Meyburg, B.-U. & R. D. Chancellor eds. 1989
Raptors in the Modern World
WWGBP: Berlin, London & Paris

Following Raptor Migration from the Ground, Motorized Glider and Radar at a Junction of Three Continents

Y. Leshem

ABSTRACT

The geographical position of Israel makes it important as a focal point for the largest concentrations of soaring birds (raptors, storks and pelicans) during spring and autumn migrations.

The purpose of the research conducted in Israel was to map the migration routes of a number of species, to learn abut the flight altitudes and velocities and to study and analyse the extent to which these variables and the routes themselves are influenced by weather conditions, time of day and time of year.

Three data-gathering systems were employed in conjunction: a network of ground observation crews, a motorized glider and two radar systems. The data thus gathered produced a clear picture of the migration routes, the altitudes, velocities and daily progress of the migration, and its relations to changes in weather conditions.

The Israel Air Force sustained heavy damage to its aircraft from collisions with soaring birds on migration. Recognizing this, it provided the finance for this research and, based on the data collected, ceased flying at the times, routes and heights at which migration occurs. As a result, no planes have been destroyed or seriously damaged over the past three years (1984-1986).

INTRODUCTION

The location of Israel at the junction of three continents - Europe, Asia and Africa - has made it part of a migration route of international importance in spring and autumn.

For most soaring birds, large bodies of water such as the Mediterranean, Caspian or Black Seas, are barriers which must be circumvented on their way from Asia or Europe to Africa. The population of Western Europe concentrates in the area of the Straits of Gibraltar; a small part of the Central European population crosses the Mediterranean at its narrowest points, such as Italy and Sicily; the major part of the North, Central and Eastern European populations as well as large parts of the Western Asian and Caucasian populations fly along the shortest route, around the Mediterranean, concentrating in the skies of Lebanon, Israel and Egypt on their way to Africa.

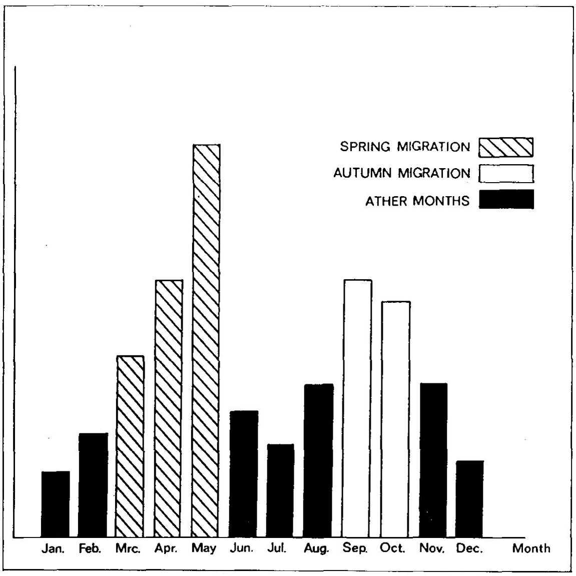
During the last decade there has been significant progress in studying the phenomenon of raptor migration over Israel. From the various surveys held it is now clear that Israel is one of the best places in the world, if not the best, to watch soaring birds on migration.

During the spring of 1985, 1,193,751 birds of prey were counted over the Eilat mountains (Shirihai 1986). In autumn 1985, 556,824 raptors were counted at Kfar Qasem (Dovrat 1986). The data of Shirihai (1987), Leshem (1984), Christensen *et al.* (1981), Bijlsma (1982), Wimpfheimer *et al.* (1983) and Dovrat (1984, 1985) confirm the information on the large numbers of soaring birds which pass over this area in spring and autumn.

After working for several years with ground crews surveying migration, it had become clear to us that the data were incomplete due to the limitations of the system used. Ground crews are unable to estimate exactly the altitude of migration and cannot see above a certain height.

As a result we decided to approach the Israel Air Force and suggest a joint programme whereby we would pass on to the IAF all migration data gathered to warn them of impending damage by migrating birds. The Air Force in turn would provide a light aircraft to be used in locating major migration routes, altitudes and behaviour of the birds, to complement the limited information from ground crews. When we first contacted IAF officers, at the end of the 1983 spring migration, it became clear that the conflict between IAF fighter planes and migrating birds was far beyond what we had imagined. Every year there were dozens of collisions between aircraft and migrating birds. The total number of these collisions between the years 1972-1982 reached into the hundreds, with cases in which fighter planes crashed and pilots were killed. (Fig. 1). The financial loss was inestimable.

FIGURE 1. Damage to IAF aircraft from birds 1972-1982. Exact numbers have been censored for security reasons, however the large number of collisions during the months of spring (March, April, May) and autumn (September, October) migration is evident.



It was clear that most of the collisions occurred during the spring (March - May) and autumn (September - October) migration seasons, when millions of migrating birds were concentrated along with hundreds of military aircraft in the limited airspace over Israel. To understand the enormity of the danger it is enough to know that an airplane flying at 800 km per hour colliding with a Kite weighing 900g is struck with a force of 22.5 tons, with a Griffon Vulture with a force of about 40 tons, whilst a Pelican weighing more than 7 kg will hit an aircraft with a force of about 100 tons.

In order to reduce the number of such collisions a study was accordingly started to define migration routes, altitudes and times of the major species and their relation to changes in weather, which data would then be used to prevent flying at certain times and in certain locations.

METHODS

1. **Ground crew surveys** to achieve maximum area coverage; a network of ground crews following migration at major passage points in Israel, based on a number of volunteer birdwatchers (up to 150 in autumn, Kfar Qasem Survey), spread over 14 observation points, covering the country from Tel-Aviv to the Mediterranean coast in the West and to the Jordan Valley in the East (see Map 1). The observers had radio transmitters for communication to prevent overlapping in counting. In some cases mobile observation points were set up with vehicles to keep up with the shifting migration axis during the day.

2. **Following migration with a motorized glider:** after 19 flight days with a military light aircraft (Cessna) we realised that although these flights helped to locate several major routes, the flight speed was too great to permit tracking of single flocks. The aircraft was adequate for days with migration "floods", but not appropriate for days with less migration. We then started looking for a smaller, slower aircraft to help us complete our data. Hang gliders were good only for localised tracking. The "Ultra-Light", a motorized hang glider, was better, but limited to two-hour flights and unstable over mountainous areas where most of the migration passes. We finally found a motorized glider, the OGAR, produced by PZL, Poland, which has a 65 h.p. engine and a wing spread of 18 m. Thanks to its motor it can take off and land independently, fly for about 8 hours on its engine, and by gliding part of the time, double its time in the air. (A spare fuel tank attached to the glider, which could be refuelled in flight, further increased the length of time in the air.) This motorised glider has 2 seats, both in front, and the propeller is behind the canopy, so that the observers have a much wider field of vision than in a light aircraft. The flocks are located in the evening at their roosting spots by mobile IRIC crews. In the morning the glider arrives at this spot about 15 minutes before the estimated time of departure, waits until the flock is in the air and then joins it, directed by radio transmitters with the ground crews. The glider's instruments enable us to track the exact migration altitude of the birds, their speed, take-off and landing times as well as counting the times the soaring birds use thermals along the way -- all this while tracking their route exactly from the time they lift off in the morning to when they descend in the evening or leave Israeli air space for neighbouring countries.

3. **Radar:** The Airport Authority at Ben Gurion Airport allowed us to use a sensitive radar screen of the ASR-8 type to track and map migration. The IAF had operators manning the radar during all migration seasons, and these drew the exact situation as seen on the screen every 20 minutes. At the same time the screen was photographed with Polaroid cameras. The radar at Ben Gurion Airport was directed very efficiently and at times could continuously follow a migrating flock when the glider landed to re-fuel. An additional military meteorological radar tracked migrating flocks of birds in the Negev.

RESULTS AND DISCUSSION

The observer ground crews were active each autumn migration season from August 20 to October 18, a total of 60 observation days, and in the spring from February 15 to May 20, a total of 95 days. Thus almost every year the migration was followed for more than 5 months during the period 1980 - 1987. The ground crew network enabled us to gather important data on several subjects. Dates of passage of a specific species are usually quite constant; Honey Buzzards *Pernis apivorus*, for example, pass over each autumn in two main waves between 3-15 September and in spring in two main waves between 3-17 May, whilst the Levant Sparrowhawk *Accipiter brevipes* passes over in large waves after the Honey Buzzards between 15-25 September and, in spring, before the Honey Buzzards between 20-30 April. The Lesser Spotted Eagle arrives in large concentrations between 27 September and 6 October, while the Steppe Eagle, *Aquila nipalensis*, arrives in spring in large concentrations from the end of February to the first week in March. By using these data from the ground crews we could provide the IAF with advance warning on expected large waves of migration. They in turn, could then stop low altitude flights during this time.

The widespread observer network, which was equipped with radio transmitters to prevent overlap in counting, enabled us to perceive clearly (though not completely) the number of raptors overflying Israel. In spring 1980, for example, 36,000 Black Kites were counted; in spring 1985, 850,000 Honey Buzzards and 75,000 Steppe Eagles; and in spring 1986 465,000 Steppe Buzzards. During the 1983 Kfar Qasem autumn migration survey 141,000 Lesser Spotted Eagles were counted and in autumn 1986 44,000 Levant Sparrowhawks. These counts are of value in estimating the size of certain European and Asian populations about which only partial information exists at present.

We first started tracking with the motorized glider in spring 1986. This sort of tracking had already been done by Pennycuick (1972, 1979). However, the basic information on migration routes which already existed enabled us to make 14 tracking flights already in the first year (spring 1986). In the autumn of 1986 there were 27 additional flights, a total of 41 flight days in which we followed flocks of Lesser Spotted Eagles, Honey Buzzards, Levant Sparrowhawks, Storks and Pelicans.

Such flights enabled us, for the first time, to gather exact data on the altitudes of the migrating flocks. Their relation to the utilization of thermals was recorded, while continuously tracking the flock from the base to the top of the thermal, and its gliding altitude till the next thermal was reached. In this way its movements were followed from the moment the flock took off in the morning until it landed at the end of the day or reached the border, while mapping exactly all thermals utilised along the way.

Figure 2 exemplifies a typical flight with a flock of Honey Buzzards in a three-dimensional flight altitude section. We can see that the flight was made on a day with 4/8 cumulus clouds at a cloud base altitude of 5,500 feet, and moved most of the time between altitudes of 2,500-5,100 feet above sea level.

In addition to the migration altitude sections we were able to systematically track a raptor flock's route while flying alongside it for 4-11 hours a day, along the length of Israel, for distances between 38 and 311 km. This method enabled us to locate important migration routes which we had not formerly known, and provided the basis for declaring certain areas off-limits for IAF aircraft.

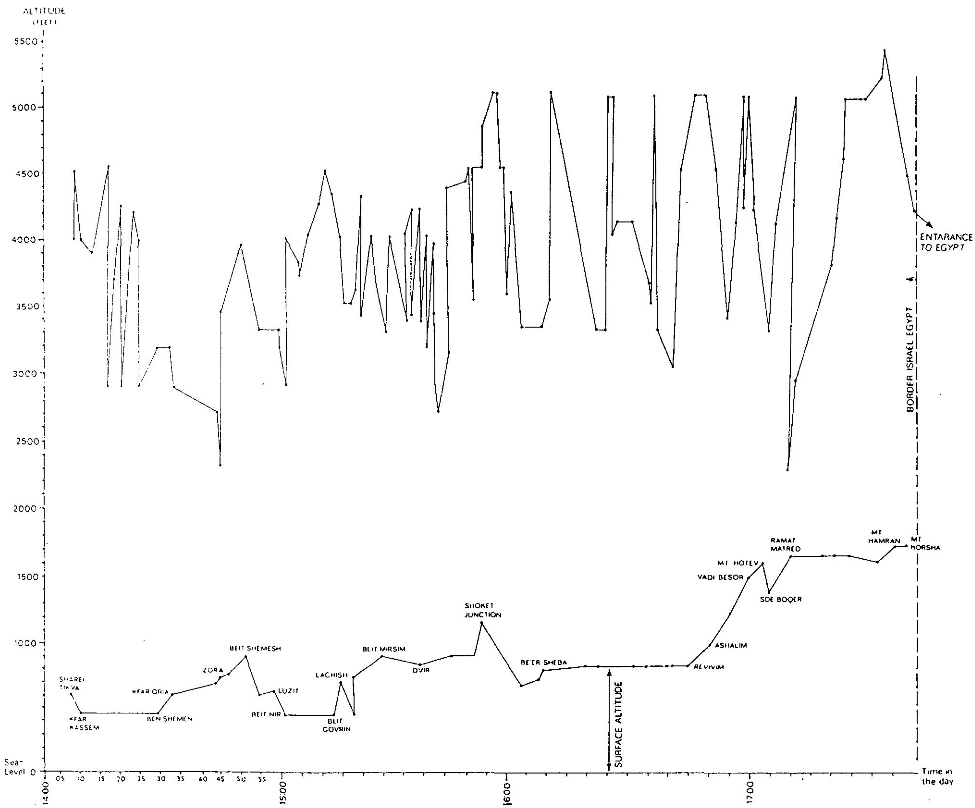
The flight speed of the flocks while gliding between thermals and the final speed per hour of migration was computed. Maximum gliding speed reached 85 k.p.h. and the average velocity was 17-65 k.p.h according to weather conditions. The average velocity of a flock is important to the air force, as we can thereby estimate its rate of progress and, with the help of the radar, warn IAF bases in advance of the time of its approach (Map 2).

The glider was also useful in checking the data provided by the various radars used. We were able to check the discovery threshold of the radar, our ability to estimate the size of a flock with it and the reliability of its coverage at different ranges.

In addition to the systematic tracking with the motorized glider, in 1986 we decided to track autumn and spring migrations with the ASR-8 arrival radar at Ben Gurion Airport. By using the data from the ground, the motorized glider and the IAF light aircraft, we found that the radar could spot migrating flocks of raptors at ranges of 30-40 miles. In spring 1986 about 40 flights were made in which the glider was directed to the migrating flocks by the radar. We found that the radar could spot flocks of 10 or more birds of prey. Air force equipment operated by two senior air control officers drew situation maps of the flocks every 20 minutes and simultaneously photographed the radar screen with a polaroid camera.

With the help of the radar at Ben Gurion Airport we were able to map major migration routes on a horizontal plane (it does not provide altitude data), and receive a rough estimate of the number of flocks and their size on a daily and seasonal basis. We learned that the migration axis has dynamics of its own: in the morning it moves 7-11 km east of the Mediterranean coastline and towards noon drifts 18-36 km further east to the slopes and summits of the mountain range which lies along the length of the country. On record migration days flocks of 20-60,000 were observed along 70-80 km in one continuous mass (Figs. 3 & 4).

FIGURE 2: **A typical section representing raptor migration (Honey Buzzards, *Pernis apivorus*) as it was made with the motorized glider in autumn 1986 (5 September). The flight started at Sha'are Tiqva (22 km east of the Mediterranean coast from Tel-Aviv) and ended at Mt. Hursha at the Egyptian border, a total of 186 km. At the bottom of the graph is the altitude above ground along the way, and the flight altitude of the raptors soaring with one thermal and gliding on to the next one. Wind: azimuth 300o, velocity - 20-25 knots, clouds - 4/8, altitude of cloud base - 5500 feet.**



The relation between climatic factors and migration

From a preliminary analysis it seems that meteorological factors play a major role in determining the characteristics of migration. On days when there is atmospheric instability and good thermals develop, the raptors manage to "climb" higher and glide for longer distances, thereby reaching an average velocity of up to 65 k.p.h. On warm, windless days gliding conditions are bad and there are even inversions, the raptors cannot reach high altitudes with the thermals, and they migrate closer to the ground, at lower speeds between 17-30 k.p.h., with only short-distance glides between climbs. According to these data, a flock of raptors migrating on days with optimal gliding conditions may cover a distance of 500-600 km in an average of 10 hours. On days with imperfect gliding conditions it can cover only 170-300 km in a day.

Changes in dates of passage

On days with barometric depressions, when good gliding conditions cannot develop and rain falls, migration seems to stop almost completely or is significantly delayed. When this occurs on the way from Europe to Israel, migration waves may come several days late, and permit the IAF to add a few more flying days.

TABLE 1: The numbers of Lesser Spotted Eagles *(Aquila pomarina)* migrating over Israel during the peak week (according to Dovrat, 1986 and preliminary summaries).

Dates	27/9	28/9	29/9	30/9	1/10	2/10	3/10
Autumn '85	7,006	11,133	4,716	8,301	2,877	7,373	24,767
Autumn '86	17,859	15,584	26,553	12,559	107	160	3,407

The week between the end of September and the beginning of October is the peak week for Lesser Spotted Eagle migration. From comparisons of data from 1985 and 1986 (not in absolute numbers) we see that during the first 3 days in October 1986 there was a *sharp* decrease in the number of migrating Eagles as compared to the previous year (Table 1). A satellite map from 29/09/86 shows a large barometric depression encroaching on the area from Russia, but central Turkey and southwards - Lebanon and Israel - are clear of clouds. On the other hand, a satellite photo from 02/10/86 shows a large depression over the Middle East, which caused heavy rain to fall over Israel. In these bad thermal conditions, compared to the previous year, the Lesser Spotted Eagles were detained until the depression passed. And so, finally, between 4-8 October 1986, when the depression had passed, another 22,151 Lesser Spotted Eagles passed over, compared to 11,151 in the same period the previous year.

The solution for the Israel Air Force

After the data from all the different sources - ground crews, motorized glider, radar - and the relation between changes in migratory patterns and meteorological factors had been analysed, the IFA introduced BPZ (Bird Plagued Zone) regulations. These regulations *forbid* fighter planes to fly during the migration seasons at the altitudes and along the routes of migration.

Since these regulations have been in effect, there has not been even one serious collision and no aircraft or pilot has been damaged or hurt.

ACKNOWLEDGEMENTS

I thank Colonel G., Lt. Colonel O. and the air force pilots without whose co-operation this project would never have become a reality. I would also like to thank Eli Peretz, Mikhael Pinkus, Rafi Luski, Rena Levinson and all the other motorized glider pilots. Pini Magor and Asher Friedman air force radar operators and Ilana Agat from the Israel Nature Reserves Authority manned the arrival radar at Ben Gurion Airport expertly. I am also grateful to the Airport Authority who permitted us to use the radar. Special thanks are due to Ehud Dovrat and the hundreds of birdwatchers who helped to gather data from the ground; to the staff of the IRIC and the SPNI who provided the framework for the study and to Esther Lachman for helping in the translation. I am grateful to Prof. Yoram Yom-Tov of Tel Aviv University, the scientific mentor of the project, to Dr. Ian Newton and Mark Fuller for their guidance and to the Office for Science and Development, the Ecology Fund and the SPNI, who helped to finance the project.

REFERENCES

BERNIS. F. 1980. *La Migración de las Aves en el Estrecho de Gibraltar.* Universidad Complutense de Madrid, 481 pp.

BIJLSMA, R. G. 1983. The migration of raptors near Suez, Egypt, Autumn 1981. *Sandgrouse* 5:19-44.

BRUDERER, B. 1971. Radar-Beobachtungen über den Frühlingszug im Schweizerisshen. Mittelland PHD Thesis, Univ. Basel.

BRUDERER, B. 1982. The air speed of migrating birds and its relationship to wind. Behw. Ecol. Sociobid *11: 19-24.*

CAMERON, R. A.D., L. CORNWALLIS, M.J.L.PERCIVAL & A.R.E. SINCLAIR. 1967. The migration of raptors and storks through the Near East in autumn. *Ibis* 109: 489-501.

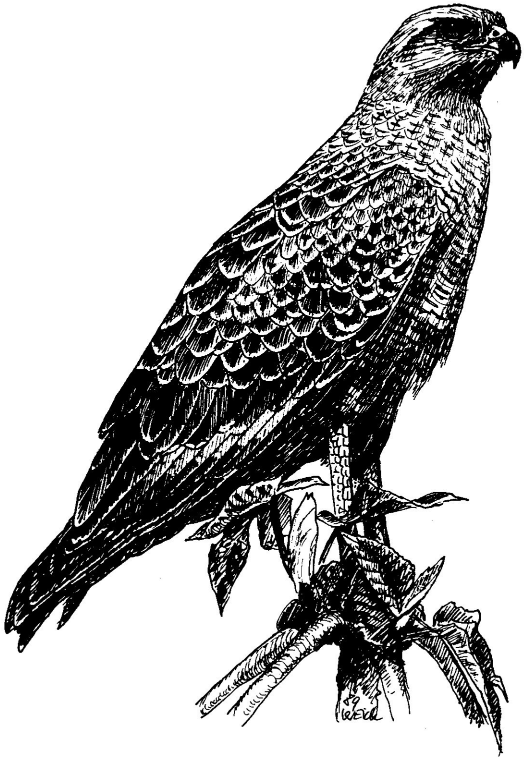
CHRISTENSEN, S. O. LOU, M. MÜLLER & H. WOHLMUTH. 1981. The spring migration of raptors in southern Israel and Sinai. *Sandgrouse* 3: 1-42.

CRAMP, S. & K.E.L. SIMMONS 1980. *The Birds of the Western Palearctic,* Vol. 2. Oxford: Oxford University Press.

DOVRAT, E. 1984. Summary of raptor migration survey, Kfar Qasem, autumn 1983. *Torgos* 8: 26-63. (In Hebrew.)

DOVRAT,E. 1986. Kfar Qasem–Cross–Samaria raptor migration survey, autumn 1985. *Torgos* 12: 63–88. (In Hebrew).
FULLER, M. & J.A. MOSHER 1981. Methods of detecting and counting raptors: a review. *Studies in Avian Biology* 6: 235-246.
LESHEM, Y. 1984. *Raptor migration in Israel.* In *I. Newton & R.D. Chancellor (eds.)* Conservation Studies on Raptors. *ICBP Tech. Pub. No.5, Cambridge.*
LESHEM, Y. 1984. *Paths in the sky - autumn migration of raptors.* Teva Va'aretz *26(5): 29-36.*
NISBET, I.C.T. & W.H. DRURY JR. 1968. *Short-term effects of weather on bird migration: A field study using multivariate statistics.* Anim. Behav. *16: 496-530.*
PENNYCUICK, C.J. 1972. *Soaring behaviour and performance of some East African birds observed from a motor-glider.* Ibis *14: 179-219.*
PENNYCUICK, C.J. 1979. *Soaring migration of the Common Crane* Grus grus *observed by radar and Prem Aircraft.* Ornis. Scan. *10: 241-251.*
RICHARDSON, W.J. 1974. *Multivariate approaches to forecasting day to day variations in the amount of bird migration. pp. 309-329* in *S.A. Gauthreaux Jr. (ed.) Proceedings of a Conference on the Biological Aspects of the Bird/Aircraft Collision Problem. Celmson University.*
RICHARDSON, W.J. 1978. *Timing and amount of bird migration in relation to weather: a review.* Oikos *30: 224-272.*
SAFRIEL, U. 1968. *Bird migration at Eilat, Israel.* Ibis *110: 283-320.*
SHIRIHAI, H. 1982. *The autumn migration of Steppe Eagles at Eilat, Israel 1980.* Sandgrouse *4: 108-110.*
SMITH, N.G. 1978. *Hawk and vulture migration in the neotropics.* In: *A. Keast & E.S. Morton (eds.)* Migrant birds in the neotropics, ecology, behaviour, distribution and conservation. *Smithsonian Inst. Press, Washington DC.*

Y. Leshem
Israel Raptor Information Centre, Society for the Protection of
Nature in Israel, Har Gilo Field Study Centre, Doar Na Zfon Yehuda,
90907, Israel.



MAP 1: Distribution of ground crews

Autumn Migration Surveys

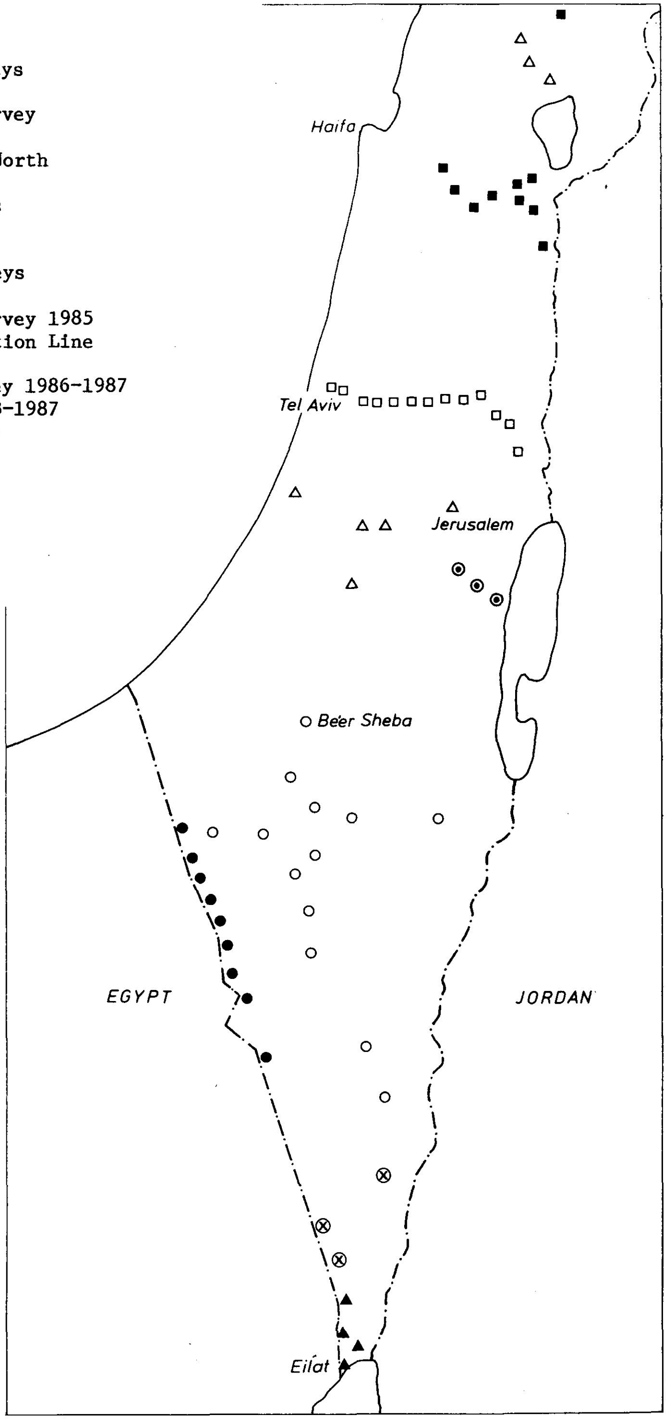
(a) Cross-Samaria Survey 1983-1986
(b) Jezre'el Valley-North Survey 1985-1986
(c) Independent crews 1985-1986

Spring Migration Surveys

(d) Judean Desert Survey 1985
(e) Egyptian Demarcation Line Survey
(f) Har Hanegev Survey 1986-1987
(g) Eilat Survey 1983-1987
(h) Independent crews

Stationary Crew

(i) mobile crew



MAP 2: Flights with Raptors, Autumn 1986

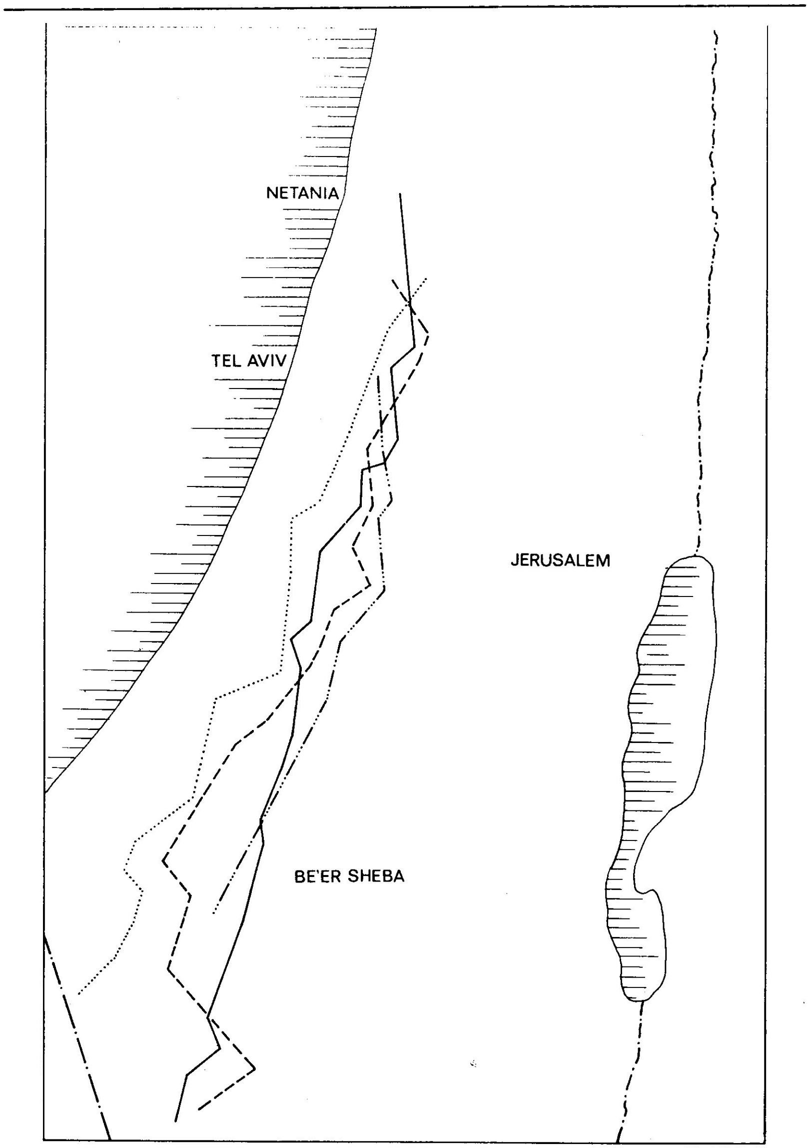


FIGURE 3: Huge flocks of Lesser-spotted Eagles *(Aquila pomarina)* 28.9.86 - 1130 hrs. Ben Gurion Radar - length of line 82km

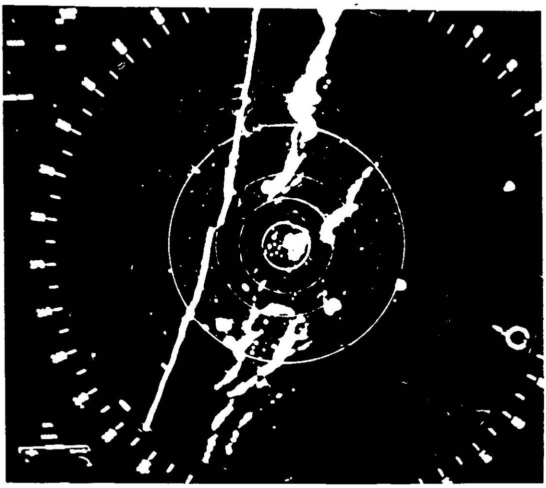


FIGURE 4: Huge flocks of Honey Buzzards *(Pernis apivorus)* 11.9.86 1047 hrs Ben Gurion Radar - length of line 75km, between 30,000 - 40,000 raptors, counted from glider.