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PREDICTION AND DETECTION OF BIRD FLIGHTS ACROSS THE CONTROL ZONE OF AIRPORTS

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SUMMARY

On the basis of West European military bird strike statistics it has been established that many hazardous bird strikes occur just outside the sphere of influence of aerodrome bird control (habitat management and bird scaring). Especially in wetland regions many birds cross the control zone of airports, often in predictable spatiotemporal patterns. Once an airport has been constructed at a location intensively flown over by birds, or when major developments creating bird activity are accomplished facts, nothing else remains than to develop warning systems for bird strike prevention. The statement of this paper is that nowadays more possibilities do exist than are utilised so far. A lot of ornithological knowledge has not yet been tailored for use in aviation. Modern geographical information systems and other forms of computer modelling offer, the possibility to integrate this knowledge into Bird Avoidance Models (SAM) at different scales (from airport or shooting range surroundings to the size of continents). Furthermore, it becomes obvious that there is an altitudinal gap between bird movement data from long-range surveillance radars, as used in some West European airforces, and the visual impressions of field observers in the lowest airlayer. Closing this gap by means of small 3-D (tracking) radars paralleled by adapted fieldwork will give birth to a wealth of new insights to be build into dynamic BAM's.

Key words: Statistics, Maps, Warning systems, Local movements, Migration, Radar, Visual observations, Forecasting

Prediction and Detection of Bird Flights Across the Control Zone of Airports

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1. Introduction

Since the beginning of aviation 52 civil aircraft have been lost due to bird strikes, involving 190 fatalities. In Europe 168 military aircraft were written off in 21 countries over a period ranging from 15 to 46 years. These figures were reported by Thorpe (1996) and Richardson (1996) respectively during the London meeting of the International Bird Strike Committee. Whether these figures are impressive compared to the total of aviation losses is doubtful. However, the burden of bird strikes, especially upon military operations, can surely be substantial. For example, the RAF summarised the yearly damage costs to aircraft as equivalent to a permanent workforce of 40 men, E13 million and a total downtime equivalent to 14.4 aircraft being permanently grounded (McCloud 1992).

In Holland the topic of bird strike prevention climbed considerably on the priority list following the Hercules disaster (15 July 1996). This sad accident, involving 34 fatalities, has indicated that even a robust turboprop aircraft like the C-130 can be brought into trouble by a flock of birds, the size of Starlings (80 grams). Also two recent AWACS crashes have indicated that serious bird strike problems are not limited to the faster jet aircraft during low level training Therefore, it is time that civil and military aviation together reconsider their efforts for bird strike prevention and develop an integrated policy which includes international cooperation.

Bird strike occurrences may indicate the year-round average altitude distribution of birds (Fig. 1, five air forces, fighters only, N=2582). This is the case when we select so-called local bird strikes, e.g. during take-off, landing and overshoot. During these flight phases the flight path of the aircraft has a fixed angle to the earth surface. Consequently, birds are sampled evenly over altitude.

In the graph I have shaded the lowest 150 feet as the altitude layer we can judge by the naked eye with respect to bird presence and behaviour. At airports this part of the bird strike problem can be handled by local bird control. It consists of two elements *which* I will not discuss in this presentation: bird scaring and habitat management. What I do want to address is bird strike prevention outside airfields. How do we cope with collisions with birds which have nothing to do with the airport but do fly through the control zone, either because they have to find food or rest somewhere in the vicinity of the airport, or because they pass through the area on migration. Also, I consider those birds that our aircraft meet during low level missions.

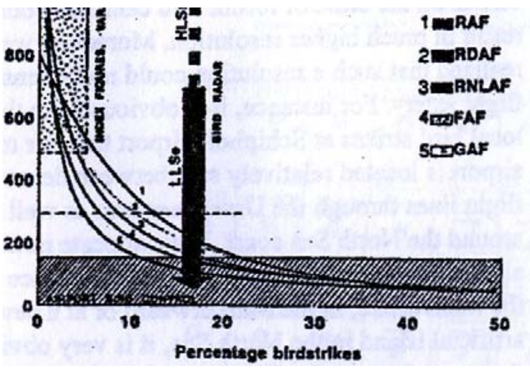

Fig. 1 Altitude profiles of 'local' bird strikes for 5 West European airforces indicating the average height distribution of bird flying activity over the year (note: 'en route' bird strikes may occur much higher when birds climb to altitudes up to and over 10.000 ft during migratory flights at a limited number of days and night per reason)! Low level bird movements (below 150 ft) can be observed and partly influenced by bird control units at airports. High level bird movements (above 300 ft) can be monitored only by (long range,) surveillance radars. The, not yet existing, ideal 'dedicated bird radar should b e able to sample the bird movements at high level and to search continually those occurring at low level. Striped line: airforces mainly operating in coastal areas (RAF, RDAF) are confronted with higher local bird movements than airforces mainly operating inland (FAF, GAF)

2. The problem

So far, the aviation world does not know of operational information systems that provide predictions about where and when to expect flying birds, including their altitudes and densities. What does exist are maps at the one hand and, in a few countries, ad-hoc radar warning systems at the other. What is missing are bird avoidance models mixing biological reference data, meteorological parameters and actual radar measurements of birds in flight. This is very curious, given the potential value of such systems and the enormous amount of Ornithological field data currently available in several countries. For instance in Holland there are tens of thousands of amateur bird watchers, organized in several hundred local clubs, who are involved in several nation-wide and even international census projects. These projects are initialized, supported and analyzed by professional biologists and institutions. The results are also exploited professionally by local, regional and national governmental bodies, the application being mostly spatial planning and nature management.

I can think of three reasons why systematic bird counts are not yet used for aviation safety purposes: Firstly, aviation authorities have not yet realized that they can indeed profit from a spatiotemporal bird information system Maybe beforehand there is a certain reluctancy to introduce such "soft" information.

This brings us to the second reason: there might be a cultural gap between the green world of naturalists and the hightech world of aviation. This gap blocks information exchange and fruitful cooperation.

But most important, in my opinion, is the third option bird mobility is still very much a terra incognito. The majority of bird movements remain hidden from the eye or occurs at a too large scale. Many birds migrate at night and/or at high altitudes. One would expect that three decades of radarornithological work should have resolved that problem. However, this did not happen. On the contrary, a lot of the radar work raised more questions than it provided answers. Only recently we started to understand that radar gives a very distorted picture of the realities of bird flight. Dutch attempts to consider radar and field observations indicated that they both detect only a part of the phenomena and that there often is a significant gap between the visual range upward and the radar reach downward (Fig. 1). To make things worse: a lot of bird flying activity occurs in this altitude band as is indicated by the bird strikes!

Once we start to understand the problems, we also have the clues to solve them. My statement of today is that the time is ripe to combine field observers and radar detection. Our modem society appreciates both the mobility provided via aviation as well as a bird rich environment. Each contribution that helps to avoid further clashes between these two ambitions should be most welcome!

3. Bird mapping

As birds often start and end their flights in bird concentration areas, a first step to understand their flyways is to map the major refugia of the problem species. This obvious approach neglects, of course, those birds that are evenly spread across the countryside. But one should start somewhere, and it is a given fact that one cannot take into account each single bird. So, twenty years ago the Dutch Civil Aviation Authority ordered the development of a simple map for their Aeronautical Aviation Publication under the title `Bird Sanctuaries and Bird Strike Risk' (Fig. 2). The map features 52 important bird areas where pilots are advised to fly over 1000 ft., for their own sake and in order to reduce disturbance to the birds.

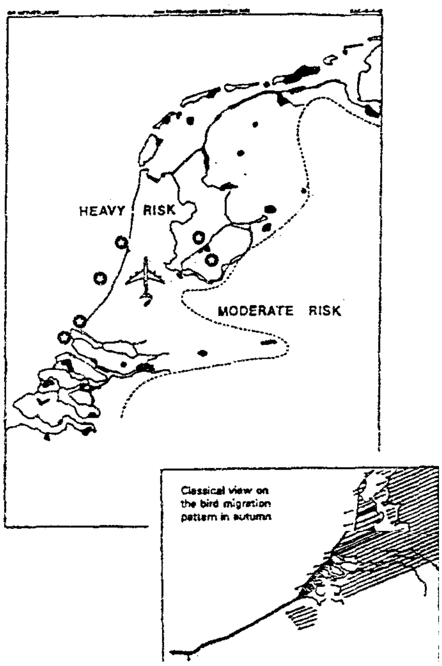

Fig. 2 Distribution of bird sanctuaries (black patches) in The Netherlands as included in the Aeronautical Information Publication. White stars indicate locations considered for construction of a new international civil airport.

This map is not up-to-date anymore and it hardly takes into account the seasonal changes in the bird distribution. More important: it does not reflect the real `bird meat underground' necessary for the reconstruction of regional and national bird flyways. One could argue that such a realistic `bird meat map' would not work for aviation purposes because the lower half of The Netherlands would appear as one big bird area. In low resolution maps this could be true. In fact, twenty years ago this was the reason that Holland was divided in two bird strike risk zones: high risk in the west and moderate risk in the east. The division fitted an international map designed at the same time.

In the meantime, however, we learned that mapping efforts on the basis of recent bird censuses could result in much higher resolution. Moreover, we realized that such a resolution could result in much higher resolution. flight safety. For instance, it is obvious from the local bird strikes at Schiphol Airport that our major airport is located relatively safe between dense bird flight lines through the IJsselmeer area as well as around the North Sea coast. If we allocate new airfield capacity outside Schiphol, for instance on the Maasvlakte, in the Markerwaard or at a new artificial island in the North Sea, it is very obvious that a much more detailed mapping effort is needed.

Given the currently available ornithological knowledge, the mapping process should be computer based as an application of a Geographical Information System. This would not only provide unlimited space for seasonal and even diurnal variations in bird distribution. It would also open facilities for creating zones around and between 'bird-hot-spots, indicating daily feeding and roosting flights. Ultimately, the electronic calendar/mapping system could be extended with overlays containing migrational flyways.

A first step in this direction has been taken by the Central Science Lab of the British Ministry of Agriculture, Fisheries and Food. They created a database of 800 bird-hot-spots behind a scanned copy of the RAF's low-flying map which also shows air corridors, no-go areas and other low-level flying hazards. Bird concentrations appear as red dots on the screen of a high performance PC after the user has selected global parameters in combination: month, time of day (dawn, day, dusk, night) height (100, 250, 500, 1000 feet or all heights) and hazard level (high, medium, low or all). Only those sites that are hazardous at the chosen setting will be displayed on the screen; e.g. gull roosts will only be displayed during the winter months, tern colonies will only be displayed when the height is set to 100 ft or all. Clicking on a site brings up a dialogue box giving further details. This bird strike hazard GIS is now operationally being tested at an RAF squadron.

As the user is not overloaded with irrelevant information, the system seems pretty ideal for flight planning purposes. But also important is the unlimited growth potential, since the key is geographical coordinates and most of the GIS (Arcview) functionality with respect to zones etc is not yet exploited.

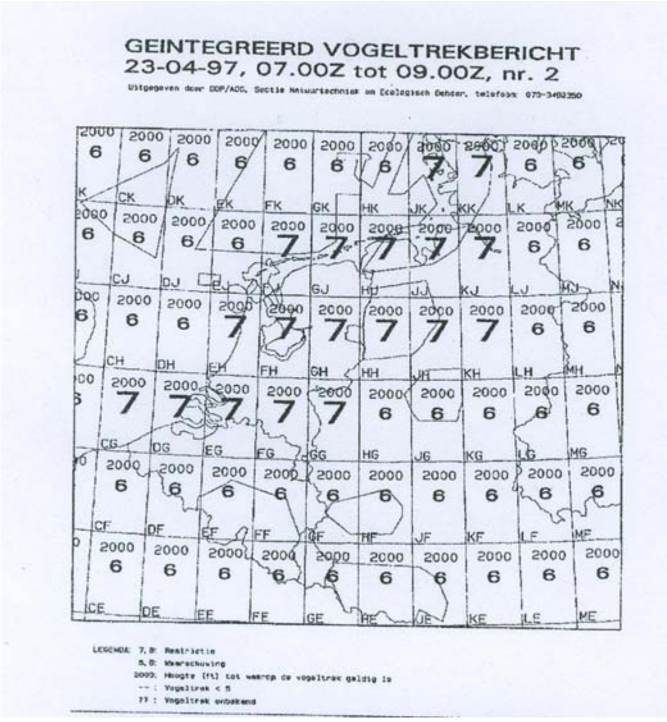

Fig. 3 Integrated Bird Migration Message. Bald figures per georef indicate the bird migration intensity at an exponential 0-8 scale. The values 7 and 8 imply flying restrictions below the altitude in ft, also indicated in each georef. Values 5 and 6 imply a warning.

Such sophisticated steps will be possible as soon as more descriptive information on flying behaviour of the birds becomes available.

4. En route bird control in the RNLAF

So far, the British system works from fine to coarse, providing `bird hot spots' and leaving it to the pilots at what distances to avoid these points. The opposite is true for the radar approach on the mainland (see Fig. 3) wherein wide areas are excluded from low level flying. For many years the air forces of Denmark, Germany, Belgium and Holland warn each other for waves of heavy broad front bird migration as registered by long range surveillance radars. The idea is that with a limited amount of flight restrictions most of the bird strikes during low level missions can be avoided. The bird density is expressed in an exponential zero to eight scale. The maximum value eight corresponds to the most intense bird migration observed during each season. Flight restrictions are usually imposed at bird intensity seven and eight. They are valid below the altitude level indicated in bird messages (socalled `hirdtams', bird notices to airman). The RNLAF integrates her own radar information with the information received by telex from the neighbowing countries into one integrated `georef' map. It is released each morning and is repeated every two hours in case the bird activity is scaled at five or more.

How do we assess bird migration intensity by radar? Fig. 4 gives an example of a time accumulated radar image with a fairly massive daytime bird migration. The computer generated 'time photo' (of 10 minutes radar image) shows short streaks across the screen caused by birds. The striped lines near Amsterdam are produced by aircraft, while the blue solid echo at the right edge represents a rainshower. The contours of The Netherlands are shown in while. Colors indicate the echo strength from weak (red) through yellow and green to blue (strong).

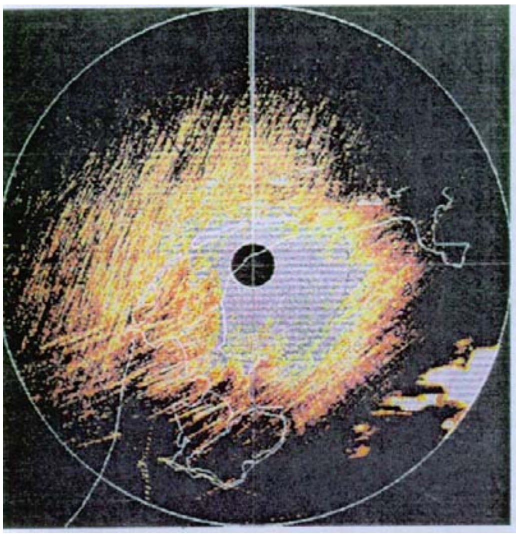

Fig 4. Digital "time exposure photo" of 10 minutrs of the radar image of the lowest beam of a stacked beam RNLAF air defence radar. The orange and yellow stripes represent SSW bird movements across the North Sea and SW bird movements across land. Green and blue colors indicate saturation of birdechoes, groundclutter and a rain cloud above the border with Germany. Stippled lines near Amsterdam represent airliners towards or from Schiphol airport.

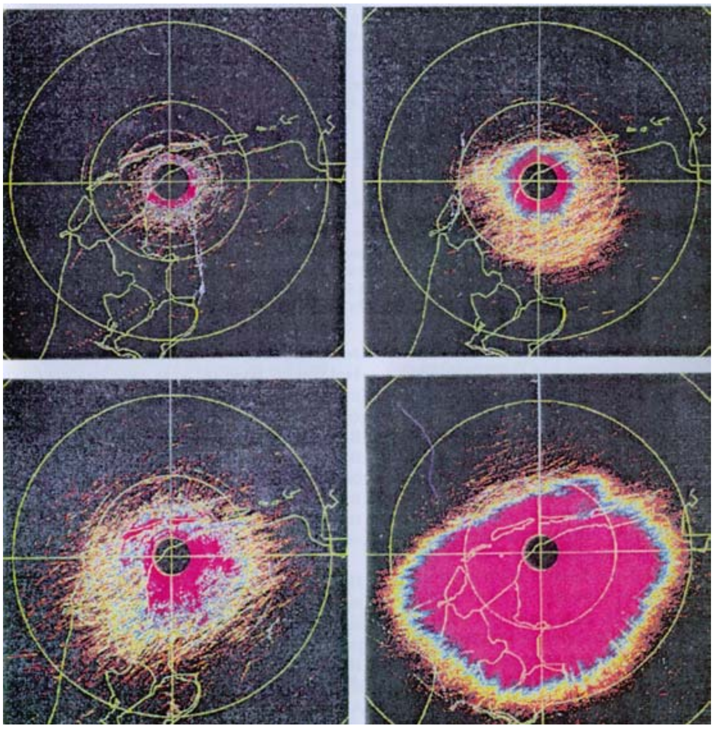

Fig 5. Four unfiltered 10-min image accumulations of 4 October 1992 provided by ROBIN. The upper imagines are from beam 2 (left 17.24-34 and right 23.24-34 h) and the lower from beam 1 (left 17.39-49 and right 19.39-49 h). Colors indicate reflection energy from weak (red) to strong (pink)

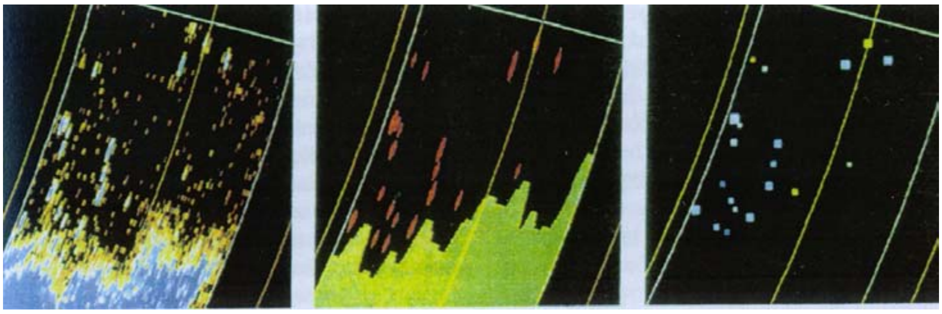

Fig 6. Unfiltered radar image showing rain at the bottom and bird echoes at the top (A), classification of rain (green) and birds (red) (B), and synthetic image in which size and strength of bird echoes are indicated in dimension and color, respectively (C)

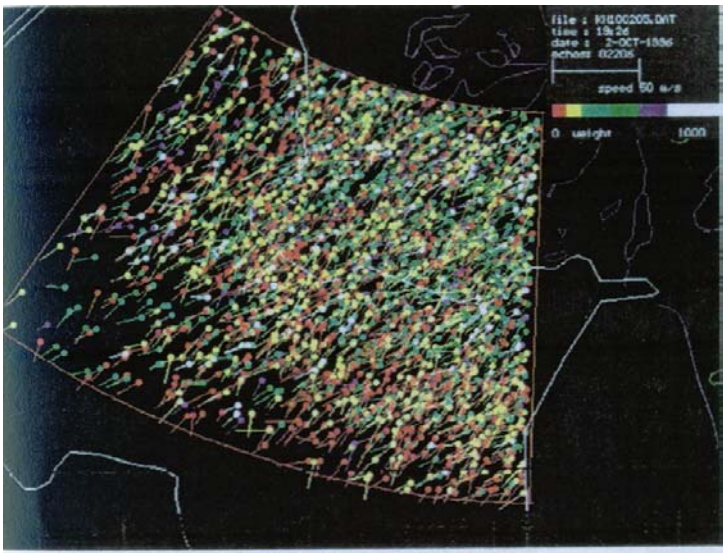

Fig. 7 Bird echo extraction over 10 antenna rotations at highest radar resolution in a window around the SW corner of the province of Friesland (Gaasterland) and parts of Luke IJsseL Colors indicate the mass of each bird (flock). Length and direction of vectors indicate the groundspeed and track direction. The sample illustrates the start of a very dense nocturnal bird migration on 2/10/96.

This bird image illustrates the so-called broad-front migration from NE towards SW, typical for the autumn. The birds form a very uniform 'blanket' over the sea and the Dutch inland areas. As the echoes do not reach the far perifery of the image, the birds do not fly at maximum altitude, especially not over land. Nevertheless, the uniformity indicates that this bird density can be extrapolated somewhat outside the radar range. The fact that the bird echoes are clearly visible individually indicates that most birds fly in flocks.

Fspecially at night, when birds usually fly higher. the radar screen may become saturated by bird reflections. This is partly caused by the fact that mam of the daytime flocks break up into solitarily t1) ing birds in the darkness. This is nicely shown during the beginning of the night of 4 October 1992, the evening of the crash of an FIAI Jumbo in
Amsterdam (Fig. 5, from Buurma 1995). Here we see four images: the lower two come from the lowest radar beam, while the upper two were produced by the second beam of the stacked beam radar. The left hand side pictures are from one hour before sunset, the right hand side images were taken one hour after sunset. The daytime echoes (left) represent moderate migration in flocks. the nocturnal movement (right) is very dense, totally saturating the radar display. Using the vertical coverage diagram of the radar and the bird distribution at the right hand side images, we can recun-struct the ceiling of the noctumal bird movement: 5000 ft.

In order to analyse in detail the bird densities and movements, the Physics and Idectronics Laboratory TNO in The Hague developed a dedicated bird video extractor called ROBIN (radar observation of bird intensity). The first version of this special hard and software configuation enables us to zoom in on the radar imagine and to use the highest resolution in order to extract bird echoes. The three picture in Fig. 6 show how the echoes in a small window with raw video (A) are Split between a raincloud (green) and bird echoes (red)(B). The pixel information is further classified according to the size of the bird echo and its average reflectivity (C). This information provides us with some first chic s liar identification. At the end of 1997 the ROBIN system was replaced y a much faster version which also provides the software o analyze the motion of individual echoes. The analysis of a small window-view around Gaasteriand (tile SW corner of the province of Friesland, Fig. 7) illustrates the capacity.

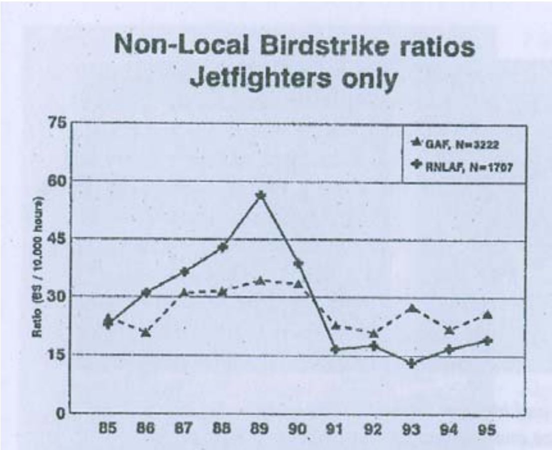

Fig. 8 Bird strike ratio for jetfighters of RNLAF and GAF over 10 years. In 1989 ROBIN was introduced

Since we introduced ROBIN in 1989 a reduction of `an route' bird strikes has resulted (see Fig. 8). I emphasise the comparison with the GAF data, because fit the same years the flying activity at extreme low level by NATO Partners over Germany was reduced.

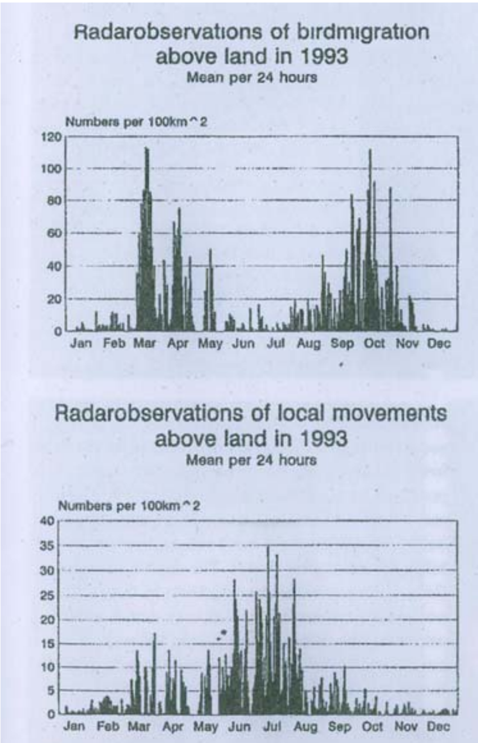

Fig. 9 Example of the datasets collected with ROBIN

Since the introduction of ROBIN, we also were able to collect nice time-series of bird echo densities within certain counting areas: Fig. 9 gives an example. You can imagine that we can exploit these reference databases for several future goals, such as comparison of migration patterns and synoptic weather charts in order to be able to predict bird migration.

5. Towards integration of field and radar data

The use of long range surveillance radar has evident advantages: as far as high altitude movements are concerned the data are large scale and continuously available day and night. In principle, they provide a firm basis for the calculation of the amount of `bird meat per, cubic kilometer' and thus the bird strike risk. However, two crucial aspects are missing which limit the use for flight safety purposes: information on flying heights and on the identity of the birds.

As I ahead, indicated in my introductory figure, most bird flying activity occurs in the lowest air layer, especially during the daytime. The radar is only scanning the upper parts if these bird movements. Most of if remains undetectable behind the radar horizon or between ground clutter, the reflection of objects on the ground. As a result we get a skewed picture of what is really happening and this seriously hampers interpretation and prediction. We have to conclude that the information of the long range surveillance radar and what we see in the field are, at the very best, complementary. Mostly, there is a gap. And as the big radar only provides echoes without bird identity, we cannot simply connect the bird movement patterns in the lowest air layer, as seen by field observers, with those higher up, which are very often totally different.

The gap between the bottom-up approach from visual studies in the field and the top-down interpretation of radar material must be bridged. This is not easy and can only be achieved by a series of special studies with registration techniques intermediate in scale. Currently the Air Staff started to study the feasibility of such a program, to be set up in close cooperation with several institutions also interested in bird densities in the air, not only in relation to the planning of new aviation infrastructure but also in relation to large scale wind power projects.

We propose to use small tracking radars for this purpose. Some experiments in the past have shown that the Flycatcher radar is a good choice provided the radar is optimized and adapted for bird observation. With the search beam of this mobile system, single birds of Starling size can be detected in side view up to 7 km. By using the track antenna as a scanner in the vertical and in the horizontal plane we can measure the spatial distribution of birds quantitatively up to its ceiling of approximately 4 kin. More important, we can track single birds and flocks as low as approximately 30 meters. This tracking facility goes along with TV identification in daylight or infrared at night.

In combination with visual observers at ground level and the big radar as a high altitude reference, the Flycatcher bird radar could be used to analyse in three dimensions the rate at which birds accumulate around coast lines and other topographical borders under varying wind conditions. Further, the patterns and altitudes of feeding and roosting flights of gulls, geese, ducks, waders and starlings could be mapped. Also the use of thermals by several bird species in different landscapes needs to be measured. A special air force priority is the 3-D modelling of mass bird movements in tidal areas such as the RNLAF shooting range at Vlieland. Also the bird activity in the control zone of existing and future airports could be evaluated.

Flycatcher studies will not only provide descriptive information of local value. They also will give birth to more general insight into the relations between bird flight, landscape and weather. The biological understanding of the spatial behaviour of birds will, for the short term, help to set up an international bird hazard GIS. For the longer term, this GIS will provide the basis for a more dynamic and predictive Bird Avoidance Model, using meteorological parameters. Actual bird movement measurements will remain necessary, but the sample size can be reduced the more we succeed in classifying the bird movements.

6. Literature

1. Buurma, L.S. (1995). Long-range surveillance radars as indicators of bird numbers aloft. Israel Journal of Zoology, Vol 41, pp, 221-236.

2. McCloud, R.C. (1992). Bird Strikes 1991. Air Clues, May 1992
3. Richardson, W.J. (1996). Serious birdstrike-related accidents to military aircraft of Europe and Israel: list and analysis of circumstances. Working paper 2, Proc. 23rd int. Bird Strike Committee, London, May 1996.