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# RADAR STUDIES ON BIRD MIGRATION IN THE SOUTH OF ISRAEL

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## ABSTRACT

adar information on the directions and the temporal and spatial distribution of bird migration was requested an expertise concerning the building of a large antenna system for Voice of America in the Arava Valley. ides the primary task, the project may provide information for bird strike prevention in the Israeli Air For- and offers unique research possibilites on bird migration in a desert environment. The paper comprises first description of the digital recording methods used in connection with the tracking radar "Superfleder-us". Qualitative data consist of flight paths and wing-beat patterns of tracked birds. Recording of quantita- data is based on conical scanning at different elevations. It provides information on the spatial distribu-on of birds in a half-sphere of 5 km radius around the radar. A few examples of results are presented and cussed. The quantitative results of the radar observations will also be used for a comparison with diffe-, more traditional observation methods, such as moon-watching, infra-red, and ceilometer observations.

# RADAR STUDIES ON BIRD MIGRATION IN THE SOUTH OF ISRAEL

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## 1. Introduction

### *1.1. Background*

Plans to build a large antenna system for Voice of America and Radio Free Europe in the Arava Valley have been in discussion since 1986. Considering the fact that the eastern edge of the Mediterranean is one of the world's most important migratory routes for birds, different organizations for nature protection opponed against the construction of this network of wires, which would reach heights between 50 and 155 m and stretch over a distance of about 1.8 km across the valley (1 additional km in the longitudinal axis of the valley is not so important in relation to bird migration). The main question was, how many birds would fly through the area of the principal antenna body and would physically be endangered by a collision with a wire. In July 1991 the Supreme Court of Israel decided that the building of the relay station should be delayed until pertinent research on the potential hazard of the antenna system for bird migration was done. Based on this decision the Swiss Ornithological Institute was asked to do a radar study on the quantities and the flight behaviour of birds migrating through the area in question. The project was named NAMIP (Negev Arava Migration Project) by the Swiss Bird Radar Team.

Besides the scientific significance of the project, the results may be of interest for bird strike prevention in the Israeli Air Force. Great success was attained up to now in preventing strikes during daytime with large flocks of soaring birds by direct warning. There were, however, no radar data available which could show the over all seasonal and diurnal variation of numbers and height distributions of migrating birds in this country. The present paper provides basic information on the aims and the methods of the current radar project.

### *1.2. The primary tasks*

1) To provide quantitative information on the spatial distribution of nocturnal migrants and the distribution of (often flocked) bird echoes during daytime in the area of the planned antenna system and at a comparison site on the plateau of the Negev.
2) To provide information on the flight behaviour (mainly directions) of representative samples of migrants in relation to meteorological conditions, as well as a rough survey of the bird types involved.

### *1.3. Secondary aims*

The unique possibility to do radar studies in a desert environment and the practical significance of the results induced additional aims for the project:

a) Seasonal fluctuations in the volume and composition of migration shall be compared with weather development and with phenological data collected simultaneously by Ben-Gurion University or with published data on seasonal changes in numbers and species composition of migrating birds.

b) The height distribution and the directions of migration shall be compared to the conditions in the lower atmosphere and will help to explain how the birds cope with constraints imposed by environment, such as wind, humidity, oxygen pressure and temperature, and by their own physiological needs. This may impose a trade-off between saving water or energy and accomplishing the journey in due time.

c) Methodological comparisons. The possibility to build optimal radar sites in a flat area, the need for the highest possible back-up for the obtained data, the scientific challenge to calibrate different methods, and the additional interest of the Israeli Army in the future use of own equipment for bird strike prevention is a compelling set of requests for a thorough comparison of different methods. We aim at comparing the information obtained by th
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## 2. Methods

### *2.1. Study area and radar s*

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formation obtained by the NAMIP system with the following other systems: small vertical beam radar, different types of surveillance radars, moonwatching, fight-beam, passive infrared.

## 2. Methods

### 2.1. Study area and radar sites

The study area (Fig.1) comprises two sites. The primary site is in the Arava Valley, in the vicinity of the moshavs Hazeva and Iddan, about 150 m below sea level. It is operated during the whole time of the survey; the methodological studies are mainly done at this station. The secondary site is on the plateau of the Negev near Sede Boqer, 470 m above sea level. It covers only part of autumn migration and four weeks of optimal spring migration. Its task is to provide a representative sample of data for a comparison between migration on the plateau of the Negev and in the Arava Valley.

Each radar is surrounded by a dam of 40 m radius and 2,5 m height in order to protect the radar as much as possible against echoes of the surroundings. In the flat area of the Arava Valley nearly all the clutter echoes could be excluded by this preventive measure.

### 2.2. The radar equipment

The basic properties of the tracking radar "Superfledermaus" in comparison with surveillance radars have been described by Bruderer (1971). Additional information on target recognition was provided by Bruderer (1969) and Bruderer & Joss (1969). Automatic tracking and first steps in digitizing flight path data and echo signatures are shown by Bloch et al. (1981). For some recent applications see Bruderer & Jenni (1990) or Bruderer & Liechti (1990). The actual recording system is presented here for the first time. It is based on digital recording of flight paths, echo signatures and spatial distribution of echos (Fig.2). Colour photos showing examples of flight paths are presented in Bruderer & Jenni (1988). Flight paths and echo signatures are referred to as "qualitative" data, the number of echoes per unit volume or time corresponds to the term "quantitative" data.

### 2.3. The quantitative methods

A half-sphere of 5 km radius above the radar is surveyed every odd hour from 19 hrs to 09 hrs (sometimes from 17 to 11 hrs). The pencil beam of the tracking radar "Superfledermaus" is successively positioned at 9 different elevations (Fig.3). At each elevation the beam scannes the surface of a cone during 18 seconds by rotating once from N- to N-position. Each cell of 30 m length along the 2,2° pencil-beam provides information on the amplitude of all detected echoes. This information is recorded in steps of 0,2°. This record of 411 kbytes per elevation is reduced by a factor of 11 by averaging 11 azimutal scans. The recorded information can be reproduced as a digital colour picture of the radar PPI on the computer screen (see Bruderer & Jenni 1988).

Data processing comprises the following steps: 1) the creation of a clutter mask by superimposing the digital video pictures of the whole season (cells occupied in more than 80% of the cases); these are excluded from further analysis; 2) interactive exclusion of variable clutter (e.g. weather); 3) automatic detection of echo peaks; 4) automatic counting of echo peaks; 5) reducing echoes closer than 3 km by digital STC (sensitivity time control = distance dependent reduction of echo strength) according to the $r^4$ law; 6) compensation for different detectability of birds at different aspects and with increasing distance beyond 3 km; 7) compensation for increasing detection probability with increasing elevation (more hits per target). The outcome of the procedure are densities (birds unit volume) for selected heightbands (in the present examples height intervals of 200 m, see Fig. 6). and selected periods.

### 2.4. The qualitative methods

The qualitative methods are based on the capability of the "Superfledermaus" radar to track selected targets. The flight path data of automatically tracked targets are recorded every second. These flight paths are visualized on the computer screen and by an XY-plotter. The data of 20 seconds are approximated by regression lines. Averaging these regression data provides mean values for track direction and ground speed. The bird's heading and air speed is calculated by subtracting the wind vector (measured by tracking pilot balloons) at the corresponding flight level from the vector of the bird's track. For easy comparison the circular distributions of tracks and headings are always presented together (tracks with a heavy line, headings with a fine line). Distributions are presented in the form of polygones, showing the percentage directional distribution in classes of 5°.

The wing-beats of birds tracked by the radar produce a fluctuation of the echo. The "echosignature" corresponds to the wing-beat pattern of the bird (Bruderer 1969) as long as only one bird is tracked (which is usually the case in nocturnal migration). Waterbirds and waders are known for their rather continuous wing-beats, while passerines (songbirds) show typical sequences of beating and pausing phases in horizontal flight. Small birds have high wing-beat frequencies, while large birds flap their wings slowly. These basic features are used for a rough classification of wing-beat pattern during the field work at the radar ( Bloch et al. 1981).

Four main wing-beat classes and a class of unidentified targets are used in the present paper for nocturnal migration:

BW = big waders and waterfowl    SW = small waders and waterfowl
BP = big passerines    SP = small passerines
U = unidentified targets

## 3. Results

It is not the aim of the present publication to enter into detailled results. The following graphs should rather provide an idea of the presentation of data and possibilities of future evaluations.

### *3.1. Basic directions at two sites in the Negev*

The basic direction (Bruderer & Liechti 1990) is the mean direction of tracks at a certain site when wind-drift is negligible. It may shift throughout the season, if the directions of the recruiting areas and/or destinations of the involved bird populations change. It is an important reference when different sites or different wind situations at the same site are compared. Due to the low wind speeds observed, the basic directions for the two sites could be based on birds flying in winds of less than 2 m/s. .

The basic direction of autumn migration above the Arava Valley was well concentrated around 192° in nocturnal migration and had three main modes centered around 195° in tracks and headings of diurnal migration (Fig.4). This direction roughly corresponds to the course of the Arava Valley (Fig.1). The basic direction at Sede Boqer was about 202° during nocturnal migration (Fig.4). In diurnal migration the scatter was very wide; it included many local birds (e.g. vultures, falcons, ravens, sandgrouse, and pigeons); for the definition of the basic direction we included only the birds between 115° and 295° (± 90° of the assumed basic direction). The directions of 202° and 208° indicate a slight spreading of the migratory stream towards SW on the plateau of the Negev, comparable to the westward shifting of the mountain ridges and the coastal plain.

### *3.2. Density of migration*

Fig.5. shows the mean altitudinal distribution of nocturnal migrants in the Arava Valley and at Sede Boqer during the period of 21 to 30 September 1991 for five measuring times. The bar diagrams show that highest densities of early autumn migration at Sede Boqer occured in a height band of 200 to 600 m AGL, while in the Arava Valley highest densities occured around 1000 m AGL (i.e. in a height band of 600 to 1600 m AGL). Correspondingly the 50% limit in the Arava is about 600 m higher than at Sede Boqer. 600 m roughly corresponds to the difference in altitude above sea level between the two sites. Densities of migration at Sede Boqer roughly doubled those at Arava in the last decade of September, while in October they were nearly equal (for explanation see discussion). Peak migration occured slightly earlier during night at Sede Boqer than at Hazeva, indicating that large areas with suitable resting areas might be closer at the Negev site. In the course of the season (from mid September to the end of October) the density of migration dropped by a factor of 5, height distribution became more scattered.

### *3.3. Different wing-beat class*

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## 4. Discussion and conclusi

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## 5. Acknowledgments

The joint Israeli/American
project to the Swiss Ornitholo
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### 3.3. *Different wing-beat classes*

Fig. 6. shows that the proportions of the different classes of nocturnal migrants changed with the progress of the season. A parallel decrease of the proportion of waders/waterfowl (BW/SW) combined with a relative increase of passerines (BP/SP) was obvious at both sites. During daytime a comparable shift from large soaring birds to flocks of passerines took place during October (Bruderer unpubl.). Compared to central Europe (Bruderer 1971) the proportion of wader/waterfowl echoes is much higher in Israel.

## 4. Discussion and conclusions

The basic directions at the two sites confirm what was already indicated by surveillance radar pictures (Alfiya 1990): i.e. that the directions of nocturnal broad-front migration slightly spread over the South of Israel, joining on the one hand the course of the Arava Valley and shifting slightly more W on the plateau of the Negev according to the general pattern of the landscape. Due to relatively low wind speeds and fairly stable trade wind conditions, the directions under all wind conditions showed no important difference to the basic directions, except slightly increased drift by westerly winds at Sede Boqer (Bruderer unpubl.). More detailled studies on the directional behaviour of different types of migrants at different flight levels and under different wind conditions are in preparation.

The densities of autumn migration were not basically different at the two sites. Higher densities in the last decade of September may be explained by moderate northwesterly winds prevailing at Sede Boqer, while at Arava winds were weaker and rather from E. Moderate northwesterly winds induce partial drift; compensation may be improved along the mountain ridges at the eastern edge of the Negev plateau and may lead to some concentration of migration at Sede Boqer and to a "lee shade" in the Arava Valley. For pilots it may be of interest that in this country, which is crossed by the most important flyway of palearctic birds migrating to Africa, densities of nocturnal migration in peak season at the levels with most intense migration may reach figures in the order of 1000 birds per km$^3$, this is about 1 small nocturnal migrant per cube of 100 m side length. It may thus be important to know when and at what flight levels such extreme densities are reached. Mean densities are much lower. Nevertheless, it becomes clear that not only diurnal soaring birds are funnelled through the area of Israel, but also nocturnal migrants occur in higher densities than elsewhere. Calculating migration traffic rates and extrapolating them to the whole width of the area between the Mediterranean coast and the Jordan mountains indicates that about one milliard of birds may cross the area in an autumn season.

The comparison of the flight levels at the two sites showes that the birds flew rather at the same level above sea than above ground. A first hypothesis to explain this observation might be that the decisive elements in the structure of the atmosphere have a similar height distribution over large areas irrespective of topography. Especially the windshear between the trade winds in the lowest parts of the atmosphere and the anti-trades was much lower above ground at Sede Boqer, impeding migration above 500 to 1500 m mainly in the first part of the season. A second hypothesis is, that the birds are avoiding flights in the lowest parts of the atmosphere mainly due to high temperatures, which are extreme in the Arava during early autumn. The second hypothesis is supported by the fact that the difference decreased later in autumn, when the temperatures were lower. These questions are most important for future research and may help to predict the flight levels at which most nocturnal migration must be expected according to the actual meteorological conditions.

## Acknowledgments

The joint Israeli/American management of the radio relais station rised the funds and assigned the radar project to the Swiss Ornithological Institute, the logistic support to the enterprise TMS. The members of the R-Team (T.Steuri, F.Liechti, D.Peter, M.Kestenholz, H.Stark, and C.Bruderer) dropped their own work and got the unexpected project going within one month. I want to thank them for good team-work, for fruitful discussions, for corrections to this text, and for all their efforts in favour of the success of the NAMIP. The whole team is grateful for good cooperation with the meteorological enterprise NIMBUS, with the Israeli collaborators at the two radar sites, and with Ben-Gurion University.

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### Captions to figures

Fig.1. The location of the two radar sites in southern Israel. For better orientation the main towns in the area are indicated: T = Tel Aviv, J = Jerusalem, BS = Be'er Sheva, SB = Sede Boqer, EA = El Arish, EL = Elat, AQ = Aqaba. Note the direction of the Arava Valley (about 190°) between the Dead Sea and the Gulf of Elat and the direction of other topographical elements (such as the Mediterranean coast, the coastal plain, and the mountain ridges of the Negev) which shift away from the Arava to the South. The main radar station is in the Arava Valley, the secondary station in the Negev near Sede Boqer (both indicated by black dots)

Fig.2. The tracking radar "Superfledermaus" and its connections to the recording and peripheral equipment (PPI-display on computer monitor, display of flight paths on computer monitor, XY-plotter for flight paths, XI-plotter for wing-beat signatures).

Fig.3. Elevation angles at which the pencil beam of the radar scans the sky in order to provide information on the spatial distribution of birds in a half-sphere of 5 km radius. The elevations are given in milles instead of degrees; 1600 %o correspond to 90°, 1° corresponds to about 17,8 %o.

Fig.4. Distribution of the main wing-beat classes of nocturnal migration for three periods in the autumn of 1991 over the Arava Valley and the area of Sede Boqer. The wing-beat classes are: BW = big waders/waterbirds, SW = small waders/waterbirds, BP = big passerines, SP = small passerines, U = unknown birds.

Fig.5. Distributions of tracks and headings under calm wind conditions (windspeed <= 2 m/s). Each graph provides the number of birds (N), the mean direction of tracks (track) and of headings (head). The polygones are percentage distributions per 5° classes.

Fig.6. Average altitudinal distribution in the decade of 21 to 30 September per measuring time throughout night (19, 21, 23, 01, 03 hrs) for Arava (a) and Sede Boqer (b). The altitude of the 50%- and 90%-limit of migration is indicated by filled and open arrows, respectively.

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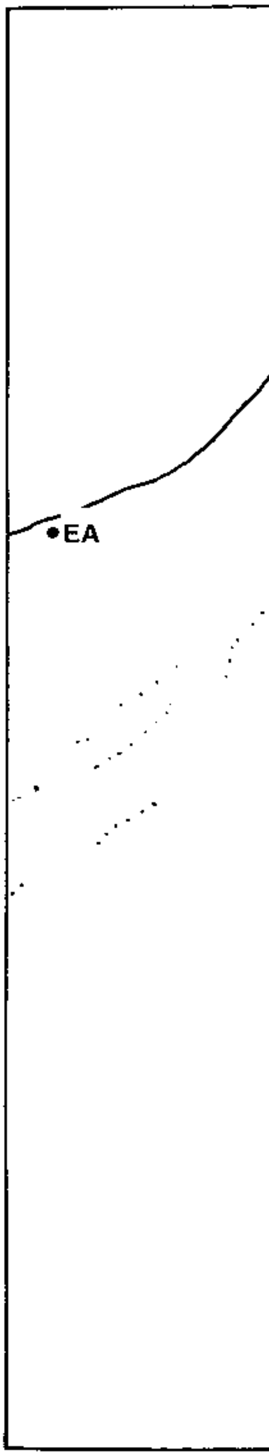

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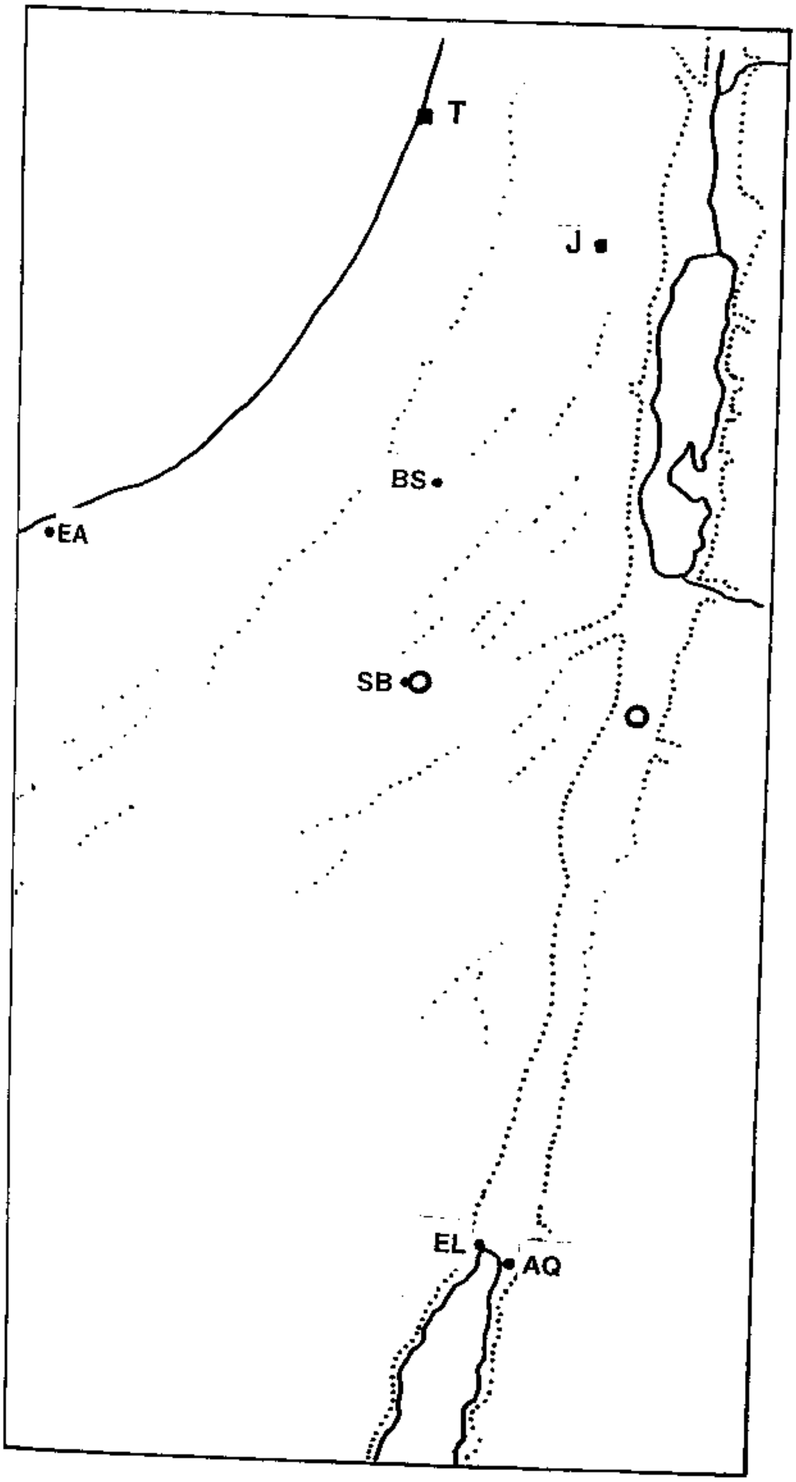
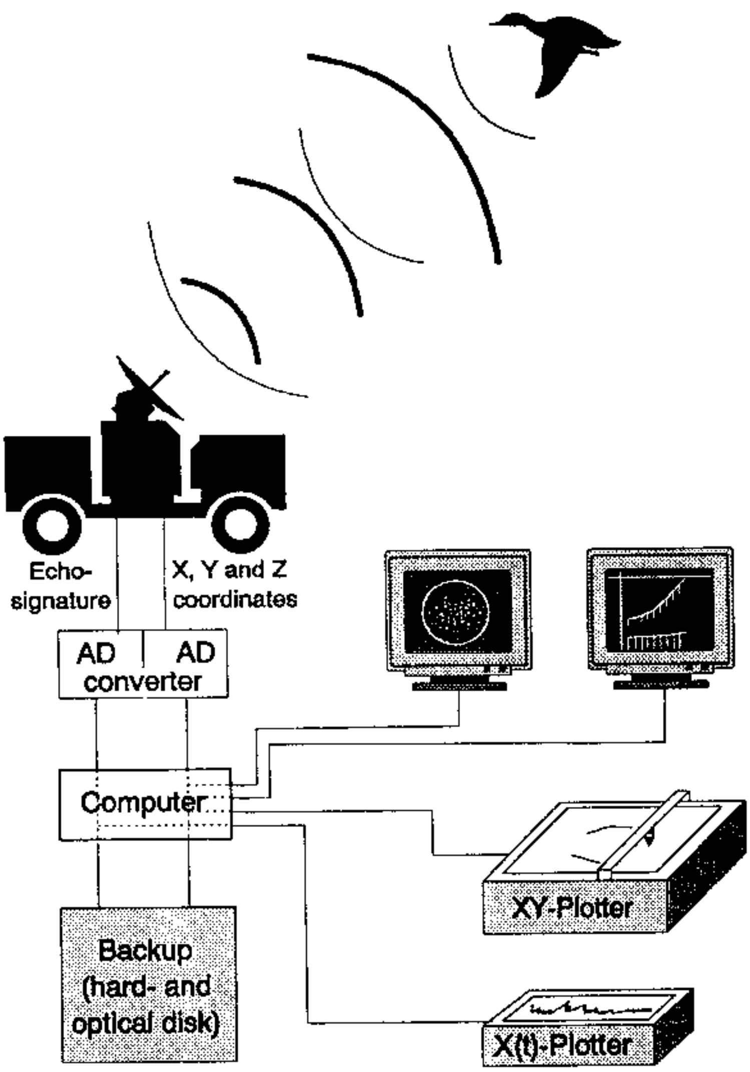
FIGURE 1

Location of the two radar sites in southern Israel



## FIGURE 2

Tracking radar "Superfledermaus" and recording equipment



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Elevations of the radar beam for conical scanning

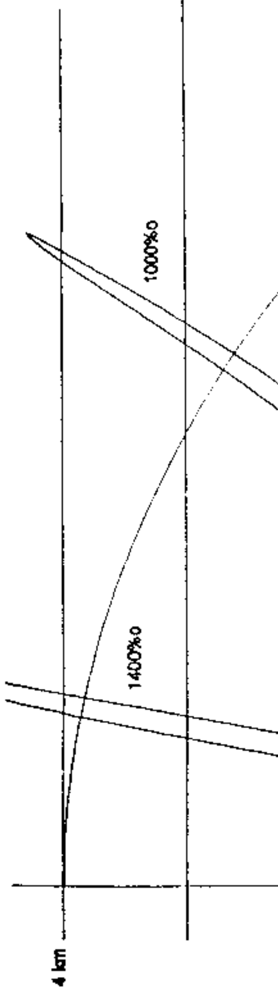
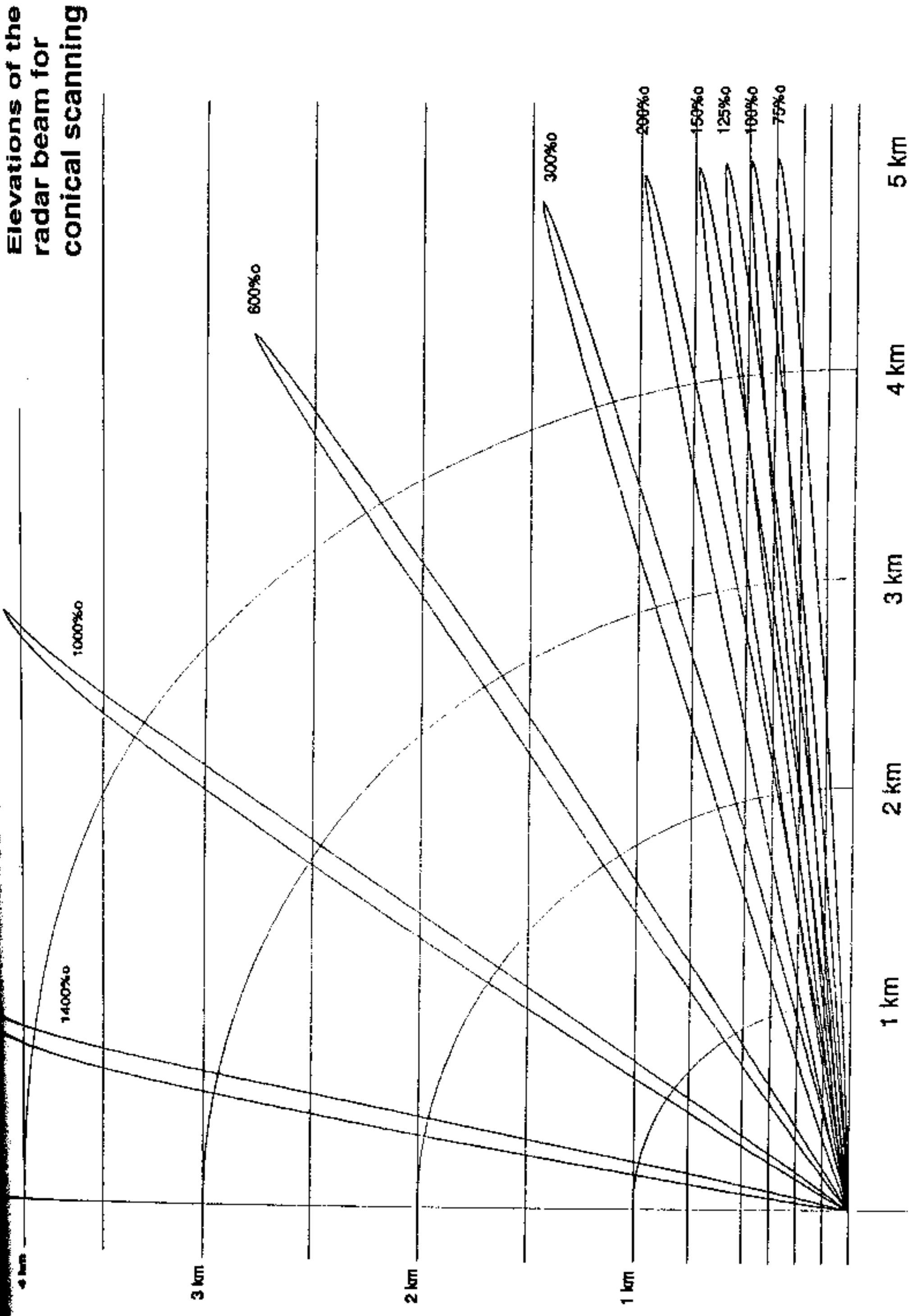


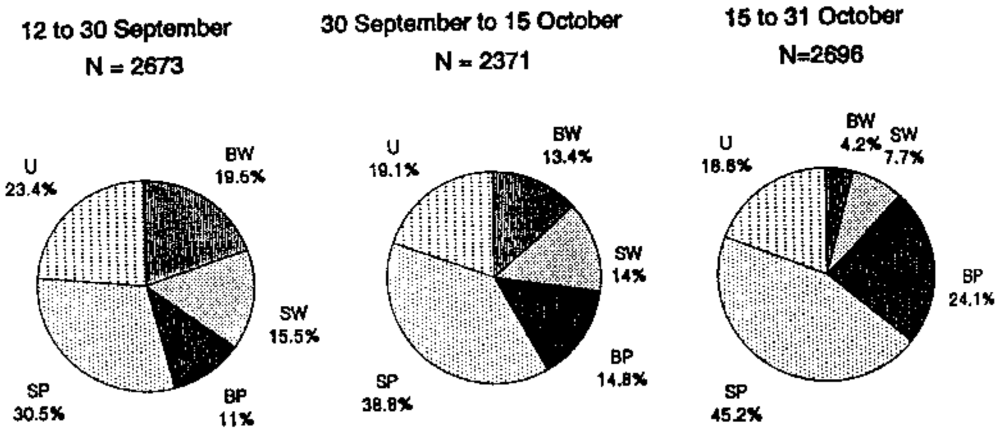
FIGURE 3

Elevations of the radar beam for conical scanning



# FIGURE 4

Proportions of wing-beat classes of nocturnal migration for three autumn periods



12 to 30 September
N = 2673

30 September to 15 October
N = 2371

15 to 31 October
N=2696

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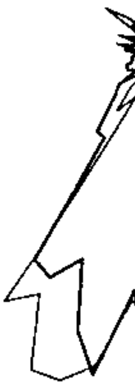

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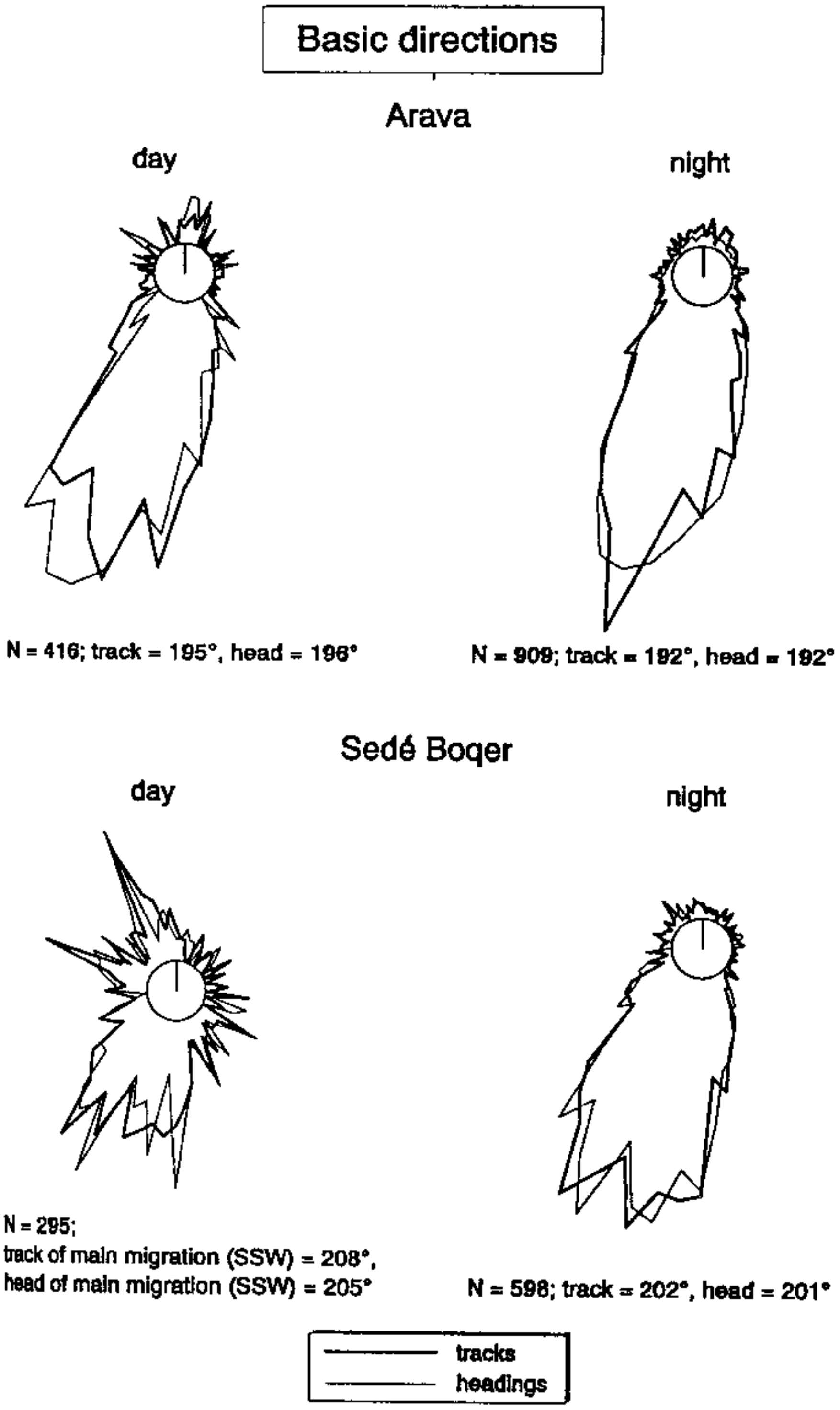
FIGURE 5



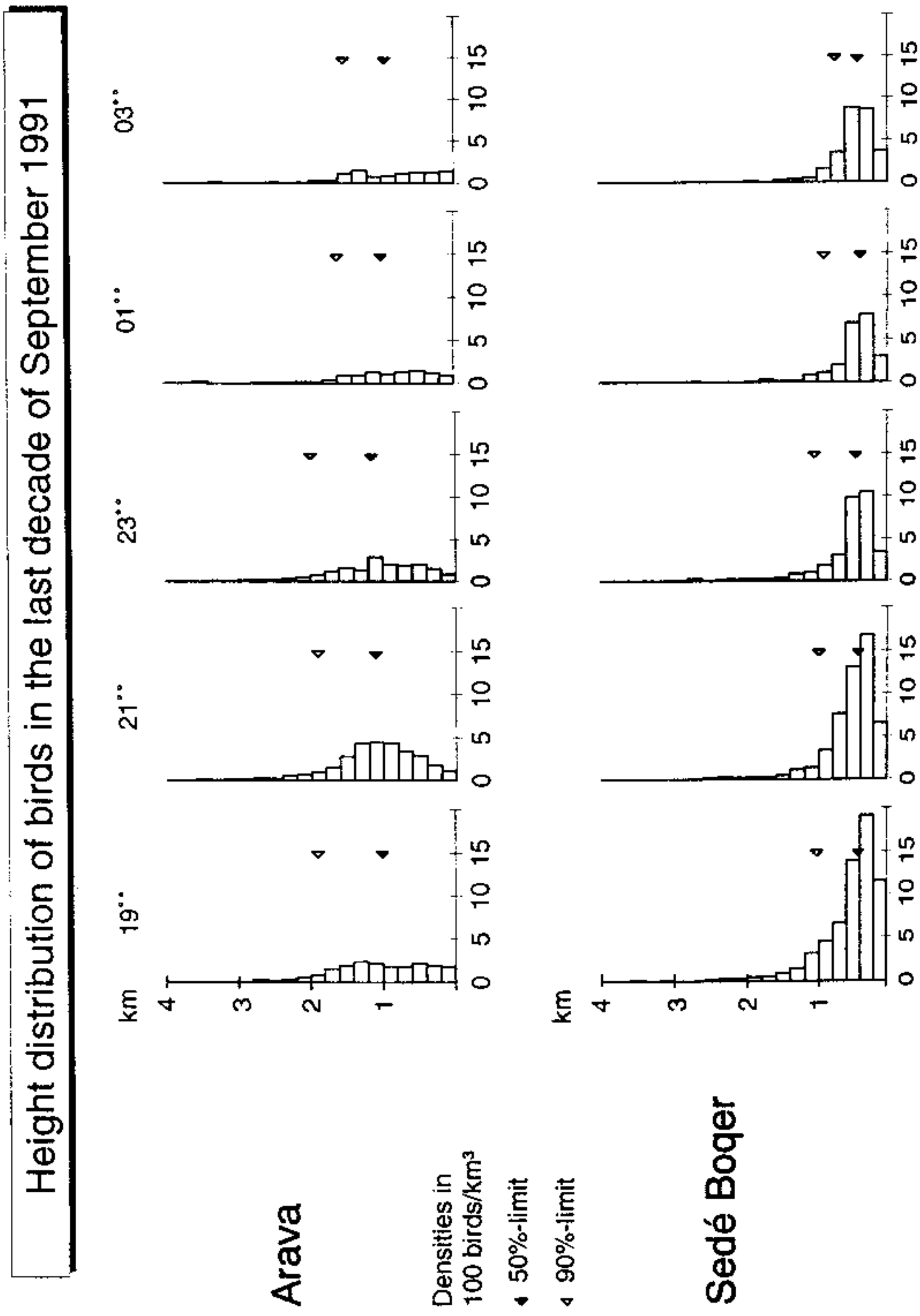
Arava, day: N = 416; track = 195°, head = 196°

Arava, night: N = 909; track = 192°, head = 192°

Sedé Boqer, day: N = 295;
track of main migration (SSW) = 208°,
head of main migration (SSW) = 205°

Sedé Boqer, night: N = 596; track = 202°, head = 201°

**FIGURE 6**



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