THE RING 30, 1/2 (2008) DOI 10.2478/v10050-008-0002-5

SOME CHARACTERISTICS OF DAYTIME BIRD MIGRATION IN ISRAEL: RADAR MONITORING DATA

Leonid Dinevich and Yossi Leshem

ABSTRACT

Dinevich L., Leshem Y. 2008. *Some characteristics of daytime bird migration in Israel: radar monitoring data*. Ring 30, 1/2: 3-17.

Bird-aircraft collisions often lead to severe plane crashes. An ornithological radar system aimed at preventing such collisions was developed and has been in operation in Israel for over three years. The system enables radar monitoring of bird migration in spring and in autumn, and yields the data in the form of special charts that are sent on-line every 15-30 min to air traffic control bodies. The data enables flight dispatchers to locate areas of massive bird concentrations, as well as directions and altitudes of bird flights, in order to channel the air traffic accordingly.

In addition, it is of high importance to have statistics on seasonal transcontinental bird migrations in order to perform long-term planning of air traffic, especially in the areas crowded with aircraft.

We analysed the radar data collected over several years, and on this basis determined the main statistical characteristics of daytime bird flights over central Israel, including: (1) average and maximum flight altitudes, (2) time of the day and the season when bird migration is especially intensive, (3) dominating directions and velocities of flights.

It was found that average daily altitude maximums of bird flights (in relation to the sea level) were within the range of 1200-3500 m in autumn, and within the range of 1000-2700 m in spring. The absolute flight maximum reached 4300 m in autumn and 3700 m in spring. In autumn, flight altitudes were higher than in spring.

The altitudes of maximum bird concentrations reached 600 m in autumn, and only in rare cases rose to 650 m, while in spring the corresponding figures were 500 and 600 m. Both in spring and in autumn, the average altitude of maximum bird concentration was located within the range of 250-400 m.

The dominant flight direction for day migration was 190-220° in autumn and 10-50° in spring.

In our study, we did not observe any pronounced impact of wind direction on the direction of bird flights, neither close to the ground level nor at the height of 600 m. In Israel, both in autumn and in spring, the winds have a distinct occidental component, and at the height of 600 m the dominant wind directions are W-NW in autumn and W-SW in spring, *i.e.* at the angle of approximately 90° in relation to the directions of seasonal bird migrations.

The average ground-speed of seasonal migrations was found to be 14 m/s in spring and 15 m/s in autumn, the minimum and maximum ground-speed values of 8 and 18 m/s, respectively. At the same time, average monthly grounds-speed values at the altitude of 600 m, at 11.00 *a.m.* local time, were found to be within the range of 4-7 m/s in autumn and 3-6 m/s in spring.

The peak of day migration intensity was observed within the time interval from 12.00 to 1.00 *p.m*. The spring migration started at the beginning of March, reached its monthly peak in April and came to the end in late May. The autumn migration started at the middle of August, reached its monthly peak in September and came to the end in November.

The results obtained in the present study should be applied for ensuring air-traffic safety in periods of bird migration and also can be of special interest for ornithologists.

L. Dinevich, Y. Leshem, George S. Wise Faculty of Natural Sciences, Dept. of Zoology, Tel Aviv University, Ramat Aviv, 69978, Israel, Tel/fax: +972-640-60-10, E-mail: dinevich@barak-online.net

Key words: radar ornithology, radar meteorology, bird migration, birds, radar monitoring, ornithology

INTRODUCTION AND PROBLEM DESCRIPTION

Israel lies on the route of intensive day migration of soaring birds. (Yom-Tov 1988, Leshem 1992, Bruderer 1994, Alfia 1995, Bruderer and Leichti 1995, Shirihai *et al*. 2000). Taking into account the fact the airspace over Israel is highly crowded with various kinds of aircraft, it is of utmost importance to know the migration parameters of large flocks of birds in order to ensure high level of air-traffic safety.

High-potential meteorological radar MRL-5, mounted in Latrun at the height of 270 m a.s.l., significantly enabled to expand the scope of monitoring large flocks of migrating birds over vast areas. The research conducted by means of the radar enabled to develop an algorithm of bird echo selection against the background of other reflecting objects. This algorithm serves as the basis for on-line radar monitoring of bird migration round the clock (Dinevich *et al*. 2004, Dinevich and Leshem 2006). Since August 2003, the on-line radar data on bird migration, including flight altitudinal distributions, direction and velocity of flights, have been entered into special charts and sent every 15-30 min. to the relevant aviation services to be used for air traffic planning and control.

In addition to the on-line data, air traffic control must take into account the statistics of seasonal bird migration. The analysis of these parameters for night-time, carried out on the basis of the radar data, is presented elsewhere (Dinevich *et al.* 2005).

The goal of the present study was to obtain statistics on the parameters of daytime bird migration.

TECHNICAL EQUIPMENT AND THE METHODOLOGY OF EXPERIMENTAL DATA COLLECTION

The technical parameters of the radar were presented in Abshayev *et al.* (1980). Several major parameters and the methodology of experimental data collection was described in Dinevich *et al.* (2005). MRL-5 radar has two simultaneously operating wave lengths of 3.2 and 10 cm. Its potentials on both wave lengths are powerful enough to detect: (a) a single stork flying at the altitude of 700 m at the distance up to 90 km from the radar, (b) a single sparrow flying at the altitude of over 200 m at the distance of 8 km and (c) a flock of 50 sparrows at the distance of up to 30 km. The radar antenna is an ellipsoid of rotation that creates two axial-symmetric pencil-narrow beams (for the two wave lengths) for emission and reception of electromagnetic energy. The narrow beam (0.5° on the 3.2 cm wave length and 1.5° on the 10 cm wave length) enables to determine, with relative accuracy, the target coordinates and altitudes, the latter being of especial importance for our task. In our study, the daytime observation range was 60 km. The distance quantization is 1024, which corresponds to resolution of 60 m; the azimuth quantization is 2048, which corresponds to resolution of 0.176°. At the distance of 50 km, the automatic measurement accuracy on the 3.2 cm wave length was not lower than ± 200 m, at the distance of 20 km the accuracy was not lower than ± 90 m.

Ornithological charts are calculated on the basis of a method described in Dinevich and Leshem (2006) – for examples see this paper. Every 30 min. (or every 15 min. if need to be) the charts are web-sent to aviation control services. The three types of charts presented (all covering the area of 60 km in radius in relation to the radar) provide information of three types:

a) summed-up echo from all the atmospheric reflecting objects (clouds, precipitation, aircraft, birds, inhomogeneities) and partially the echo from nearby hills;
b) the vector field of migrating birds over all the altitudes, including the velocity spectrum and distribution of birds over altitude for any sector of observation;
c) volumetric bird echo distribution.

In order to obtain the statistics on bird migration based on the charts, a database was formed in EXCEL including the following parameters:

a) daily average, monthly average and season average maximum flight altitudes;
b) altitudes of maximum bird concentration;
c) seasonal spectrum of flight directions;
d) velocity spectrum;
e) time of the day when the number of migrating birds reaches its maximum.

THE CORPUS OF EXPERIMENTAL DATA AND THE METHODOLOGY OF DATA ANALYSIS

During the period from August 2003 to June 2005, and partially during the spring of 2006, data were obtained over 5 migration periods (for certain parameters, during 6 periods), which totals to over 8000 measurement results collected during 500 days. The measurements were taken in the daytime, from 8.00 *a.m.* to 5.00 *p.m.*

The following bird migration characteristics were selected as research parameters:

a) daily average maximum flight altitudes over various time intervals – $\overline{H_{max}}$,
b) maximum flight altitudes – H_{max},
c) maximum bird concentration altitudes – $\overline{H_{max.con}}$,
d) seasonal flight directions,
e) seasonal flight velocities.

The calculations of altitude parameters for time periods of a day, a month and a season, were performed by the following formulas:

$$\overline{H_{max}} = \frac{1}{m}\sum_{i=1}^{m}\frac{1}{k}\sum_{j=1}^{k}h_{mij}$$

$$H_{max} := \max\{\max[h_{mij}]\}$$

$$\overline{H_{max.con}} = \frac{1}{m}\sum_{i=1}^{m}\frac{1}{k}\sum_{j=1}^{k}h_{m.con.ij}$$

where:

$\overline{H_{max}}$ – the mean value of the maximum flight altitudes observed during a given time period (obtained in a series of observation during a single day or another period),
H_{max} – the largest maximum of maximum bird flight altitudes over a given period of observations,
$\overline{H_{max.con}}$ – the mean value of maximum bird echo concentration altitude (obtained in a series of observation during a single day or another period),
j (from 1 to m) – the number of daily observations,
i (from 1 to k) – the number of half-hour-long observations performed during a given day,
h_{mij}, $h_{m.con.ij}$ – the maximum flight altitude and the maximum bird concentration altitude obtained in a given single observation.

In each measurement, the flight altitude h was assumed to be the maximum altitude at which the radar located at least one bird echo.

All the altitudes were determined relative to the level of radar.

ANALYSIS OF OBSERVATION DATA

Maximum flight altitudes

Each studied parameter describes different aspect of the migrating birds stream. The maximum flight altitude at the moment gives information on the highest observed bird. This parameter fluctuates much from one observation unit to another. The daily average of these values gives information about the general level of top part of migration (Fig. 1-2, left panels, for spring and autumn). Really outstanding maximum observations are given on right panels of these figures. Above these levels there were no birds at all. It was found that absolute maximum flight altitudes were 3700 m in spring and 4300 m in autumn. Cases when birds flew at altitudes over 3500 m (both in autumn and in spring) constituted not more than 1% over all the years of observation.

Calculated over the data collected in observations, these altitudes were found to be within the range of 1000-2700 m in spring and within the range of 1200-3500 m in autumn (Table 1). For 90% of the migrant birds, the mean maximum altitudes were found to be within the range of 1.7-2.3 km in spring and 2.0-3.0 km in autumn. In autumn, the seasonal mean maximum altitude were higher than in spring. The typical feature of all the graphs is a high variance in both parameters.

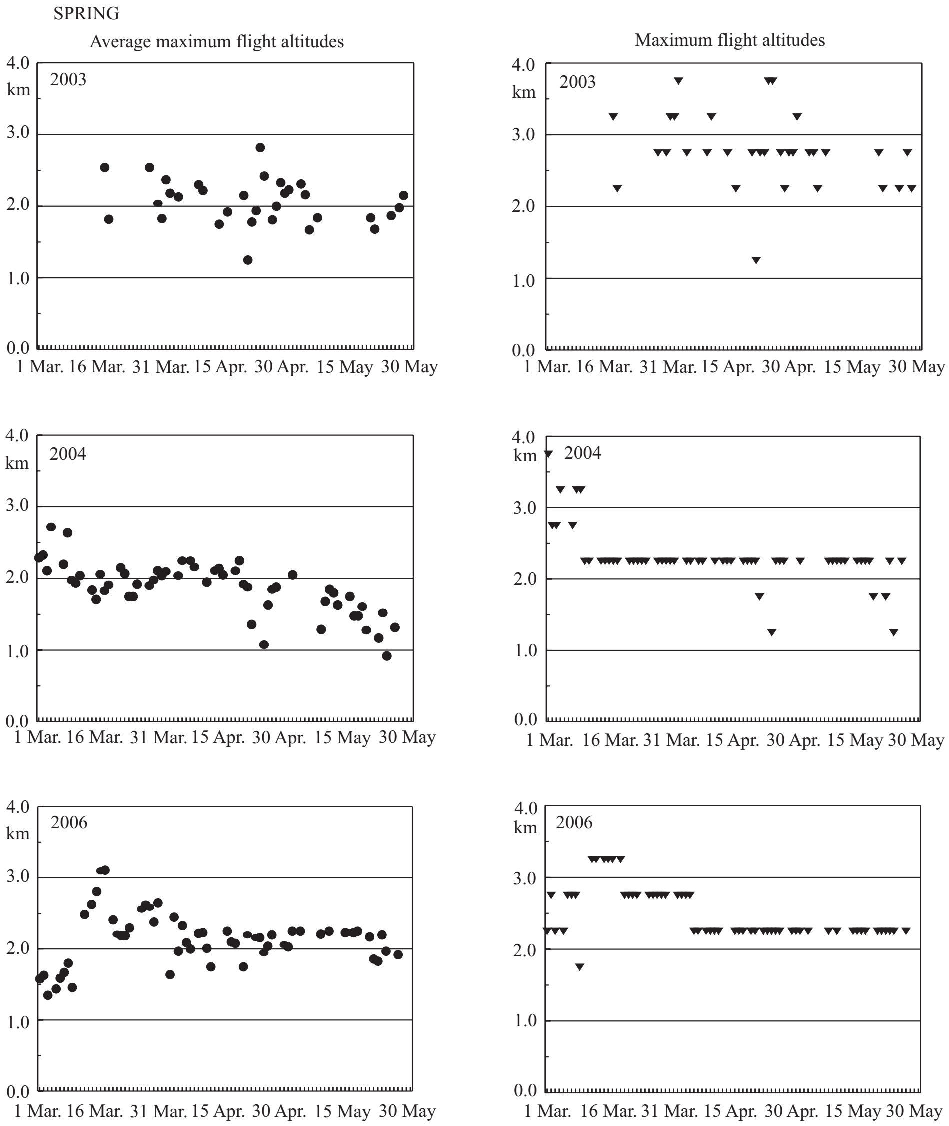

Fig. 1. Maximum flight altitudes in spring in different years. Left panels: average daily maximum altitudes, right panels: absolute maximum flight altitudes.

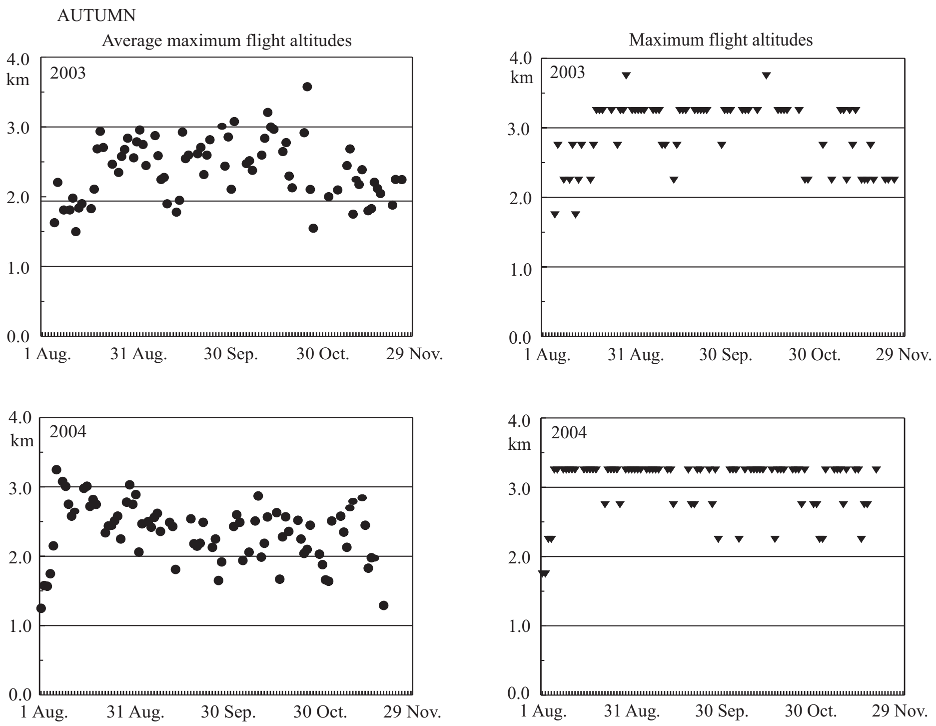

Fig. 2. Maximum flight altitudes in autumn in different years. Left panels: average daily maximum atitudes, right panels: absolute maximum flight altitudes.

Table 1
Altitude parameters of daytime bird migration in central Israel

Flight altitudes (m)	Spring	Autumn	Spring/Autumn 90% of all observations
Average maximum flight altitudes (m)	1000-2700	1200-3500	1700-2300/2000-3000
Maximum flight altitudes (m)	1500-3500	1700-4300	=2700/3500
Extreme maximum for entire observation period (m)	3500*	4300*	–
Average level of maximum bird concentration for entire period (m)	250-400	250-400	–
Extreme level of maximum bird concentration for entire period (m)	500 (600*)	600 (650*)	–

* not more than 1% of all observations

Altitudes of maximum bird concentration

The values of this altitude parameter is, in our opinion, of utmost importance for preventing aircraft-bird collisions. These altitudes had been chosen by birds as a result of a centuries-long migration experience that has nothing to do with human activity.

Radar observations clearly show that distribution of daytime bird migrants over height is uneven. Most often, birds occupy a certain altitude level in the surface air up to a certain maximum. Many birds fly within the air layer of just 200 m high or even less. Regardless the occupied air corridor, the phenomenon of maximum bird concentration at a certain altitude is always observed.

Figure 3 shows the variance for the altitudes of maximum bird concentrations during seasonal migrations. Both in spring and in autumn, the altitudes of maximum bird concentration were observed within the range of 250-400 m, while in some cases the maximum was observed at 650 m in autumn and at 600 m in spring.

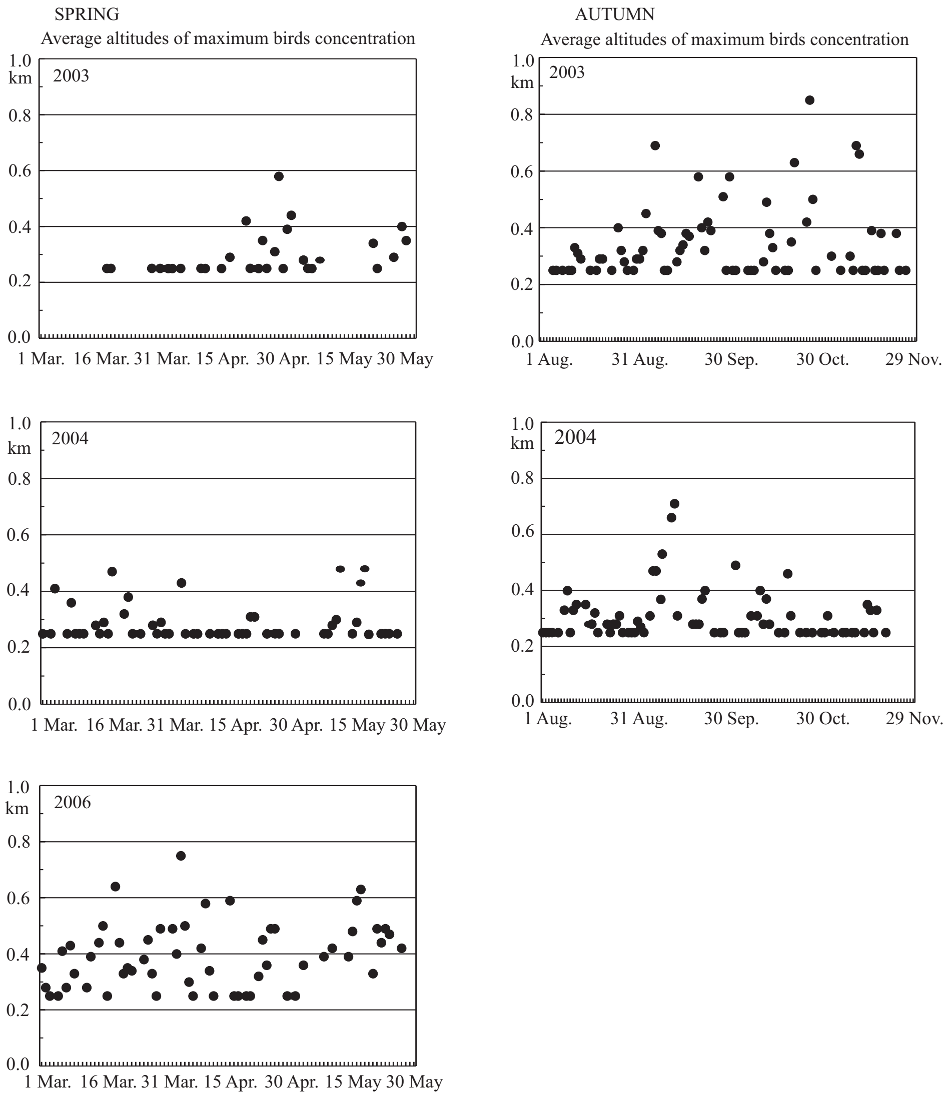

Fig. 3. Average altitudes of maximum bird concentrations in spring (left panels) and in autumn (right panels).

The monthly variance of the altitudes of maximum bird concentration in the daytime reveals the same pattern as that of night-time flights (Dinevich *et al.* 2005), namely, that at the beginning and at the end of a season the values of all the parameters considered above are lower than those in the mid-season.

In Israel, weather conditions in early spring differ significantly from early autumn. The spring bird migration season starts in March, when it is rather cool, windy and often rainy. The autumn bird migration season starts in late August, when the weather is extremely hot, dry and windless. The differences in temperatures over the twelve daytime hours between August-September and March may be as high as 15°C. The difference in the troposphere conditions is even more pronounced: for instance, the difference in the zero isotherm levels in August and March may be as high as three kilometres (Table 2). Yet, despite the drastic differences in weather conditions in the beginning and the end of seasonal migrations, it was found that the above considered altitude parameters of daytime migrations vary along the same trends. This phenomenon requires an explanation.

Table 2
Climatological parameters for spring and autumn in central Israel based on the data on average daily air temperatures, the altitude of the zero isotherm and the tropopause*

	Spring bird migration			Autumn bird migration			
Atmospheric parameters	Mar.	Apr.	May	Aug.	Sep.	Oct.	Nov.
Average temperature (°C)	15	18	21	26	25	22	18
Altitude of zero isotherm (km)	2.615	3.333	3.999	5.263	4.742	4.028	3.313
Altitude of tropopause (km)	11.227	12.024	13.058	16.740	16.967	14.613	13.224

* The climatological data obtained in observations made at Dahan Meteorological Station, Tel Aviv

In our view, there is only one factor that can account for this similarity in trends. Both in autumn and in spring, migration is started by low-flying birds that are apparently less dependent on the weather conditions. The impact of weather on flight altitudes becomes significant later, when high-flying birds join the migration.

Similar to other altitude parameters, the average altitudes of maximum bird concentration in the daytime are slightly higher in autumn than in spring. In contrast, these values for night-time bird migrants are higher in spring than in autumn (Dinevich *et al.* 2005).

Differences in altitude values within the same season may be accounted for by the fact that in spring, from March to May, the temperature of the underlying terrain rises alongside with the atmospheric temperatures, the altitude of the tropopause also rises, and as a result, positive convection currents over land occur more frequently. Another cause for steady convection current over land is breeze and higher mountain-valley circulation (Burman 1969, Dinevich and Leshem 2002). In the early spring, the sea is still cool, and in the cloudless daytime weather the land is much warmer than the sea, which makes for the positive convection component in the surface air due to the breeze factor. The upper level of convection created by these process usually does not exceed 400-600 m, though in some cases it can reach as high as 1 km. This is the range of altitudes where maximum concentration of day-migrating birds is observed. Towards evening, these land-sea temperature differences shrink, the breeze ceases, and the convection component in the atmosphere can even change its sign to negative. As the surface air and the troposphere get warmer and warmer, the migration "campaign" is joined by birds whose flight parameters are far more dependent on the weather. Birds with larger weight and wider wingspan have to fly at other altitudes, taking advantage of the convection currents in order to minimize energy consumption.

A different situation is observed during the summer-autumn transition in Israel. In August, when bird migration starts, as well as in September, October and early November, the underlying terrain and the surface air remain warm and cool quite slowly. The temperature contrasts between the sea and the land are not as drastic as in spring. In the evening, the difference between the land and the sea temperatures shrinks, while at night the sea is warmer than the land. As a result, the convective component over land is even negative. Only in late November the temperatures drop.

Inhomogeneous and hilly underlying terrain has a serious impact on formation of convective flows and mesofronts. The upper levels of such convective flows can be higher than those formed under the impact of breeze, which enables birds with larger weight and wider wingspan to fly at higher altitudes.

The upstreams formed by breeze circulation are different from those created by ground inhomogeneities. However, upstreams of both types create atmospheric spurts and mesofronts, of which migrating birds take full advantage. The differences in the origin of atmospheric spurts accounts for different conditions under which migrating birds choose optimum flight altitudes.

Flight directions

Figure 4 shows the spectra of average season migration directions. In spring, the dominant direction of daytime migration was found to be 10-50% for over 70% of the birds, and the variety of flight directions was much wider that in autumn. In autumn, the dominant direction of daytime migration was found to be 190-220° for over 70% of the birds. In spring, the variety of daytime bird flight directions was exactly the opposite, as birds were flying in the reverse direction, with a slight deviation to the east.

Figure 5 shows the climatological wind rose drawn on the basis of the data obtained by Beit Dahan Meteorological Station (the Tel-Aviv area) at 11.00 *a.m.*, local time, at two altitudes – at the ground level and at 600 m a.s.l. The altitude of 600 m was chosen because the maximum daytime bird concentration was observed approximately at this level. The hour of 11.00 *a.m.* is close to the observed peak of daytime bird migration. As can be seen in these figures, both in autumn and in spring the dominant wind direction is from the sea to inland. At the altitude of 600 m, the dominant wind direction is W-NW in autumn and W-SW in spring. At the ground level, the direction of W-NW remains dominant both in autumn and in spring. Comparing Figures 4 and 5 we can see that neither in autumn nor in spring the dominant directions of bird migration coincide with the wind directions. Moreover, the areas of dominant

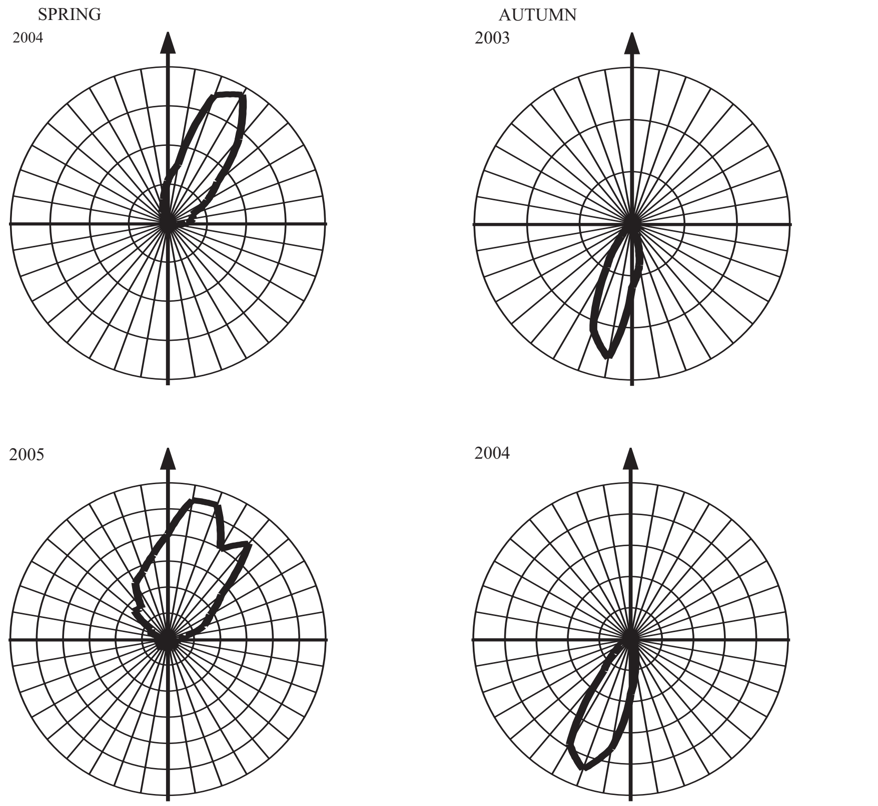

Fig. 4. Distributions of birds headings in different seasons according to 10° sectors. Left panels – spring, right panels – autumn.

directions of bird migration are those where the wind directions are of the most infrequent pattern, both in autumn and in spring. In central Israel, winds most often blow sideways in relation to the direction bird migration. No significant wind impact was found either on the direction or on altitude distribution of daytime bird migrants.

Flight velocities

The distribution of flight velocities for seasonal bird migration over altitude is shown in Figure 6 and Table 3. In spring, the mean velocity of daytime migration was found to be about 14 m/s (50.4 km/h). For over 24% of the birds, flight velocities were within the range of 10-12 m/s, for over 35% of the birds – within the range of 12-14 m/s, and for the remaining 14% of the birds the velocities were highly diverse. At the altitude of 600 m (close to the altitude of the maximum daytime bird migration) the wind velocity in the season was within the range of 3-6 m/s.

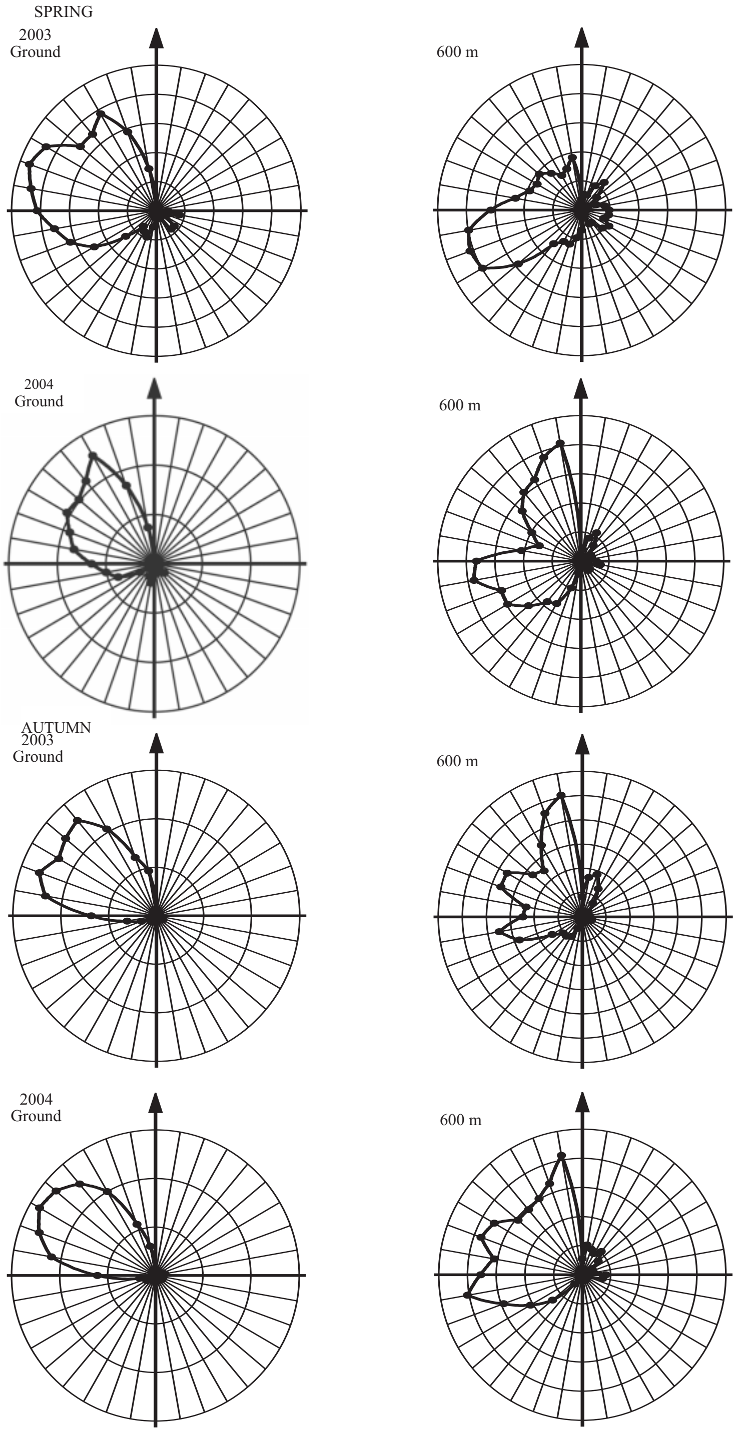

Fig. 5. Wind-roses for seasons (spring and autumn) in different years at the ground level (left panels) and at the level 600 m.

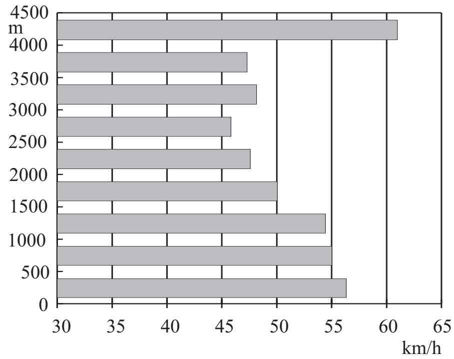

Fig. 6. Birds passage speed (km/h) at different hight layers in spring.

Table 3
Migration speed (km/h) at different flight altitudes

	Spring			Autumn		
	2004	2005	**Total**	2003	2004	**Total**
0-500 m	55.9	56.4	**56.13**	57.5	57.0	**57.22**
500-1000 m	54.6	55.1	**54.86**	56.2	55.7	**55.93**
1000-1500 m	54.0	54.5	**54.23**	55.9	550	**55.46**
1500-2000 m	49.3	50.4	**49.87**	502	50.6	**50.36**
2000-2500 m	46.5	48.3	**4739**	46.7	48.2	**47.42**
2500-3000 m	44.3	47.2	**45.73**	44.5	47.0	**4574**
3000-3500 m	47.6	48.6	**48.09**	47.6	48.6	**48.09**
3500-4000 m	47.2	47.2	**47.17**	47.3	47.2	**4722**
4000-4500 m	60.8	60.8	**60.83**	60.8	60.8	**60.83**

The mean value of daytime bird flights in autumn was found to be about 15 m/s, while for 7% of the birds flight velocities were within the range of 13-14 m/s, for 70% of the birds – within the range of 14-16 m/s, for about 11% of the birds the velocities reached 16-17 m/s, and for the remaining 12% of the birds the velocities were highly diverse. In autumn, the wind velocity at the altitude of 600 m was within the range of 4-7 m/s.

In case a bird's flight direction coincides with the wind direction, the bird's proper velocity (without taking into account the wind velocity) is the difference between the corresponding velocities. However, as was mentioned in the previous paragraph, the wind in the areas under observation most often blows sideways relative to bird flight direction. In this case, the wind neither accelerates the bird's shift relative to the radar, nor slows this shift down. This fact enables to conclude that the velocities presented are close to proper velocities of bird flights.

Bird flight velocity depends on the time of the day. Both for autumn and for spring, there are three well-pronounced time intervals characterized by maximum bird flight velocity (about 8.00 *a.m.*, 12.00 and 3.00 *p.m.*). It is possible that the morning velocity peak is related to the end of the night-time flights. The mid-day velocity peak is likely to be attributed to the period of maximum convection. In such conditions, birds spend less of their own energy to keep their weight at the altitude. The energy thus released is used by the birds to perform horizontal shifts. It is yet unclear what factors are responsible for the third velocity peak. It can be supposed that there is an impact of specific meso-scale circular processes, formed under the influence of land-sea interaction.

THE TIMES OF THE DAY WHEN THE NUMBERS OF FLIGHTS REACH THEIR PEAKS

Figure 7 presents data on times when the numbers of birds reached their daytime maximum; the values were found to be highly dispersed. In spring, the said maximum is often reached around 12.00 *p.m.*, however, sometimes this maximum took place even as early as 8.00 *a.m.* or as late as 3.00 *p.m*.

The dispersion of this parameter values was higher in autumn than in spring, and was found to be within the range of 8.00 *a.m.* – 5.00 *p.m.* In early autumn, the migration peak most often occurred at 1.00 *p.m.*, and in late autumn – between 10.00 *a.m.* and 12.00 *p.m*.

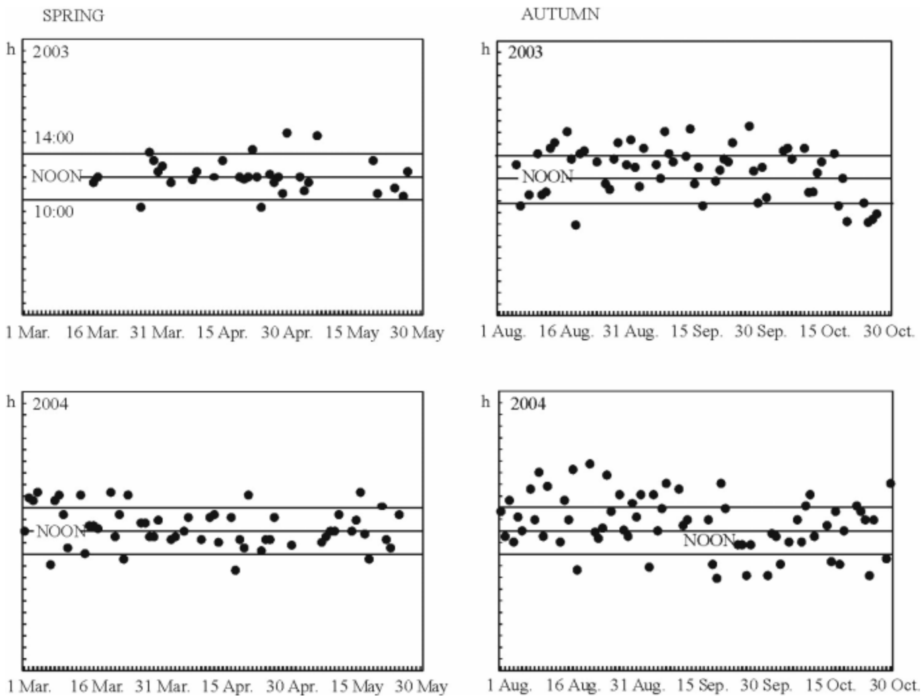

Fig. 7. Time (hours) of the highest intensity of migration in different seasons (spring – left panels, autumn – right panels). Noon ± 2 hours are shown by horizontal lines.

CONCLUSIONS

1. In the research, a large corpus of experimental data was obtained that enabled to estimate altitude parameters of daytime bird migration over central Israel. These parameters can be used to develop recommendations to aviation services concerning the optimum flight routing. Table 1 presents major altitude parameters of daytime bird migration over central Israel.
2. The variance analysis of altitudes of maximum day-migrating birds concentration showed that these altitudes had a single, feebly marked maximum approximately in the middle of the season migration period, and two minimum values – at the very beginning and at the and of this period. It was found that, regardless the significant difference in autumn and spring weather conditions, the initial values of the altitude parameters of daytime seasonal migration were similar, and their changes in the course of the season followed the same trend. In our opinion, this phenomenon is accounted for by the fact that both in autumn and spring, seasonal migration is started by low-flying birds that are less dependent on weather conditions. As to high-flying species, their daytime altitude parameters are lower in spring than in autumn.
3. All the altitude parameters of bird migration are characterized by high variability, changing from day to day and from month to month. There is no possibility to express this high variance by simple mathematical dependencies. However, we can assume that it is accounted for by two factors: the meteorological factor and the ornithological one.

   The meteorological factor reflects the parameters of the atmospheric conditions and the presence of circular processes of macro-, meso- and micro-scale in the area of bird migration. It may be assumed that the integral parameter of all these processes in the surface air can be the value of the instability energy and the altitude of its peak. These parameters that depend on the changes in distribution of temperatures and humidity occurring with height, determine the status convection in the surface air.

   Under the impact of the meteorological factor, birds, especially species with larger mass and wider wingspan, have to choose the altitudes with most favourable convective flows in order to minimize energy consumption. It may be found that altitude parameters of bird migration are well correlated with this easily predicted meteorological parameter. Obtaining such a correlation would enable to provide the aviation services with a forecast of bird migration altitudes at least 24 hours in advance. On the other hand, in absence of clouds, the average altitude of daytime bird migration would serve as an indicator of convective processes in the surface air.

   The ornithological factor is the variety of bird species migrating during different periods of autumn and spring. As a rule, migration is started both in autumn and in spring by bird species whose flight altitudes do not significantly depend on the weather factor. However, the ornithological factor is not only a function of biological processes in birds, but also a phenomenon that had formed under the impact of climatic parameters of certain habitats and migration routes.

The variance graphs obtained in the present study enable to continue the research using the regular meteorological data, that will either prove or disprove the hypothesis.

4. The dominant flight direction of daytime bird migration was found to be 190-210° for 70% of birds in autumn, and 20-40° in spring. No correlation was found between the direction of flights and the wind direction.
5. The average ground speed of migrating birds was found to be about 15 m/s in autumn, and about 14 m/s in spring. No correlation was found between the ground speed and the wind direction.

ACKNOWLEDGEMENTS

The authors express their gratitude to the Department of Research of the Ministry of Defense of Israel and the Israeli Ministry of Immigrant Absorption for the financial support of the project; to Ilan Setor, Director of the Israeli Meteorological Agency, for the courtesy of providing the research with meteorological data; to Dmitry Shtivelman for the technical support in the radar maintenance.

REFERENCES

Abshayev M., Burtsev I., Vaksenburg S., Shevela G. 1980. [*Guide for use of the MRL-4, MRL-5 and MRL-6 radars in urban protection systems*.] Hydrometeoizdat, Leningrad. (In Russian).

Alfia H. 1995. *Surveillance radar data on nocturnal bird migration over Israel, 1989-1993*. Isr. J. Zool. 41, 3: 517-522.

Bruderer B. 1994. *Radar studies on nocturnal bird migration in the Negev*. Ostrich 65: 204-212.

Bruderer B., Liechti F. 1995. *Variation in density and height distribution of nocturnal migration in the south of Israel*. Isr. J. Zool. 41, 3: 477-489.

Burman E. 1969. [*Local winds*.] Hydrometeoizdat, Leningrad: pp. 11-113. (In Russian).

Dinevich L., Leshem Y. 2002. *Opportunities of radar tracking way towards research of breeze and mountain – valley air circulation influence on diurnal bird migration*. Sci. Isr. – Technol. Adv. 4, 1-2: 61-80.

Dinevich L., Leshem Y. 2007. *Algorithmic system for identifying bird radio-echo and plotting radar ornithological charts*. Ring 29, 1-2: 3-39.

Dinevich L., Leshem Y., Pinsky M., Sterkin A. 2004. *Detecting birds and estimating their velocity vectors by means of MRL-5 meteorological radar*. Ring 26, 2: 35-53.

Dinevich L., Leshem Y., Matsyura A. 2005. *Some characteristics of nocturnal bird migration in Israel accordding to the radars surveillance*. Ring 27, 2: 197-213.

Leshem Y. 1992. *Predicting the regularity of bird migration in global bottleneck areas on a daily, seasonal and yearly se ale, and its implementation in the Israel Air Force and civilian flight*. Proc. 21st BSCE, Jerusalem: pp. 243-255.

Shirihai H., Smith J.P., Kirwan Guy M., Alon D. 2000. *A guide to the birding hot-spots of Israel*. vol. 1-2. Israel Ornithological Center.

Yom-Tov Y. 1988. *Bird migration in Israel*. In: *The zoogeography of Israel*. W. Jung Publishers, Dordrecht-Bîston-Manchester: pp. 497-574.