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AIRCRAFT FLIGHTS OF THE FUTURE DEMAND A DEEPER UNDERSTANDING OF NOCTURNAL MIGRATION

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ABSTRACT

In the future, most aerial fighting will take place at night. The improvements in nocturnal visual equipment and advanced technology make low altitude night flights a real possibility. These changes will be expressed by the change in the proportion of night flights time in relation to day flights time. Low-altitude night flights in the air force necessitate a preliminary study of nocturnal migration, which is much greater numerically (two orders of magnitude) than diurnal migration. As a result the probability of birdstrike at night is much greater. The nocturnal migration study held in Israel, in the eastern Mediterranean, shows that the character and species composition of nocturnal migration is different than those of diurnal migration. Although the birds migrating at night fly actively, they do not cross the Mediterranean directly to north Africa, in order to avoid dehydration, the fatal results for those individuals who do not reach the coast in time to avoid the heat of the sun. Selective pressure has led birds to shorten the time spent over the sea to minimum, and most cross the Mediterranean between Europe and Israel in no more than 5-6 hours, continuing overland to Africa. This has made Israel a major intercontinental cross-roads for nocturnal migrants. The number of birds migrating over Israel in spring and autumn reaches hundreds of millions each season. In order to continue flight training at high safety levels it is necessary to find methods of co-existence between migration and flights, especially in nocturnal migration in time and space. In bottleneck areas and major migration cross-roads, where the migrant population is varied and composed of many populations, arriving from different areas, the migration pattern is extremely complex. The "best solution" in this case is a real-time warning system, based on radar data.

INTRODUCTION

Birds that migrate during the day, such as birds of prey, storks and pelicans, soar with thermals to reach their destinations. This fact explains why Israel, as a land bridge between Europe, Asia and Africa, is a bottleneck for millions of diurnal migrants. These birds fly along well defined routes, where the frequency of thermals is especially high. As a result, the dimension of time and space in diurnal migration are clear and show a constant pattern, which repeats itself yearly, as observed during the past decade (Leshem, 1992 & 1994).

Nocturnal migrants, on the other hand, fly while actively using their wings, and are composed mainly of passerine and water birds. Migration takes place individually or in small groups, along a broad front, with no defined and constant routes. Since they do not use thermals, flocking does not occur, which points to the fact that the main function of flocking is in locating thermals.

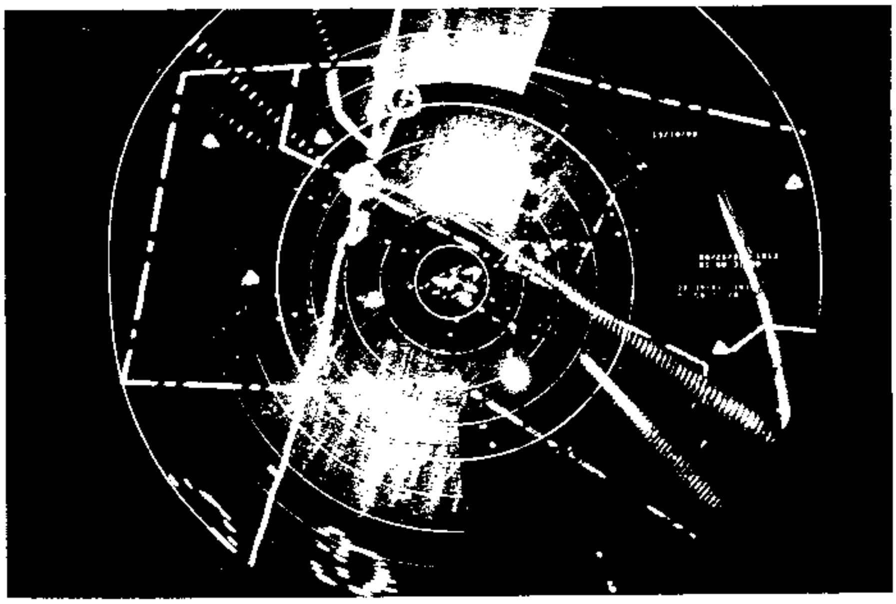
Active flights in nocturnal migrants produces large amounts of heat, which the bird must dissipate, otherwise it will become hyperthermic and die. Thus, these birds must terminate their flight before the worm daylight hours. This limiting factor influences the duration of continuous flight and ability of actively flying birds to cross large bodies of water. The theoretical flight range of most birds shows that they are able to cross the Mediterranean. In this case it would be expected that nocturnal migrants fly on a direct southerly route, without lengthening their flight as do diurnal migrants, and no bottleneck effect be observed. To our surprise, as far back as 1989 (Alfiya, 1990), we observed that a large part of nocturnal migrants extend their route, in order to shorten their flight over the Mediterranean. Instead of crossing directly from Europe to North African shores, many of them migrate to the Israeli coast, continuing south from there. Continuous flight bordering on their maximal flight length ability, combined with strong winds and slight drift in orientation, can end in hyperthermia and drowning, as sometimes happens to many birds. This phenomenon is probably due to the location of Israel adjacent to a large water obstacle, which creates a bottleneck of migrating birds from north and southwest. As a result, Israel is a migration cross-roads for nocturnal as well as diurnal migrants. Unlike areas that are not bottlenecks and migration cross-roads, such as those in the northern parts of the globe, many and varied populations of birds reach Israel. Their timing is influenced by various weather areas, and as a result their arrival pattern is complex. It is not possible to discern migration waves with clear intervals between them, as in Europe, in those areas where migration is a result of local populations migrating in one main direction.

In 1991, during the Gulf war, it become clear that future air battles would take place at night. Improvements in night vision equipment and technology make low-altitude night training flights. Since at night the number of migrants is greater by two orders of magnitude, the probability of aircraft-bird collisions will rise. Nocturnal low-altitude flights make it imperious to study the phenomenon of nocturnal migration in order to provide accordingly.

During the past five years nocturnal migration has been studied over Israel. The main objectives of this research were:

1. Determination of migration seasons.
2. Determination of the distribution pattern of nocturnal migration in time.
3. Determination of the distribution pattern of nocturnal migration in space.
4. Development of forecast and warning methods.
5. Development of nocturnal flight regulations in the presence of birds.

PHOTO 1: Nocturnal migration on a broad front from the north, autumn 1989. At the center - Ben-Gurion International Airport; The solid line on the left side of the screen is the Israel coastline. Migration on a broad front can be seen from 16 miles north of Ben-Gurion Airport to 14 miles south of it. Radius lines are at a distance of 2 miles from each other. On the Circumference are compass directions relative to Ben-Gurion.



METHODS

Surveillance radar - the radar used in this study was an ASR-8 surveillance radar, beam width 35°/4.8°, 10 (cm), used for air traffic control at Ben-Gurion International Airport, Tel Aviv. Nocturnal migration can be seen on the radar screen for radius of 20 miles.

The radar screen was photographed with a Nikon reflex camera, diaphragm opening 4.5, continuous exposure of 10 minutes for each still photograph. Photographs were taken once every $\frac{1}{2}$ hour during the night in spring and autumn. Control photographs were taken during the day at 0900, 1200, and 1500 hours, using the same method (Alfiya, 1990).

Magnitude of migration was determined by the rate of flashes received from migrating birds echoes on the radar screen photographs. A scale of 5 migration degrees was established and the rate of migration during each hour of the night determined accordingly. The degrees were: 1-no migration, 2-weak migration, 3-medium migration, 4-heavy migration, 5-very heavy migration.

This radar makes it possible to study migration speed and direction over a relatively large range. Its drawbacks are the inability to measure migration altitude, determine bird species or exact numbers of migrating birds.

Migration directions were determined according to the frequency of track directions, which the birds marked on the screen during flight, during a 10 minute exposure (photo 1).

Five other methods were used in addition to the surveillance radar, and they complemented, in variant degrees, the radar data.

Data on bird-aircraft collisions - The disadvantage of this method, is that it reflects mainly aircraft activity. However, it should not be discarded

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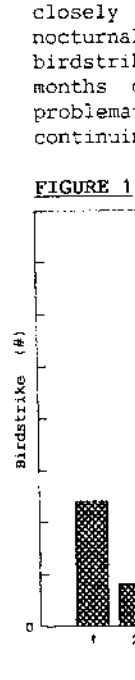


lightly, since if the aircraft activity is well understood, the data gathered can provide reliable information. For example: the beginning and end of the migration season can be inferred from this data. Migration flyways on the other hand, cannot be inferred, since the data is related to the aircraft routes.

Listening to bird calls - This method is very limited. Its major advantage lies in the ability to identify the bird species exactly in many cases. However, since not all birds call out when in hearing or recording range, the data gathered is very limited.

Telescopic tracking of birds in the moonlight - This is a relatively good method for quantitative estimates of migration and identification of the migrating species. Identification, of course, depends largely on the length of time the species was observed and how close it was to the observer. The main disadvantages of this method is that it necessitates a great deal of expertise and that without comparison to another method, there is not much significance to the quantitative estimate.

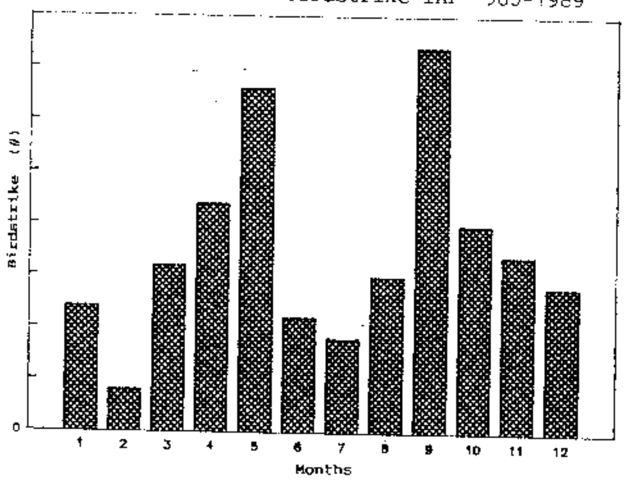
Flight in light aircraft at a 90° angle to the direction of migration - birds at different altitudes were counted by the light of a projector. This method is very expensive because of the high price of flight hours, and does not allow species identification, since the birds are seen for only a fraction of a second.

Use of FURONO 8100 radar with a fixed pencil beam 1° wide - this method enabled us to study the distribution of migration altitude throughout the night. The use of this radar necessitates using an additional sensor, which can serve as a control for determining the actual volume and efficiency of the radar beam in discovering birds, and the ability to differentiate between birds and insects. We will discuss this method further in the workshop at the end of the conference.

RESULTS AND DISCUSSION

Nocturnal migration over Israel has been studied for the past five years (1989-1993). From the start this was an applied research project. The motivation behind it lay in the fact that the rate of nocturnal birdstrike is closely related to the migration months (fig. 1), and that the rate of nocturnal birdstrike in the military flight system is 50% higher than diurnal birdstrike. Fig. 1 shows that the major problem is during the migration months of March-May and August-November. Winter months, mainly December, are problematic as well, due to birds which over-winter in Israel instead of continuing south to Africa and south Asia.

FIGURE 1: Nocturnal birdstrike IAF 1985-1989



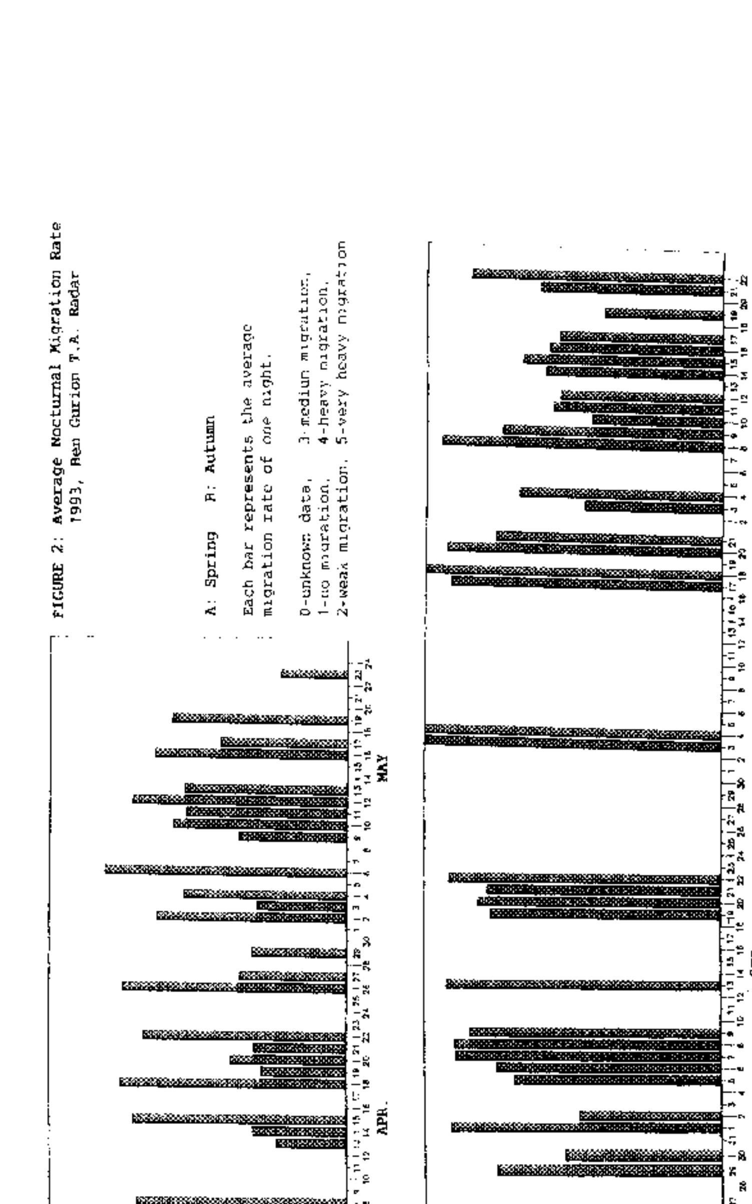


FIGURE 2: Average Nocturnal Migration Rate 1993, Ben Gurion T.A. Radar

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TABLE A:
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The approach radar at the Ben-Gurion International Airport - A scanning radar, model ASR-8, has been the major tool in studying nocturnal migration over Israel, during the past five years, 1989-1993. Nocturnal migration is studied from still photographs of the radar screen. Each photo is a continuous 10 minute exposure, taken every half hour, from nightfall to dawn. The photos enable determination of migration direction, magnitude, times and flight velocity. Migration was plotted on a scale of five magnitude degrees. Quantitative migration magnitude degrees were estimated by comparison to the number of nocturnal migrants as observed from light aircraft and by comparison to the data from Dr. B. Bruderer's Superfledermouse radar from the Swiss Ornithological Institute at Sempach. Comparison of results from five years of tracking enabled us to determine that nocturnal migration times, seasonal variations in migration magnitude and changes in migration direction during the night show a constant pattern, which repeats itself yearly.

Nocturnal migration on the radar screen - Photo 1 shows the actual accumulation of bird reflections during a continuous 10 minute exposure. When watching the radar screen a clump of light dots, the size of pin heads, moving at 40-100 kilometers per hour can be seen. Their velocity is determined by the distance they covered during a minute or two.

As opposed to diurnal migration which is seen on the radar screen along definite, clear routes, nocturnal migration is characterized by movement along a broad front, which covers a large part of the radar screen. this is a result of scattered migration of individuals or small groups of birds.

Migration magnitude during migration seasons - The variations in the average migration magnitude degrees during the night over the year fall into a bell-shaped curve which has repeated itself during the 5 years of migration (Fig. 2-a,b). Migration in spring peaks at the end of March-beginning of April. In autumn it peaks during September and October. The spring peak is lower than the autumn peak. Comparison of the average migration magnitude between spring and autumn (Table A), shows clearly that the migration rate in spring is about 50% greater in autumn, for each year (autumn 1989 compared to spring 1990; autumn 1990 to spring 1991, and so forth). This is probably as a result of migrant deaths, for many of whom this is their first year of life. Comparison of the frequency of migration degrees between 1989-1993 (Table B), shows that both in spring and autumn, during many of the tracking hours, no migration at all was recorded (degree 1). The distribution of migration magnitude degrees repeats itself yearly. During spring there is a higher frequency of degrees 1-2 and a lower frequency of degrees 4-5. In autumn there is a higher frequency of degrees 4-5 and a lower frequency of degrees 1-2. The combination of fig. 2 and tables A-B shows that safe low-altitude flight is possible during 25% of migration nights.

TABLE A: Seasonal average migration degree, 1989-1993

year	Ave. degree **Autumn**	Ave. degree **Spring**
1989	3.67	2.08
1990	3.09	2.46
1991	3.08	2.16
1992	2.83	2.38
1993	3.38	2.29

TABLE B: Frequency distribution of migration degree 1-5, autumn and spring, 1989 - 1993

	SPRING					AUTUMN				
degree / year	1 %	2 %	3 %	4 %	5 %	1 %	2 %	3 %	4 %	5 %
1989	35	33	23	7	2	16	7	10	28	39
1990	30	25	21	17	7	27	13	12	20	28
1991	42	22	20	10	6	29	10	15	21	26
1992	31	24	22	16	7	30	15	19	14	22
1993	48	11	16	14	11	20	10	17	18	35
Ave.%	37	23	20	13	7	24	11	15	20	30

<u>Dates of night migration in Israel</u> - The results of five years of tracking nocturnal migration show that migration dates follow a regular pattern. Table c presents data on migration dates in spring and autumn. The beginning of the season was determined according to the first night with average migration magnitude 2. In the same manner, the end of the season was determined by the last night with average migration magnitude ≥ 2. (Table C.)

TABLE C: Nocturnal migration dates in spring and autumn 1989 - 1993

Season	Spring		Autumn	
Year	Start	End	Start	End
1989	-	* 21/5	* 17/8	-
1990	8/3	16/5	15/8	21/11
1991	19/3	20/5	19/8	21/11
1992	12/3	17/5	10/8	15/11
1993	22/3	19/5	15/8	25/11

* Partial data

<u>The bottleneck phenomenon</u> - This phenomenon was observed already in 1989 (Alfiya, 1990). it seems that the birds migrating over Israel in autumn come from the north during the whole night. From midnight, birds which left the shores of eastern Europe, start coming in from the sea. This phenomenon repeats itself in spring, but in the opposite direction.

<u>How to reduce the rate of bird-aircraft collisions at night</u> - At night there are no defined migration routes as can be found in the daytime. No clear pattern of night hours with no migration taking place was found. It is only possible to state that during the second half of the night the migration rate is about 30% lower on average than during the first half of the night. No

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pattern of migration waves or intervals in migration was found during the seasons (fig. 2). As stated earlier, this is a result of Israel being a bottleneck, into which birds converge from various directions and different areas. The general normal curve perceived (fig. 2) is a result of many overlapping migration waves (normal curves).
Migration altitude is different in spring and autumn (Bruderer, 1994), and is strongly related to the direction, altitude and strength of the wind. Migration rate, on the other hand, can be determined early in the evening. According to the first three hours of night, it is possible to know, with 80% probability, whether there will be migration or not on the given night. This forecast ability permits use of about 25% of the migration nights. The forecast, which can be calculated from estimates of migration rates directly from the radar screen at Ben-Gurion International Airport, must be based on an orderly system, working in real-time, in case of a mistaken forecast.

This study has enabled us to know when the nocturnal migration season occur and when to recommend nocturnal flight limitations. At the same time, the real-time forecast ability, based on radar data, permits low-altitude flights even at the height of the migration season. Balance between 100% real-time warning system based on long-term migration patterns depends on the geographic location on the globe. The closer we are to the migration departure point, the migration pattern is relatively clear and simple, and can be relied on its own.

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