they cannot see approaching predators, and therefore feel uncomfortable. The result is that the airfield as a whole is made less attractive to birds and the areas on which birds are found is reduced and restricted to those areas which are more accessible to bird control staff.

A chemical applied to a grass strip either side of the main runway kills worms, which can be found in their thousands on the hard standing in wet weather. These are highly attractive to gulls. The general public visiting the airort must be dissuaded from feeding birds. All catering operations must be well managed to ensure that birds are not attracted by edible waste. Areas of standing water which could attract feeding birds should be filled in, treated, or restructured to reduce the diversity of animals and plants which attract birds.

Bird roosts can be made unavailable or inaccessible. A large starling roost located in the gardens surrounding the terminal building at Manchester was successfully dispersed following an extensive pruning programme. Birds nesting in buildings are excluded using netting or, as in one case involving several hundred starlings, by simply closing windows.

Birds have been excluded from high mast lighting towers by using bird repellent jelly. Breeding and loafing sites can be similarly treated, although bird scaring techniques and nest destruction are also effective.

Detailed observations of the birds at the airport will provide the information which will make habitat management more effective. In the longer term, the proactive approach has required the inclusion of bird control design criteria into landscaping, engineering, and building work.

Habitat modification is an essential component of any bird hazard management programme. However, since this is never totally effective, the cornerstone of bird control remains an efficient bird detection and dispersal operation.

Although an airport is intrinsically attractive to some species of birds, others visit it while flying to other sites, and may only use it at certain times of the day. Even those airports on which the number of resident birds is comparatively small, can face a serious bird hazard where the environment surrounding the airport is full of birds.

The result is that, in theory, flocks of birds may appear over the perimeter fence at any time, and from any direction, and land on the runway. The only truly effective method of detection involves the provision of dedicated staff who can spend their entire working day patrolling the airfield, if the extent of the bird hazard demands it.

Those birds which use the airport on their way to other sites can often be dispersed with comparative ease. However, those species which are attracted to the airport itself will tend to be more persistent.

There is a tendency for flocks of birds which are loafing in remote corners of an airfield (and even, sometimes at sites quite close to the runway) to be allowed to remain there if they show the least sign of persistence. This practice, which is at best short-sighted, and at worst dangerous, arises both because of the limitations in the amount of time which can be allocated to bird control, and also because bird dispersal carries with it a degree of hazard to aircraft, and air traffic controllers are sometimes unwilling to allow dispersal to take place. A good relationship with ATC is therefore essential.

All flocks of birds should be dispersed at the earliest reasonable opportunity because a flock of birds on the ground acts as an attractant to others, and small flocks are easier to disperse in a controlled manner. While a flock remains on the ground it offers no immediate threat to an aircraft (unless, of course, it is on the runway). However, it may be disturbed at any time and fly up in a dangerous and uncontrolled manner. The bird officer can select when, and in what way, to disperse the flock.

If a flock is allowed to remain on an airfield for any length of time, the birds become more resistant to dispersal action. In the short-term they learn that with a little persistence they will be allowed to settle again, in the long-term they start to include the airport as part of their daily routine. Bird dispersal may take only minutes, although a persistent flock may require continuous dawn to

Bird control unit on patrol at Manchester Airport.

dusk scaring for a number of days in order to break its allegiance to the airport.

Birds are most easily dispersed if attacked before they have settled on the airfield. Observations of the movements of different types of birds will indicate the direction in which they will most easily be driven off. This requires the maintenance of detailed records, and also an intimate knowledge of the local bird populations.

A variety of techniques are used to scare birds, the most effective being the Very pistol and cassette tapes of birds in distress. The Very pistol, which fires an explosive flare, is fast-acting and can be used to shepherd a flock, but its use can be limited in the vicinity of aircraft and buildings. Distress tapes have a longer lasting effect but are limited in their use by ambient noise and high winds which distort the sound being broadcast. The birds can become habituated to the sound if it is used repeatedly without reinforcement.

Birds of prey are used at some airports although they are costly to maintain, cannot be flown in extreme weather, and are not effective against certain species of birds. Finally, of course, they do constitute a bird hazard in themselves, and in some countries are banned for this reason.

Automatic bird scaring equipment has a number of major limitations, and yet it is still regarded as a cheap and convenient method of control. It is non-directional, it can be dangerous and go off at the wrong time (when an aircraft is taking off or landing), and it does not respond to the reactions of the birds. As a result, the birds become habituated to, and ignore, the equipment, particularly if the scaring is never reinforced with human intervention and the use of a shotgun.

Birds have brains which are far more sophisticated than even the most complex microchip-controlled bird scaring device. By and large, such equipment is ineffective in comparison to the results which can be achieved by trained bird-control staff. However, it is of use at sites in remote corners of the airfield which are difficult to gain access to.

A culling operation has been introduced to reduce the size of a rookery on the southern boundary of Manchester Airport. In general, the trapping, shooting, or killing of birds has limited value and while the shotgun is a very useful adjunct to other types of scaring equipment, the large scale slaughter of birds unacceptable environmentally, legally, and politically. Where protected species are involved, a programme of trapping and removal to another suitable site should be considered.

The extent of the bird hazard on an airport is a function of both the attractiveness of the airfield itself and the diversity and richness of the countryside in which it is set. Since gulls will fly 20, 30 or even 40km each day in search of food, the extent of the hazard on the airfield can be determined by conditions at sites many kilometres away, which therefore, must also be considered for bird control activities. The identification of such sites and the action which can be taken against them is discussed by Thomas (Royal Aeronautical Society Symposium, *Bird Hazards in Aviation* 1987).

Action required to reduce the gull hazard at Manchester Airport has included the encouraging of the closure of waste disposal sites, the production of information for farmers on how to modify their farming practice, the development of a programme designed to disperse the night roost from the nearby lake, and an agreement with the local water authority that sewage spraying on farmland close to the airport be stopped during the winter months. This has disrupted the traditional dispersal pattern of the birds from their night roost, and in so doing has reduced the bird hazard on the airfield.

Manchester Airport created the post of Bird Control Officer and in so doing became the first civil airport in Britain to allocate full-time staff to this problem. Following a study, a bird hazard management programme was drawn up and a three-person bird control unit was established.

The work of this unit has resulted in a decline in the bird-strike rate; a reduction in the proportion of strikes involving gulls and lapwings; a decline in the number of birds which regularly use the airfield; and a reduction in the effort required to disperse those birds which do come (as measured by the number of bird scaring cartridges used). This has a secondary benefit in providing significant financial savings.

The hazard posed by birds to aircraft is a complex biological problem with environmental and operational implications. It cannot be properly assessed by engineers or airport managers without training in this field. At many airports, the level of bird activity is so low that the risk of a serious incident is almost zero. However, at most airports it is necessary to employ a suitably qualified individual to carry out a short-term study as a pre-requisite to the development of a comprehensive bird hazard management programme, which should then be implemented by a small, dedicated team. —

Year	**1983**	**1984**	**1985**	**1986**	**1987**	**1988**
Bird control	part-time			full-time		
No of strikes	38	38	38	30	28	28
No of movements	86 265	92 096	95 600	111 576	126 000	144 715
Bird strike rate	4.4	4.1	4.0	2.7	2.2	1.8
Number strikes involving gulls and lapwings	18	27	19	12	8	2
% total strikes	47%	71%	50%	40%	29%	7%
Cartridges used	14 417	10 329	4 210	3 000	1 841	2 402
Approximate cost	£12 891	£9 193	£3 747	£2 670	£1 638	£2 138

Table 3. The effectiveness and costs of bird control at Manchester Airport.

Reprinted from
Airport Technology Internation
Published by
Sterling Publications Ltd

ADF616449

BSCE 20 / WP 50
Helsinki, 21-25 May 1990

The Development Of An Expert System To Minimize Bird Strikes At Airports

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One of the most significant factors which prevents the development of an effective bird control strategy at an airport is the turnover of staff and the consequent loss of expertise and knowledge of the local bird problem. In addition, managers who have to allocate limited staff resources often lack the detailed information to do this effectively due to the variable and highly specialist nature of the bird problem.

Manchester Airport and Leicester Polytechnic are currently working on a project to develop a computer based system which will rapidly and conveniently supply both the manager and those who carry out bird control operations with the expertise developed over a number of years by those working in the field.

This is only a prototype, but the objective of bringing it to you in this way is to obtain your comments before we take the project further and adapt it for use at any airport.

YOUR COMMENTS PLEASE

ADF616450

BSCE 20 / WP 51

Helsinki 1990

DESIGN OF AVIATION ENGINE ELEMENTS FOR BIRD STRIKE ACTION

Shorr B.F.

The approximate engineering method for the calculation of the bird strike action on the blades of the fan or compressor is suggested. This method rests on sufficiently proof substantiations and is suitable for performing the optimized calculations at the design stage. The results of the typical design are given.

While developing the measures directed towards improving the aviation engine reliability at bird ingestion into the gas-air-flow passage, the recent years significant consideration is given to the development of the calculation procedure for the evaluation of the compressor and fan blade resistance to the impact loads resulted from the collision with birds along with a direct experimental test. This permits to predict the bird resistance of the blades as early as a design stage and if necessary to consider potential structural measures of its increase.

In design approaches basically two directions began to show: on the one hand, the receipt of the simplified emperical criteria, or, alternatively, the development of rather complicated analytical methods using the universal computational programs for the numerical calculations ([1,2]and others). However, in our opinion the first approach gives much too general evaluation, the second is excessively complicated if one takes into account a very uncertain data on the bird ingestion conditions and its interaction with the blades. In the given paper the approximate engineering method for the calculation of the bird impact action on the blades is suggested. This method rests on sufficiently proof substantications and at the same time it is relatively simple and suitable for performing the optimized calculations at the design stage.

The theoretical analysis and available experimental results permit to use the following assumptions:

- Compared to the blade, a striking body (bird) is soft, that is absolutely plastic with a negligible strength limit; it is broken as it runs against the blade, the bird piece speed before coming them into contact with the blade remains constant during the whole impact;
- Disintegrated particles do not rebound from the blade surface and do not adhere to it, throwing away by centrifugal forces;
- Disintegrating-particle pulse that is normal to the blade surface is completely absorbed by the blade;
- While moving the bird pieces along the blade, the friction forces are neglected;
- During the impact the blade displacements are small against the bird moving, that allows to determine the impact point position of their particles through an undeformed state of the blade;
- Specific bird configuration which is described with difficulty can be replaced by an equivalent body of the simplest shape, for example, by the parallelopiped, having the same density, volume and length-to-transversal size ratio;
- The estimation of the most possible stresses at the impact is performed without consideration the energy dissipation in the medium while using the simplest model of the elastic-plastic body.

From the mentioned assumptions one of the full transmission of the normal bird particle pulse to the blade is of particular importance.

It follows from the theory of the longitudinal collision of two unstrained elastic bodies with the density of ρ_1 and ρ_2 and with the moduluses of elasticity of E_1 and E_2 that the ratio of the momenta of the body particles adjacent to the boundary will be [3]:

$$L_1/L_2 = \sqrt{\rho_1 E_1/(\rho_2 E_2)}$$

Taking $E_1/E_2 \approx 0.01$ and $\rho_1/\rho_2 \approx 0.25$ for the bird collision with the titanium blade we shall derive $L_1/L_2 \approx 0.05$. Therefore, even with allowance for the bird body elasticity as a liquid the accepted assumption would be justified.

The momentum loss of the bird mass piece for the time of dt, which crosses over the blade along the normal to its surface on the area of dF, is equal to the pulse change of the normal force to this surface $\rho_1 v_n^2 dt\,dF = p\,dF\,dt$, where p is an impact pressure. If the normal component of the relative velocity v_n is constant

$$p = \rho_1 v_n^2$$

The contact area boundaries, defining the value and position of the total dynamic load, are changed with time according to kinematic conditions of crossing over the trajectories of the blade and bird relative movement (See Fig.1, where a is a state after the impact initiation, b - in the intermediate point, c - before the end).

In studies of the dynamic blade behaviour the blade can be represented both as a three-dimensional body and as a thin non-uniform shell, with mid-surface limited by an oblique-angled tetragon in plan and variably curved and twisted.

Not to turn to the complicated numerical methods of the time integration of the continual systems some equivalent descrete mechanical system-model was suggested to consider. This system-model meets the following requirements: the matrix of masses $[\mathcal{M}]$ and their spatial position on the model and in the design points of the nature agree, the matrix of the static pliability $[\alpha]$ is in agreement with the similar matrix formed by the components of the displacement vector $\{y\}$ in the blade design points caused by the components of single forces, applied in all these points.

The matrix of pliabilities can be calculated according to any appropriate programs. In the work it is determined by Ritz for the rotating blade-shell in the statement similar to used previously for the dynamic blade analysis [4].

The system of the motion equations for a discrete model takes the form

$$[\mathcal{M}]\{\ddot{y}(t)\} + [c]\{y(t)\} = \{Q(t)\}$$

where $[c] = [\alpha]^{-1}$. At the given change law of the load vector $\{Q(t)\}$ the change law of the displacement vector $\{y(t)\}$ is defined by numerical integration.

For the evaluation of the strength the stress intensity is determined in the surface points. It is convenient to use influence coefficients $\gamma_{jk} = (\sigma_i)_j / P_k$, where $(\sigma_i)_j$ is a stress intensity in j-design point from P_k force, acting in k-point. In dynamic analysis $P_k = Q_k - \mathcal{M}_k \ddot{y}_k$, so that $(\sigma_i)_j = \sum_{k=1}^{n} \gamma_{jk} (Q_k - \mathcal{M}_k \ddot{y}_k)$, n is a number of the design points. The basic calculation is performed in the elastic region but at the strength evaluation the formation of the local plastic zones is considered. According to Neuber hypothesis for these zones the elastic parameters of σ_e and $\varepsilon_e = \sigma_e / E$ are related to the parameters of $\sigma(\varepsilon)$ and ε on the stress-strain curve as

$$\sigma_e \varepsilon_e = \sigma_e^2 / E \cong \sigma(\varepsilon)\varepsilon$$

Taking that the failure occurs at the stress equal to the strength limit $\sigma(\varepsilon) = \sigma_b$ and at the plastic strain equal to the relative rupture elongation $\varepsilon_p = \varepsilon - \sigma/E = \delta$, we shall receive the strength condition, expressed in the conventional elastic stresses by

$$\sigma_i < \sigma_{e\,rupture} = \sigma_b \sqrt{1 + E\delta/\sigma_b}$$

The method of the variable elasticity parameters [5] is used for more detailed consideration of the blade plastic deformation process as a whole.

Some results of the typical calculation are given below. The relative deflection-time history in three characteristic blade points is shown in Fig.2a: 1 - in the impact initial point, 2 - on the blade tip at the leading edge, 3 - on the blade tip at the trailing edge; Fig.2б gives the stress intensity-time history at the attachment in point 4. The properly blade-bird impact interaction is ended at the moment of $\bar{t}=1$, however the most blade deflection and maximum stresses are reached at $\bar{t}>1$.

The estimated blade deflections at different moments of time $\bar{t}$ are given in scaled up in Fig.3. The impact direction and the place of the blade collision with the bird are shown by the arrow.

Fig.4 shows the dependence of the relative stresses in the impact point $\bar{\sigma}_*$ and maximum stresses $\bar{\sigma}$ max on the angular rotor speed $\bar{\omega}$ under otherwise equal conditions. This relationship is of a very sharp character due to a significant increase in the normal component of the relative speed of the bird running.

The author is much obliged to V.A.Rudavetz and V.E.Turkina for the participation in developing the method and performing the calculations.

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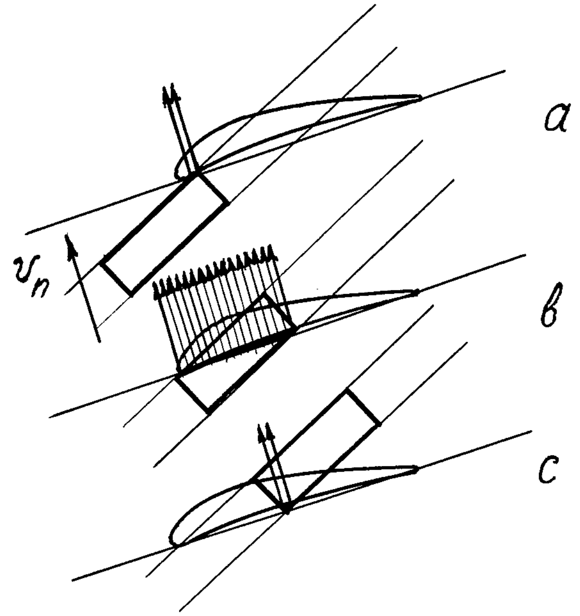
FIGURE 1. Change of contact area during impact.

FIGURE 2. Deflections $\bar{y}$ and stresses $\bar{\sigma}_i$ -time history in characteristic points of blade.

FIGURE 3. Blade deflections at different moments of time $\bar{t}$

FIGURE 4. Dependence of stresses $\bar{\sigma}_i$ on angular rotor speed $\bar{\omega}$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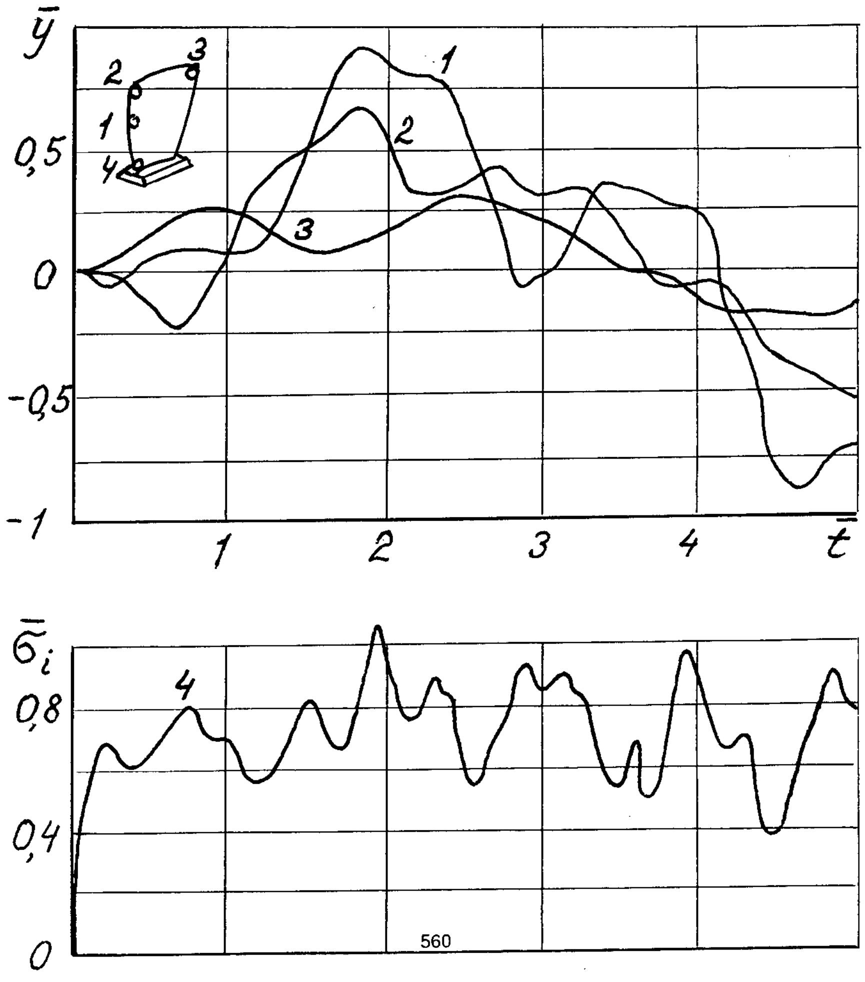
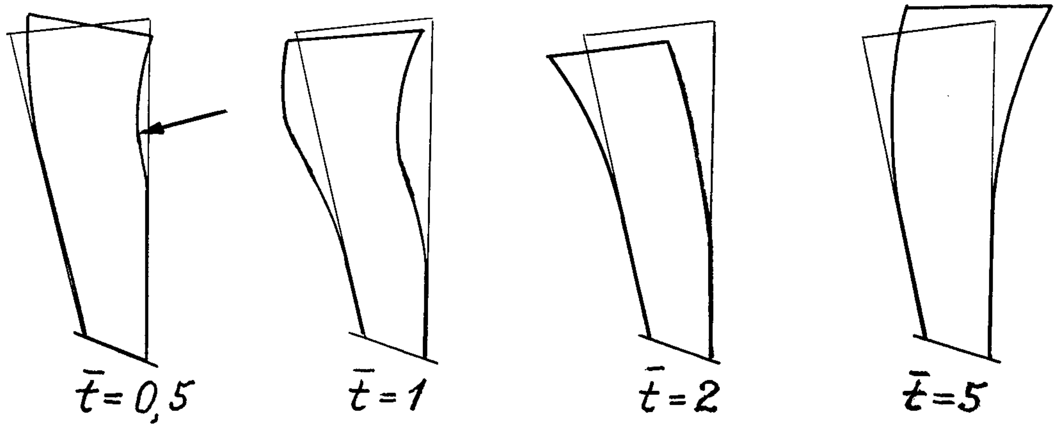

$\bar{y}$
0,5
0
-0,5
-1
1
2
3
4
$\bar{t}$
1
2
3
2
1
3
4
$\bar{\sigma}_i$
4
0,8
0,4
0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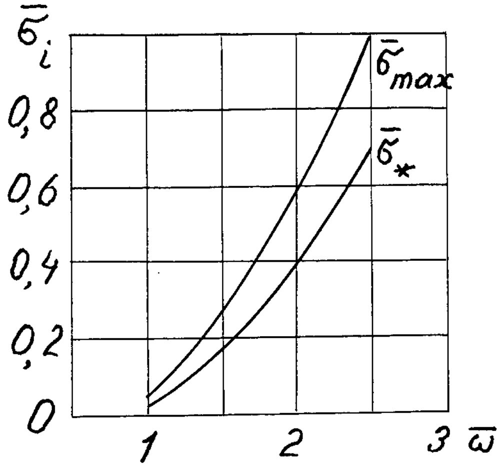
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BSCE 20
HELSINKI
May 21st-25th, 1990

BSCE 20 / WP 52

Helsinki 1990

BIRD MIGRATION
A FLIGHT SAFETY RISK

Training film of the
German Federal Armed Forces
presented by

J. Becker
German Military Geophysical Office

SUMMARY

The video tape starts with the history of aviation, and describes the flight safety hazards to modern aviation caused by migrating birds. The video shows the procedures of the Federal Armed Forces with the intention of reducing the birdstrike hazard, especially the existing observation-, reporting-, warning- and forecast system of the German Military Geophysical Service with respect to large scale bird migration.

(Length of the training film: 19 minutes).

ADF616452

BSCE 20 / WP 53
Helsinki, 21-25 May 1990

Revised Index For BSCE Working Papers Issued During The Period 1966-1990 Including Papers Presented At The 1977 World Conference In Paris Which Was Organized Partly By BSCE

(Presented by H. Dahl, Denmark)

In the below Index, the first figure in the right column indicates the number of the BSCE meeting (however, the World Conference is indicated as WC), and the second figure indicates the working paper number followed in papers presented at the World Conference and at the BSCE meetings in 1984, 1986 and 1988 by page number(s) in the report.

The fact that a paper appears below does not imply that the contents of the paper have been endorsed by BSCE.

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0.3 Bird Migration
0.4 Bird Ecology
0.5 Bird Ethology

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ADF616453

BSCE 20
WP 54
Helsinki 1990

Reducing Gull Hazards to Aviation by Controlling Nesting Populations

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ABSTRACT

Gull nesting colonies established adjacent to airports cause serious aviation hazards, and the colony in Jamaica Bay, N.Y. is a current example. These birds can cause damage or the loss of aircraft and occupants when ingested into one or more turbine engines, usually during takeoffs, and populations have increased in many countries -- exacerbating hazards. Gulls are controlled routinely to benefit other birds, but less often for aviation safety. If significant hazard reduction cannot be accomplished quickly by other methods, there should be no reluctance to making habitat unsuitable for nesting or killing gulls using humane methods. Countries that reduce adult gull populations have accepted the premise that if gulls become hazards then they should be controlled. Various strategies are discussed for alleviating or eliminating hazards from nesting colonies adjacent to airports. Gull hazards that originate beyond airport boundaries should be controlled even if the authority to do so must be based on litigation. Enhancement of U.S. bird management programs is needed and would require higher priorities, greater resources, and the adoption of a stronger safety ethic by the responsible agencies.

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1.0 Introduction

This paper is prompted by a serious gull hazard problem at John F. Kennedy Airport (JFK), N.Y., N.Y. caused by a colony of nesting laughing gulls (See Appendix A for scientific names) located in Jamaica Bay Wildlife Refuge within 0.4 km (0.25 mi) of the airport. The refuge consists mostly of open bays and salt marsh islands and is part of Gateway National Recreation Area administered by the U.S. National Park Service (NPS).

The gulls nest on three islands encompassing 477 acres: Joco Marsh, East High Meadow, and Silver Hill Marsh. The gulls arrive in April and migrate south in October. The nesting population began with 15 pairs in 1979, increased to 325 pairs in 1981, 2741 pairs in 1985, an estimated 3000 pairs in 1989 (Table 1.0), and about 6000 pairs in 1990 (R.A. Dolbeer, pers. commun.). This accelerated growth was much greater "than could have occurred from reproduction in the colony, suggesting that many of the gulls immigrated from expanding colonies in New Jersey" (Dolbeer et al. 1989:38). New Jersey laughing gull colonies are about 113 km (70 mi) from JFK and were censused in 1989 using a helicopter. About 59,000 birds were counted. This figure represents a minimum estimate of the total population (R.M. Erwin, pers. commun.)

Collisions between laughing gulls and aircraft have increased considerably from two strikes in 1979 to 180 strikes in 1988 and 179 in 1989 (Table 1.0). These high numbers of strikes in 12-month periods probably were only exceeded in the United States by the large numbers of Laysan and black-footed albatrosses struck or killed by aircraft on Midway Island (Robbins 1966).

Table 1.0 Birds involved in strikes with aircraft, JFK Airport, and estimated number of nesting pairs in laughing gull colony on Jamaica Bay, 1979-89 (Excerpted from Dolbeer et al. 1989, Table 2).

	Number of gulls (% of all gulls)					Estimated
Year	Laughing gulls	Other gulls	All gulls	Other birds	All birds	Nesting Pairs a/
1979	2 (2)	111 (98)	113	25	138	15
1980	19 (17)	96 (83)	115	28	143	235
1981	18 (22)	63 (78)	81	40	121	325
1982	14 (17)	70 (83)	84	61	145	715
1983	43 (29)	106 (71)	149	55	204	1,805
1984	60 (30)	139 (70)	199	90	289	2,802
1985	86 (30)	199 (70)	285	100	385	2,741
1986	62 (57)	46 (43)	108	25	133	3,000
1987	137 (65)	75 (35)	212	32	244	2,875
1988	180 (55)	149 (45)	329	32	361	2,665
1989	179	109	288	29	317	>3,000
Totals	800 (41)	1,163 (59)	1,963	517	2,480	

a/ Laughing gulls -- Jamaica Bay Wildlife Refuge.

In addition to the great number of laughing gull strikes at JFK, airport records indicate that since 1986 three DC-10 takeoffs were aborted because of laughing gull ingestions into engines. One incident required an engine change and another involved a damaged engine. Therefore, even though the laughing gull weighs less than several other species commonly involved in bird strikes, e.g., herring, great black-backed, and the ring-billed gull (See Appendix B for bird weights), this species is hazardous to aircraft since even one 10-12 ounce (284-283g) bird can cause severe engine damage. Furthermore, laughing gull strikes involving three or more birds have been increasing (Dolbeer et al. 1989). Because laughing gulls account for the majority of strikes at JFK, it would seem prudent that all measures should be taken to reduce this hazard.

For suggestions and technical information I thank D.G. Buechler, R.R. Cowser, W.H. Drury, J.L. Guarino, C.H. Halvorson, C.A. Ramey, and J.E. Seubert.

2.0 Actions to Resolve the Laughing Gull Hazard at JFK Airport

In 1989, at the invitation of the NPS, a panel of four biologists from other countries assessed the hazard at JFK caused by laughing gulls nesting on NPS marshes in Jamaica Bay, and made recommendations for reducing the hazard. Their report states in part, "that the laughing gull colony in its present location presents an unacceptable hazard to aircraft operations at JFK." The panel also expressed the opinion that an effective control program for the 1990 nesting season should include the oiling of all eggs in the colony (Thomas et al. 1989).

3.0 Bird Hazards to Aviation

3.1 Incidents and Accidents

An extensive literature documents that many species of birds, especially gulls, are serious hazards to aviation in many countries. Most of the serious incidents are bird strikes on engines and windscreens. Gulls account for a high proportion of bird strikes, and they have caused damage to many aircraft and even the loss of aircraft and occupants (Seubert 1963, 1977, Hild 1969, Blokpoel 1976, Rochard and Horton 1980, Frings 1984, Thorpe 1988, Thorpe and Hole 1988, DeFusco 1988, Hovey and Skinn 1989).

One gull (or bird) at the wrong place at the wrong time can cause an aviation tragedy or high economic loss, especially if ingested into a turbine-powered engine. Although an engine manufacturer has stated that "one bird was not a hazard, and that from a manufacturing viewpoint, he could take responsibility for one bird and for a one engine out situation" (Weaver 1989:8), the accident records show quite clearly that one bird in an engine can result in serious incidents or accidents as follows. A Convair 580 crashed at takeoff at Kalamazoo, Michigan, when one American kestrel was ingested into an engine (Thorpe 1984). A 737 overran a runway at a Gosselies, Belgium, while attempting to abort a takeoff after one wood pigeon was ingested into an engine (the aircraft was a total loss) (Thorpe 1984). At Rio de Janeiro, a CFM 56 engine of a 737 failed during takeoff after a barn owl was ingested. The aircraft successfully continued the takeoff on the remaining engine, but the damage to the failed engine was substantial (B.C. Fenton, pers. commun.).

At the Dublin, Ireland Airport on 7 December 1985, the No. 1 engine (JT8D-9A) of a 737 failed in an uncontained manner during takeoff after ingesting one or possibly two black-headed gulls. The aircraft successfully continued the takeoff on the remaining engine in spite of serious associated problems as described in the official accident report (McStay 1987:24) as follows:

> "The sudden loss and displacement of the No. 1 engine, the loss of the nose cowl, the abrupt reduction in the rate of climb, the slamming closed of the power lever controlling No. 1 engine, the audio and visual warnings and the buffeting and behavior of the aircraft presented the flight crew with an emergency not rehearsed or envisioned."

There are other examples where several birds were ingested into an engine with disastrous results: an aero commander turbo prop crashed at takeoff into Lake Michigan, Chicago, Illinois, after ingesting gulls (Larus sp.) into one engine (Seubert 1978) and a DC-10 was destroyed by fire at JFK after ingesting great black-backed gulls into the right engine (Seubert 1976).

In addition, very costly and extremely dangerous incidents have occurred when birds are ingested into more than one engine. An example of such an event occurred at Los Angeles Airport in September 1989 when a 747-300 ingested four domestic pigeons into the No. 1 engine and five into the No. 2 engine on takeoff. Violent compressor stalls occurred on both engines. The No. 1 engine recovered, but the No. 2 did not, and was shut-down. Fuel was dumped and the aircraft landed at 630,000 pounds, gross weight. The No. 1 engine suffered extensive fan damage, and the No. 2 engine underwent transverse fracture of one fan blade, extensive fan and cowl damage, and loss of tailcone. These bird ingestions occurred during a critical takeoff regime -- at rotation, where the pilot was committed to continue the takeoff. If the No. 1 engine had not recovered in this incident, it is doubtful that the takeoff could have safely continued.

3.2 Bird Hazards to Turbofan Engines

Although birds are seldom ingested into turbofan engines, when this does occur it results in damage in about one half of the incidents. To obtain a better understanding about this problem, the Federal Aviation Administration (FAA) has been conducting studies to assess the extent of bird hazards to engines. Some of their results are presented in this paper, since they bear directly on my concerns regarding bird hazards to aviation, especially when large numbers of a hazardous species are nesting very close to an airport.

The FAA has assessed the potential hazards of <u>dual</u> engine bird ingestions to large, high-bypass turbofan engines during the take off/climb phase of flight (Cheney et al. 1981). The executive summary and conclusions include the following:

- Parties concerned about bird hazards to aviation, such as aircraft and engine certification personnel, airframe and engine manufacturers, and airport evaluators, have difficulty in assessing overall bird strike hazards and in identifying safety trends because of a fragmented data base for bird strikes.

- The risk of bird strikes will increase with the addition to air fleets of more wide-body transport aircraft with high-bypass turbofan engines in the short and medium haul airline markets.

- An analysis of the best bird engine ingestion data available indicates that a dual engine failure involving a current wide-body aircraft will occur within the service life of the aircraft type, and it is estimated that several additional dual engine failure events will occur within the service life of newly certified wide-body aircraft.

- Overall bird strikes and engine ingestions involving flocks of birds can be significantly reduced through airport bird control procedures, especially at major foreign and domestic airports.

The study by Cheney et al. (1981) presented good information for its time (B.C. Fenton, pers. commun.). However, another similar study (FAA) presently underway, will provide a much greater base of data for the years 1989-1991. A final report should be completed in early 1992.

In 1981, an investigation was begun by the FAA to determine the numbers, weight, and species of birds that are ingested into large high-bypass ratio turbine aircraft engines during service operation and to determine what damage, if any, resulted (Frings 1984). This information was requested from the three major engine manufactures under contracts with the FAA. The aircraft involved were the DC8, DC10, B747, B757, B767, A300, A310, and L1011. The executive summary and conclusions included the following:

- Most bird ingestions, engine damage, and engine failures occurred in the bird weight range between 9 ounces (255g) and 24 ounces (680g). United States birds are heavier than birds in foreign environments. For example, Rochard and Horton (1980) report that during an 11-year period in the United Kingdom, 62.5 percent of 1541 bird strikes involved species weighing 10.6 ounces (300g) or less.

- Gulls are the most commonly ingested bird worldwide, accounting for 35 percent of all ingestions.

- Four-engine (wing-mounted) aircraft experience about twice the ingestion rate of wing-mounted two-engine aircraft.

- The majority of bird ingestions resulted in either minor or some damage to engines.
- Most ingestions occurred during takeoff or landing.
- The probability of an engine failure resulting from the ingestion of one or more birds is about five percent.

The FAA also has a 3-year study underway to determine the numbers, sizes, and type of birds that are ingested into medium and large inlet area turbofan engines and to determine what damage, if any, results. Bird ingestion data are being collected for the B737 aircraft equipped with either JT8D or CFM 56 engines. Preliminary findings were presented in the executive summary and conclusions of an interim report that covered the first year of this 3-year study (Hovey and Skinn 1989). The findings include the following:

- Ingestion rates appear to be proportional to either the inlet area or diameter of the engine, since no statistically significant difference in the ingestion rate of the two engines was detected after the data were adjusted for inlet area or diameter.
- When more severe damage is inflicted on an engine, unusual crew actions are more likely.
- The majority of bird ingestions (273 of 302) involved a single bird and a single engine on the aircraft and resulted in little or no engine damage.

A final report covering three years of data collection will not be completed until late 1990.

3.3 Engine Out Procedures

Transport turbofan aircraft with two, three, and four engines are designed to be able to takeoff even if one engine fails at V-1 [a/] or later (FAA 1989). If an engine fails during takeoff the pilot can take action to abort the takeoff up to V-1. If an engine fails at V-1, the pilot can either abort or takeoff. If there is an engine failure above V-1, then the pilot is committed to takeoff (Federal Aviation Administration 1978) and should be successful if all remaining engines and systems function properly. Unfortunately, accidents have occurred with one engine out (See Bird Hazards to Aviation). The matter becomes more serious in a worst case scenario (aircraft at maximum weight), if power is lost in more than one engine shortly (a few seconds) after V-1 and the pilot is committed to continue the takeoff.

[a/] V-1 - Takeoff decision speed. Formerly denoted as critical engine failure speed. [Speed that an aircraft can accelerate to and still abort a takeoff.]

To obtain some idea about the performance of various aircraft, I asked several experts if either 2, 3, or 4-engine aircraft would be able to continue a takeoff shortly after V-1 if thrust was lost from the equivalent of 1 1/2 engines. Such a situation would result in a loss of 75 percent of the thrust in a 2-engine aircraft, 50 percent loss in a 3-engine aircraft, and 37.5 percent loss in a 4-engine aircraft. The consensus was that the takeoff probably could not continue.

Also, Cheney et al. (1981:39) discuss a worst case scenario involving a dual engine failure during the takeoff or climb regime. The authors state that "figures do not directly estimate the probability that an aircraft will be lost due to such an occurrence" and that "there are too many variables to predict the sequence of events following a dual engine failure at or above V-1, but that it should be assumed that the aircraft will overrun the runway or make a forced landing at best."

A bird ingestion into a large high bypass ratio turbine engine "is considered a rare (2.33 x $10.^{-4}$) but probable event" (Frings 1984:ix). Nevertheless, in my opinion, one would not want to lose even one engine to a bird(s) on a heavily laden aircraft shortly after V-1.

4.0 Gull Populations

4.1 Growth

The large growth in the NPS laughing gull colony adjacent to JFK is not unique. Gull populations in many countries have grown dramatically during the past 40-50 years. Drury (1963) and Kadlec and Drury (1968) document increases in New England herring gull populations, and conclude that these populations had been doubling about every 12 to 15 years, growing to an estimated 623,700 birds by 1965 (excluding the Great Lakes and the Gulf of St. Lawrence). Harris (1970) reports that herring gulls have increased greatly in Britain, probably doubling in numbers between 1950-1970. Hickling (1969) reports that black-headed gulls increased in England and Wales in excess of 25 percent during a 20-year period. A colony of silver gulls increased from 8 pairs in 1970 to 50,000 pairs in 1986 at Devonport, in northern Tasmania, according to P.M. Davidson (pers. commun.). The black-headed gull and the herring gull increased significantly in Denmark during the past several decades (Asbirk and Joensen 1974). Herring gulls increased in The Netherlands to such an extent that gulls have been controlled since 1934 (Bruyns 1958). Gibson (1979) states that a silver gull population breeding on the Five Islands, New South Wales, Australia, increased spectacularly from about 1000 pairs prior to 1940 to over 50,000 pairs in 1978. In 1989 (P. Straw, pers. commun.) estimates this population at 30,000 pairs.

An enormous increase in the number of gulls (*Larus* sp.) in the Ontario, Canada, portion of the Great Lakes has occurred since 1976, when the ring-billed gull (RBG) population increased from 40,787 to 163,593 nests in 1984. The RBG population in the entire Great Lakes area increased from 281,000 pairs in 1976 to 648,000 pairs in 1984 -- an average annual growth rate of 11 percent. Substantial future increases are predicted in the numbers of RBGs nesting in the Great Lakes and St. Lawrence River region (Blokpoel 1983, Blokpoel and Tessier 1986). The growth of the RBG population at the Eastern Headland of the Toronto Outer Harbour is another good example. In 1973, 21 pairs of RBGs nested; in 1982 and 1983 there were 75,000 to 80,000 pairs (Blokpoel 1983:2).

The increase in gull populations has been attributed mainly to legal protection, availability of nesting habitat, characteristics of gulls that are suitable to man's environment, and an abundance of food -- man's waste, especially garbage, and fish waste in some areas. The use and importance of garbage is well documented (Bruyns 1958, Harris 1965, Drury and Nisbet 1969, Spaans 1971, Kihlman and Larsson 1974, Conover et al. 1979, Burger 1981, Horton et al. 1983, Patton 1988).

4.2 Gull Problems and Control

The destruction by gulls of the eggs and chicks of many other species (e.g., Sandwich, common, Arctic, and roseate terns; black guillemot; Atlantic puffin; razorbill; redshank; storm petrel; common eider; avocets) nesting on their traditional breeding grounds and gull hazards to aviation are the principal problems caused by gulls (*Larus* spp). These problems have become exacerbated by the growth of gull populations. Many countries have implemented control programs and the principal methods have been the oiling or pricking of eggs; shooting; harassment; exclusion; collection of eggs; destruction of eggs and nests; the use of narcotics (alpha chlorolose, alpha chlorolose plus seconal); or the use of poisons (3-chloro-4-methyl benzeamine hydrochloride [DRC-1339] or strychnine).

4.3 Rationale for Gull Control

Many countries have accepted the fact that if certain bird species are to be retained and if aviation hazards are to be reduced, other species that are detrimental to man's interests must be controlled (Monaghan 1984, Blokpoel and Tessier 1986, Mullen and Goettel 1986). Thus, for many people concerned about gull depredations and hazards to aircraft, moral or ethical questions regarding such control activities have long since been resolved.

4.4 Gull Control to Benefit Other Birds

Many world-wide examples of gull control to reduce damage to other birds have been reported: Europe (Bruyns 1958, Drost 1958); Great Britain (cited by Thomas 1972, Duncan 1978); and the United States (Kress 1983, Mullen and Goettel 1986, Folger and Drennan 1988). Some are as follows: About 38,000 herring gulls were killed with alpha chlorolose (A-C) on the Isle of May in Scotland during the years 1972-1977 (Duncan 1978). In a moorland colony near Lancashire, England, about 50,000 herring and lesser black-backed gulls were killed with A-C during the period 1978-1982 (Wanless and Langslow 1983). In The Netherlands, about 29,000 herring gulls were killed with strychnine during the period 1954-1956 (Bruyns 1958). A total of 3000 great black-backed and herring gulls were killed with DRC-1339 in 1987 and 1988 at Matinicus Isle,. Maine (T.A. Goettel, pers. commun.).

The destruction of eggs and nests was used successfully during a 5-year period to limit gull production on Monomoy National Wildlife Refuge, Massachusetts (Lortie et al. 1984) and on Matinicus Rock, Maine during the late 70's (Mullen and Goettel 1986). According to T.A. Goettel (pers. commun.), herring and great black-backed gull nests located in the middle third of South Monomoy Island, Monomoy National Wildlife Refuge, Massachusetts were sprayed with oil and formalin in 1979 with a high degree of effectiveness. Ring-billed gull eggs have been sprayed with oil and formalin or oil during the period 1984-1990 to control reproduction on an island in Banks Lake, Washington. J.G. Oldenburg and M.E. Pitzler (pers. communs.) report that the number of RBG nests declined from 5445 in 1986 (the first year that all nests were sprayed), to 3626 nests in 1990 -- a decrease of 34 percent. An estimated 958,421 herring gull eggs were pricked or oiled during the period 1934-1952 in gull colonies located on islands along the northeastern U.S. coast mainly to reduce gull populations (method reported to be 95 percent effective), but in part to benefit terns (Gross 1952).

4.5 Gull Control to Reduce Hazards to Aviation

Gulls have been controlled frequently for the benefit of other birds, however, examples are fewer where this has occurred for reasons of air safety, even when nesting colonies are very near an airport (Dolbeer et al. 1989, Tessier 1989). Since gulls are viewed by those concerned with aviation safety as a serious hazard, there are instances where actions have been taken to reduce or eliminate dangerous local populations. My first experience with a serious airport gull hazard was in 1961 when I observed about 750 pairs of herring gulls on breeding territories at Logan Airport, Boston, Massachusetts (Drury 1963). The U.S. Fish and Wildlife Service immediately recommended that the gulls should be killed. The airport population was controlled as the result of two years of shooting -- 4468 gulls were killed (Seubert 1963).

A colony of about 8000 silver gulls, on a small coastal island near the city of Devonport in northern Tasmania, Australia, was eliminated after two years of baiting (1986-1987) with A-C bread baits. The colony was about 2.5 km (1.6 mi) from the airport. No nesting occurred on the island in 1988, although some gulls still fed at a local solid waste site. This is an example where local population elimination was very successful (P.M. Davidson, pers. commun.).

Caithness (1968, 1969, 1984) presents a chronology of 19 years of effort to control a nesting colony of southern black-backed gulls located about 0.4 km (0.25 mi) from an airport at Napier, New Zealand. Alpha chlorolose was used very successfully to kill several thousand gulls, but repeated poisoning (and some shooting) has been necessary to keep the colony free of birds each nesting season. The author believes that the control efforts have reduced bird strikes at the airport, but does not have pre-control strike statistics with which to compare. The control program will continue.

Thousands (ca 44,000) of RBG eggs were collected in 1985 and 1986 at Mugg's Island 1 km (0.62 mi) from Toronto Airport and on the airport to reduce and eliminate threats to air safety. During the same years a RBG colony of 75,000 - 80,000 nests located at the Eastern Headland, Toronto Outer Harbor, was reduced to 40,160 pairs through non-lethal means (e.g., harassment, distress calls, flying raptors). This colony is about 5 km (3.1 mi) from the Toronto Airport (Blokpoel and Tessier 1987, Tessier 1989).

Efforts to reduce herring gull hazards at Kastrup Airport, Denmark, have been reported by Lind 1971, Lind and Glennung 1977, 1984, Dahl 1984, Lind 1986, Glennung 1988. Thousands of eggs were oiled beginning in 1969 at a nesting colony located 5 km (3.1 mi) from Saltholm Island. The oiling reduced the 1969 breeding population (ca 40,000 pairs) to about 20,000 pairs by 1976. To accelerate the reduction, A-C was used for several years beginning in 1976 until the population was reduced to 5,000 pairs. Only oiling has been used since about 1987. Gull control measures at Saltholm resulted in fewer herring gulls and fewer herring gull strikes at the airport during 1976-1981. However, the total number of strikes has not decreased since 1981, and the authors suggest that the black-headed and common gulls have become more prominent. They have requested that they be able to include these species in the control program.

Finland has had an extensive gull control program for many years to reduce gull hazards at the Helsinki-Vanta Airport (and to benefit other species). To reduce the number of young herring gulls that concentrated in the airport area, the reproduction of about 6500 nesting pairs was restricted at almost all colonies in the Helsinki Archipelago located within 40 km (24.8 mi) of the airport. Collecting eggs twice during the nesting season was the most frequently used control method. Birds also were shot on the airport and shot and trapped at a garbage dump located 4 km (2.5 mi) from the airport. The trapped birds were killed with carbon monoxide. These measures have resulted in reduced gull hazards at the airport (Kunsela and Stenman 1979, Helkamo et al. 1982, Helkamo and Stenman 1984, O. Stenman, pers. commun.).

Rochard (1987) reports that a mixture of A-C and seconal was used successfully over a 3-year period to control great black-backed and herring gull colonies located on the Royal Air Force Tain Air Weapons Range. He also reports that 350 nests in a herring gull colony located in an explosive storage area were treated successfully with the same narcotic mixture. An effort to control Mediterranean gulls at RAF Gibraltar was not successful.

Also, many thousands of gulls have been shot at airports. For example, 3840 gulls were shot at the Aalborg Airport, Denmark during a 12-month period (Eis 1986). In 1978, more than 1000 herring and black-backed gulls were shot at the Helsinki-Vanta Airport, Finland (Kunsela and Stenman 1979).

5.0 Strategies for Controlling Nesting Colonies of Gulls Near Airports

The selection of methods to control nesting gull colonies should be based on the gull species involved, other birds that might be affected, the distance of a colony from an airport, the history of bird strikes, the degree of continuing risk aviation authorities are willing to assume, Federal and State regulations, the attitudes of conservation interests, and bird biology and behavior. Each problem situation requires an ecological assessment before control measures are selected and implemented. Various control strategies are as follows.

5.1 Habitat Elimination or Alteration

Much of the literature about bird hazards to aviation places the utmost importance on habitat modification as the key to permanent or long-term solutions. Aldrich et al. (1961:6) state that "steps should be taken to make the habitat on and in the vicinity of an airport less attractive to them (birds)." This early recognition of the importance of habitat has been acknowledged by many subsequent researchers. But the emphasis has been on the airport per se and not to the environment surrounding an airport except for concerns about garbage dumps. In the airport services manual published by the International Civil Aviation Organization (ICAO) methods are discussed in Chapter 7, Part 7.10, for reducing gull populations in nesting colonies that occur only in the immediate vicinity of airports (ICAO 1978). No mention is made, however, about managing or altering the habitat of nesting colonies on or off an airport. The value of environmental management is emphasized, however, under Part 6.1.3 (ICAO 1978:15) where it is stated that "with reference to bird hazards to aircraft on an airport, killing and scaring birds are therefore palliatives that should be temporary, but environmental management is the basic remedy."

Thomas (1987:5) discusses the importance of adopting a program for bird management beyond an airport, so that the numbers of birds coming to the vicinity of an airport can be reduced, thereby decreasing the amount of bird control needed on an airport. He states that "it is self evident that the close proximity of a breeding colony to an airport is incompatible with aviation safety; however, sites of this nature can often be of significant biological importance so the case for control has to be strong." Burger (1983) reports that the carrying capacity of the environment can be altered by habitat manipulation that includes the elimination of roosting areas, food sources, and fresh water. Burger (1983:123) does not include nesting colonies, yet states that "the most effective means of reducing bird strikes and maintaining low rates of them near airports are to use habitat manipulation to reduce drastically the carrying capacity of the environment for birds,...."

Wright (1968:104 and 105) reviews various methods of bird control by means of habitat modification and states that the "ultimate answer is to make airfields and their immediate surroundings unattractive to birds, or at least those species that constitute the major hazard." He further states that "Environmental control is costly, but it offers the best hope for a long-term solution to bird control." The author suggests that species that breed on the ground might be discouraged by cultivation of the land.

Thomas (1972:122) examines habitat modification, including breeding habitat, as one means of limiting adult and immature gulls, and is of the opinion that habitat change to limit gull numbers could be a costly and time-consuming activity that "could have profound implications on non-gull species as well." He further states that habitat modification activities might have to be restricted to areas where only gulls occur in high numbers, and "to places where extreme habitat manipulation could be tolerated (e.g., alongside airstrips)." Solman (1970, 1973a, 1984) also stresses the importance of habitat modification, especially on airports, as a means of effecting long-term hazard reduction.

If as a last resort, a decision was made to eliminate or alter U.S. gull nesting habitat for reasons of aviation safety, it would be very difficult to accomplish because of the need to comply with Federal regulations concerned with environmental protection (unless prompted by an aviation disaster caused by gulls from a nearby colony). For example, if the destruction of nesting habitat would entail the placement of fill material in a wetland, a permit would be required from the Army Corps of Engineers in accordance with Section 404 of the Clean Water Act (Corps of Engineers, Department of the Army 1986). The Corps issues such permits in accordance with Section 404(b)(1) guidelines promulgated by the Environmental Protection Agency (EPA 1980). These guidelines have specific requirements for considering practical alternatives to such filling activities, and for mitigating unavoidable impacts (replacement of habitat). The procedures these agencies will use to define mitigations are addressed in a recent Memorandum of Agreement (MOA) between these agencies (EPA 1990, D.G. Buechler, pers. commun.).

Furthermore, if an action by a Federal agency might potentially adversely impact migratory birds, the need to prepare an Environment Assessment (EA) must be considered under the National Environmental Policy Act (NEPA). If such an EA determines that a significant impact will occur, an Environmental Impact Statement (EIS) would be required. Also, any taking of a migratory bird or its eggs or young requires an advance permit from the Law Enforcement Division of the U.S. Fish and Wildlife Service (USFWS) (D.G. Buechler, pers. commun.).

Under the USFWS Coordination Act, the USFWS, the National Marine Fisheries Service, and State Fish and Wildlife agencies are consulted for advice under both the Clean Water Act and NEPA. The USFWS recommendations regarding habitat will be provided in accordance with its Mitigation Policy which states a preference for replacement of in-kind habitat values on or near a project site for a species regarded as important (USFWS 1981, Buechler, pers. commun.).

In NEPA, the term mitigation includes: "(a) avoiding the impact altogether by not taking a certain action or parts of an action; (b) minimizing impacts by limiting the degree or magnitude of the action and its implementation; (c) rectifying the impact by repairing, rehabilitating, or restoring the affected environment; (d) reducing or eliminating the impact over time by preservation and maintenance operations during the life of the action; and (e) compensating for the impact by replacing or providing substitute resources or environments" (USFWS 1981:7657). These steps are also essentially described in the USFWS mitigation policy which the Service follows when fulfilling its advisory role to the Corps of Engineers. This sequence of mitigation is further defined in the recent MOA between the Corps and the EPA which provides guidance on how to meet the requirements of EPA's Section 404(b)(1) guidelines (EPA 1990, D.G. Buechler, pers. commun.). Mitigation is generally considered to include avoiding or minimizing adverse impacts on fish and wildlife and their habitat, and compensating for unavoidable losses of those resources (Soileau et al. 1985).

The acquisition of permits to alter habitat involves a complex process. Nevertheless, if other options are inappropriate or unavailable, there should be no reluctance to obtain permits to alter or remove habitat if <u>such actions are needed to accomplish a permanent solution to a serious bird hazard</u>, even if the habitat is located at a sanctuary or refuge. An example of how aviation hazards might be affected by the modification of gull nesting habitat very near to an airport is given in Table 5.1.

Table 5.1 Eliminate or Alter Nesting Habitat a/

	Result/Outcome
Degree of Control Achieved	100 percent
Number of Gulls b/	None
Number of Young Produced	None
Degree of Hazard c/	None

a/ Plow, cultivate, plant, dredge, fill, pack, etc.
b/ In nesting colony.
c/ If habitat change was made between nesting seasons, and if gulls returning to nest would not remain in the airport area.

5.2 Gull Population Control

Although there have been only a few instances where gull nesting colonies have been depopulated for reasons of air safety, the methods used have been very successful and hazards to aviation presented by these colonies have been eliminated or significantly reduced. If gulls establish nesting colonies in very close proximity to an airport and pose a serious hazard to aviation, colony depopulation is an option that should receive serious consideration. However, because of societal concerns for the environment and wildlife and because of international agreements and State and Federal regulations that safeguard man's environmental interests, the killing of a migratory species, even for purposes of aviation safety, would require very strong justification and a broad base of support from all interested parties. A proposal to depopulate a gull colony in the United States would require adherence to mitigation procedures under the USFWS Mitigation Policy.

In North American there appears to be little hesitancy (with few exceptions) on the part of resource managers, biologists, State and Federal agencies, and conservation organizations to support the killing of gulls on local nesting grounds for the benefit of other birds. My perception is that there is less enthusiasm for killing gulls on nesting grounds for aviation safety. Control of regional gull populations by use of narcotics or poisons is purported to be: impractical, too time consuming, too costly, ineffective because of immigration of birds from other areas, a potential hazard to nontarget species, subject to criticism from animal rights organizations, socially unacceptable in many countries, unfeasible, logistically difficult, and probably would require international cooperation (Thomas 1972; Solman 1973b, 1983; Blokpoel 1976, 1983, 1984; Blokpoel and Tessier 1986). These are real concerns, however, these potential drawbacks should not preclude the use of lethal measures to eliminate local gull nesting populations that pose hazards to aviation. Thomas (1972:125) states that "at homogeneous colonies of gulls, direct narcotization or poisoning seem the most efficient methods even if the work must be done annually, and one does not have to resort to the laborious time-consuming activities directed against eggs and chicks."

My point is that local gull nesting populations have been successfully eliminated or significantly reduced and the concerns heretofore mentioned regarding large scale population control programs have not been obstacles. When gull nesting colonies cause severe hazards to aviation, there should not be a reluctance to kill gulls, <u>if significant hazard reduction cannot be accomplished quickly by other methods.</u> Logically, gull control to benefit aviation safety should have a higher priority (or just as high a priority) than control to benefit other birds, and should not require a greater level of justification than needed to control gulls for the benefit of other birds. For society to place a higher value on bird life rather than human life is sheer hypocrisy. The knowledge and means exist today that would permit the control of nesting gull populations humanely, safely, and efficiently. An example of how aviation hazards might be affected by the depopulation of gull nesting colonies very near to airports is given in Table 5.2.

Before programs to kill gulls for aviation safety could be initiated, however, various necessary elements must be present as follows: (1) high motivation to enhance aviation safety; (2) strong justification for a proposed action supported by biological data and objective ecological rationale documenting that alternative measures were evaluated; (3) the availability of approved or registered lethal or narcotic agents; (4) the availability of humane methods; (5) professional public relations programs about the need for a proposed action; (6) adequate resources and time; (7) effective program management; (8) adherence to all applicable State and Federal regulations; (9) program monitoring and assessment; and 10) international cooperation (if needed).

Table 5.2 Depopulate Nesting Colony, i.e., Kill Adults a/

	Result/Outcome
Degree of Control Achieved	Almost 100 percent
Number of Gulls b/	None/Very Few
Number of Young Produced	None/Very Few
Degree of Hazard c/	None/Very Low

a/ Use DRC-1339 or alpha chlorolose; some shooting required. Control method would be needed each year that gulls nested.

b/ In nesting colony.

c/ The hazard probably would be high the first spring of control before gulls are killed. Hazard probably would be low to moderate in successive springs prior to subsequent depopulations, depending on the number of new gulls that would attempt to nest.

5.3 Control of Reproduction

5.3.1 Collect Eggs or Destroy Eggs and Nests

Examples have been given in this paper about programs to reduce or eliminate gull depredations on other birds and gull hazards to aviation either through collection of gull eggs or the destruction of eggs and nests. For such strategies to be most effective, control of colonies (elimination or reduction) should be accomplished when they are relatively new, when only a few gulls are involved, and before they have become well established. New gull colonies can increase to thousands of birds in two or three years (Blokpoel and Tessier 1987), especially if there are other populations nearby that could be a source of immigrants. The laughing gull colony in Jamaica Bay, N.Y. is a good example.

If airports with a gull problem similar to that at JFK were not able to effect more permanent solutions to abate gull hazards (e.g., alter gull nesting habitat or depopulate a colony), a strategy of collecting eggs or egg and nest destruction might be considered. However, Morris and Siderius (1990:125), state that "Removing eggs usually proves unsatisfactory because adults will renest after a brief refractory period." Thus, egg collections must be made several times during the nesting season, and the adults could cause aviation hazards between nesting attempts.

According to the Royal Society for the Protection of Birds (RSPB), if the intent is to prevent gull nesting, the success of egg and nest removal (destruction) could depend on the species of gull (RSPB 1982:2). The RSPB statement is as follows:

> "The removal of eggs and nests is successful in discouraging the breeding of gulls in small, new gull colonies and also in the large

> colonies of black-headed gulls. Herring and lesser black-backed gulls however, do not respond to such methods when in large colonies. They remain faithful to their nesting territories and fight off all other gulls and terns."

Thus, if other gull species reacted as do black-headed gulls to egg and nest destruction, nesting would be discouraged and the control method might be used at a colony located adjacent to an airport so long as gull activity between nesting attempts did not cause increased aviation hazards. However, if other gull species reacted to egg and nest destruction as does the herring gull in Great Britain, additional measures such as harassment might be necessary. This was the case in several Canadian operations where harassment was used in addition to egg collections to reduce or eliminate ring-billed gull colonies (Blokpoel and Tessier 1987). Egg and nest destruction or the collection of eggs plus harassment, would not be an appropriate strategy at a gull colony located adjacent to an airport because harassed birds could present hazards to aviation. An example of how aviation hazards might be affected by the collection of eggs or the destruction of eggs and nests at a gull colony very near to an airport is given in Table 5.3.1.

Table 5.3.1 Control of Reproduction: Collect Eggs or Destroy Eggs and Nests a/

	Results/Outcome
Degree of Control Achieved	>95%
Number of Gulls b/	Many thousands
Number of Young Produced	Very Few
Degree of Hazard c/	High

a/ Control method would be needed each year that laughing gulls nested; some shooting would be required.
b/ In nesting colony.
c/ The hazards (mostly adults) probably would be high before nesting, between nestings, and after final egg collection or egg and nest destruction (if most of the adults remained in the airport area).

5.3.2 Oil Eggs

As has been reported earlier, gull reproduction has been controlled by spraying eggs in nests with a mixture of oil and formalin. The treating (spraying) of eggs with petroleum products appears to have a direct toxic effect on embryos (Eastin and Hoffman 1978). White, et al. (1979) reported that when No. 2 fuel oil was applied experimentally to laughing gull eggs in the field (20u/per egg), embryonic mortality occurred in 83 percent of the eggs. Morris and Siderius (1990) experimentally treated

RBG eggs in the field with two or three applications of a mixture of 65 percent light grade commercial petroleum oil (dormant oil) and 35 percent water. The authors report that with two applications of the oil, irrespective of the stage of embryo development, the hatchability of RBG eggs was reduced to zero. Also of considerable interest is that incubation of treated eggs continued for more than 6 weeks after the usual time of hatching. Gull reproduction appears to be effectively controlled by oiling eggs, especially if more than one application of oil is made in the case of the RBG. An example of how aviation hazards might be affected by the oiling of eggs at a gull colony very near to an airport is given in Table 5.3.2.

Table 5.3.2 Control of Reproduction: Oil Eggs a/

	Results/Outcome
Degree of Control Achieved	>95%
Number of Gulls b/	Many thousands
Number of Young Produced	Very Few
Degree of Hazard c/	High

a/ Control method would be needed each year that laughing gulls nested; some shooting would be required.

b/ In nesting colony.

c/ Hazard (mostly adults) probably would be high before nesting and after nest abandonment (if most of the adults remained in the airport area), and low while clutches of oiled eggs are being incubated.

Before gull eggs could be oiled operationally in the United States, a State or an EPA registration would be needed. If a Federal registration were needed, considerable time and expense could be required. Field research can be conducted under an Experimental Use Permit (EUP) if issued by EPA. Gull control operations per se must be conducted under a State-issued Special Local Needs Registration (24-C), or under a Federal EPA Section 3 Registration that usually includes all of the United States. A Section 18 Special Exemption may be issued by EPA to resolve an acute health, safety, or economic problem (EPA 1989).

If the goal is to prevent the production of young to stabilize or reduce nesting populations, the technique of oiling gull eggs appears to be an effective management strategy (Gross 1952, Lind 1971, Dahl 1984). However, if the goal is to eliminate gull colonies because they present unacceptable hazards to aviation, oiling would be a very poor strategy, because no information from world-wide sources indicates that oiling of eggs has ever resulted in gulls completely abandoning a colony. Thus, oiling would curtail reproduction, but a significant reduction in the adult breeding population is highly unlikely. If a colony were adjacent to an airport, many adult gulls would be in close proximity to the airport during nesting seasons and present hazards to aviation as long as the population existed.

To rely on interference with gull reproduction at nesting colonies located very near airports as a means of controlling hazards to aviation exposes air carrier passengers and crews to unnecessary risks in view of the availability of more effective means of hazard reduction. Gull control measures should be used that will eliminate hazards as soon as possible.

5.4 Other Control Methods

Other methods have been examined for preventing gulls from nesting at a colony very close to an airport, but for one or more reasons were not considered appropriate.

Harass birds using pyrotechnics (shell crackers), broadcast distress calls, owl models, the flying of raptors, vehicle patrols, foot patrols, whistles, tethered hawks and owls, dead gulls thrown into the air (Blokpoel and Tessier 1987), propane cannons, shellcrackers, scarecrows (Lortie et.al. 1984), shooting, and human disturbance (Kress 1983). According to H. Blokpoel (pers. commun.), RBGs can be prevented from nesting with intensive harassment using a variety of methods. Constant harassment of herring and black-backed gulls eventually results in the temporary abandonment of a colony site (Mullen and Goettel 1986). Harassment, however, could adversely affect nontarget birds, and probably would cause increased hazards to aviation. For example, Lortie et al. (1984) reported that laughing gulls either ignored harassment or were seriously disrupted.

Introduce predators such as red foxes and raccoons. Decreases in the size of herring gull colonies and the abandonment of islands as breeding sites occurred after red foxes and raccoons were released on gull nesting islands (Kadlec 1971). Predators, however, would adversely affect nontarget birds, and disturbance of a colony could cause increased hazards to aviation.

String wires or monofilament lines above ground to exclude gulls from nesting habitat (Blokpoel and Tessier 1983). Gulls would be excluded from the wired or lined areas, however, the suitability of this technique would depend on the size of an area, the nesting density, topography of a site, type of substrate, and the availability of resources to ensure proper maintenance -- repair structure and remove birds that became entangled (H. Blokpoel, pers. commun.). Nontarget birds could be adversely affected.

Mow or burn vegetation. Nontarget birds could be adversely affected.

6.0 Discussion

I view any situation where thousands of gulls are in a nesting colony very close to an airport (e.g., < 1.6 km or < 1 mi) as a very serious hazard -- one that warrants prompt and aggressive corrective measures. Furthermore, allowing such a colony to continue to exist places airport managers in the untenable position of being responsible for ensuring that an airport is safe from bird hazards, yet leaves managers unable to control the source of such hazards. Persuading those in control of such sites to eliminate hazards probably would be difficult, especially if nesting colonies were located on sanctuaries or refuges. Those responsible for airport safety could be practicing the state-of-art in bird management on an airport, but with thousands of birds nearby, could they ensure a high level of safety? Thus, in case of accidents caused by gulls from nearby colonies not under the control of airports, the courts would be faced with a dilemma - who would be held responsible?

Scorer (1988), a solicitor who has been involved in bird hazard litigation, discusses how airports may avoid liabilities due to bird strikes by the adoption of effective, efficient, and well documented bird control procedures. His paper does not indicate, however, how an airport can protect itself from being overwhelmed with birds, when bird attractants, such as breeding colony sites, roosts, and garbage dumps are near an airport, and cause high hazards to aviation when the birds intrude onto or over the airport.

The record clearly shows that when even one bird of relatively light weight is ingested into a turbine powered engine during a critical takeoff regime, severe engine damage, engine failure, and the loss of an aircraft and occupants can occur. Thus, overall airport bird management should have the goal of providing safe airport environments vis-a-vis bird hazards regardless of the source of birds. Therefore, management of birds and habitat beyond airport boundaries must receive a much higher priority -- even if litigation is needed to obtain approval to eliminate certain highly hazardous bird species or alter their habitats.

Actions have been taken or are underway in the United States to address certain aspects of the problem. Completed or near-completed FAA studies to determine the hazards from birds ingested into turbofan engines will be "useful in re-evaluating engine certification test criteria specified in 14 CFR 33.77, and, as a result, future jet engines can be designed to withstand more realistic bird threats" (Cheney et al. 1981, Frings 1984, Hovey and Skinn 1989:1). In a very recent development, the FAA issued a new order in January 1990 (5200.5A Waste Disposal Sites On Or Near Airports), that provides guidance on the establishment, elimination, or monitoring of landfills, open dumps, waste disposal sites or similar facilities on or in the vicinity of airports.

In addition to these FAA activities, the Aerospace Industries Association (AIA) has a propulsion subcommittee on bird ingestions with the objective of reviewing FAA Federal Air Regulations (FAR) regarding the adequacy of 14 CFR 33.77, Bird Ingestion Standards, and of making recommendations for changes, if needed. The Flight Safety Foundation (FSF) has established an ad hoc power plant working group to: identify airports throughout the world viewed as the most hazardous to transport aviation with regard to flocking birds; advise airport and government officials about the significance of bird hazards at certain airports to create an appreciation of the magnitude of the concern of industry; and offer, if requested, technical advice on methods of hazard reduction (A.K. Mears, pers. commun.).

Although some progress is being made to reduce hazards, integrated bird hazard management programs are needed that involve all aspects of the problem -- what Miller (1985) might identify as a program of "System Safety." He defines "system safety" as "the application of engineering, operations, and management tasks specifically organized to achieve accident prevention over the life cycle of the air vehicle under consideration." The FAA made a commitment to air safety in their policy statement of March 1972 (still current), that states, in part, that ..."The agency will assume the initiative not only in attempting to identify unsafe conditions, but also in seeking to implement improvements or corrections before actual incidents occur..." (Cited by Miller 1985:3.2-4-5). There are examples, however, where safety measures were not adequately enforced, even though the hazards that caused them had been previously identified (Seubert 1976, Briscoe 1989).

In my opinion, significant enhancement is needed in the United States in bird hazard reduction programs. This includes: a much higher priority and greater resources; less concern about personal and institutional philosophies that oppose controlling bird species to benefit aviation safety -- safety should be the overruling priority; and the adoption of a stronger safety ethic of proactive hazard reduction by the responsible agencies -- the need is for the full implementation of safety measures as soon as bird hazards develop, not after serious incidents or accidents.

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8.1 **Appendix A**

Common and Scientific Names

Birds

American Kestrel	Falco sparverius
Arctic Tern	Sterna paradisaea
Atlantic Puffin	Fratercula arctica
Avocet	Recurvirostra avosetta
Barn Owl	Tyto alba
Black-footed Albatross	Diomedia nigripes
Black-headed Gull	Larus ridibundus
Black Guillemot	Cepphus grylle
Common Eider	Somateria mollissima
Common Gull	Larus canus
Common Tern	Sterna hirundo
Great Black-backed Gull	Larus marinus
Rock Dove (domestic pigeon)	Columba livia
Herring Gull	Larus argentatus
Laughing Gull	Larus atricilla
Laysan Albatross	Diomedea immutabilis
Lesser Black-backed gull	Larus fuscus
Mediterranean Gull	Larus melanocephalus
Razorbill	Alca torda
Redshank	Tringa totanus
Ring-billed Gull	Larus delawarensis
Roseate Tern	Sterna dougallii
Sandwich Tern	Sterna sandvicensis
Silver Gull	Larus novaehollandiae
Southern Black-backed Gull	Larus dominicanus
Storm Petrel	Hydrobates pelagicus
Wood Pigeon	Columba palumbus

Mammals

Red Fox	Fulvus vulva
Raccoon	Procyon lotor

8.2 **Appendix B**

Bird Weights

Common Name	Weights	Source
American Kestrel	F-120±9.2g M-111±9.3g	Dunning 1984
Barn Owl	F-490g(382-580g) M-442g(299-580g)	do
Black-headed Gull	Avg. wt of 275g (116-390g)	Brough 1983
Great Black-backed Gull	F-1488g(1033-2085g) M-1829g(1380-2272g)	Dunning 1984
Herring Gull	F-1044g(717-1385g) M-1226g(755-1495g)	do
Laughing Gull	325±15.9g	do
Ring-billed Gull	F-471±46g M-566±42g	do
Rock Dove (domestic pigeon)	542±32.2g (494-616)	do
Wood Pigeon	Avg. wt. of 465g (258-739g)	Brough 1983

REPORT OF THE CHAIRMAN

Monday, 21 May 1990

For the first time in the history of BSCE, we convene in Helsinki, the capital of Finland.

When I went through my files, I could see that the first indication of the possibility to meet here dates from a meeting 8 years ago between Lars-Olof Turesson and Helkamo during our meeting in Moscow, but the final decision was only revealed to us during the Rome meeting 6 years ago. This fact will illustrate that you have to plan well in advance of a BSCE meeting and I shall use this opportunity to urge countries which would like to act as host countries to contact me as soon as possible.

Since our last meeting in Madrid, the Steering Committee has met once. It was in Copenhagen in November last year. We made preparations for this meeting and had a discussion on some other items.

Among those items I shall mention the following:

1. We are faced with the deplorable fact that Vital Ferry whom we saw for the last time in Rome and who has participated in the meetings right from the beginning, will no longer be available. In fact, he retired in the beginning of this year. This fact has left us with the problem of the chairmanship of one of the working groups, the Communications Working Group. At the Steering Committee meeting it was, however, decided to dissolve this working group and transfer the work to other working groups. It is the Bird Movement and Low-Level Working Group and the Radar Working Group.

2. At the Steering Committee meeting we also discussed at some length the terms of reference both of BSCE and of the various working groups. If you compare the terms of reference of BSCE in the Invitation Letter with the terms of reference to be found previously, you will notice the addition of a new subpara. b) reading "establish liaison on further research programme in order to avoid duplication". In the same Invitation Letter you will also find

under para. 6, terms of reference of the various working groups as worked out during the Steering Committee meeting. You will remember from the last meeting that your chairman was asked to work out terms of reference of Bird Remains Identification Working Group and change the terms of reference of the Working Group Structural Testing of Airframes. At the Steering Committee meeting we used the opportunity to refrase the terms of reference of all the working groups to make them more consistent, but I would like at this point to stress that the terms of reference in the Invitation Letter are only tentative and that we expect in a Plenary meeting later this week to come to a decision as to the final terms of reference based upon proposals from the various working groups. Those of you who have participated in the past will also have noticed that the Analysis Working Group has been renamed Statistics Working Group. In this connection, I would add that I am aware that there will be a discussion within the Bird Movement and Low-Level Working Group to the effect that the name of this working group should be changed to Working Group Military Low-Flying Bird Strike, and that the Radar Working Group would like to be renamed Working Group Remote Sensing of Bird. It was further agreed that BSCE needed PR. Consequently, our Finnish hosts have arranged a press conference later today. I have made a press release regarding the work of our Committee and at the press conference, which is scheduled to take place just before lunch, I will face the Finnish press together with John Thorpe, Luit Buurma, H. Helkamo and S. Kirjonen. If you had turned on the Finnish channel 3 early this morning, you would also have seen Mr. Kirjonen discuss bird strike problems in the Finnish TV.

3. At the Steering Committee meeting we also agreed on some changes in the Invitation Letter as to our way in structuring and presenting the working papers. Among other things, you will see, and I will stress the importance of it that it is assumed that participants to the meeting have already studied the working papers, at least the working papers available at the beginning of the meeting. This should have as a consequence that the oral presentation of a working paper should be reduced to a summary of the paper and not take more than 15 minutes in order to allow time for discussion. To some extent, we have seen that the lecturers have taken good notice of our recommendation that working papers should contain

references to proceedings of earlier meetings to avoid recapitulation of the work done in the past.

I am quite satisfied that we this year have received 28 working papers compared with the 20 working papers received before the deadline two years ago.

As to the papers received after the extended deadline, you will find them at the entrance of the meeting place, and if you would like to present more working papers, you should address my secretary, Kirsten Mortensen, who will be responsible for numbering the papers so that we can avoid the confusion we to a certain extent had at our last meeting.

I shall now turn to the work performed the last two years in the various working groups, and the first will be the **Aerodrome Working Group** with Heikki Helkamo as chairman. The main task of the Aerodrome Working Group has been the updating of the BSCE Green Booklet, "Some Measures Used In Different Countries For Reduction Of Bird Strike Risk Around Airports", and publishing the fourth edition of this Booklet. It was in my hands yesterday. Members of BSCE have been very active by sending their contribution for the new edition following the recommendation of our meeting in Madrid in 1988. I am sure that the Green Booklet, as it is now, will be an effective tool in our work for reduction of bird strike risk. The importance of this Booklet should not be under-rated. From time to time, I receive requests to obtain samples of the Booklet from all parts of the world, and I think that this Booklet has been of great importance as to make our existence known all over the world, at least in aviation business.

In this connection, I draw your attention to the work being performed by ICAO in amending the new edition of the ICAO Airport Services Manual, Part 3, Bird Control and Reduction. After the Steering Committee meeting we indicated that we were willing to assist in the preparation of the new edition, and I have been informed by ICAO that they were very pleased to accept that offer. The best way to do that will of course be to have consolidated BSCE comments on the draft updated Manual. The draft is, by the way, to a certain extent based on the information contained in the third edition of the Green Booklet. This common approach I consider, however, is impracticable, but Mr. José Santamaria from ICAO has sent copies of the draft to all members of the Steering Committee. As usual, our German friends have already answered, and I can promise that ICAO will also have an answer from the Danish authorities before 1 July, and I shall urge other countries to do likewise and inform both the chairman of the Aerodrome Working Group and me.

Next comes the work performed by the **Statistics Working Group**, or as it was previously named the Analysis Working Group.

At our last meeting, this group was left with 5 recommendations:

1. Military low-level en route strikes should be analysed separately by BSCE members after working out separate forms. This I am happy to announce has been implemented.

2. Details of military accidents and serious incidents should be sent by BSCE members to Dr. Becker, Germany, for inclusion in a paper describing serious strikes to military aircraft. This has also been implemented.

3. As to the third recommendation, the Working Group Chairman has written to ICAO and requested that the new field be added to the IBIS data base regarding the proposal that means should be provided to handle civil data to be analysed by reporter's occupation. We know that the United Kingdom and other countries have used this data for some years, and the appropriate authorities in other countries should be urged to provide it to ICAO.

4. Regarding the fourth recommendation that civil BSCE members should ask their major airlines for their movement data at airports in their system and that this data should be combined with reports from airports and be passed to the Working Group Chairman so as to indicate those airports where a bird strike problem exists, it is hoped that this recommendation be progressed at our meeting.

5. Regarding the fifth recommendation that BSCE analysis should be sent by BSCE members to the Working Group Chairman for civil analysis and to Dr. Becker for military data to the agreed timetable, I can inform you that some countries have been able to provide their data. I am further aware that the working group will propose that five-years papers be produced instead of

the annual analysis. The result of this will be that civil data for 1981-1985 will be presented at our meeting this year, and it is suggested that the data from the years 1986-1990 be presented at our next meeting.

Concerning the work of the **Working Group Bird Movement and Low-Level**, I have been informed that the chairman has not received any information concerning new bird hazard maps in the national AIP'ies, nor airport vicinity maps as recommended during our last meeting. We should take into account that maps of protected areas and other areas of ornithological importance can be based on the Technical Publication No. 9 of the International Council for Bird Preservation, Important Bird Areas in Europe, which was revised last year.

Regarding an exchange of actual data concerning medium and high bird intensities, we emphasized at our last meeting that the procedures of bird strike warnings are mainly significant for military aircraft flying at low level. Consequently, the military participants agreed to intensify the contacts on this subject besides the regular meeting of the whole Working Group. This objective was realized at two meetings held in Germany in September 1988, and in September 1989. The work in session of experts also from the Radar Working Group took place in February 1989, and participants from the Belgian Airforce, Canadian Airforce, German Airforce, Royal Netherlands Airforce, Royal Airforce, and US Airforce surveyed the actual situation and agreed to the following recommendations:

1. Nations should pursue the aim of calibrated electronic assessment of radar data concerning the low level bird hazard.

2. Nations should evaluate the capability of currently deployed radar systems and the future or projected radar systems to fulfil the aim of electronic assessment of such radar data.

3. Nations should investigate the possibility of contributing to a dedicated multi-national system for detecting and reporting of actual data concerning medium and high intensities of bird migration as well as the disseminatic of bird strike hazard warnings.

4. And finally, that national air staffs should consider or reconsider how the bird strike warnings can be obtained without delay and loss of information.

Next, I will turn to the **Radar Working Group**, and I am very happy to report that the chairman has brought with him a booklet on The Application Of Radar For Bird Strike Reduction. It is a collection of empirical experiences. You will observe that the work on the booklet has just been finished, if you look at page 75 with the picture of a NF-5 grounded after collision with racing pigeons 4 May 1990, Holland.

Regarding the other work of the Radar Working Group, I will take my starting point in a discussion we had at our Steering Committee meeting and which I have very briefly mentioned in the beginning of my report.

The Steering Committee expressed some concern regarding the not too clear separation of tasks among the working groups Bird Movement and Low-Level and Radar.

During a recent meeting of some of our experts in the beginning of last month mainly composed by members of the Bird Movement and Low-Level Working Group, the participants agreed upon a proposal which, I understand, will be discussed in the working groups concerned. The participants were aware that the meeting, which was convened as a Bird Movement and Low-Level Working Group meeting, could not be considered as a pure working group meeting of that working group. A roughly equal amount of time was spent on matters related to the work of the Statistics Working Group, the Bird Movement Working Group and the Radar Working Group. Matters which belong to the working groups Structural Testing and Aerodrome also arose.

In a way, the discussion at the recently held meeting was restricted as it was reduced to the military aspects and only for a limited number of airforces, namely those that fly above Germany. The representatives, however, agreed that this meeting should not lead to a separation from BSCE and the bird problems in civil aviation. As most of you know, BSCE had as starting point the problem regarding bird strikes which faced the military, but we also know that the civil side has taken more and more interest. We are aware that solutions for civil aviation can often best be tested by the military. One fact is that economical contraints are mostly less severe in that sector.

This has had as result that the Chairman of the Working Group Bird Movement and Low Level during the Working Group meeting will propose that the Working Group be changed to a Working Group Military Low Flying Bird Strike, and that the Chairman of the Radar Working Group will propose that the name of that Working Group be changed to Working Group Remote Sensing of Birds.

The reason for these proposals are as follows: By using the new name for the Bird Movement and Low Level Working Group we achieve a better indication of the items which are discussed and the work which is done, i.e. discussion of all aspects of the prevention of en route bird strikes which up to now, as all know, is mainly a military problem. During BSCE meetings, this Working Group is open for the civil representatives and has a broad scope. Outside BSCE meetings, more specific military problems can be solved, including classified aspects if they occur.

You do not miss much in leaving out the words "Bird Movements". The aim of the Working Group is not to study bird movements in itself, i.e. in a biological sense, but how to implement the results of bird movement studies into warning procedures.

Thirdly, bird movements, as a biological issue within BSCE meetings, mostly show up during Radar Working Group meetings. The simple reason for this is that biologists can illustrate the potentials of different remote sensing technics by means of case studies, and consequently, the words "bird movement" are replaced to the old Radar Working group.

Fourthly, with the new name and the new procedure of the work being done, the Working Group Military Low Flying Bird Strike can include military bird strike statistics. There are good reasons to deal with military bird strike reports during the meetings usually held in Traben-Trarbach between the BSCE meetings. These "in-between" meetings could serve as a check of prevention measures, and we have to recognize that the Air Forces Flight Safety Committee Europe can consider the Working Group also as their specialist group. Finally, the platform for discussion on maps which was formerly an important topic within the old Bird Movement Working Group, could be either the Aerodrome Working Group for airport vicinity maps or the Working Group Remote Sensing of Bird Movements, because methodology of how to produce such maps is, even in case of use of networks of visual observers essentially a matter of remote sensing. I feel certain that when the Working Group Chairmen present their reports to the Plenary at the end of the meeting, we will be able to come to an agreement on the above proposals, but I have felt it appropriate already at this stage of the meeting to go into these details.

The fifth working group I shall deal with is the **Working Group Testing of Airframes and Engines**. This Working Group was left with one recommendation, and it was that BSCE members should seek information on the retention of bird strike capability after extended in service usage of engines and airframes. The Chairman has been in contact with the industry urging them to cooperate with the Working Group. Since the Madrid meeting, there has been a conference on aerospace transparant materials and enclosures in Monteroy, California, and the Chairman of the Statistics Working Group has attended that meeting presenting a paper on windshield strike data.

Regarding our sixth working group, the **Working Group Bird Remains Identification**, previously called the Feather Identification Sub-Group. Unfortunately, the chairman, Tim Brom, has fallen ill and will not attend. We welcome Dr. Wattel, also from Amsterdam, and I am also pleased to announce that Dr. Bentz from Norway will chair the meetings. A very interesting paper, it is Working Paper 24, has been prepared by Tim Brom with a suggestion to set up a European center for bird remains identification in order to standardize identification.

I shall now turn to the relations between BSCE and other international organizations. Regarding **ICAO**, we regret that this organization due to other commitments has not found it possible to be represented at this meeting. I have already mentioned our cooperation with ICAO concerning the new edition of the ICAO Airport Services Manual, Part 3, Bird Control and Reduction.

BSCE as such was invited to participate in the first **Eastern and Southern African Workshop** on reduction of bird hazards to aviation which was held in Nairobi in June last year. Luckily, John Thorpe was available for participation, and we have been informed that the Workshop was well organized and was attended by seven member states, the number of which were perhaps surprisingly active in the field in view of their limited ressources. Regarding **ECAC**, after some difficulties I think that we have found a way to present the outcome of our work at the annual meeting of the ECAC Technical Committee.

Regarding **EEC**, I have nothing to report as to the EEC Directive on Bird Conservation. Another aspect has, however, popped up and you will see from the list of papers to be presented that the Danish delegation will present a paper in the Aerodrome Working Group, it is Working Paper 13, concerning EEC regulations to reforest farm land.

Finally, regarding **IATA**, we have noticed with great pleasure the interest IATA has shown towards our work, and I welcome the presence of pilots both as representatives from IATA and as members of national delegations.

I will also like to inform you that the 21st BSCE meeting will be held in Israel in the early spring of 1992, late March.

My last words during this session will be a repetition of what I have already indicated in the Invitation Letter. We suppose that all participants to the meeting have studied or will have the opportunity to study the working papers and consequently, the lecturers are kindly requested to avoid reading the paper so that a question and answer period is always available after the presentation of a paper. If not, we will be, as we have been before, faced with the problem of not having enough time. I wish you a successful meeting in the various working groups.

CHAIRMAN'S REPORT

AERODROME WORKING GROUP

1. General

The Working Group was attended by 71 participants representing 17 countries.

2. Agenda of the Working Group meeting

The following agenda was proposed and approved:

a) Approval of agenda

b) Recommendations from the 19th meeting, Madrid, May 1988.

c) Presentation of "The Green Booklet", 4th edition.

d) Presentation of Aerodromes Working Group papers.

e) Other business.

f) Recommendations.

3. Recommendations from the 19th meeting

The chairman reminded the participants of the 2 recommendations which were adopted at the Madrid meeting.

4. Presentation of "The Green Booklet", 4th edition

Mr. Olavi Stenman presented the updated edition of the Green Booklet to the Working Group. He noted that

- some European countries had not revised their methods since the last edition,
- some European countries did not communicate the information asked for,
- for the first time, the USSR had provided information to be included in the booklet. Also from Japan, some information had been received.

5. Working papers presented

WP 2	Bird Control At Geneva Airport (Mr. Jacques Fritz, Switzerland)
WP 4	Influence Of Bird-Shooting On The Relation: Numbers Present/Incidents (Ing. A. Klaver, The Netherlands)
WP 9	Bioacoustic Scaring Of Birds In Airports (A.I. Rogachyov, USSR)
WP 10	Analysis Of Bird Collision With Planes And Possibility Of Utilization Of The Bird Strike Prevention Measures (V.E. Jacoby and A.N. Servertzov, USSR)
WP 13	EEC Regulations Regarding Reforesting Of Former Farm Lands (H. Dahl, Denmark)
WP 15	Starling Abatement At Pirinclik Air Station In Eastern Turkey (L.S. Buurma and R. MacKenna, The Netherlands)
WP 21	Results Of Ornithofauna Study At Some Soviet Airfields 1972 - 1988 (J.E. Shergalin, USSR)

WP 27 HWH Airport Lawn Mover Type HS-2 Triplex And Experience Gathered At Aalborg Airport, Denmark
(N.E. Petersen, Denmark)

WP 31 Advising On Aerodrome Bird Control, Some Requirements And Complications
(N. Horton, UK)

WP 33 Nocturnal Bird Problems On Aerodromes
(T. Brough and N. Horton, UK)

WP 37 Scaring Away Birds By Laser Beam
(J.D. Soucaze-Soudat, France)

WP 45 Experiments Taking Place: Tests Of The Frightening Away Of Birds By Means Of Laser Gun
(M. Laty, France)

WP 47 The Impact Of A Lumbricide Treatment On Airfield Grassland
(Dr. J. Allan, UK)

WP 49 Bird Hazard Management At Manchester Airport
(C.S. Thomas, UK)

WP 50 The Development Of An Expert System To Minimize Bird Strikes At Airports
(M. Kretsis and C. Thomas, UK)

The two last papers were not presented at the Working Group meeting itself, but will be published in the proceedings of this meeting.

6. Other business

No points were brought up.

7. Recommendations

The Working Group proposes the following recommendations:

a) BSCE members from EEC countries are urged to ask the appropriate authorities to take into account, when dealing with applications for grants, that changes in land use may affect the potential birdstrike problem at a neighbouring aerodrome and that consultation with aviation authorities and aerodrome authorities might be desirable.

b) The BSCE members should draw the attention of the appropriate authorities to the existence of expert systems to integrate bird data, weather data and control methods. These systems will provide critical information for new personnel assigned to bird control and will assist management in scheduling efforts.

Heikki Helkamo

Chairman, Aerodrome Working Group
24 May 1990

CHAIRMAN'S REPORT

BIRD MOVEMENTS AND LOW-LEVEL WORKING GROUP

1. Title

Bird Movements and Low-Level Working Group.

2. Terms of reference

Implementation of data concerning bird concentrations and movements with the purpose of developing preventive measures to minimize the bird hazard to low flying aircraft.

3. Progress report

3.1 The chairman did not get any information concerning new bird hazard maps in the national AIPs as well as airport vicinity maps as recommended during BSCE 19.

A circular from 5 January 1990, should remind the members of the working group to the recommendations, but only Denmark did answer. Belgium presented the draft of an actualized set of maps during the 5th meeting "Bird Hazard at Low Level".

3.2 The military participants of the working group agreed to intensive contact on the prevention of birdstrikes during low-level flights. The following expert meetings were held since BSCE 19:

- 3rd meeting at GMGO Traben-Trarbach/FRG, 12-20 September 1988,

- working session of radar experts at CFB Lahr/FRG, 27–28 February 1989,
- 4th meeting at HQ RAFG Mönchengladbach/FRG, 4–5 September 1989,
- 5th meeting at GMGO Traben-Trarbach/FRG, 2–4 April 1990.

The results of the meeting are presented to BSCE 20 in a working paper.

4. Future programme

a) As the objective of the working group is the implementation of data obtained by remote sensing of bird movements (as selected by a radar working group) into flight safety procedures especially for military aircraft flying at low level, BSCE members agreed in renaming the "Bird Movements and Low-Level Working Group" into "Military Low Flying Bird Strike Working Group".

b) The main purpose of the renamed working group will be the exchange of actual data concerning medium and high intensities of bird migration as well as birdstrike warnings (BIRDTAM) in a standardized format via the civil and military Air Traffic Control or Weather (Wx) networks.

c) Implementation of bird hazard maps for the national civil and military AIPs should still be a matter to be dealt with in the Military Low Flying Bird Strike Working Group, while the scientific and methodological preparations should be taken care of by the (former) Radar Working Group to be renamed "Remote Sensing of Birds Working Group".

d) According to the recommendations of BSCE 19, airport vicinity maps should be drawn up in close co-operation with airport authorities.

Therefore, this objective of the Working Group will be transferred to the "Aerodrome Working Group".

e) The renamed Working Group will include military bird strike statistics for the verification of the warning and forecast procedures. General data concerning military bird strikes as well as serious bird strikes to military aircraft will be furthermore presented at the "Statistics Working Group".

5. Recommendations

a) The BSCE members should urge the appropriate national authorities to investigate the possibility of contributing to a dedicated multi-national system for the detection and reporting of actual data concerning medium and high intensities of bird migration.

b) The BSCE members should urge the appropriate national authorities to provide warnings (BIRDTAM) as well as bird movement forecasts which are available also for civil transport and general aviation.

c) The BSCE members should urge national air staffs and Air Traffic services to consider/reconsider how the warnings and forecasts can be obtained by pilots without delay and loss of information according to national necessities.

Jürgen Becker

Chairman, Bird Movement and Low Level Working Group
23 May 1990

CHAIRMAN'S REPORT

RADAR AND OTHER SENSORS WORKING GROUP (old title)

1. Terms of reference (from the Madrid meeting)

Exchange of information on methods used and results obtained regarding the use of radar sensors in the surveillance and identification and the risk assessment of bird presence and movements.

2. Activities and progress since the Madrid meeting

Following the recommendations of the 19th meeting with respect to the further development of electronic assessment of bird hazards by radar, contacts with countries active in this field were intensified. Most of the discussions were held during the specialist meetings in Germany (see the chairman's report of Bird Movements and Low Level Working Group). Apart from many contacts with the air forces performing low level flights over Germany, the chairman visited the US, Israel and Turkey for exchange of information. Dr. Larkin, working on the NEXRAD project in the USA, also visited The Netherlands to study the ROBIN system.

According to recommendation b) from the Madrid meeting, the RNLAF ornithological research continued to assess the quantitative importance of low level migration. Similar work was stimulated and performed in Germany and Switzerland.

Industries in the USA, Switzerland, Sweden and The Netherlands were approached with the BSCE specifications of dedicated bird radar. Serious talks with a Dutch/French company are still going on. The specifications have been included in the Radar Booklet, which was presented during this meeting.

3. Summary of discussions per nation

In the USA the USAF is improving the Bird Avoidance Model (BAM) primarily aimed at helping low level operations be performed along the most safe routes. The static information derived from a database consisting of bird distributions and phenology as well as birdstrikes has the potential of becoming more dynamic when also weather data will be fed into the model. This is possible, because BAM is based on a Geographical Information System (GIS, a certain class of software packages).

The first NEXRAD system will come into operation this year. It remains to be seen how well these radars will perform with respect to bird algorithms, because their functionality is tailored to detect meteorological phenomena optimally which may make the radar be optimal for bird detection. However, the potential of NEXRAD radars as indicators of hazardous bird densities in the air is enormous, especially in combination with the BAM.

Finland has a very old tradition in monitoring mass movements of arctic migrants and has established good cooperation with radars in the Baltic countries.

Renewing Vantaa Airport radar will cause a problem with respect to bird detection capability, but closer cooperation with the Finnish Air Force may not only solve this problem, but may also lead to improvements which can prevent collisions between birds and military aircraft flying low level as well. Finland has a high level of field ornithology which is incorporated in flight safety. The Finnish delegation was completely right in emphazising the importance of the human mind as a flexible computer.

USSR. Since 1966, Professor Jacoby used the surveillance radar of Tallin Airport for bird strike prevention. This work has been intensified during the last four migration seasons resulting in approximately 100 warnings, used by civil as well as military aircraft. Since 1986, there has been a close cooperation with Vantaa Airport with respect to monitoring arctic migrants. Also here, new radar equipment may cause future problems. Latvian radar is supporting Soviet airlines. In Lithuania Dr. Zhalakjavichius performed extended radar studies over 8 years ending up in a thesis next year.

Sweden. Based on regional bird maps and weather forecasts a computer model is predicting bird presence including altitudes for 5-hour periods. Despite very sophisticated research it still does not seem possible to avoid all en route birdstrikes without real-time radar measurements which are not performed at the moment.

Norway. Because of the huge size of the country, building up a network of bird watching radars seems not feasible. Norway relies upon bird distribution maps and data from field ornithologists. Monitoring bird migration with a radar in the south may support the international BIRDTAM system.

Denmark. 3 radars continue to measure ad hoc the bird density by means of the FAUST system.

UK. Because migration is supposed to stop in the UK, a bird warning system has not been judged necessary. However, especially along the eastern coast, detecting birds by radar should make sense as has been shown by many old radar ornithological publications. Recently, the aviation bird unit (within the Ministry of Agriculture, Fisheries and Food) has proposed to map hot spots of bird flying activity within the flying routes.

Belgium. A video featuring the BOSS system at Semmerzake radar exemplified the possibilities to use modern radar types for bird detection. Belgium is trying to implement a network of airfield radars in the warning system.

France. Using more and more secondary radar, the French do not see possibilities to use civil Air Traffic Control radars. New interest in radar ornithology comes from l'Office National de la Chasse with the aim to monitor waterfowl migration.

Spain. The Spanish territory is considered too large to be covered by bird measuring equipment. Studies by Hilgerloh in the south of Iberia show that it may make sense to monitor concentrated migration. An obvious category of birds to be detected are soaring birds (see Israel).

Italy. The recently established Italian Bird Strike Committee is improving BIRDTAMs for airports and their vicinity. What has been said for Spain is valid for Italy too.

Austria. Studies of bird migration have been performed. A warning system does not exist.

Switzerland. Civil as well as military aviation is relying upon the continuing sound studies of the vice chairman, Dr. Bruno Bruderer, who was prevented from attending.

The advanced work done in Israel, Germany and The Netherlands has been illustrated in several working papers during the meeting.

4. Future programme

As was explained in the Chairman's Report, the close co-operation between the old Bird Movement and Low Level Working Group and the Radar Working Group has resulted in a more natural separation of the fields of work. This is reflected in the new title and recommendations of both Working Groups.

5. New Terms of Reference

Exchange of information on the use of radar and other sensors in the surveillance, identification and the risk assessment of bird presence and movements.

6. Recommendations

a) BSCE members should urge national authorities to encourage the appropriate military and civil personnel to evaluate the capability of radar and other remote sensors to monitor bird presence and bird movements.

b) BSCE members should join attempts to further develop the electronic assessment and calibration of remote sensor output with respect to the bird hazard.

c) BSCE members should continue to cooperate with industry in the development of small, dedicated, commercially available bird-observation radars in accordance with the principles described in the BSCE radar booklet.

d) BSCE members should encourage the use of Geographical Information Systems (GIS) when quantifying the density, identity and potential hazard of bird movements, particularly at the lowest flight levels.

Luit S. Buurma

Chairman, Remote Sensing of Birds Working Group (new title)
24 May 1990

CHAIRMAN'S REPORT

WORKING GROUP TESTING OF AIRFRAMES AND ENGINES

1. Working Papers

a) WP 6 **Improving Bird Strike Resistance Of Aircraft Windshields** by Ralph Speelman and R.C. MacCarty, Air Force Aeronautical Laboratories, USAF

Continuing his work, Mr. Ralph Speelman presented ongoing efforts to improve the windshield system bird strike resistance of different USAF aircraft.

The windshield improvements obey the following imperatives:

1. knowing what philosophy you will follow
   - damage acceptance
   - hazard avoidance
   - damage reduction;
2. the bird strike improved resistance should not compromise the aircraft performances, nor the optical qualities and life duration of the windshield;
3. global cost reduction and maintainability increase must be taken into account.

Different technical voids were studied such as computational simulation, glass materials and sealand improvements, composite frames or frameless windshield.

In conclusion, M. Speelman insisted on the high payoff of windshield improvements.

b) **Contribution** of Mr. Rolph Wegmann, SAAB SCANIA, Sweden

Rolph Wegmann presented a short talk related to his Monterey Meeting paper.

SAAB has developed a computational tool used for windshield development in order to predict the windshield deflection under birdstrike. Results obtained fit quite good with the impact description, as tests have shown. A second development phase is presently beginning to introduce failure criteria in the model.

SAAB also presented a video on the tests done - Gun characteristics were also given to the working group members.

c) WP 51 **Design Of Aviation Engine Elements For Bird Strike Action**

by Dr. Shorr, Central Institute of Aviation Motor, Moscow, USSR

Dr. Shorr presented an approximate engineering method for the calculation of bird strike action on fan or compressor blades. This method is suitable for performing the optimized calculations at design stage.

Dr. Shorr gave some typical design results, and, answering a question, precised that tests will be done to check the model.

d) WP 38 **Static Blade Under Load Program**

by J.P. Devaux, DGA/CEPr, France

The paper showed an attempt to analyse foreign object damage installation effects on the final results.

Due to surprising first results on high by-pass ratio engines blades, CEPr has mainly aimed its study first at projectile effects comparisons and secondly at propeller blades pre-qualification, with satisfactory results.

e) WP 39 **Propeller Foreign Object Damage Testing**

by J.P. Devaux, DGA/CEPr, France

CEPr proceeded with bird strike tests, that were started six years ago, on both metallic and composite propellers in order to qualify the latest.

Methods being used and results obtained were shortly presented. Test campaigns conclusions indicated clearly that current test requirements must be arranged in order to ensure test reliability and to decrease test cost.

A video of some tests was shown.

f) WP 40 **Propfan Bird Ingestion Testing**

by J.P. Devaux, DGA/CEPr, France

A short presentation of the main results obtained by CEPr in its preliminary study for propfan bird ingestion testing was made.

CEPr results showed that propfan behaviour will be between propeller and HBPR engines ones. As a consequence, regulations and test requirements should now take into account more precisely this fact.

2. Other items

2.1 Terms of Reference of the Working Group

The working group agreed to change the terms of reference as follows:

"Exchange of information on the methods of prediction, the test methods and test results for:

a) bird impact research and development, design and testing of materials, structural specimens, windscreens, engines, etc.

b) test to show compliance with airworthiness requirements.

Part 3 of the old terms suggesting that BSCE members should assist national organization in the production of design guidance, will be put as a recommendation by the working group.

2.2 Recommendations

BSCE members should:

a) Encourage the studies on composite materials bird strike resistance.

b) Analyse the influence of transparency systems bird strike impact on the structure adjacent parts, with particular emphasis on vibrations.

c) Send information on the state of the art technology used for protecting all parts of an aircraft in order to edit a BSCE Guide of Airframe and Engines Protection. This guide will also include airworthiness regulations and tests methods used.

d) Encourage studies about "substitute bird" to replace real birds in testing.

e) Seek information on the retention of bird strike capability after extended in service usage of airframes and engines.

2.3 The working group plans a meeting in Paris at CEPr Saclay on 16 May 1991 for testing airframes and engines specialists. Main topics of the meeting will be the "substitute bird" and testing booklet.

2.4 As Mr. Chalot will no more be able to continue BSCE work, he proposed to the members of the group to be replaced by Mr. Devaux from France. The proposal was accepted.

As Mr. Peresempio (Italy) had not attended the last three meetings, the working group members were asked if someone volunteered to replace him. Mr. Wegmann from Sweden was proposed and will give an answer within six months.

2.5 John Thorpe (UK) has indicated that new requirements are being discussed by JAR (European common regulations) for bird strike windshield resistance of helicopters and general aviation aircraft.

Jean-Pierre Devaux
Chairman, Testing of Airframes and Engines Working Group
24 May 1990

CHAIRMAN'S REPORT

BIRD REMAINS IDENTIFICATION WORKING GROUP

The Bird Remains Identification Working Group which was established during the 19th BSCE Meeting in Madrid had its first ordinary working group meeting on Tuesday 22 May 1990 in Helsinki. 21 participants from 11 countries made this meeting a very successful one and the future of the working group is really promising.

1. Terms of Reference

Exchange of information on the methods used and the results obtained on identification of bird remains.

2. Presentation of Working Papers

Six working papers were presented:

a) Feathers found in the wreckage of the Convair aircraft which crashed in the Skagerak in 1989 did not support the theory that a bird strike caused the accident (P.-G. Bentz, Norway & T.G. Brom, the Netherlands - WP 35)

b) Microstructures of the rachis, rami and rachidial barbules were discovered, by scanning electron microscopical (SEM) analysis, to show intraspecific differences (K. Perremans, Belgium - WP 3).

c) Electrophoresis of proteins extracted from feather keratin allows identification to the species level provided there is enough plumaceous or pennaceous feather elements. The techniques on protein extraction have been refined and standardized (H. Ouellet & S.A. van Zyll de Jong, Canada – WP 8).

d) Feather colours (pigmentary and structural colours), studied by means of light- and scanning microscope can be used to a limited extent for identification to species level. Gull species cannot be separated due to the lack of colour differences (J. Dyck, Denmark – WP 48).

e) Use of a comparison microscope allows ducks, geese and swans to be distinguished relatively easily by means of differences in sizes of feather barbule features. This method is useful to break down the weight range of the Order Anseriformes (N. Horton, UK – WP 32).

f) A proposal for the establishment of a European Centre for the identifications of bird remains was presented. Such a centre could give an important contribution to the standardization of bird remains identification and thus give better and more reliable statistics (T.G. Brom, presented by J. Wattel, the Netherlands – WP 24).

3. Recommendations

a. That the acting chairman of the BSCE Bird Remains Identification Working Group develop a checklist to inform Accident investigators of the steps necessary to ensure that bird strike as a possible accident cause is not overlooked and any evidence is properly protected and handled.

b. That the chairman of the BSCE Bird Remains Identification Working Group should exchange information on activity so as to prevent expensive duplication.

Per-Göran Bentz

Acting Chairman, Bird Remains Identification Working Group
24 May 1990

CHAIRMAN'S REPORT

STATISTICS WORKING GROUP

1. Change of Name

At the Copenhagen Steering Committee Meeting in November 1989 it was decided to change the name of the Analysis Working Group to "Statistics Working Group". This was endorsed by the Working Group meeting in Helsinki on 21 May 1990.

2. Recommendations from Madrid Meeting

The Working Group was left with four recommendations from the Madrid meeting of May 1988:

(i) That military "low-level" en-route strikes should be analysed separately by BSCE members. Separate forms will be necessary.

Response

The RNLAF Flight Safety Division has made a pilot study of 1988 data from six European Air Forces. The study demonstrates the feasability and usefulness of such a system of co-operation between members of the Air Force Flight Safety Committee Europe.

(ii) That details of military accidents and serious incidents should be sent by BSCE members to the German Geophysical Office (Dr. Becker) for inclusion in a paper describing Serious Strikes to Military Aircraft.

Response

Is has not been possible to implement this recommendation, but members were able to provide some information during the Helsinki working group meeting.

(iii) BSCE members should urge that means be provided to handle civil data by reporter's occupation. Members who already have this information should urge the appropriate authorities to provide it to ICAO.

Response

The Working Group Chairman has written to ICAO requesting that a new field be added to the IBIS data base. ICAO have responded that this will be considered at the next review of the Reporting Form layout and content, as well as a computer field "Reporter".

(iv) BSCE analyses should be sent by BSCE members to the Working Group Chairman for civil analysis and to Dr. Becker for military data, to the agreed timetable.

Response

Some countries have been able to provide their data. The Helsinki meeting agreed that a 5 year-paper be produced rather than attempting to produce annual papers at 2-yearly meetings. It was agreed that the objective should be a paper covering the years 1986-1990 for presentation at the 1992 meeting. The military analysis is dealt with in para 2 (i).

3. Activities Between Madrid and Helsinki Meetings

a) The Working Group Chairman attended the Conference on Aerospace Transparent Materials and Enclosures in Monterey California, January 1989. He presented a paper on Windshield Strike Data and co-chaired the session on Bird Hazards.

b) The Working Group Chairman also attended the first ICAO ESAF Workshop on Reduction of Bird Hazards to Aviation in Nairobi, June 1989. The well organized workshop was attended by Ethiopia, Kenya, Malawi, Rwanda, Swaziland, Tanzania and Zimbabwe. A number of countries were surprisingly active in the field in view of their limited resources. A visit was made to Nairobi Jomo Kenyatta airport to be shown the measures that had been taken to reduce bird hazards. The Working Group Chairman presented several papers and was able to gain a great deal from the workshop. (Note: Copies of papers can be made available).

4. Papers Presented at 20th Meeting, Helsinki

a) The Working Group Chairman gave a visual presentation of two papers, WP 28, "Analysis of Birdstrikes Reported by European Airlines 1981-1985" and WP 29, "Serious Birdstrikes to Civil Aircraft 1987-1989". Certain recent events were highlighted, including the 1988 B737 fatal incident in Ethiopia, due to speckled pigeons (Columba-Guinea at 320 gm) which killed 35 people, and the nighttime incident with herring gulls (larus argentatus) to a BAe 146 on take-off from Genoa, Italy, resulting in all 4 engines being changed. The 18 April 1990 accident which killed 20 of 22 on board a DHC6 Twin Otter just after take-off from an island near Panama City, was briefly described. The birds which damaged the engine are as yet unknown. Further information on an AN 24 accident in Poland on 2 November 1988 was requested. Discussion accepted the future use of 5 year-papers (see Recommendation No. 2).

b) WP 14, "Towards a European Data Base of Military Bird Strikes" by Mr. A. Decker & Mr. L.S. Buurma, the Netherlands, was presented. This paper covered the need for a combined database containing reliable, useful information. Input using computer/floppy disc was proposed. This paper has resulted in Recommendation No. 3.

c) WP 20, "Bird Strike Analysis in Estonia 1951-1988", was presented by Mr. J.E. Shergalin, USSR. Bioacoustics were used on airfields, pyrotechnics were not used. Egg removal and destruction had been used to control black-headed gulls, over 17,000 eggs per year were destroyed.

d) WP 25, "Finnish Air Force Bird Strike Summary 1981-1989", by Maj. J. Hipeli, Finnish Air Force. The paper showed that gulls were the major problem, trainer aircraft being involved in 60% of strikes, 2/3 of strikes were below 500 ft. More than 2/3 of strikes occur in June, July and August, the peak is in August (1/3 of all strikes). Flying is approximately equal each month.

e) WP 30, "The Use of Birdstrike Statistics to Monitor the Hazard and Evaluate Risk at UK Civil Aerodromes" by Mr. T. Milsom, UK Aviation Bird Unit. The paper suggests that simplistic interpretation may be misleading in determining if:

- the risk is increasing
- the bird control is effective.

The paper stressed the need for good reporting and for bird surveys as well as intelligent use of data to direct bird control efforts effectively. There was considerable discussion on the definition of an "acceptable standard".

f) WP 43, "Bird Strikes to USAF Aircraft 1988-1989" was presented by Maj. R.L. Merritt, USAF. The paper analysed data from 6,444 strikes costing 20 million US dollars per year. This included two aircraft destroyed. The paper, with the Proceedings, will include bird weight distribution.

g) WP 42, "US Navy Bird Aircraft Strike Hazard Problem 1985-1989" by B. Bivings & K.A. Medve, US Navy. Over 2,000 strikes per year were experienced, and these had cost 30 million US dollars since 1981. Two aircraft had been lost.

h) WP 16 and WP 17, Statistical Papers by N.A. Nechval and V.Y. Biryukov, USSR, were not presented as the authors were not present. The papers are included in the Statistics Papers.

5. Other Items and Discussion

a) Owing to the absence due to illness of the Vice Chairman, Bertil Larsson, Maj. Ron Merritt, USAF, volunteered to act as Vice Chairman for the meeting.

b) The USAF loses one aircraft for about every 1,500 reported bird strikes (the US Navy about one per 2,000).

c) As accident investigators may be unaware of the possibility that birds could be the cause of an accident it was suggested that a check list be developed to act as a reminder – see Recommendation No. 1 from Bird Remains Identification Working Group.

d) The need for a poster on Reporting and proper identification of remains, including feather remains was discussed. This would, if it was developed by BSCE, be useful publicity for BSCE (see Recommendation No. 1).

e) Military aircraft losses were described, Norway had lost two aircraft in the 1980's and the UK RAF had lost a Tornado in 1989. A factor was that the flight had been delayed and the Bird Control Unit was not on duty.

f) The effectiveness of the "eye" markings on engines used by a Japanese airline was questioned. Is was stated that the supposed effectiveness may not be statistically sound but anything that draws people's attention to the problem is to be encouraged.

g) Discussion on the effectiveness and trials of strobe lights revealed that many USAF studies had shown that they were not effective in reducing birdstrikes. In any case, strobes were necessary for air traffic see-and-be-seen purposes.

h) The Working Group Chairman thanked the speakers for their excellent presentations and commended the high quality of contributors' visual material.

6. Recommendations

a) That a poster be developed by the Steering Committee of BSCE to inform pilots, airport personnel, aircraft mechanics etc of the need to report bird strikes and to ensure that any remains, including feathers, are properly identified.

b) That civil BSCE members are urged to provide the Working Group Chairman with an analysis, or analyses, covering the years 1986–1990. The data should be sent to the Working Group Chairman by September 1991 so that a paper can be prepared for the March 1992 meeting.

c) That the military BSCE members urge that the Royal Netherlands Air Force work on Military Data analysis be continued in co-operation with Air Force Flight Safety Committee Europe (AFFSC(E)).

John Thorpe

Chairman, Statistics Working Group
22 May 1990

BSCE 20
HELSINKI
May 21st-25th, 1990

MINUTES OF THE PLENARY MEETINGS 24-25 MAY 1990

1. Opening of the Meeting

The meeting was opened by the Chairman.

2. German Video

J. Becker presented a training film of the German Federal Armed Forces starting with the history of aviation and describing the flight safety hazards to modern aviation caused by migrating birds. The video showed the procedures of the Federal Armed Forces with the intention of reducing the bird strike hazard, especially the existing observation, reporting, warning and forecast system of the German Military Geophysical service with respect to large-scale bird migration.

3. WP 24, Proposal For The Establishment Of A European Centre For The Identification Of Bird Remains

J. Wattel, The Netherlands, presented Working Paper 24. The central thesis of this Working Paper was that the statistics on bird strike problems must be unbiased to be really useful, and to achieve this not only the very obvious and easy remains should be identified, but also remains which are hardly recognizable as bird material. People should also send in the remains and not keep them to themselves or think that they are impossible to identify. A quick reporting system should be set up not only to aviation authorities, but also to airfield managers and even to pilots to inform them of the species of birds involved. A quick reporting system will significantly help in keeping these people, who are in the position to find bird remains, motivated to send them in. One of the obvious weaknesses of the present system, that many bird remains were simply considered too small to be of any use, could in this way be removed. In The Netherlands, work has been going on along these lines for a long time, and the Zoological Museum in Amsterdam now proposes to extend their services on a more European scale by setting up a centre for difficult identification work. Such a centre would quickly and reliably report identification to all people interested and involved and this quick reporting system would be the principal incitement to continue the collection of bird remains. Such a facility would moreover guarantee that identification would be standardized. A centre being at a university would have the possibility to develop new techniques. It would also have a research and development function, and as these techniques are rapidly becoming more and more sophisticated an academic environment might be of a great help in bird identification. Having a centre would provide for continuity of expertise and not just hinge on one man/woman working only part of the time.

During the discussions of the Working Paper in the Working Group, the idea took shape as follows:

Those countries where there already exists a national centre for identification continue to operate this in a standardized way. These national centres could be encouraged to make use of a central facility in Amsterdam in those cases where very sophisticated techniques would be needed to solve the problem. Consequently, the European Centre in Amsterdam would in a way constitute a second-line facility. Regarding the countries that have only very limited facilities at present, such countries should either establish their own national centre or they could go directly to the European Centre. In that way, the European Centre could even be a first-line facility as it has been for a long time for The Netherlands.

John Thorpe, UK, stressed the need to encourage the sending in of even the smallest bird remains and the advantage of information on that matter to appear on the national reporting forms of where remains are supposed to be sent. At the meeting in the Statistics Working Group, the need for a poster was recognized, a poster to inform pilots, airport staff, engineers, mechanics where they should send their remains and to the fact that remains are important. The Statistics Working Group will phrase a recommendation that the Steering Committee develop a poster to publicize these matters.

J. Wattel agreed and regretted that the airport personnel very often identified the birds involved themselves without sending remains of the bird to the identification centre. In this way the Centre would not be able to store the remains for further documentation and getting more information for instance on sex and age of the bird. Storing the remains indefinitely would make it possible for the Centre to apply new techniques as they become available.

M. Noel, Belgium, mentioned that it had been decided to open as a north centre of Europe the University of Louvain to be able to offer the same service as proposed at the Amsterdam Centre.

J. Wattel, The Netherlands, promised the cooperation if a Belgium centre exists or comes into existance and saw advantages in having two locations instead of a single centre for cross-wise second opinions if the identification is particularly critical. He was also aware of the fact that new techniques are being developed in Canada.

Y. Leshem, Israel, considered that something could be said for having a world centre which especially would be an advantage for the smaller countries.

J.-P. Devaux, France, considered that it would be preferable to establish a standard of working in bird remains and identification before deciding what centre should be used.

J. Wattel, The Netherlands, considered that it should be a task for the Working Group on Identification of Bird Remains to set up a standard, but what he intended and what his Belgium colleagues intended was an offer of the service of the knowledge gained in the two countries over many years of work. He added that out of every 100 bird strikes probably only 15 are now properly identified.

L.S. Buurma, The Netherlands, stressed the importance of continuity of the work of proper identification of the bird involved. This could be ensured by the existence of the centres in Amsterdam and Louvain.

T. Brough, UK, appreciated J. Wattel's approach. In the UK a reasonably good system for identifying bird remains is available, but the UK is very happy to accept the invitation to have more difficult cases identified by other authorities such as the University of Amsterdam. If, however, a UK aircraft which suffered a birdstrike in the USA, the UK authorities might prefer to go elsewhere for bird remains identification. He considered that most countries would probably feel that in the first instance it is their right to identify their bird remains. He was a little worried as he understood J. Wattel's presentation as an indication that, provided enough bird remains would be sent to the University, the Amsterdam University would be tempted to analyze the data that was coming in and perhaps placing its own interpretation upon it. He thought it unwise to have just one unit which has collected all the data and interpretated these.

J. Wattel, The Netherlands, considered that interpretation of data is the free right of every authority, but considered that interpretation of data should be dealt with in the Statistics Working Group with the object of coordinating and centralizing the statistical questions.

After T. Brough, UK, had drawn the Meeting's attention to the fact that for instance the Smithsonian in Washington has got considerable experience in identifying bird remains, the Meeting agreed to a proposal from the Chairman that a recommendation should be made along the lines that BSCE members are urged to inform the appropriate authorities of the existence of European centres where bird remains could be identified adding that such centres are for example the Universities of Amsterdam and Louvain.

J. Thorpe, UK, observed that the Statistics Working Group would make a recommendation to the effect that the Steering Committee develop a poster to publicize the need to report and the need to have bird remains properly identified.

The Chairman observed that there was no opposition to the suggested recommendation from J. Thorpe and indicated that the further work would be done in the Steering Committee.

4. WP 26, Bird Control On Aerodromes, French Regulations

Ph. Vuillermet, France, presented Working Paper 26. The Paper deals with the new French regulations regarding bird control on French aerodromes and explains the reasons why a bird control service has been implemented on 143 aerodromes, the organization of the service in terms of personnel, equipment, procedures and the role of the different partners as far as funding is concerned. Relying on the expertise of Mr. Briot and Mr. Laty, the 143 areodromes are split in 5 categories depending on the risk, an A-airport being an airport where there is low traffic and estimated low risk, a B-airport being an airport with rather light traffic and moderate risk, a C-airport being an airport with much more important traffic and an average moderate risk, and ending with an E-airport where there is heavy traffic mainly by turbojet traffic and obviously a higher risk regarding the birds.

J.L. Briot, France, elaborated on the splitting up of the different aerodromes and indicated that account has been taken of the local ornithological situation, the volume of commercial traffic, the most frequent type of aircraft and an analysis of bird strikes over the last 10 years. He added that the environmental actions included changes in the grass cutting technique, changes in cultivation of the area and that the scaring techniques included selected distress calls, broadcast by onboard synthesizers, pyrotechnic devises, hunting shotguns reserved for allowed species of birds and on some airports noise-makers places along runways. All other methods tried in the past, like falconry, have been stopped.

After the oral presentation, a funny, instructive video concerning an example of ecological expertise was shown.

5. WP 36, The Application Of Radar For Bird Strike Reduction

L.S. Buurma, The Netherlands, presented Working Paper 36. The Booklet contains a collection of emperical experiences that could serve as a reference for discussions on the application of radar for bird strike reduction and starts with an identification of the en route bird strike problem on the basis of bird strike statistics, continues with a short biological treatment of bird movement partly based on radar ornithological studies and concludes with a collage of short introductions and illustrations on radar.

6. WP 22, Soviet Bibliography About Aviation And Radar Ornithology 1982 - 1990

J.E. Shergalin, USSR, presented Working Paper 22.

The bibliography is compiled with the aim to make persons engaged in bird strike matters familiar with literature about aviation and radar ornithology after the 16th BSCE meeting, 1982. The literature has mainly been published in rare, separate editions with limited circulation and as a rule only in Russian without summaries. The bibliography covers 160 reports of 92 Soviet specialists.

7. USSR Bird Scaring Devises

V.Y. Biryukov and Z. Lapinskis demonstrated bird scaring devises used on USSR airports.

8. WP 40, Propfan Bird Ingestion Testing

J.-P. Devaux, France, presented Working Paper 40 covering the main results obtained by CEPr (Centre d'Essais des Propulseurs).

9. WP 7, Contact Persons Regarding Bird Strike Subjects

The Chairman presented Working Paper 7 indicating that the list was based on replies from persons appearing in former lists and if no such replies had been received, repeated the information from the former lists. He asked that changes or errors be notified to him by the end of July 1990 that he might be able to present a revised list for inclusion in the Proceedings.

10. Bird Remains Identification Working Group - Chairman's Report

P.-G. Bentz, Norway, presented as acting chairman the report from the Bird Remains Identification Working Group.

After discussion which concentrated on the second recommendation, the following recommendations were adopted by the Meeting:

1. That the acting chairman of the BSCE Bird Remains Identification Working Group develop a checklist to inform Accident investigators of the steps necessary to ensure that bird strike as a possible accident cause is not overlooked and any evidence is properly protected and handled.
2. That the chairman of the BSCE Bird Remains Iden-

tification Working Group should exchange information with which he is familiar on activity so as to prevent expensive duplication.

The Chairman of BSCE paid tribute to Mr. P.-G. Bentz who with a very short notice agreed to act as chairman of the Working Group.

11. Statistics Working Group - Chairman's Report

J. Thorpe, UK, presented the chairman's report from the Statistics Working Group.

The following recommendations were adopted by the Meeting:

1. That a poster be developed by the Steering Committee of BSCE to inform pilots, airport personnel, aircraft mechanics etc of the need to report bird strikes and to ensure that any remains, including feathers, are properly identified.
2. That civil BSCE members are urged to provide the Working Group Chairman with an analysis, or analyses, covering the years 1986-1990. The data should be sent to the Working Group Chairman by September 1991 so that a paper can be prepared for the March 1992 meeting.
3. That the military BSCE members urge that the Royal Netherlands Air Force work on Military Data analysis be continued in co-operation with Air Force Flight Safety Committee Europe (AFFSC(E)).

To a question from McCloud, UK, J. Thorpe indicated that because of Recommendation 3, Statistics should no longer be sent to the German Military Geophysical Office, cf. Recommendation b from BSCE 19. After an intervention by M. Purdie, UK, J. Thorpe added that only the collection, analysis and presentation of the statistics have moved to RNLAF, but the identification of remains and other activity of the German Military Geophysical Office will continue as normal.

The Chairman of BSCE finally paid tribute to the Working Group's acting vice-chairman, Major R. Merritt, US, who at a very short notice due to the illness of the vice-chairman, B. Larsson, Sweden, took on the task as vice-chairman.

12. Aerodrome Working Group - Chairman's Report

H. Helkamo, Finland, presented the chairman's report from the Aerodrome Working Group. He paid tribute to Mr. O. Stenman who is the principal editor of the 4th edition of the Green Booklet, and suggested that the Green Booklet be updated in the future, say every fourth year.

The following recommendations were adopted by the Meeting:

1. BSCE members from EEC countries are urged to ask the appropriate authorities to take into account, when dealing with applications for grants, that changes in land use may affect the potential birdstrike problem at a neighbouring aerodrome and that consultation with aviation authorities and aerodrome authorities might be desirable.
2. The BSCE members should draw the attention of the appropriate authorities to the existence of expert systems to integrate bird data, weather data and control methods. These systems will provide critical information for new personnel assigned to bird control and will assist management in scheduling efforts.

To a question from M. Purdie, UK, to the effect that the recommendations should be rephrased so as the Chairman of BSCE and not only BSCE members should communicate the recommendations directly to the appropriate authorities, the Chairman of BSCE indicated that BSCE is a rather inofficial body and that it was agreed during the last meeting to phrase the recommendations as done by the Aerodrome Working Group.

The Chairman of BSCE finally paid tribute to the work being done by the Aerodrome Working Group in presenting the 4th edition of the Green Booklet.

13. Bird Movement and Low Level Working Group - Chairman's Report

J. Becker presented the chairman's report from the Bird Movement and Low Level Working Group and informed the Meeting that his Working Group and the Radar Working Group on Tuesday this week had a combined meeting.

Regarding future programme a), the Meeting adopted the following title of the Working Group: Military Low Flying Bird Strike Working Group.

Regarding future programme b), the Meeting approved that the terms of reference of the Working Group should be an exchange of actual data concerning medium and high intensities of bird migration as well as birdstrike warnings (BIRDTAM) in a standardized format via the civil and military Air Traffic Control or Weather (Wx) networks.

Regarding future programme c), the Meeting agreed that implementation of bird hazard maps for the national civil and military AIPs should still be a matter to be dealt with in the Military Low Flying Bird Strike Working Group, while the scientific and methodological preparations should be taken care of by the Remote Sensing of Birds Working Group.

Regarding future programme d), the chairman of the Aerodrome Working Group, H. Helkamo, agreed that the responsibility concerning airport vicinity maps be transferred to the Aerodrome Working Group.

Regarding future programme e), the chairman of the Statistics Working Group, J. Thorpe, agreed that the responsibility concerning military bird strike statistics for the verification of the warning and forecast procedures be transferred to the Military Low Flying Bird Strike Working Group, whereas general data concerning military bird strikes as well as serious bird strikes to military aircraft will continue to be presented at the Statistics Working Group.

The Plenary agreed to the above-mentioned transfers of responsibilities.

The following recommendations were adopted by the Meeting:

a) The BSCE members should urge the appropriate national authorities to investigate the possibility of contributing to a dedicated multi-national system for the detection and reporting of actual data concerning medium and high intensities of bird migration.

b) The BSCE members should urge the appropriate national authorities to provide warnings (BIRDTAM) as well as bird movement forecasts which are available also for civil transport and general aviation.

c) The BSCE members should urge national air staffs and Air Traffic services to consider/reconsider how the warnings and forecasts can be obtained by pilots without delay and loss of information according to national necessities.

14. Testing of Airframes and Engines Working Group - Chairman's Report

J.-P. Devaux, France, presented the chairman's report from the Testing of Airframes and Engines Working Group.

The following terms of reference of the Working Group were adopted by the Meeting:

Exchange of information on the methods of prediction, the test methods and test results for:

a) bird impact research and development, design and testing of materials, structural specimens, windscreens, engines, etc.

b) test to show compliance with airworthiness requirements.

The following recommendations were adopted by the Meeting:

BSCE members should:

a) Encourage the studies on composite materials bird strike resistance.

b) Analyse the influence of transparency systems bird strike impact on the structure adjacent parts, with particular emphasis on vibrations.

c) Send information on the state of the art technology used for protecting all parts of an aircraft in order to edit a BSCE Guide of Airframe and Engines Protection. This guide will also include airworthiness regulations and tests methods used.

d) Encourage studies about "substitute bird" to replace real birds in testing.

e) Seek information on the retention of bird strike capability after extended in service usage of airframes and engines.

J. Thorpe, UK, indicated that the new requirements are being discussed by JAR (European common regulations for bird strike windshield resistance of helicopters and general aviation aircraft), but no final decision has yet been taken.

As P. Chalot, France, has indicated that he would no longer be able to continue as chairman, the Working Group had elected J.-P. Devaux, France, as chairman.

As the vice-chairman, Peresempio, Italy, had not attended the 3 last meetings, R. Wegmann, Sweden, was proposed by the Working Group as vice-chairman and would give a definite answer within 6 months.

The Meeting agreed to the above changes of chairman/vice-chairman, and the Chairman of BSCE paid tribute to the work done by P. Chalot in the Working Group and in BSCE.

15. Radar and Other Sensors Working Group - Chairman's Report

L.S. Buurma, The Netherlands, presented the chairman's report from the Radar and Other Sensors Working Group.

After discussion it was agreed that para. 3 should be named "Summary of Nations' Reports".

At the request of Krziwanek, Austria, the section describing the activities in Austria should read: Studies of bird migration have been performed. A warning system does not exist.

The Meeting approved that the terms of reference of the Working Group should be as follows:

Exchange of information on the use of radar and other sensors in the surveillance, identification and the risk assessment of bird presence and movements.

The following recommendations were adopted by the Meeting:

a) BSCE members should urge national authorities to encourage the appropriate military and civil personnel to evaluate the capability of radar and other remote sensors to monitor bird presence and bird movements.

b) BSCE members should join attempts to further develop the electronic assessment and calibration of remote sensor output with respect to the bird hazard.

c) BSCE members should continue to cooperate with industry in the development of small, dedicated, commercially available bird-observation radars in accordance with the principles described in the BSCE radar booklet.

d) BSCE members should encourage the use of Geographical

Information Systems (GIS) when quantifying the density, identity and potential hazard of bird movements, particularly at the lowest flight levels.

The Chairman of BSCE paid tribute to the work done by the Working Group and especially the chairman indicating that the Radar Booklet would be of utmost interest to people engaged in bird strike work.

16. Cooperation with ICAO

The Chairman referred to his report on Monday, 21 May.

J. Thorpe, UK, gave the following information on the ICAO regional meeting in June 1989: The meeting was well organized by the local office of ICAO in Nairobi. Nairobi/ Jomo Kenyatta is a real bird strike problem airport for European airlines, in fact the worst airport for damage in the British Airways network. On the parking area you could observe black kites collecting garbage. There is a game park just on the edge of the airport attracting birds of prey circling over carcasses in the park. There were attendance from Ethiopia, Kenya, Malawi, Rwanda, Swaziland, Tanzania, Zimbabwe together with representatives from the African states or aerodrome organizations, Canada, Italy, the UK, IATA and the Airport Associations Coordinating Council (AACC). A number of papers were presented by local states and he got the impression that the states in that part of the world, such as Kenya and Ethiopia, are doing something about birdstrike problems. At the Addis Ababa airport a number of European airlines and aircraft engaged on famin relief have had birdstrikes. The Meeting received a description of the fatal accident at Bahar Dar Airport, Ethiopia, involving a Boeing 737. In Zimbabwe they have also a problem consisting in the presence of elephants knocking down the fences around the ILS installations when leaning against them.

J. Thorpe, UK, continued to report on the ICAO IBIS system and informed the Meeting of the data is sent out from ICAO to all states containing world analysis, and added that if they did not have access to them, they should find where they were held in their country.

17. **Cooperation with ECAC**

The Chairman informed the Meeting that at the Steering Committee meeting last year it was decided that he should act as rapporteur to ECAC succeeding Vital Ferry and Elisabeth Dallo.A working paper had been made and presented to the annual ECAC meeting in the Technical Committee last week.

18. **Cooperation with the EEC**

The Chairman drew the attention of the Meeting to the recommendation from the Aerodrome Working Group regarding reforesting of farm lands. He had no information on the EEC Council Directive of 2 April 1979 on the conservation of wild birds, cf. Proceedings from the Copenhagen Meeting, page 452, and the Madrid Meeting, page 663.

19. **Cooperation with IATA**

S. Kirjonen, Finland, informed the Meeting that he was a member of IATA Safety Advisary Committee and as such would liaise between IATA and BSCE. At last meeting in that Committee he was informed that many countries and many companies, especially in Africa, indicated major bird problems, and he had informed his colleagues that if possible they could use BSCE expertise.

The Chairman was very pleased that BSCE could rely on S. Kirjonen as a sort of liaison officer between IATA and BSCE.

20. Other Work Done Since the Last Meeting

On behalf of R. Merritt, USA, J. Thorpe, UK, informed the meeting on the Canadian Bird Strike Committee meeting in Montréal June last year. It was run in cooperation with ICAO and there were approximately 40 representatives from Transport Canada, Canadian Air Force, Air Canada, Canadian Airline Pilots' Association, United States Air Force and the US Department of Agriculture. At the 3 day meeting the main items were: Aspects of contracting airfield bird control, the use of strobe lights mounted on aircraft for bird avoidance, electrophoresis for feather identification, general recording and statistics and demonstration of radio-controlled aircraft at Rockville Airport, and problems associated with landfields near airfields. The contact person is Paul McDonnald of Transport Canada. The meeting resulted in recommendations, among others: Research data and literature on the use of strobe lights should be collected. The possibility of the creation of a Bird Strike Committee North America should be investigated.

B. Bivings, USA, informed the Meeting on the 4th US Navy/US Air Force BASH workshop in Little Rock, Arkansas, in April 1990 being the first workshop in 4 years. The workshop was oriented towards teaching the flight safety and airfield management people and operations people how to do the things, and it was a hands-on and interactively oriented programme. Lectures were given by Dr. Ron Larkin on NEXRAD radar and by Roxie Laybourne. There were two basic working groups, one on military low level applications, and one on aerodrome applications being attended by about 130 delegates.

L.S. Buurma, The Netherlands, informed the Meeting on the approaching conference in the second week of December this year from 2 to 9 December in New Zealand arranged by the International Council for Bird Protection and the International Ornithological Congress. Together with T. Brom, The

Netherlands, he would represent BSCE at the meeting and he had promised to organize a round-table discussion, the theme being how to have mutual interests between aviation and flight safety people and ornithologists, i.e. the identification aspect and the bird movement aspect.

21. The Mike Kuhring Award

Having explained the background for the Mike Kuhring Award, the Chairman informed the Meeting that the Steering Committee at the November 1989 meeting in Copenhagen had decided to confer the 8th Mike Kuhring Award to John Thorpe in recognition of his work for almost two decades for the benefit of flight safety in collecting, analyzing and presenting data and case stories on bird strikes. He indicated that the work of John Thorpe was of vital importance for the work within BSCE as the data help decision-makers to understand that even costly measures to reduce the bird strike risk are worthwhile.

J. Thorpe, UK, was most honoured to receive the Award and accepted it on behalf of the work done by his Working Group.

22. Planning of future meetings of BSCE

The Chairman announced that the 21st BSCE meeting will be held in Jerusalem, Israel, starting on 23 March 1992 and ending on 27 March 1992.

He had also been in touch with delegates from other countries in order to make arrangements for future meetings in the 1990'ies.

On behalf of the Israeli delegation, Eyal Shy invited the meeting to Israel indicating that the time was chosen because of the weather and because of the possibility to watch migration of birds.

23. **Other Matters**

J.E. Jansen, Norway, considered the meeting as very successful and an eye-opener to newcomers like him. He suggested, however, an arrangement of the papers in another way than done at the meeting, for example to indicate with a mark on the paper what kind of paper it is and to which working group it belongs.

The Chairman answered that the idea brought forward by Jansen would be considered in a Steering Committee meeting. He further indicated that the Invitation Letter asked for a summary of the paper on the 3rd page, the aim being to facilitate the aquisition of the contents of the papers.

J. Thorpe, UK, informed the meeting of the existence in the UK of a video on the subject of bird strike. As the video was now about 20 years old and is a mixture of military and civil, there had been discussions in the UK about the production of a new video aimed at civil airports, the reason being that this is a man/management problem and that there is a need to make the people who work on airports to keep birds away enthusiastic. In the UK a video is considered a good means of communications and is used for all forms of life, from advertising and so on. He put the question if anybody had any opinion about the usefulness or advisability of trying to produce a BSCE video aimed at civil pilots.

Y. Leshem, Israel, suggested that the Steering Committee not only discussed a video film, but a marketing film of the BSCE issuing the coming decade. He indicated that the Israeli Raptor Centre would be happy to produce a video from all the material shown at this meeting provided free of charge for anyone who wanted it.

The Chairman replied that the suggestion of Y. Leshem would be discussed at the Steering Committee meeting.

J. Thorpe, UK, informed the meeting on the working papers as follows:

WP 5 is really only an abstract of WP 3. WP 6 is also only an abstract, but if anybody requires further information, they should approach the author, R. Speelman. WP 47 and WP 48 have not been issued, but will appear in the final Proceedings.

Finally, the Chairman announced that a revised Index for the BSCE working papers issued during the period 1966 - 1990 would appear in the Proceedings as WP 53.

24. Israeli video

Y. Leshem, Israel, presented the video, Flying With The Birds.

25. Termination of the Meeting

The Chairman expressed the gratitude of all the participants of the meeting to the National Board of Aviation in Helsinki indicating that the meeting will be remembered for the very efficient way in which it has been performed and for all the arrangements of a social character the participants had enjoyed. He mentioned the get-together party hosted by FINNAIR, the visit to the Sinebrychoff Art Gallery, the cocktail party in the City Hall of Helsinki and the cruise in the afternoon on Thursday as well as the dinner hosted by the National Board of Aviation.

On behalf of the spouses, he thanked the hosts indicating that the spouses had enjoyed the visits to the Arabia Factory, the Kalevala Koru Jewel Factory, the Brunberg Confectionary Factory and the visit to the Sibelius House and the FINNAIR Catering and Service Training Center.

He thanked every person from the host country who had performed all sorts of work, and a special thank went to the person in charge of the project.

He thanked all participants of the meeting for their work and for their patience towards him.

His special thanks went to the members of the Steering Committee and to his secretary who as usual had been of invaluable help to him. Like the elephants in Zimbabwe leaning against the fences of the airports, he had leaned against the Steering Committee for help, but on this occasion there was no damage.

He indicated that BSCE was happy to see new faces at the meeting, but also missed familiar faces. At the beginning of the meeting he had been informed that Dr. Schabram from the German delegation had passed away immediately after the last meeting. He had had telephone calls from Colonel Schneider, Denmark, and from Lars-Olof Turesson, Sweden, that they were sorry not to be able to attend the meeting, and he knew that Roxie Laybourne, John Seubert, USA, and Tim Brom, The Netherlands, likewise deplored that for different reasons they had not been able to attend the meeting.

In declaring the meeting closed, he finally indicated that in his opinion the 20th meeting had been a very successful meeting.