# ASSOCIATE COMMITTEE

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# BIRD HAZARDS TO AIRCRAFT

NATIONAL RESEARCH COUNCIL, OTTAWA, CANADA

FIELD NOTE NUMBER

54

## A FURTHER ATTEMPT TO FORECAST BIRD MIGRATION OVER COLD LAKE, ALBERTA

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# A FURTHER ATTEMPT TO FORECAST BIRD MIGRATION OVER COLD LAKE, ALBERTA

by

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In the belief that rapid exchange of information is of the utmost importance to a solution of the bird problem, the Associate Committee on Bird Hazards to Aircraft has decided to release rough field notes as soon as they are produced, rather than to wait until these data would normally appear in formal reports.

These field notes are produced for information and will not usually receive the editorial care usually given to formal reports.

It is hoped that other groups will contribute similar notes on an exchange basis.

M.S. Kuhring,
Chairman,
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## INTRODUCTION

During fall 1968 experimental forecasts of the intensity of nocturnal migration were made at Canadian Forces Base Cold Lake, Alberta (Blokpoel, in press). Since they were considered sufficiently accurate for flight planning, they were continued on a routine basis in fall 1969 and used at briefings for night flying.

This report describes the preparation and accuracy of these routine forecasts and discusses their usefulness.

## METHODS AND MATERIALS

### A. Forecasting the intensity of nocturnal migration

As in 1968, we based forecasts of the intensity of all nocturnal migratory and other bird movements on correlations between SE migration and the following weather factors (for details, see Blokpoel, op. cit.):

| | Favourable | Neutral | Unfavourable |
|---|---|---|---|
| Wind at surface | W-N or calm (0-3 mph) | N-E S-W | S-E |
| Wind at 3,000' | " | " | " |
| Wind at 5,000' | " | " | " |
| Precipitation | None | A few widely scattered showers | Extensive fields of drizzle, rain or snow |
| Sky cover | Scattered clouds | Clear sky | Thick extensive cloud layers |
| Pressure tendency | Rising | Steady or no clear tendency | Falling |

Wind directions were considered the main factors. Heavy SE migration sometimes occurs- especially in September - with SW surface

winds (a neutral factor), therefore surface winds between S and W, especially when they are WSW, may be slightly favourable. A SE surface wind of 4-6 mph was regarded as less unfavourable than one of 10 mph or more.

Extensive, prolonged precipitation was thought to "suppress" migration almost completely, even with favourable winds at all levels. Sky cover and pressure tendency were not considered important.

We used the same guidelines as in 1968 (Blokpoel, op. cit.):

(1) If all weather factors are neutral, the migration will be of average intensity. If most factors are favourable (or unfavourable), the intensity of migration will be above (or below) average, maximum (or minimum) intensity occurring when all weather factors are favourable (or unfavourable). If some weather factors are favourable and others unfavourable, they may "neutralize" each other and migration will be of average intensity.

The average intensities for 15-30 September and 1-15 October are given in Figure 1 as examples. Maximum and minimum intensities for September and October 1966 may be seen in Table 1. The average, maximum and minimum intensities during the last week of August are similar to those in September.

(2) When all or most weather factors have been unfavourable for three consecutive nights, their influence decreases; in other words, the birds start to fly under unfavourable conditions in numbers greater than usual.

(3) In October, when all or most weather factors have been favourable for two or three nights, the number of migrating birds decreases on subsequent nights even though the favourable weather conditions continue.

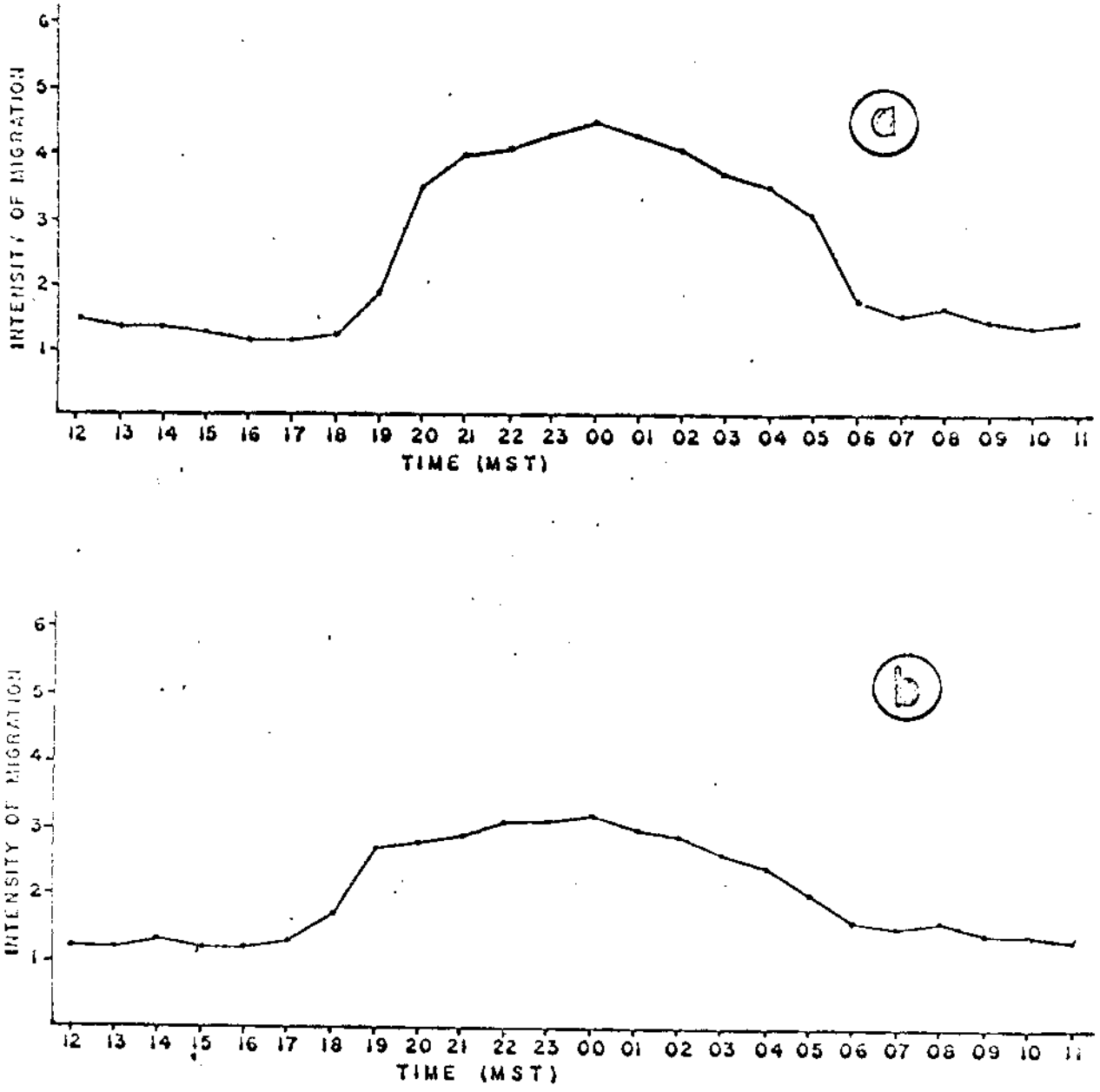


Figure 1. Average hourly intensity of migration over CFB Cold Lake, Alberta and its surrounding area (radius 75 n. mi.). Data were obtained from radar film, assessed according to Fryers' (1966) code. Intensities were determined on the hour. a: 15-30 September (1965, '66, '67), b: 1-15 October (1965, '66).

Table 1. Minimum and maximum intensities of migration during the night (1700 through 0600 hrs. MST) for September and October 1966, as observed on radar film from Cold Lake, Alberta.

| Date (Sept. '66) | Minimum and maximum intensity of migration during the 1700 through 0600 hrs. period. | Date (Oct. '66) | Minimum and maximum intensity of migration during the 1700 through 0600 hrs. period. |
|---|---|---|---|
| 1- 2 | 1-4 | 1- 2 | 1-3 |
| 2- 3 | 1-6 | 2- 3 | 1-4 |
| 3- 4 | 1-1 | 3- 4 | 1-6 |
| 4- 5 | 1-4 | 4- 5 | 1-7 |
| 5- 6 | 1-2 | 5- 6 | 2-6 |
| 6- 7 | 1-2 | 6- 7 | 1-3 |
| 7- 8 | 1-5 | 7- 8 | 1-2 |
| 8- 9 | 1-3 | 8- 9 | 1-3 |
| 9-10 | 1-5 | 9-10 | 1-3 |
| 10-11 | 1-5 | 10-11 | 1-1 |
| 11-12 | 1-6 | 11-12 | 1-2 |
| 12-13 | 1-6 | 12-13 | 1-2 |
| 13-14 | 1-4 | 13-14 | 1-3 |
| 14-15 | 1-7 | 14-15 | 1-5 |
| 15-16 | 1-4 | 15-16 | 1-4 |
| 16-17 | 1-5 | 16-17 | 1-3 |
| 17-18 | 1-5 | 17-18 | 2-4 |
| 18-19 | 1-6 | 18-19 | 0-2 |
| 19-20 | 1-5 | 19-20 | 0-2 |
| 20-21 | 1-4 | 20-21 | 1-3 |
| 21-22 | 1-6 | 21-22 | 2-3 |
| 22-23 | 1-2 | 22-23 | 1-3 |
| 23-24 | 1-4 | 23-24 | 1-1 |
| 24-25 | 1-1 | 24-25 | 2-4 |
| 25-26 | 1-7 | 25-26 | 0-1 |
| 26-27 | 1-2 | 26-27 | 1-2 |
| 27-28 | 1-6 | 27-28 | 2-3 |
| 28-29 | 2-4 | 28-29 | 1-2 |
| 29-30 | 1-3 | 29-30 | 1-2 |
| 30-10 | 1-3 | 30-10 | 1-2 |

Daily bird forecasts for the Cold Lake area were made from 27 August through 30 October 1969 (24 forecasts by P. P. Desfosses, on contract with NRC; 6 by Lt. D. G. McDonald, Project Manager; and 34 by H. Blokpoel, Project Biologist). The bird forecasts were based on the latest (1500 hrs) meteorological information, provided on a special form by the Base Meteorological Office, and covered the 1700-0600-hours period. They were used at the briefing for night flying usually held at 1600 hrs.

The bird forecaster was scheduled to study the previous night's radar film to verify the last forecast but was rarely able to do so since it was not usually available. However, radar film for two nights previous was usually at hand. The forecasts, therefore, were not made under optimal conditions, although the weather data were as good as possible.

B. Postpredicting the intensity of nocturnal migration

Because forecasted weather did not always materialize, migration "after-forecasts" (postpredictions) were based on records of the actual weather. In February 1970, I made the postpredictions without knowing the actual or forecast intensity, and checked them against the actual intensity obtained from radar film before making the postprediction for the next night.

The method for postpredicting was the same as for forecasting. However, using the final results of the study on weather-intensity correlations (Richardson, in press; Richardson and Gunn, in press), pressure tendency and cloud cover were not considered. The weather reports for CFB Cold Lake were provided by the Base Meteorological

Office. When they did not give upper-air wind data this information was obtained from weather maps, provided by the same office.

C. Determining the accuracy of migration predictions

To check the accuracy of predictions, time-lapse films were made of the Plan Position Indicator scope of the 23-cm surveillance radar near CFB Cold Lake (range 75 n. mi.). Desfosses assessed the films for the hourly intensities, using Fryers' (1966) intensity scale - a set of nine pictures showing standard intensities running from 0 (no bird echoes at all) through 8 (the whole scope covered with bird echoes). Assessing the radar films was difficult, and sometimes impossible (Table 2) when "weather" was present on the radar screen or when the radar personnel used special techniques to eliminate undesired echoes, including those of birds. But wherever possible, Desfosses recorded both the intensity as actually seen and an estimate of what it might have been had those techniques not been used. In checking the accuracy of the migration forecasts, I accepted such estimates if they did not differ by more than one unit from the observed intensity. Data were lost because of radar setting, camera failure, radar maintenance and unknown causes. Table 2 shows that 512 hours (57%) of a potential number of 896 (64 nights with 14 hours) were used for this report.

A predicted hourly intensity was considered accurate if it did not differ from the actual intensity by more than one unit.

The accuracy of the weather forecast had to be taken into account since it might influence the results. As the weather forecast was not usually detailed enough to determine its accuracy per hour, I used the

Table 2. Information on 896 potential hours with radar data on nocturnal migration over Cold Lake, Alberta. 27 August-30 October 1969.

| | | |
|---|---|---|
| A. Numbers of hours with film (total 662 hours) | | |
| | Observed and estimated intensities the same | 304* |
| | " " " " differing one category | 208* |
| | " " " " differing more than one category | 22 |
| | Films unassessable | 128 |
| B. Number of hours without film | | 234 |
| Total | | 896 |

*Data used for this report.

following categories per night:

Inaccurate - (a) when the actual wind direction at ground level, at 3,000 feet or at 5,000 feet was clearly in another category of favourableness than forecast during most of the period for which radar data were available, or

(b) when heavy precipitation occurred in extensive areas during most of the period for which radar data were available, while occasional light or no precipitation was forecast and vice versa.

Accurate - when not inaccurate.

To evaluate the accuracy of migration predictions per night I used the following categories:

Accurate - (a) when

$$\frac{\Sigma|\text{predicted hourly intensity} - \text{actual hourly intensity}|}{\text{number of hours with radar data}} < 1.5$$

and (b) when no difference between predicted and actual intensity was greater than 2 and no difference of 2 occurred more than twice in a row.

Inaccurate - when not accurate.

## RESULTS

The results of the migration forecasts and postpredictions for the periods 27 August-30 September and 1-30 October 1969 are given in Table 3. This table shows that the accuracy per hour of the post-predictions for these two periods (90% and 87%, respectively) was higher than that for the forecasts (67% and 77%).

For actual intensities of five or higher (i.e., those of special interest to the military), Table 4 shows that 52% of the total of 130 hours were accurately forecast and 75% accurately postpredicted.

Table 3. Frequency of differences between forecast and actual hourly intensities and between post-predicted and actual hourly intensities, CFB Cold Lake, Alberta. A prediction is deemed accurate if it differs by less than 2 units from the actual intensity. A: 27 August-30 September (277 hours with radar data), B: 1-30 October (235 hours with radar data).

A

| | | Difference between the forecast and actual hourly intensity (left column) and between the postpredicted and actual hourly intensity (right column) | | | | | | | | | | | | | | | | Accurate prediction | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | -5 | | -4 | | -3 | | -2 | | -1 | | -0 | | +1 | | +2 | | +3 | | % | |
| Actual hourly intensity | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | | |
| | 1 | - | - | - | - | - | - | - | - | - | - | 52 | 23 | 14 | 38 | 1 | 6 | - | - | 99 | 91 |
| | 2 | - | - | - | - | - | - | 2 | - | 26 | 2 | 17 | 34 | 3 | 9 | - | 3 | - | - | 96 | 94 |
| | 3 | - | - | - | - | - | - | 12 | - | 8 | 12 | 6 | 9 | 2 | 9 | 1 | - | 1 | - | 53 | 100 |
| | 4 | - | - | - | - | 6 | - | 6 | 2 | 11 | 9 | 2 | 6 | 4 | 18 | 2 | 2 | 6 | - | 46 | 89 |
| | 5 | - | - | 2 | - | 11 | - | 8 | 5 | 11 | 10 | 3 | 13 | 9 | 15 | 4 | 5 | - | - | 48 | 79 |
| | 6 | 2 | - | 3 | - | 4 | - | 9 | 5 | 2 | 13 | 8 | 9 | 2 | 4 | 1 | - | - | - | 39 | 84 |
| | 7 | - | - | 1 | - | 5 | 3 | 2 | 3 | 5 | 6 | 2 | 3 | - | - | - | - | - | - | 47 | 60 |
| | 8 | - | - | 1 | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | | |
| Totals | Numbers | 2 | - | 7 | 1 | 26 | 3 | 39 | 15 | 63 | 52 | 90 | 97 | 34 | 93 | 9 | 16 | 7 | - | 277 | 277 |
| | Percent | 1 | - | 3 | 0 | 9 | 1 | 14 | 5 | 23 | 19 | 32 | 35 | 12 | 34 | 3 | 6 | 3 | - | 100 | 100 |
| | Percent per group | ← 27% | | | 7% | | | → | | ← 67% | | | 87% | → | | ← 6% | | 6% → | | 100 | 100 |

B

| | | -5 | | -4 | | -3 | | -2 | | -1 | | -0 | | +1 | | +2 | | +3 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Actual hourly intensity | 0 | - | - | - | - | - | - | - | - | - | - | - | - | 2 | 1 | - | 1 | - | - | 100 | 50 |
| | 1 | - | - | - | - | - | - | - | - | 2 | - | 26 | 14 | 16 | 33 | 2 | - | 1 | - | 94 | 100 |
| | 2 | - | - | - | - | - | - | - | - | 17 | 8 | 13 | 26 | 4 | 3 | 3 | - | - | - | 92 | 100 |
| | 3 | - | - | - | - | - | - | 15 | 2 | 28 | 18 | 18 | 27 | 6 | 22 | 3 | 4 | 3 | - | 71 | 92 |
| | 4 | - | - | - | - | 5 | - | 9 | 6 | 13 | 12 | 6 | 8 | 3 | 13 | 4 | 2 | 1 | - | 54 | 80 |
| | 5 | - | - | - | - | 2 | - | 3 | 3 | 6 | 6 | 3 | 10 | 5 | 4 | 4 | - | - | - | 61 | 87 |
| | 6 | - | - | - | - | - | - | - | 2 | 2 | 3 | 4 | 2 | 1 | - | - | - | - | - | 100 | 71 |
| | 7 | - | - | - | - | - | - | - | 4 | 2 | 1 | 3 | - | - | - | - | - | - | - | 100 | 20 |
| | 8 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | | |
| Totals | Numbers | - | - | - | - | 7 | - | 27 | 17 | 70 | 48 | 73 | 87 | 37 | 76 | 16 | 7 | 5 | - | 235 | 235 |
| | Percent | - | - | - | - | 3 | - | 11 | 7 | 30 | 20 | 31 | 37 | 16 | 24 | 7 | 3 | 2 | - | 100 | 100 |
| | Percent per group | ← 14% | | | 7% | | | → | | ← 77% | | | 90% | → | | < 9% | | 2% > | | 100 | 100 |

Table 4. Distributions of accurate and highly inaccurate migration predictions.. 27 August - 30 October, 1969. CFB Cold Lake, Alberta.

| | Number of Hours | Accurate Prediction* | | | | Highly Inaccurate Prediction** | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Forecast | | Postprediction | | Forecast | | Postprediction | |
| | | % | # | % | # | % | # | % | # |
| Actual intensity 5 or more | 130 | 52 | 68 | 75 | 98 | 24 | 31 | 3 | 4 |
| Actual intensity 4 or less | 382 | 78 | 299 | 92 | 355 | 6 | 23 | 0 | 0 |
| Forecast (post-predicted) intensity 5 or more | 90 (134) | 64 | 58 | 85 | 114 | 12 | 11 | 0 | 0 |
| Forecast (post-predicted) intensity 4 or less | 422 (378) | 73 | 309 | 91 | 344 | 10 | 43 | 1 | 4 |

* i.e. $|\text{actual hourly intensity} - \text{predicted hourly intensity}| \leq 1$

** i.e. $|\text{actual hourly intnesity} - \text{predicted hourly intensity}| > 2$

Highly inaccurate hourly forecasts totalled 24%, highly inaccurate postpredictions only 3%.

For predicted intensities of five or higher, Table 4 shows that the forecasts were 64% accurate, postpredictions 85%. Forecasts were highly inaccurate for 12% of the 90 hours. There was no highly inaccurate postpredictions.

Table 4 also shows that for hours with actual or forecast intensity of four or less, the postpredictions were more accurate than the forecasts.

Another way to judge the accuracy of the predictions is to consider nights rather than hours (see Methods). Table 5 gives the accuracy per night of the forecasts and postpredictions. Of the 52 nights 52% (27) had accurate forecasts, 87% (45) accurate postpredictions.

Data for the nights with at least one actual hourly intensity of 5 or higher are given in Table 6. Of the 22 such nights, 32% (7) were accurately forecast, and 82% (18) postpredicted.

In all but one case a reasonable explanation for the inaccuracy of the migration forecast was possible. All explanations included one or more of the following factors:

(1) Unusual situation (e.g., an increase in intensity in the early morning).

(2) Inaccuracy of the weather forecast (see Methods).

(3) Faulty use of prediction guidelines (e.g., forecasting very high intensity in October after three consecutive nights with very favourable weather).

Table 5. Accuracy of predictions by nights. Forecasts in the left and postpredictions in the right column. 17 August-30 October 1969. CFB Cold Lake, Alberta.

| Period | Nights with at least 1 hr. usable radar data | % of nights with accurate | | % of nights with inaccurate | |
|---|---|---|---|---|---|
| | | Forecasts | Postpre-dictions | Forecasts | Postpre-dictions |
| 27 Aug - 1 Sept | 4 | 50 | 100 | 50 | 0 |
| 1 Sept- 1 Oct | 25 | 48 | 88 | 52 | 12 |
| 1 Oct -30 Oct | 23 | 57 | 83 | 43 | 17 |
| Total (nights) | 52 | 52 | 87 | 48 | 13 |

Table 6. Accuracy of predictions for nights with at least one hour of intensity 5 or higher. Forecast in the left and postpredictions in the right column. 27 August-30 October 1969. CFB Cold Lake, Alberta.

| Period | Nights with at least 1 hr. by intensity of 5 or more | % of nights with accurate | | % of nights with inaccurate | |
|---|---|---|---|---|---|
| | | Forecasts | Postpre-dictions | Forecasts | Postpre-dictions |
| 27 Aug - 1 Sept | 3 | 33 | 100 | 67 | 0 |
| 1 Sept- 1 Oct | 14 | 29 | 79 | 71 | 21 |
| 1 Oct -30 Oct | 5 | 40 | 80 | 60 | 20 |
| Total (nights) | 22 | 32 | 82 | 68 | 18 |

(4) Use of old guidelines where pressure tendency and cloud cover were considered (these weather factors were not taken into account when postpredicting).

(5) Inexperience in forecasting migration. Since intensities 0 and 8 are rarely recorded they should never be predicted. Instead 1 and 7 or perhaps even 2 and 6, are to be predicted to obtain the greatest amount of accuracy, using the criteria in Methods (when postpredicting this "trick" was used throughout.)

Table 7 shows all nights with an inaccurate migration forecast and possible explanations for the inaccuracies. Where a combination of factors formed the possible explanation, Table 5 gives only those considered as the main part of the explanation.

For the 25 inaccurate bird forecasts, Table 7 shows the following possible explanations: unusual situation (7 times), inaccurate weather forecast (7), faulty use of guidelines (6), use of old system (4), and inexperience in forecasting migration (4). In four cases, a combination of two factors formed the possible explanation. For one case there was no known explanation.

Since an accurate migration forecast based on an inaccurate weather forecast could be considered as inaccurate, the accuracy of the weather forecast was also checked for nights that had an accurate bird forecast. Table 8 shows seven such nights. Accurate migration forecasts for six of these nights could reasonably be explained and may therefore be considered accurate. The migration forecast for 11-12 October had to be considered inaccurate. Therefore the conclusion from Table 5 must be modified slightly to 50% (26) accuracy of the 52 nights, not 52% (27). Conclusions from Tables 3 and 4

Table 7. Accuracy of weather forecast and possible explanations for nights with inaccurate migration forecasts. See text for criteria. 27 August-30 October 1969, CFB Cold Lake, Alberta.

| Date | No. of hours with data | Extremes of intensity | Weather forecast | Poss. expl. inaccuracy migr. forec. | Remarks |
|---|---|---|---|---|---|
| 27-28 Aug | 8 | 2-6 | I* | F* | Occasional rain misjudged. |
| 28-29 " | 14 | 1-6 | I | W* | Winds NW at 10 mph, not variable. |
| 1-2 Sept | 5 | 1-8 | A* | F+U* | Intensity 8 at 2100 hrs. |
| 4-5 " | 13 | 1-3 | A | Y* | Used intensity 1 throughout the night. |
| 10-11 " | 14 | 1-5 | I | W | Winds favourable, not neutral, |
| 12-13 " | 12 | 2-4 | I | W+F | Winds neutral, not favourable. |
| 15-16 " | 14 | 2-5 | A | Y | Intensity 7 for 3 hours. |
| 16-17 " | 13 | 1-5 | A | U | Intensity 5 into headwind. |
| 17-18 " | 9 | 1-5 | I | W | Wind favourable, not unfavourable. |
| 18-19 " | 5 | 3-6 | I | W+F | Winds favourable, not neutral, misjudged precipitation. |
| 19-20 " | 6 | 3-5 | A | U | Intensity 4 at 1700 hrs. |
| 24-25 " | 14 | 2-7 | I | O* | Cloud cover considered. |
| 26-27 " | 6 | 5-7 | I | O | Cloud cover considered. |
| 28-29 " | 7 | 3-7 | A | O | Cloud cover considered. |
| 30S-1 Oct | 9 | 1-4 | I | W | Wind favourable, not unfavourable. |
| 1-2 " | 10 | 1-4 | A | (N) | |
| 4-5 " | 10 | 2-5 | I | W | Wind neutral, not favourable. |
| 5-6 " | 14 | 1-7 | A | U | Intensity 5 at 0600 hrs. |
| 6-7 " | 14 | 3-5 | A | F | Guideline #2 not used. |
| 9-10 " | 12 | 1-4 | I | O+Y | Intensity 1 five hours in a row, cloud cover considered. |
| 10-11 " | 14 | 3-4 | A | Y | |
| 14-15 " | 14 | 1-4 | I | U | Intensity increased in early morning. |
| 15-16 " | 14 | 2-4 | A | U | " " " " " |
| 16-17 " | 12 | 3-4 | A | U | " " " " " |
| 26-27 " | 6 | 1-2 | A | F | Guideline #2 misused. |

*A - accurate
I - inaccurate
F - faulty use of guidelines
W - inaccuracy of weather forecast
U - unusual situation
N - no known explanation
O - use of old system
Y - inexperience in forecasting migration

See text for details.

Table 8. Possible explanations for the accuracy of the migration forecast for nights with an inaccurate weather forecast. See text for criteria, 27 August-30 October 1969, CFB Cold Lake, Alberta.

| Date | Inaccurate part of weather forecast | Possible explanation for accuracy migration forecast |
|---|---|---|
| 3-4 Sept. | Wind at 5,000' neutral, not unfavourable | Precipitation suppressed all migration, regardless wind direction. |
| 9-10 Sept. | Wind at 3,000' neutral, not favourable | Data available only for 1700-2100 hrs. Forecast intensity accurate but higher than actual one (5 and 7 at 2000 and 2100 hrs instead of 4 and 5). |
| 29-30 Sept. | Precipitation from 0100-0600 hrs not forecast | The migration forecast was very low already because of very unfavourable winds at all levels. |
| 2-3 Oct. | Wind at surface favourable, not neutral | Data available only for two hours. Forecast intensity accurate but lower than actual one (1 and 3 at 1800 and 2100 hrs instead of 1 and 5). |
| 7-8 Oct. | Wind at 5,000' neutral, not favourable | The forecast was above average but not yet inaccurate. |
| 8-9 Oct. | Wind at 5,000' neutral, not unfavourable | Precipitation suppressed all migration regardless wind direction. |
| 11-12 Oct. | Winds at 3,000' and 5,000' favourable, not neutral | No explanation. |

would hardly change when data for the night 11-12 October were deleted, and conclusions from Table 6 would not change at all.

For three of the five nights with inaccurate postpredictions, Table 9 shows the following possible explanations: faulty use of prediction guidelines (1 time), unusual situation (1) and a combination of these two factors (1).

## DISCUSSION

The postpredictions were much more accurate than the forecasts for the following reasons:

(1) Weather reports and maps were used for postpredictions instead of forecasts.

(2) The actual intensities of the previous night were carefully checked against the postprediction before making the next postprediction. In this way a good idea was obtained of the general bird situation. As mentioned before (Methods) this was not always possible when forecasting.

(3) All postpredictions were made by the same, presumably most experienced person at leisure; whereas the forecasts were made by one or another of three persons, usually in a hurry.

(4) All postpredictions were made in the winter which eliminated some personal bias (caused by the "nice warm weather" or "migrating geese" observed earlier that day).

(5) Cloud cover and pressure tendency were not considered when making the postpredictions since Richardson (in press) had found that "once [surface] wind direction had been used to predict migration volume at Cold Lake, the use of other weather parameters does not seem

Table 9. Possible explanations of inaccurate postpredictions. See text for criteria and terminology. 27 August-30 October 1969. CFB Cold Lake, Alberta.

| Date | No. hours with radar data | Extremes of intensity | Possible explanation inaccurate post-prediction | Remarks |
|---|---|---|---|---|
| 1-2 Sept. | 5 | 1-8 | U*,F* | Intensity 8 at 2100 hrs. |
| 8-9 Sept. | 14 | 2-7 | F | Over-estimation of unfavourableness of SE wind at 3,000' at 4 mph. |
| 26-27 Sept. | 6 | 5-7 | U | Postpredicted intensities (6 at 2300, 2400 and 0100 hrs) were lower than the unusually high actual intensities (7 from 0100 through 0400 hrs). |
| 1-2 Oct. | 10 | 1-4 | (N*) | Not very inaccurate. |
| 3-4 Oct. | 14 | 2-7 | (N) | Not very inaccurate. |

*U - unusual situation.

F - faulty use of prediction guidelines.

N - no explanation.

See text for details.

to give a statistically improved predictive ability". (The other weather factors used - wind at 3,000 and 5,000 feet and precipitation - were not studied by Richardson).

(6) I aimed at a high rate of "accuracy" (i.e., ±1 unit different from actual intensity) in making postpredictions rather than at the actual intensity. If, for example, the weather situation for a September night was highly unfavourable it still would be unlikely that the actual intensity would be 0 or 1. By predicting an intensity 3, I "covered" both intensity 2 (most likely) and intensity 4 (very unlikely, but more likely than intensity 1).

The postpredictions were made under optimal conditions, the forecasts were not. The fact that (a) the postpredictions had a high rate (87%) of accuracy and (b) 92% of the inaccurate forecasts could be reasonably explained indicates that migration forecasts made under the right conditions could be sufficiently accurate for operational use.

Compared with the results for fall 1968 the predictions for fall 1969 had a slightly higher accuracy:

| | Accuracy forecast % | | Accuracy post-prediction % | |
|---|---|---|---|---|
| | 1969 | 1968 | 1969 | 1968 |
| August-September | 67 | 63 | 90 | 77 |
| October | 77 | 76 | 87 | 92 |

Operational usefulness of migration forecasts. Three flying squadrons at CFB Cold Lake regularly operated at night during fall 1969. Night flying was cancelled on several occasions because a high-density migration was forecast, but details are not available for military

reasons. During the forecast period night-time bird strikes were reported on three nights:

| | Number of reported strikes | Time of strike (MST) | Intensity at time of strike | |
|---|---|---|---|---|
| | | | Actual | Forecast |
| 11 September | 2 | 2030 | 6 | 6 |
| | | 2030 | 6 | 6 |
| 24 September | 3 | 2100 | 5 | 4 |
| | | 2130 | 6 | 4* |
| | | Unknown | - | - |
| 25 September | 2 | 1700-1800 | 3 | 2 |
| | | 2140 | 7 | 7 |

*See Table 7 for possible explanation of inaccuracy.

As was expected, the majority of the strikes happened with high intensity bird migration.

No claim is made that the system is based on a complete understanding of the causation of migration. Table 5 may show why the predictions were wrong but it does not explain why the birds were flying in unexpected intensities (the "unusual situations"). Since the extent of the influence of individual weather factors was unknown, predicting migration was, as in 1968, an art rather than an exact science. Personal bias may, therefore, influence the results, and repeating a prediction may not always give exactly the same results even when done by the same person. Elaborating and rewriting the prediction guidelines may reduce the amount of personal error.

Well prepared migration forecasts can be of considerable value for military operations but it is unlikely that there will be enough

biologists to make migration forecasts at all air bases in Canada. It should therefore be investigated whether it is feasible for the Meteorological Office to use a migration forecast manual to make routine forecasts. Such a study can best be carried out during fall 1970 at CFB Cold Lake. With sufficient support to work under optimal conditions the study should (a) show the usefulness of the best migration forecasts, and (b) determine the feasibility to have forecasts prepared by Meteorological Office staff.

## CONCLUSIONS AND SUMMARY

(1) From 27 August through 29 October 1969 daily forecasts of the hourly intensity of migration were routinely made at CFB Cold Lake covering the 1700-0600-hours period. The forecasts were based on local weather forecasts and were used during briefings for night flying.

(2) To check the forecast system, I later made "postpredictions" - i.e., migration forecasts based on records of the actual weather.

(3) Comparisons of predicted and actual <u>hourly</u> intensities (obtained from radar film) showed the accuracy of forecasts and postpredictions (according to described criteria) as 67% and 90%, respectively, for 27 August through 30 September (277 hours) and as 77% and 87% for 1 through 29 October (235 hours).

(4) Of a total of 52 nights 50% (26) were accurate in forecasts (according to described criteria) and 87% (45) in postpredictions. Of a total of 22 nights with at least one hourly intensity of 5 or higher, 32% (7) were accurately forecast and 82% (18) postpredicted.

(5) The fact that the postpredictions were more accurate than the forecasts is explained and it is suggested that with sufficient support,

experience and care, migration forecasting could be accurate enough to be useful in military operations.

(6) It is recommended that forecasting migration be continued at CFB Cold Lake during fall 1970 and that a feasibility study be made to determine whether the staff of the Base Meteorological Office can make routine migration forecasts.

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