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Weather-dependence of Height, Density and Direction of Migration in Switzerland

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Proposals for action arising from this paper

- Raw video information is necessary for bird observations. Besides all digitalisation this information should be kept accessible at every larger radar center.
- If operational use of radar data on birds is previewed, speeding up evaluation (e.g. by electronic counting systems) seems to be necessary.
- A possible preference of larger birds for higher flight levels has to be tested by echosignature-analysis.
- Cooperative studies of France, Germany and Switzerland should be carried out in order to find out, how far from the Alps their deflecting influence is still recognicable.
- The possibility that small passerines may be concentrated along pronounced leading-lines should be tested with long range lo cm radars in Switzerland.
- Predicting models for intensity of bird migration in Switzerland should be improved.

1. Introduction

Since bird hazards to aircraft have become a real problem for flight safety, the interest of aviation people in the old field of bird migration research has increased rapidly, and the interest of biologists in radar observations has opened a wide field of cooperation.

If cooperation shall go on, it is necessary that radar technicians are aware of this cooperation and take care that, besides all digitalisation of modern radar arrays, the possibility to work with raw video displays will be maintained.

If radar information on birds should be used in an operational manner, even further support by radar specialists is necessary, in order to speed up the evaluation of radar data (e.g. by electronic counting systems).

Biologists have to interpret radar data, to transform it into biological information and to make this knowledge available for flight safety again.

The probability of a bird strike depends on the density of birds at the flight level of the aircrafts. In the present paper I try to summarize the present knowledge on vertical and horizontal distribution of migration above Switzerland, to show the problems of forecasting day-to-day variation in migratory activity in an Alpine environment and to indicate the gaps in our knowledge.

2. Methods and Acknowlegments

Our knowledge on migration in Switzerland is based on field observations in the lowlands and at observatories in the Jura and the Alps, on surveillance radar studies at Zurich airport and on studies with the tracking radar "Superfledermaus".

Aiming the pencil-beam of the tracking radar vertically upwards or moving it up and down in a plane perpendicular to the principal direction of migration, we got information on the height distribution of birds and on density variations in time. These quantitative data were complemented by qualitative data on direction, speed, altitude and wing-beat pattern of single migrants and on upper winds: we tracked about 15o birds and 2 to 3 pilot balloons per night.

Most of the studies have been supported by the Swiss National Foundation or by the Dr. Fritz Hoffmann-La Roche Foundation. The tracking radar was made available to us by the Firm Contraves AG, Zurich, and by the Swiss Army.

3. Altitudinal distribution of bird migration

a) in the Swiss lowlands

The average height distribution shows highest concentrations of birds at levels below 5oo m AGL (about 6o% of day migrants and about 4o% of night migrants). The bird density decreases with altitude. 9o% of the birds fly below the limit of 2ooo m AGL. Besides the slightly higher median of night migration and the tendency of the lowest birds to fly farther off the ground at night, the adaptation of flight levels to environmental conditions seems to be similar in day and night migration.

In disturbed weather the altitude of migration decreases. Close to a pronounced frontal system, nearly all birds may be concentrated within the lowest 5oo m, especially when bad weather is combined with opposed winds.

In fine weather flight levels are generally higher than in the mean distribution. Highest densities of birds may be found at levels up to 25oo m AGL. The optimal flight levels are primarily determined by the distribution of winds: During the first hours of the night birds seem to search favorable flight levels. During the following part of the night they concentrate at altitudes with strongest tailwinds or weakest side- or headwind components.

b) in the Alps

In fine weather the upper limit of migration reaches 55oo m ASL, while the main mass of migration passes at or slightly above the mean level of the Alpine ridges (about 3ooo m ASL). Under tailwind conditions even at a pass at 2ooo m ASL the visible part of migration may be negligible.

In disturbed weather and opposed winds, migration is concentrated in valleys and passes. At an observatory in the western part of the Swiss Alps the number of birds passing per day may reach half a Million.

c) open questions

There are indications that larger birds prefer higher flight levels. We hope to get information to this problem in the near future by the analysis of echo signatures.

4. Horizontal distribution of bird migration

It is often assumed that important leading-line effects are confined to diurnal migration and that, apart from the soaring birds (using updrafts along mountain ridges), inland guiding-lines are negligible compared to the effects of coast-lines. However, observations on immens concentrations of passerines at Alpine passes during day and night and new radar observations suggest that inland leading-lines have been under-estimated during the last years.

a) concentration of rooks along the Rhine valley and the Jura
Unpublished observations by Sutter with the 23 cm radar at Zurich airport show that rooks (Corvus frugilegus), probably migrating in a height band of 1ooo to 15oo m AGL had a strong tendency to follow the lowest parts of the landscape along the Rhine. Approaching Basel, where the Rhine turns northward, many of the flocks left the Rhine valley and crossed the low hills to the north of the Jura. They reached the first higher ridges of the Jura about 25 km SE of Basel, and followed again the lowest parts of the Jura-Highlands (basin of Delsberg).

b) local concentrations of small songbirds
It is difficult to judge whether the impressive masses of birds at an Alpine pass are primarily due to a vertical compression of the broad front migration above the Alps into the valleys, to a horizontal concentration of birds by local leading-lines, or by a large scale effect of the Alps.
Tracking radar studies in the Alps showed that leading-line effects may be very common also for passerines. Many of the night migrants, even when flying 1ooo m or more AGL, are prone to follow a valley, the slope or the top of a ridge, or even an artificial element like a funicular.
The possibility of leading-line effects on passerines in the lowlands has to be re-considered, using the new 1o cm surveillance radars at the Swiss airports. After the experience in the Alps it may be assumed that also in the lowlands pronounced topographical elements deviating at a small angle from the principal direction of migration cause concentrations of passerines.

c) large scale deviation of bird migration along the Alps
Surveillance and tracking radar studies in the Swiss lowlands showed that the principal direction of night migrants is in the order of 24o to 25o$^{\circ}$ in autumn and about 6o$^{\circ}$ in spring, regardless of visibility and flight level. In contrast to this finding the flight directions of night migrants to be expected from cage experiments and ringing results are in the order of 21o to 22o$^{\circ}$ in autumn and

about 3o° in spring. Thus, the densities of night migration in the Swiss lowlands may be somewhat higher in autumn and somewhat smaller in spring compared to the smoother landscape north and west of Switzerland. Further studies in collaboration with Germany and France are necessary to show, how far from the Alps their influence is still recognicable.

5. Measurements of bird numbers

a) parameters for the intensity of migration

The intensity of migration may be indicated as the frequency of birds passing a certain line perpendicular to the principal direction of migration. Adding all the frequencies found for the different altitudes we get the migration traffic rate (MTR = birds per km of front per hour). MTR depends on the ground speed of the birds and hence on the prevailing winds; it may be considered as a measure of the progress of migration during the night in question.
With respect to the bird strike problem it is more important to know the density of birds airborn above a certain surface or within a certain volume of air. In order to get figures comparable to MTR we calculate the volume of migration (VM = birds within an air column above a surface of 1 km in breadth and 5o km in length).

b) densities of nocturnal migration at 4 height bands under optimal meteorological conditions

height band km AGL	birds/5o km^2	spring average birds/km^3	spring fine weather birds/km^3	autumn average birds/km^3
o-1	225o	45	11	13o
1-2	18oo	16	45	5o
2-3	4oo	8	2o	25
3-4	1oo	2	5	6
total (= VM)	35oo	7o/km^2	8o/km^2	2oo/km^2

In the day-time the total number of birds may be similar, but they are not distributed uniformly throughout the air space; instead they are congregated in flocks. If we assume a mean flock size of 1o in spring, we get 1oo to 175 targets/5o km^2. In autumn the number of migrants may reach three times the spring numbers, but the number of flocks increases less, because of larger average flock size.

6. Variations of migratory activity from night to night

A comparison of the changes in MTR and VM from night to night with the corresponding synoptical weather maps indicates that in spring and autumn there is a tendency for highest intensities of migration to occur when a high-pressure area lies to the right and/or a low-pressure area lies to the left of the main vector of migration in the area considered. However, in Switzerland this general tendency seems to be somewhat concealed by deflecting or concentrating effects of the mountain ranges of the Jura and the Alps.

Our first trials with multiple regression analyses presented at the BSCE meeting in 1974 failed to support the general theory. In the mean time we tried to exclude possible sources of errors by: 1) taking as dependent variable only the movements in the main sector of migration (in autumn SW), 2) accounting for the seasonal change in the amount of migration, 3) improving the exclusion of insects, 4) introducing square terms for the independent variables, in order to get better approximations of non-linear relationships.

The preliminary results given in the Table below (based on 60 autumn nights) come closer to the general theory than the results of 1974: Positive correlation with tailwind and negative correlation with crosswind can be explained with respect to the synoptical situation, but the correlation with the square of the pressure trend is far from any explanation, and the low correlation coefficients are not very convincing.

DEPENDENT VARIABLE: Volume of SW-migration

	weather factor	simple r	r^2	multiple R	R^2	predicting value in final equation
step 1	tailwind 1 km)^2	0,50	0,25	0,50	0,25	36%
step 2	pressure trend ^{2}	-0,25	0,06	0,61	0,36	23%
step 3	crosswind surface	-0,05	0,00	0,65	0,42	14%
step 4	date	-0,31	0,10	0,69	0,47	14%
step 5	crosswind 1 km)^2	-0,13	0,02	0,73	0,52	13%

regression equation:

$$VM = 0{,}62 \cdot \text{tailwind}^2\ (1\ \text{km}) - 0{,}39 \cdot \text{pressure trend}^2 - 0{,}25 \cdot \text{crosswind surface} - 0{,}24 \cdot \text{date} - 0{,}23 \cdot \text{crosswind}^2\ (1\ \text{km})$$