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# Temporal characteristics of night bird migration above Central Israel — a radar study

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**Dinevich L., Matsyura A., Leshem Y. 2003. Temporal characteristics of night bird migration above Central Israel — a radar study. Acta Ornithol. 38: 103–110.**

**Abstract.** The purpose of the research was to find a time frame for the beginning, duration of maximum intensity, and end of nocturnal bird migration. The research was carried out using photo registration on a radar screen during the spring and autumn seasons of 1999–2001. Examination of the average length of daylight at the beginning of migration and the onset of civil twilight yielded a high correlation factor for both spring and autumn. The results showed that, on average, nocturnal migration began at the onset of civil twilight, that is, half an hour after sunset. The time elapsing between the onset of migration and the maximum concentration of migratory birds averaged about 70 minutes in both spring and autumn. Nocturnal migration usually came to an end within the one and a half to two hours after sunrise. We ascertained the seasonal time shift for the onset of nocturnal migration corresponding to the seasonal time shift related to the approach of darkness. The average times of the beginning, maximum intensity and end of nocturnal migration were found to be related to photoperiodic factors.

**Key words:** bird migration, weather radar, time features

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## INTRODUCTION

The problem of temporal daily features of bird migration at night was studied by many investigators (Table 1). Some of them cite data of time characteristics for migration from results of visual supervision of bird flights, which especially in evening and nighttime, could not be accurate. Also, non-specialized radar units used in the research have had limits for detecting the range of birds' characteristics, and their technical characteristics did not allow for estimation of the flight altitudes. Time characteristics of migration depend on local features of territory, weather, and climate; thus the data received in one particular place can differ from similar data of any other region.

Most of the authors specify an exact time for the beginning of migration irrespective of spring or autumn months. Some researchers adhere that night migration begins at the time of sunset; separate researchers specify the beginning of night migration before sunset, at the same time others state that it is after sunset. In addition, the difference of time between the data of some and the data of others varies by about three hours. Moreover, observations carried out in Israel demonstrate that all three of these temporal characteristics of migration have significant daily and monthly variability. Therefore, the task to determine the time characteristics of bird migration is still an important one.

## MATERIALS AND METHODS

Since 1997, research of seasonal bird migrations have been conducted in Israel with the help of meteorological radar MRL5. The radar was located at Latrun (34°98'N, 31°83'E) midway between Tel Aviv and Jerusalem, 18 km southeast

Table 1. Time characteristics of night bird migration according to various studies (from Moreau 1972, Richardson 1978b, 2000, Bruderer 1999). pas — data for *Erithacus*, *Sylvia*, *Turdus*, *Regulus* spp., wad — waders, wf — waterfowl. Methods: r — radar, m — moonwatch, ? — no data available.

| Study (objects) | Locality (method) | Migration start | Migration peak |
|---|---|---|---|
| Lowery 1951 | NE Canada (m) | ? | 22.00–24.00 |
| Richardson 1971, 1972 | E Canada (r) | 40–45 min. after sunset | ? |
| Blokpoel & Burton 1975 | Canada (r) | "after dark" | 21.00–24.00 |
| Graber & Hassler 1962 | USA (r) | ? | 23.00–01.00 |
| Hassler et al 1963 | USA (r) | depending on wind | depending on wind |
| Nisbet 1963 | USA (r) | ? | 2.5–4 hrs after sunset |
| Drury & Nisbet 1964 | USA (r) | 45 min. after sunset | ? |
| Bellrose 1967 | USA (r) | 18.00–19.00 | 22.00–01.00 |
| Graber 1968 | USA (r) | ? | 21.00–24.00 |
| Flock & Bellrose 1970 (wf) | USA (r) | ? | from sunset till midnight |
| Gauthreaux 1972 | USA (r) | 30–45 min. after sunset | 1.5–2.5 hrs after sunset |
| Grimes 1977 (wad) | USA (r) | about 2 hrs before sunset | ? |
| Beason 1978 (wf) | USA (r) | ? | 22.00–24.00 |
| Richardson 1978b | USA (r) | 23–33 min. after sunset | ? |
| Richardson 1979 (wad) | USA (r) | after 0.5–1 hrs after sunset | ? |
| Hall & Bell 1981 | USA (m) | 1–1.5 hrs after sunset | ? |
| Richardson 2000 | USA (r) | 0.5–1 hrs after sunset | ? |
| Lack 1960, 1963 (wad) | England (r) | "soon after sunset" | 21.00–22.00 |
| | | 2 hrs before sunset | ? |
| Parslow 1968 | England (r) | 38–39 min. after sunset | ? |
| Casement 1966 | Mediterranean Sea (r) | 40–50 min. after sunset | ? |
| Alerstam 1972 (pas) | Sweden, Baltic coast (r) | 18.45–19.00 | after 24.00 |
| (wad) | | ? | 18.45–19.00 |
| (wf) | | ? | 18.45–21.00 |
| Alerstam 1976 | Sweden (r) | 32 min. after sunset | 2 hrs after migration start |
| Bruderer 1999 | Israel (r) | 0.5–1 hrs after sunset | 1–2 hrs after sunset |
| Alfia 1995 | Israel (r) | 20.00 | 21.00–22.00 |

of the Ben Gurion International Airport. This location is within the borders of the migratory route, which is a geographical area that has hundreds of millions of birds flying to their wintering sites and back (Leshem & Bahat 1999). Application of high potential meteorological radar on this extensive migration has allowed collection of data on night bird migration over a large territory.

The study is based on data received by using the radar MRL5 during 1999–2001. Application of this high potential radar the study of night bird migration, including the change of intensity and flight direction was associated with time and various heights. The technical characteristics of the MRL5 radar used in our research were described by Dinevich & Kaplan (2000).

Daily time features, which are accepted in astronomy, were used for this research, namely the time of sunset, time of civil twilight (when the center of the sun is geometrically 6 degrees below the horizon for this geographical latitude, corresponds to a half-hour interval after sunset), time of night (when the sun is 18 degrees below the horizon), and time of sunrise.

Reception of track, instead of dot radio echoes from the birds, was carried out in a simple way. For this purpose, the camera lens was opened during a given (in our case 3 minutes) time frame while performing radar screen shots. The radar diagram rotates at the speed of 6 revolutions per minute. Thus, the dot radio echo from a moving bird forms a line on the radar screen, which we have named a track. The track from the air plane represents a dotted (faltering) line.

To prove the time of the beginning of migration more precisely, the screen shots before sunset were carried out with a periodicity of 10 minutes with a successive increase in the angle of elevation from 0 up to 5–6 degrees with a range increment of 1.5 degrees. Thus, aerial elevation was carried out with a range increment equal to the width of its diagram for a wavelength of 10 cm. In later nighttime, these shots were carried out using the same technology, but with an interval of 30 minutes, and after the passage of the peak period — an interval of one hour. Sometimes, screen shots were performed throughout the night until 7.00 in the morning.



The temporal radar-tracking parameters of migration are the following:

— the moment of evening time when there were a great number of nonchaotically focused radio echoes that appeared as tracks (stripes) on the radar screen, and were formed by moving birds;

— the moment of nighttime with a maximum quantity of radio echoes as in the above-stated tracks;

— the moment of time when these radio echoes became weak, and their orientation became chaotic, which means that the migration has almost stopped.

The time units for this current research were the following: the beginning of migration $t_1$, maximal intensity of migration $t_2$ and end of migration $t_3$ in a daily range of time.

**Time of the beginning (start) of migration $t_1$.** Radar station MRL5, because of its characteristics, can detect all changes in any quantity of radar-tracking signals from birds, including their distribution regarding height in day and nighttime and independently based on weather conditions (Dinevich & Kaplan 2000, Dinevich et al. 2000). There is an opportunity to choose the number of bird radio echoes as an experimental unit that can be easily measured with the help of radar. The birds are present in the air space almost all the time. However, the usual flight directions of these birds are chaotic. For the beginning of the night migration we chose a time when the birds' radio echoes were detected in a radius of review (30 km for nighttime) looked like tracks directed in a rather close direction on the radar screen. In spring, this direction for our region was to the north, and in autumn — to the south. Also, the intensity of bird flight on radar screen accounts for no more than 1–2 points on an eight-point scale of screen saturation (Richardson & Gunn 1971), and then quickly grows.

**Time of the maximal (peak) intensity of migration $t_2$.** The moment of night when the quantity of strips from the birds' radio echoes reaches its maximum value is accepted as the time of maximal intensity of migration.

**Time of end of migration $t_3$.** The moment when the number of strips from the birds' radio echoes decreases up to a minimum value and their orientation in space becomes chaotic is accepted as the time of the end of migration.

During the analysis, about 10 000 photos (from more than 600 days) were processed. There were also constant visual supervisions on the radar screen with permanent registration of the information in a special diary. The long sequences of data collected in autumn and spring of 1999–2001 were used for the analysis of the first two characteristics $t_1$ and $t_2$. The estimation of data sufficiency gave us the basis to believe, that the received results for the studied region have a high statistical significance and can be presented to researchers for discussion. The parameter $t_3$ has not as long a data sequence. It was measured only selectively within 33 days of two incomplete autumn months of 2001, and thus the estimations of characteristics are only preliminary.

Data smoothing was made using the standard program by a method of sliding average with Step 4, used as an averaging of complex data.

## RESULTS AND DISCUSSION

### Time of the beginning (start) of night migration

The missing data for holidays, days off, and days allotted for repair of the equipment total 110 days for three years. The data for the missing days of supervision were equated to the last day with correct measurement before a missed day. Such an approach creates an error in estimating results, but in such a long experiment (630 days for three years) these missing days cannot have an essential influence on the general picture of migration. Deviations of the time of the beginning of night migration reach 2.5 hours in proximate days. Nevertheless, the curve gained by averaging this characteristic is well coordinated to the curve of changes in the time of civil twilight (Fig. 1).

Correlation between the averaged time of the beginning of night migration and three astronomical time characteristics had high value (Table 2).

We discovered regularity in the distribution of the average time of the start of migration. The later the sun sets in the spring, the later the night migration began. The earlier the sun sets in autumn, the earlier the night migration started. The start of migration coincided well with the civilian twilight (Table 2). Thus the primary factor for the beginning of night migration is a photoperiodic one — daylight hours.

Night migration began with the moment darkness approached, and there is a seasonal shift in this time. This shift coincides well with a similar one in the time of approach of civil twilight. It is noticed also that roughly half an hour before the time of sunset, the usual diurnal bird flights cease almost completely, and renew only with the beginning of night migration. Nevertheless, significant

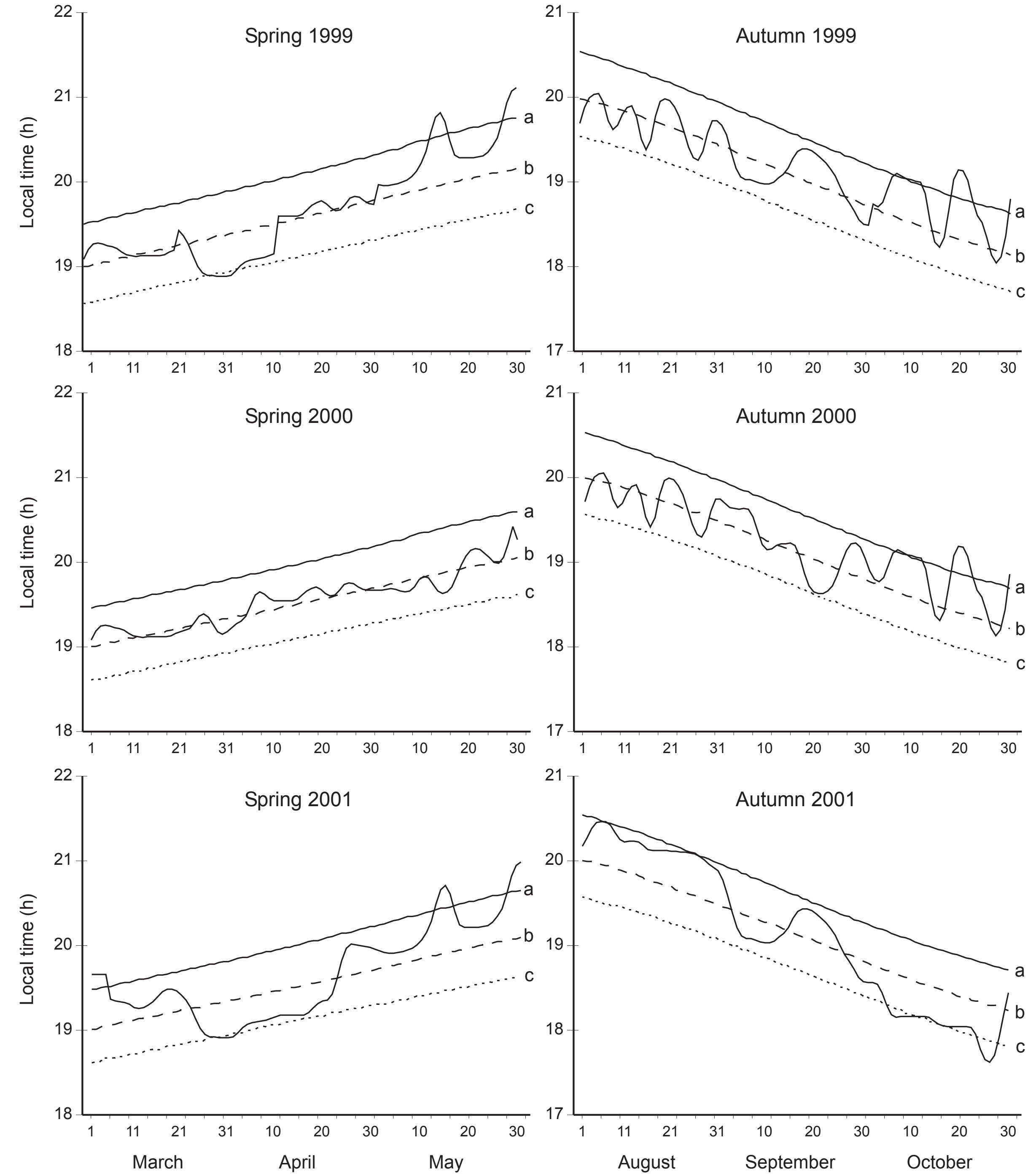


Fig. 1. Beginning of night migration (local time) related to the time of night (a), civil twilight (b) and sunset (c) in spring and autumn 1999–2001. Smoothed curve — sliding averages.

daily deviations from the revealed average values are connected to some other causal reasons which should be investigated further. Fluctuations in time of the beginning of night migration were substantially connected to the weather conditions (presence of rain, strong wind, and dense overcast). However, weather conditions are not the only cause.

Thus, we have chosen the time of the approach of civil twilight for the indicator value of time for the beginning of night migration for this region.

### Time of the maximal intensity of night migration

Peak of migration during night time matched to the start of night migration (Fig. 2). The difference



Table 2. Correlation (index r) between time of night migration and chosen astronomical parameters. Pearson coefficients, all are significant at $p < 0.001$.

| | Sunset | | | | Civil twilight | | | | Night | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time feature | 1999 | 2000 | 2001 | total | 1999 | 2000 | 2001 | total | 1999 | 2000 | 2001 | total |
| Start time | 0.83 | 0.78 | 0.82 | 0.81 | 0.84 | 0.79 | 0.90 | 0.85 | 0.84 | 0.78 | 0.87 | 0.83 |
| First peak | 0.74 | 0.71 | 0.80 | 0.75 | 0.74 | 0.71 | 0.85 | 0.77 | 0.75 | 0.71 | 0.84 | 0.77 |

between the time of the beginning of migration and the time of its maximum intensity averaged about 70 minutes in spring and autumn (Table 3). Average time of the beginning of night migration almost coincides with the time of civil twilight, and the average means that it is increases from 19.20 in the beginning of spring to 21.00 at the end of spring and on the contrary decreases from 20.00 in the beginning of autumn to 18.20 at the end of autumn.

The value of changes in the time of the beginning of night migration differs by more expressed stability in relation to the time of civil twilight. For example (Table 2) the correlation factors between the time of civil twilight and the averaged time of start and the daily peak of night migration are, therefore, equal to 0.813 and 0.749 (Table 2). The same difference is very noticeable on the appropriate curves (Fig. 2) Variations of the curve of night migration peak were more common and their amplitudes more significant, than on the curve at the beginning of migration.

From the data in the literature (Richardson 1990, Bruderer 1999), the beginning of night migration is mainly triggered by waterfowl and waders. The

Table 3. Temporal characteristics of night migration and astronomical parameters, data from 1999–2001.

| | Spring | | Autumn | |
|---|---|---|---|---|
| | Mean | Min.–Max. | Mean | Min.–Max. |
| Start of migration (S, local time) | 19.44 | 18.40–22.08 | 19.10 | 17.35–20.52 |
| Time of maximum intensity (M, local time) | 20.51 | 19.54–22.21 | 20.17 | 18.27–22.04 |
| Difference between S and M (min.) | 68 | 13–119 | 67 | 31–116 |
| Difference between S and civil twilight (min.) | 8 | 44–129 | 5 | 44–60 |

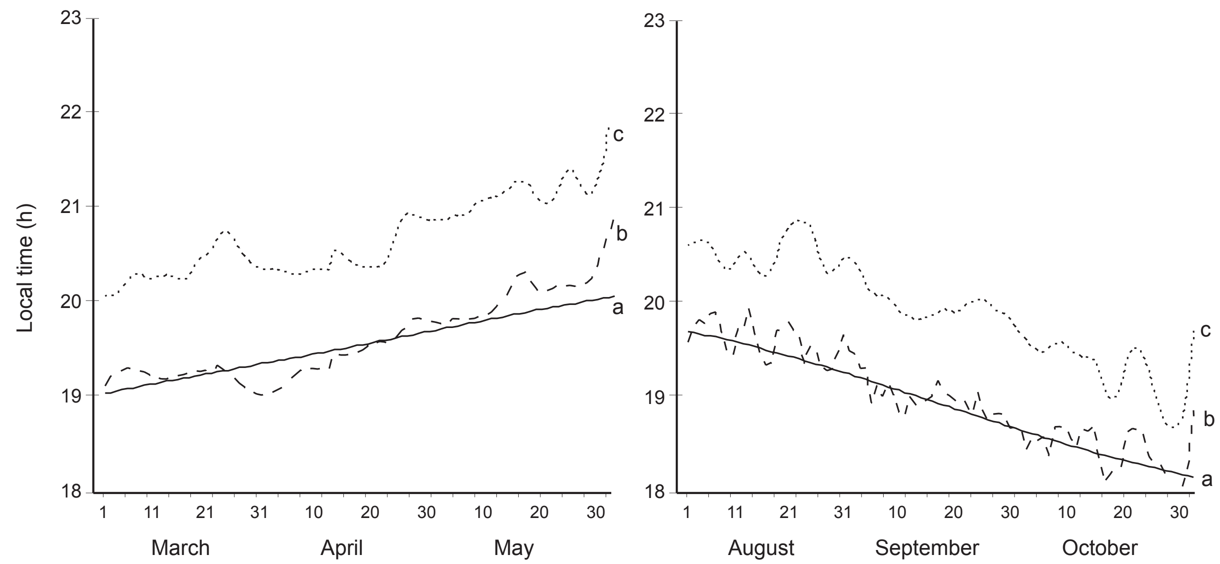


Fig. 2. Time (smoothed curves) of the beginning (b) and maximal intensity (c) of night migration in relation to the time of civil twilight (a), 1999–2001.

passerines that comprise the quantitative majority of the migratory stream determine the maximum of intensity of night migration (Richardson 1990, Bruderer & Leichti 1995, Bruderer 1999). Largely, it is the flight of single birds or small groups that begin the migration from various roosting sites. The affinity or remoteness of these birds to the radar defines the time of maximal saturation of the screen. The choice of roosting sites is determined by the presence of fodder resources and the physiological condition of birds before (in autumn) or after (in spring) crossing of ecological barriers like Negev desert. By virtue of the morphometric and aerodynamic features, the passerines, in comparison to waterfowl, are more influenced by adverse weather conditions. This factor also determines the variability of time of the maximal intensity of migration.

Birds migrating early spring have different timing than other migrants — these birds start their flights after the time of civilian twilight (Fig. 2). This phenomenon could be caused by bird specific composition and weather conditions corresponding to these time periods.

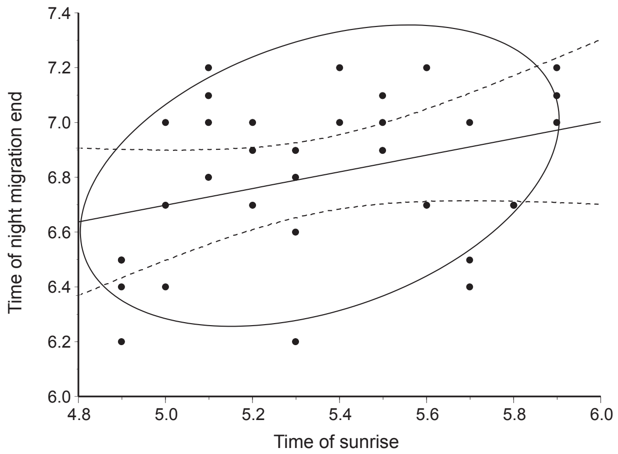


Fig. 3. Changes in time of night migration end towards time of sunrise for 33, casually selected days of autumn 2001. The values of time are submitted as decimal fractions (i.e., 60 min corresponds to 1). Value of each experimental point on this diagram is designed as an average from three appropriate points of each experimental year. Time of migration end (y) = 5.2 + 0.30 x (time of sunrise), p = 0.01.

**Time of end of night migration**

As already indicated, the volume of the data on the time of the end of night migration ($t_3$) is not sufficient for exact estimations. Therefore, the results of the research submitted in this paragraph demonstrate preliminary estimations of characteristics for discussion of the chosen technique.

After 23.00–24.00 the intensity of night migration weakened. The minimum came by five o'clock in the morning, and by seven the migration rate was almost zero. The index of saturation of the radar screen with the tracks from moving birds felt to a value of 1–3.

Night migration continued after sunrise with "languid" intensity still occurring for almost one and a half to two hours. This factor was noted in the research in the Arava Desert (Bruderer 1999). Many night migrants, especially herons, ibises and spoonbills, often continue their flight after the approach of morning.

In the diagram showing the changes in the time of the end of night migration (Fig. 3), the disorder of points has formed some graph area that is characterized by regression line and lines of confidential interval of normal distribution.

The continuous lines in this figure represent lines of regression and confidential interval of normal distribution with a factor of 0.95, i.e., 95 % of all cases, which can be described by the area of regression, are situated in graph limits. The faltering line reflects a confidential interval of regression. The confidential interval determines the borders in which the statistically significant values of regression are situated (Fig. 3).

The concentration of experimental points within the regression line is small. Nevertheless, the curve and area of regression $t_3$ even for the short autumn period tend to grow as well as is the case with parameters $t_1$ and $t_2$. The later the sun rises, the later the night bird migration stops.

## CONCLUSIONS

The following results of the research are offered for discussion:

— nocturnal bird migration above Central Israel begins on the average from the moment of approach of civil twilight that, for this geographical latitude, corresponds to a half-hour interval after sunset;

— the interval between the time of the beginning and the maximal concentration of night migration averages about 70 minutes both for spring and autumn periods;

— migration is not uniform during the nighttime. Its sharp recession, as a rule, falls to the time period of 23.00–24.00. By 5 o'clock in the morning, migration has reduced by up to 1–2 points based on an 8-point scale. The end of night migration comes between one and a half to two hours after sunrise;



— time characteristics of night migration have significant daily variability. Occasionally, the amplitude of time of the beginning of migration, even for proximate days, reaches about 135 minutes. The maximal deviation from the average time of the beginning of migration for the experimental period is 144 minutes in spring and 95 minutes in autumn;

— the seasonal shift in the time for the beginning of the night migration was determined. This shift corresponds to a similar seasonal shift for the time of the approach of darkness;

— the averaged values of time for the beginning, maximal intensity, and end of night migration are caused by photoperiodic factors;

— the birds, migrating early spring have different timing of migration than other migrants. This phenomenon could be caused by weather and bird specific composition for the corresponding period;

— dynamics of time of maximal intensity of night bird migration on various days and months matches a pattern of similar changes in the time of the beginning of night migration in general. The curve of time for maximal concentration of night migration has a larger variability on frequency and amplitude than similar parameters of the curve of time for the beginning of night migration. Probably, this difference is caused by the influence of weather. Additionally, the remoteness of roosting sites and feeding places of night migrants related to the radar disposition could be significant as well. The maximum night concentration of these birds on the radar screen comes then when the birds enter the detection zone of the radar after take-off from various feeding and roosting sites.

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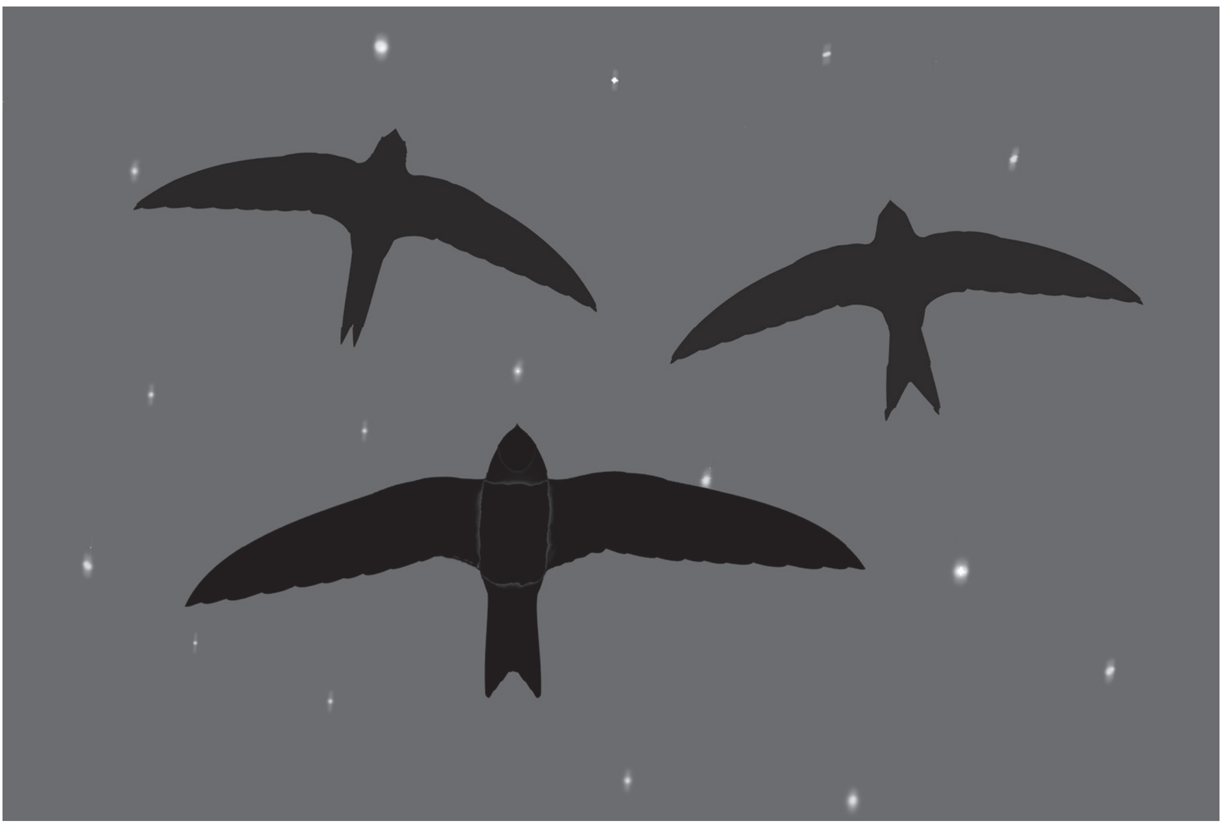
STRESZCZENIE

**[Nocna dynamika przelotu wędrówkowego ptaków nad środkowym Izraelem — badania radarowe]**

Celem pracy było poznanie pory wieczornego początku i porannego zakończenia przelotu, oraz pory jego głównego nasilenia w nocy. Zagadnienie to było już przedmiotem zainteresowania szeregu badaczy (Tab. 1) w różnych krajach. Materiał stanowiący podstawę pracy zebrano w sezonach wędrówek wiosennej i jesiennej w latach 1999–2001, przy wykorzystaniu lotniczego radaru meteorologicznego zapewniającego dużą precyzję śledzenia przelotu ptaków.

Stwierdzono, że początek przelotu następował najczęściej w czasie zmierzchu, t. j. około pół godziny po zachodzie słońca (Fig. 1 i 2, Tab. 2 i 3). Największe nasilenie przelotu, wiosną i jesienią, następowało około 70 min. po jego rozpoczęciu, a zakończenie — półtorej do dwóch godzin po wschodzie słońca. Te parametry przelotu wykazywały znaczną zmienność w różnych dniach (Tab. 3). Przesuwały się też w ciągu trwania sezonu stosownie do zmieniającego się czasu trwania dnia (Fig. 2), co wskazuje na uwarunkowanie przelotu czynnikiem fotoperiodycznym.



*T. Cofta*