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UDK 574.2:574.3

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PRELIMINARY RESULTS OF RADAR OBSERVATION OF NOCTURNAL BIRD MIGRATION IN ISRAEL

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The results of radar-tracking supervisions over the night migration in Israel are submitted. The determination of flight altitudes, flight speeds, heights of maximum birds’ concentration, and migratory directions was performed. The average flight altitudes of night migration were 985 m in autumn and 1465 m in spring of 1998-2000, maximum flight altitudes were 2068 m and 2655 m correspondingly. The mean track direction of the night bird migration is 183° in spring and 6° in autumn. The migration of waterfowl over the Mediterranean Sea in the low altitude band was registered. Their average headings differ from the general migratory path, averaging 135° in autumn and 315° in spring. The average birds’ groundspeed was 14 m/s (50 km/h) in spring and 13 m/s (47 km/h) in autumn.

Key words: Israel, radar, nocturnal bird migration.

О В. Мацюра

ПОПЕРЕДНІ РЕЗУЛЬТАТИ РАДАРНИХ СПОСТЕРЕЖЕНЬ НІЧНОЙ МІГРАЦІЇ ПТАХІВ В ІЗРАЇЛІ

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Представлено результати радарних спостережень за нічною міграцією в Ізраїлі. Виконано оцінку висот польотів, швидкостей польотів, напрямків міграції та висот максимальної концентрації птахів. Середні висоти польотів склали 985 м восени і 1465 м навесні в 1998-2000 рр. Максимуми висот польотів склали 2068 м і 2655 м відповідно. Середній напрям нічний міграції був 183° навесні та 6° восени. Була відзначена міграція водоплавних птахів над

Середземним морем на невеликих висотах. Напрямок прольоту водоплавних птахів відрізнявся від головного вектору міграції - 135° восени і 315° навесні. Середні швидкості міграції склали 14 м / с (50 км / ч) навесні і 13 м / с (47 км / ч) восени.

Ключові слова: Ізраїль, радар, нічна міграція птахів.

А. В. МАЦЮРА

ПРЕДВАРИТЕЛЬНЫЕ РЕЗУЛЬТАТЫ РАДАРНЫХ НАБЛЮДЕНИЙ НОЧНОЙ МИГРАЦИИ ПТИЦ В ИЗРАИЛЕ

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Представлены результаты радарных наблюдений за ночной миграцией в Израиле. Выполнена оценка высот полетов, скоростей полетов, направлений миграции и высот максимальной концентрации птиц. Средние высоты полетов составили 985 м осенью и 1465 м весной в 1998-2000 гг., максимумы высот полетов составили 2068 м и 2655 м соответственно. Среднее направление ночной миграции было 183° весной и 6° осенью. Была отмечена миграции водоплавающих птиц над Средиземным морем на небольших высотах. Направление пролета водоплавающих птиц отличалось от главного вектора миграции - 135° осенью и 315° весной. Средние скорости миграции составили 14 м/с (50 км/ч) весной и 13 м/с (47 км/ч) осенью.

Ключевые слова: Израиль, радар, ночная миграция птиц.

Israel is a major flyway for migrating birds that breed in the western Palaearctic and winter in Africa (Moreau, 1972). Numerous studies have been devoted to soaring bird migration over Israel (Yom-Tov, 1988, Leshem & Yom-Tov, 1996, Shirihai et al., 2000). Due to technical constraints, nocturnal migration is not studied as intensely. The application of radar in the ornithological studies helps to obtain reliable data on the nocturnal migration. Several studies describe nocturnal migration in Israel (Bruderer, 1994, Bruderer and Leichti, 1995, Alfia, 1995). The huge concentration of nocturnal migrants requires the development of systematic radar-tracking techniques covering the bird migration routes. The systematic radar-tracking of nocturnal bird migration over central Israel began in 1997 (Dinevich et al., 2000). The aims of this study were to apply techniques developed for systematic migration tracking to describe and quantify spring and autumn migration over central Israel.

MATERIAL AND METHODS

The meteorological radar station MRL5 was used for the long-range observations of nocturnal bird migration. The MRL5 has two wavelengths 3.2 and 10 cm, and therefore has a high capacity to detect the birds (Dinevich et al., 2000). For specifications and performance of the radar see Abshayev et al., 1980.

The high potential dual-band meteorological radar MRL5 is located in Latrun, Central Israel (34´98´´N, 31´83´´E; 270 m a.s.l.). The data of six migratory seasons (three springs and three autumns) were collected between 1997 and 2000, comprising more than 600 nights of observations and of about 40,000 photographs.

In 2001-2002, the data on flight directions and speeds of more than 20,000 nocturnal migrants were collected by the direct supervision and measurements of radio echoes on the radar screen and on the oscilloscope.

Recording radar echoes

Initially, time-exposure photography was used to record information. The radio echoes from various reflectors, including birds, clouds, and hills are simultaneously observed on the radar screen. In order to identify bird echoes a simple yet efficient system was developed. A 35mm camera was used to monitor the radar screen. During a three-minute exposure 18 revolutions of the radar beam were recorded. Using time-lapse photography, single consecutive echoes of bird movement were recorded as tracks. The length of a track can be used to calculate flight speed. Stationary echoes, which do not change their spatial position in time, are not reflections from birds and considered ground clutter. These echoes are generally formed by the reflections from the hills, high buildings, trees, and the reflections from the side lobes. Echoes from planes can easily be identified because of the high flight speed.

Guided a radar beam strictly toward the north or toward the south, we obtained the data on bird speed and direction by observing of the shift of dot signal for the preset interval (three minutes, for example) on the radar screen or on the oscilloscope. The vertical scanning were performed in each hourly series of observations at 3.2 cm wavelength in four azimuths (0°, 90°, 180° and 270°; sometimes we executed these measurements in two azimuths 190° and 270°). We extracted the data on distribution of birds' heights and altitudes of the maximal birds' concentration from the radar images. The error in calculation was equal to half of the cross-section diameter of directional diagram. For 3.2 cm wavelength at the distance of 10 km the error does not exceed 50 m, at the distance of 25 km – 100 m.

Two databases were used for the calculations. One database included the information from radar images of conical scanning at various altitudes; another one was consisted of the records of single birds' tracking during the direct observation over the radar screen or the oscilloscope in the manual aerial mode. The direction and speed of bird movements were calculated from well-allocate tracks on the radar screen.

RESULTS AND DISCUSSION

In spring the average altitudes of the maximum birds' concentration were higher, than in autumn. So, in 1999, this height was 1490 m in spring (SD = 578.91) and 980 m in autumn (SD = 445.84); in 2000 – 1440 m (SD = 605.35) and 990 m (SD = 504.32) respectively. On separate days, the heights of the maximal birds' concentration attained 2000 m in autumn and even more than 3000 m in spring. The absolute height of the maximum birds' concentration in these years was noted in the spring of 1999 and composed 3750 m.

The maximum flight height for the period of autumn 1998-2000 was 2068 m (SD = 755.35), for the spring period it was 2655 m (SD = 760.07). During all considered periods the birds flew higher in spring than in autumn. The flight heights were: in autumn of 1998 – 1808 m (SD = 741.30), in 1999 – 2557 m (SD = 466.75), in 2000 – 1977 m (SD = 785.25); in spring of 1999 – 2861 m (SD = 601.97), in 2000 – 2429 m (SD = 850.49). In spring the upper altitude of bird flights grows from March to May; in autumn the height of migration either insignificantly decreases from August until November or it practically does not change, it decreases only at the end of November - Fig.1.

The probable reason for this change in the flight heights is the weather conditions. In spring, from March to May, the temperature of the atmosphere increases together with the temperature of a spreading surface; the level of tropopause sharply rises, and the positive convective streams are observed more often above the land. The influence of breeze processes plays an important role in the formation of steady convective streams above the land surface. During this period the sea is not sufficiently warmed yet. During daytime the land is warmer than the sea, in the first half of the night the contrasts of temperatures between the sea and the land are never equal. These factors lead to the unstable stratification of the air temperature above the land and cause the airlift.

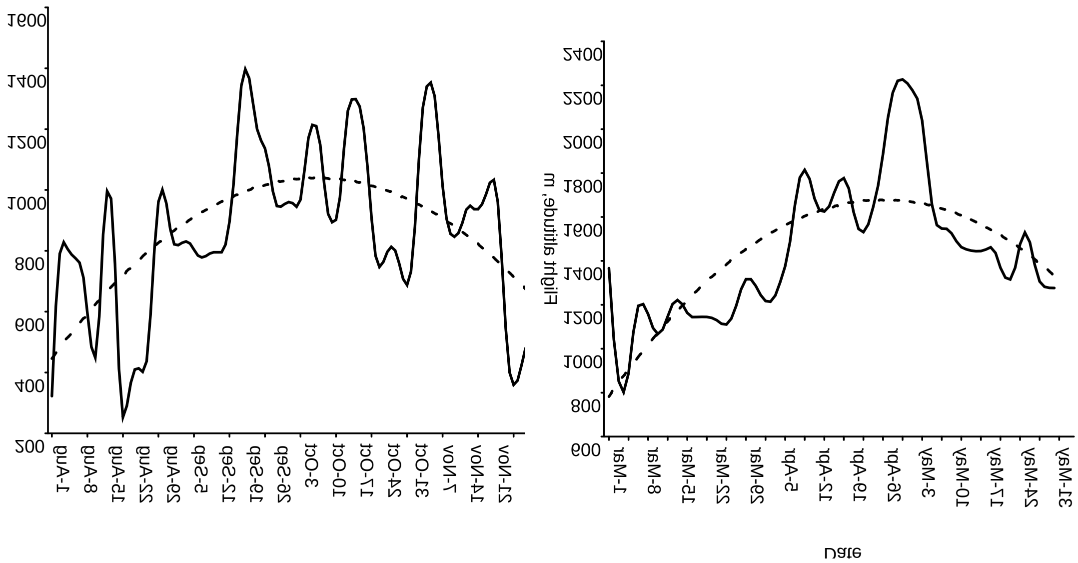

Fig. 1. The average flight heights of night bird migration in spring and autumn 1998-2000; dashed lines - the smoothed curves.

This process at the transition period from the summer to the autumn in the conditions of Israel develops in another way. In autumn, the spreading surface and the lower layers of atmosphere in Israel are warm, and they are slowly changed into the autumn type of the weather. The contrasts of temperature between the sea and the land are considerably less than in spring. The alignment of temperatures of the sea and the land begins in the evening. At night the sea becomes warmer than the land; the convective component above the land is the negative. Only at the end of November is a temperature drop registered, accompanied by the reduction in the maximums of flight altitudes. The warmer the month (except for August in which the flights begin), the higher the maximal flight height.

Two factors could be the reasons for this dependence:

- meteorological: increase of tropopause level and the temperature of the spreading surface. Thus birds aspire to fly in the cooler air layers.

- ornithological: change of the migratory birds' specific composition during the different periods of spring and autumn.

The mean direction of the night migration in autumn was 183°. In spring the pattern of distribution of flight directions is directly contradictory to the autumn – the birds fly in the opposite direction with the small deviation to the east, caused by correction for the western wind. The mean direction of spring night migration is 6°.

For the analysis of directions of bird migration from the ground surface to 2000 m four altitude bands in steps of 500 m were selected. Comparison of the directions of bird flights according to these bands revealed some distinctions in the flyways (Table 1).

We established the increasing of the spectra of migratory flight directions with climbing motion in spring and autumn. The probable reason for this fact can be the aspiration of birds to use the wind for the optimization of power expenses during the distant flights. The wind speed increases with the height in the troposphere. We've also concluded that the large-scale circulating processes in our region govern the direction of wind in the upper air, which coincides with the direction of bird migration (see Jaffe, 1988).

In the lower altitude band (below 500 m), we noted the migration of birds to the side of the Mediterranean Sea in spring and from the side of the Mediterranean Sea in autumn. The sector of these directions differs from the general sector of seasonal migrations, averaging 135° in autumn and 315° in spring.

In most cases these flights were observed during the first two hours after the beginning of night migration at altitudes from 250 m to 350 m. The probable explanation of this deviation it is the migratory flight of waterfowl over the Mediterranean Sea in low altitude band.

Our experimental data are confirmed by the conventional fact, that night migration is triggered by the waterfowl (Bingman et al., 1982, Jones, 1985, Kerlinger and Moore, 1989, Alerstam, 1990, Bruderer and Liechti, 1995) and well correspond to the regional schemes of waterfowl migration suggested by Yom-Tov (1988).

Table 1

Circular statistics data for the night migratory birds' headings
($p<0.001$, Rayleight test of uniformity)

Altitude band, m	Mean vector, μ˚	Circular SD,˚	Length of resultant vector, r˚
Autumn			
0-500	356.90	18.01	0.94
500-1000	0.37	11.89	0.95
1000-1500	17.26	14.79	0.96
1500-2000	12.13	17.34	0.97
Spring			
0-500	173.80	19.57	0.95
500-1000	187.08	12.36	0.98
1000-1500	185.15	14.23	0.97
1500-2000	187.53	15.98	0.96

The distribution of speeds on heights in autumn and spring is shown in Fig. 2 (in this research we measured the birds' flight speed concerning the place of radar location, i.e., groundspeedand were not considered the wind influence).

The average speed of bird night migration in spring was about 14 m/s (50 km/h; n = 9350), more than 24 % of all birds fly in the range from 10 m/s to 12 m/s, about 35 % - in the range from 12m/s to 14 m/s, and almost 27% - in the range from 14 m/s to 16 m/s.

Average speed of bird night migration in autumn was about 13 m/s (47 km/h; n = 11320), about 7 % of all birds fly in the range from 10 m/s to 12 m/s, about 75 % - in the range from 12 m/s to 16 m/s and almost 21 % - in the range from 16 m/s to 18 m/s.

We've estimated the tendency of birds to increase flight speed with the climb in spring. In autumn such speed increase was insignificant; moreover, at the transition from one air layer to the next one the flight speed was not changed and even reduced.

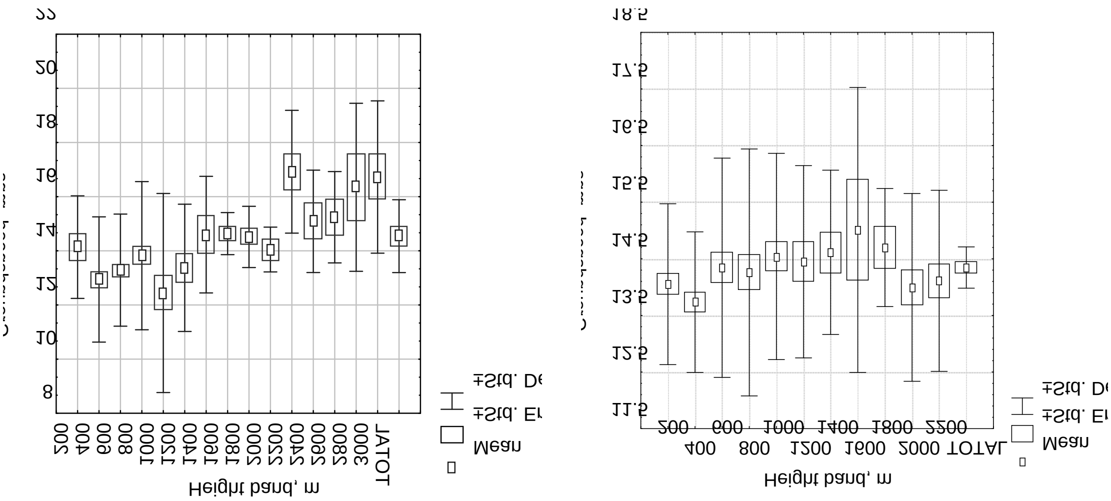

Fig. 2. The box plots of bird groundspeeds per altitude bands
in spring (left) and autumn (right) 2001.

CONCLUSIONS

1. The maximum flight altitudes of night migration were 2068 m in autumn and 2655 m in spring of 1998-2000. In spring the altitude grow from March to May, in autumn the height of migration either insignificantly decreases from August until November or it practically does not change. It begins to decrease only at the end of November. Absolute maximum of flight altitude was 5000 m in spring of 2000 and 6000 m in autumn of 1999.
2. The average heights of the maximum concentrations of birds were 1490 m in spring and 980 m in autumn of 1999; 1440 m and 990 m – in spring and autumn of 2000 respectively. The upper height of the maximum birds' concentration was registered in spring of 1999 and composed 3750 m. During investigated period the birds flew higher in spring than in autumn.
3. The mean track directions of night migration are 183° in autumn and 6° in spring.
4. The migration path over the Mediterranean Sea in spring and autumn was noted. The average headings differ from the general migratory path, averaging 135° in autumn and 315° in spring. The number of birds, migrating in the specified directions, is considerably greater in autumn than in spring. Migratory flights of waterfowl over the Mediterranean Sea can be the probable explanation of this deviation from the general migratory direction in the lower altitude band.
5. The average groundspeeds of nocturnal migrants were 13 m/s in autumn and 14 m/s in spring.

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