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"HIGHLIGHTS OF THE NATO-GIBRALTAR BIRD MIGRATION RADAR STUDY"

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INTRODUCTION

A Royal Air Force - Royal Radar Establishment team have been [illegible] bird migration radar study with Belgium, Denmark, France, Germ[illegible] Norway, Sweden, Switzerland and the Canadian Armed Forces in [illegible] exercise, coordinated by the Bird Strike Committee Europe, is [illegible] bird strikes on aircraft. The study has had support and funds [illegible] Scientific Council of Nato.

A chain of radars, visual observation posts and meteorologica[illegible] Scandinavia to the Mediterranean have been employed to watch [illegible] birds. Migrations to be seen from Gibraltar are narrow-front [illegible] raptors (eg eagles, vultures, buzzards, kites, harriers and h[illegible] soaring birds, and broad-front movements of passerines (eg th[illegible] pipits and wagtails) and waterfowl across the Mediterranean, [illegible] migrations in and out of the Mediterranean.

Visual observations at Gibraltar have been made before and th[illegible] by a team of ornithologists lead by Ernest Garcia. Visual ob[illegible] limited in range coverage, provide valuable evidence of speci[illegible] often a record of birds flying below the radar beam.

The radars operated by the Royal Air Force at Gibraltar are [illegible] movements over the Iberian Peninsula, across the Straits and [illegible] Spring they enable "early warning" to be given of the migrat[illegible]

An S-band air traffic control radar provides early warning a[illegible] surveillance of bird movements. A twenty-four hour, 16 mm [illegible] time record was made of the PPI for assessment of echo inte[illegible] tracks of bird movements every day during Spring and Autumn.

A high-resolution X-band tracking radar was used to obtain [illegible] echo characteristics of single birds or of single-echo domin[illegible] birds. Positional and echo data, together with time-code an[illegible] tions of each tracking radar engagement were recorded on 7-t[illegible] tape for subsequent analysis.

Visual observations and observations by both radars are nece[illegible] possible to assess height and species without a radar tracke[illegible] movements can be missed without visual observations.

Although the attempt to correlate bird movements and weather [illegible] chief feature of this cooperative project, it will be some t[illegible] country has evaluated their analysis results. These regiona[illegible] then be assembled by the BSCE working group and coordinated [illegible] they try and explain some riddles of pan-european migration.

There are, however, many results of the Gibraltar study that [illegible] immediately for improving air safety in the region, and whic[illegible] with results from other European countries, could help pan-e[illegible]

SOME ATC RADAR RESULTS

An example of information available for immediate use is that obtained from a preliminary survey of the PPI films taken during Spring 1969, and Spring and Autumn 1971-72. RRE was helped in this survey by Dr P Evans (Zoological Dept, Durham University). Dr Evans and Sir Gerald Lathbury have made use of this data in their paper on the passage of raptors at Gibraltar (1). Many of their results and conclusions should prove useful in flight planning in the region. For example they give mean dates and standard deviations for Spring and Autumn main passages of most important species. Peak numbers of two of the most abundant species, the Black Kite (Milvus migrans) and the Honey Buzzard (Pernis apivorus) move through the Iberian Peninsula within a spread of a few days of mean dates in Autumn, and over a wider spread but still restricted periods in Spring.

Visual observers have records of up to several thousands of Honey Buzzards passing Gibraltar during a single day in the peak periods of May and early September, but the PPI film record reveals that the visual passages are only part of the movement seen by radar. PPI film records during May and September show tracks of long chain-like or indian-file echoes, painting solidly, usually overland, but also sometimes well offshore during daylight hours. Although there are indications that Black Kite flocks generate thin chain-like echoes it is the more concentrated, box cross-sectioned, long formations, of Honey Buzzards that generate intense indian-file echoes (the Black Kite formations might always be revealed as chain echoes also by a more powerful radar). Some of these echoes indicate that Honey Buzzard columns can extend up to 15 nautical miles or so.

Some obvious effects of changes in the weather on bird movement can be seen on PPI film when the target is an extended one utilizing many radar resolution cells. This is quite pronounced in the case of indian-file echoes generated by Honey Buzzards. For example on 29th August 1972 the wind blew from WNW and the PPI film record shows the Honey Buzzard echoes making a southerly passage near Gibraltar, turning there and crossing Algeciras Bay to Point Carnero and finally crossing the Strait and entering Morocco just West of Ceuta. By the morning of 30th August the wind had changed direction and was blowing from the East and Gibraltar was experiencing what is called locally "levanter conditions". The wind at 2000 ft increased in speed from 10 kts on the 30th August until it reached 24 kts approx by midday on the 1st September, and the wind remained in the same quarter. The effect of this East wind was to 'drift' the Honey Buzzard formations to the west as they moved southwards down Spain. Under the influence of the East wind they do not pass near to Gibraltar. With a wind as strong as 20 kts Honey Buzzard chains can be 'blown' or 'drift' almost over the West coast of the Iberian Peninsula; there they turn and head back east on a serpentine course over the mountains. How much help they obtain by working in the lee of hills is difficult to say, but as they can be clearly seen by radar they are not using hills as simple protective screens. Although the Honey Buzzard has been shown from radar tracking records to be capable of flying at an airspeed of 30 kts in a 10 kt headwind the tortuous course they make beating back from the west coast suggests they are probably using thermals as well as wing effort. Eventually the Honey Buzzard formations turn southwards, cross the coast in the vicinity of Tarifa and fly across the Strait into Morocco far west of Ceuta. This behaviour of Honey Buzzards under the influence of the prevailing East and West winds is quite typical and recurs year by year. The journey under the easterly wind is of greater length than that influenced by westerly winds, but the passage appears continuous and there are no indications from the PPI record that the flocks alight to rest in Spain on the longer passage. However, during storm conditions and driving rain individuals alight and find shelter even on the shorter Gibraltar passage.

SOME TRACKING RADAR RESULTS

The tracking radar was used to obtain flight and echo signal characteristics on the largest migratory movements during the day and night. The method adopted was for the Project Officer to view the general migratory situation on the ATC PPI and after selecting a suitable target to direct the tracking radar on to it. The tracking radar was then methodically scanned through the assigned target in elevation. During migration large numbers of birds can be acquired without accurate "putting on" information if the target area is in the centre of gravity of a migratory movement. Generally 30 to 40 birds were tracked for not less than 2 minutes per engagement per watch. During the day the tracking radar was sometimes "put on" large raptor formations by means of the telescope fitted to the radar aerial.

Although the radar could look down to the sea in some sectors, the presence of sea clutter on some days was an obstacle to low elevation operation.

Although it is fairly easy to locate an object by radar it is very difficult to identify it. Certain large scale movements of birds, such as those just mentioned or Starlings (Sturnus vulgaris) leaving their roost at dawn generate characteristic echo patterns which have been identified from deductions made from correlated visual and radar data, but generally species cannot be identified from the PPI record.

Although the pilot of a damaged aircraft does not care whether he was struck by a flock of Mallard or Gadwall duck, the difference may be vital in deciding what course of action to be taken in avoiding a similar incident in the future. The importance of identification of species is illustrated by an extreme case which occurred in Texas. There a night-flight training program was jeopardized by strikes thought to be caused by birds. Eventually a species of migrant bat was identified and its habits allowed a flight rescheduling solution.

Birds modulate radar echo signals with low frequency waveforms related to their wing beat frequencies, wing flapping and wing rest periods, and other body movements. The bird activity modulation (BAM) waveforms generated by many migrant birds are quasi-periodic and relatively constant in mean level and modulation index. Such tracks are produced by birds flying straight tracks, at constant heights and relatively constant velocities.

BAM waveforms can be catalogued by "putting on" a tracking radar to a known species and obtaining flight and echo signal data from it. Waveforms and flight data can be filed away on magnetic tape and compared with that of data from an unknown species at a later date. The catalogue can be extended by including data obtained by analyzing the wingbeat cycles of known species photographed with a calibrated (frame-speed) camera.

At Gibraltar the operator i/c was told to concentrate on birds with wingbeat frequency rates below 15 Hz.

The waveform and spectrum of a single bird are shown in fig 1. The waveform consists of repetitive bursts of quasi-sine waves generated by wing flapping, separated by quiescent periods produced by wing pauses. The chief frequency component of the waveform, shown on the spectrum diagram, is 8 Hz approx and corresponds to the physical wingbeat frequency of the bird. This waveform was obtained after sunset at a range of over 2 nautical miles from a bird flying at 19 kts airspeed on a straight track at a constant height of 5800 ft. The wingbeat frequency, the long duration (seconds instead of tenths of a second) pauses and bursts of wing activity correspond closely to the known echo and flight characteristics of the Swift (Apus apus); a small bird weighing 40 gm and found in abundance in Europe by day and by night in Spring and Summer.

Bird activity modulation waveforms of soaring birds, such as the raptors, are quasi-periodic in the wing flapping mode, but the rest periods are not usually repetitive. Depending upon conditions a raptor may soar, glide or it may flap along for long periods without a pause. As a result of body changes or head scanning a raptor often generates both a fluctuating mean level and a fluctuating modulation index.

A waveform of a single raptor is shown in fig 2. The flap and rest periods are not repetitive. The clean 3.1 Hz spectral line as shown in the spectral diagram corresponds to the physical wingbeat frequency. This waveform was obtained two hours after dawn at a range of 1.7 nautical miles from a bird flying at 10 kts airspeed a relatively straight track at 2700 ft. The echo waveform and the flight characteristics could have been produced by a number of raptors, but as the data was obtained by "putting on" to a Honey Buzzard formation it is most likely to be due to a Honey Buzzard. The wingbeat frequency of a Honey Buzzard has been measured as 3 Hz approx by cine-photography.

BAM waveforms obtained on 11th May 1973 from two birds flying after sunset are shown in fig 3 and fig 4. They are of great interest because their wing-beat frequencies are much slower than any yet catalogued by cine-photography. As bird mass is very approximately inversely proportional to wingbeat frequency these birds could be quite big. Both birds are following very nearly the same straight track, but the data obtained from the bird generating data fig 4 was obtained 75 minutes earlier. The data in fig 3 was obtained from a bird flying at 20 kts ground-speed at a constant height of 4800 ft, while the data in fig 4 was obtained from a bird flying at 27 kts ground speed at a constant height of 4000 ft. The BAM waveform in fig 3 is a continuous triangular wave with a fluctuating modulation index and mean level, while that in fig 4 is a similar waveform but with relatively constant index and mean level. The fundamental spectral components of fig 3 and 4 are 1.7 Hz and 1.5 Hz respectively. The lowest recorded wingbeat frequency is 2.6 Hz for the Heron (Ardea cinerea).

Another possibility besides that of being large birds, such as Storks, would be for them to be both exceptions to the inverse proportional rule.

DISTRIBUTION OF WING BEAT FREQUENCY WITH HEIGHT

Both flight and echo properties can be combined to give estimates of the height and weight distribution of bird movements. The empirical relationship between wingbeat frequency and bird mass, which has a physiological basis and enables an estimate to be made of the bird hazard in a region (2), shows that with a few exceptions, heavier birds flap their wings more slowly than lighter birds. The charts in fig 5 and 6 show the distribution of birds found at various heights generating specific wingbeat frequencies in Spring and Autumn. Consider the chart for Autumn, the chief day movements lie in the wingbeat frequency and height ranges of 2-5 Hz and 300-1800 metres respectively, while at night there are three main groups between 2-4, 5-8 and 10-12 Hz within the height range of 300-2400 metres.

The day movements contain large numbers of raptors (eagles, vultures, buzzards, kites etc) that weigh between 400-10,000 gm while the night movements are of passerines, doves, waders and duck weighing in the range 20-2000 gm. Bearing this in mind a consideration of these charts leads to the opinion that the Gibraltar region can be especially hazardous to aircraft during day migration.

HIGHLIGHTS OF THE GIBRALTAR RADAR STUDY

Some highlights of the preliminary analysis of results from Gibraltar are as follows:

1 Radar evidence that the narrow-front diurnal movement of raptors, especially the spectacular 'indian file' movements of Honey Buzzards, are on a much bigger scale than estimates based upon visual observations.

2 There is radar confirmation that the passages of certain hazardous species are of short duration and occur at about the same dates, year by year.

3 The weather has a dramatic influence on the routes taken by some raptors, such as Honey Buzzards, to reach Africa and this is clearly shown up by radar.

4 The use of a height-finding radar has enabled the height distributions of potentially hazardous species to be measured. Contrary to local evidence raptor movements do not take place mainly below 1000 ft but above 1000 ft.

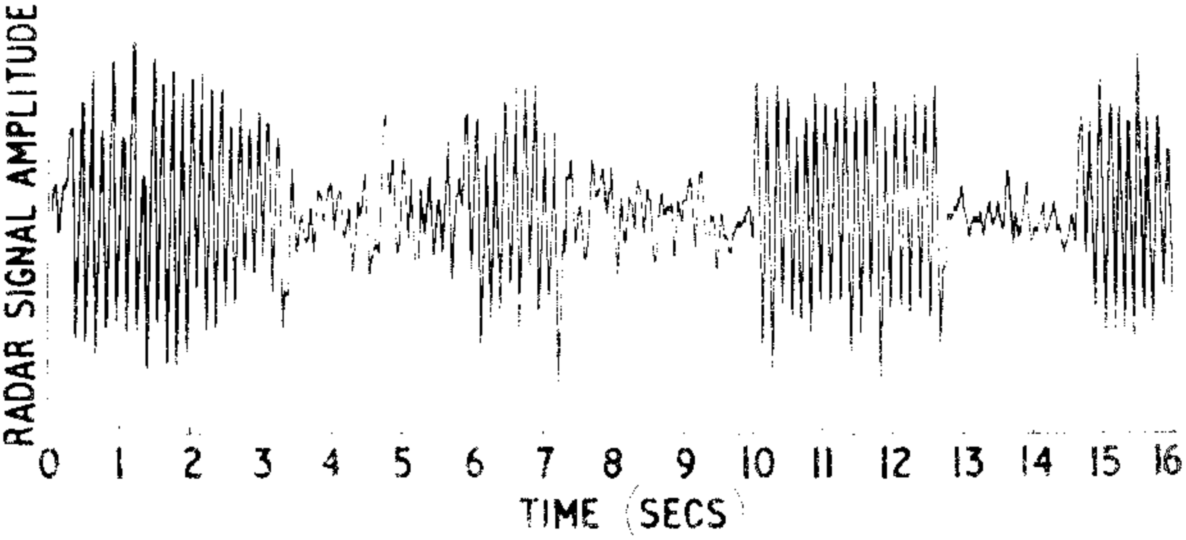
5 Charts of wingbeat frequency versus height for diurnal and nocturnal bird movements for Spring and Autumn have been made using tracking radar data. These charts reveal that the Gibraltar region is often dangerous to aircraft.

This information should be of great value to flight safety planning.

REFERENCES

1 Evans, P R and Sir Gerald Lathbury: (1973): "Raptor Migration Across the Straits of Gibraltar", to be published.

2 Houghton, E W and Blackwell, F: (1972): "Use of Bird Activity Modulation Waveforms in Radar Identification", 7th Meeting Bird Strike Committee Europe, London Conference.



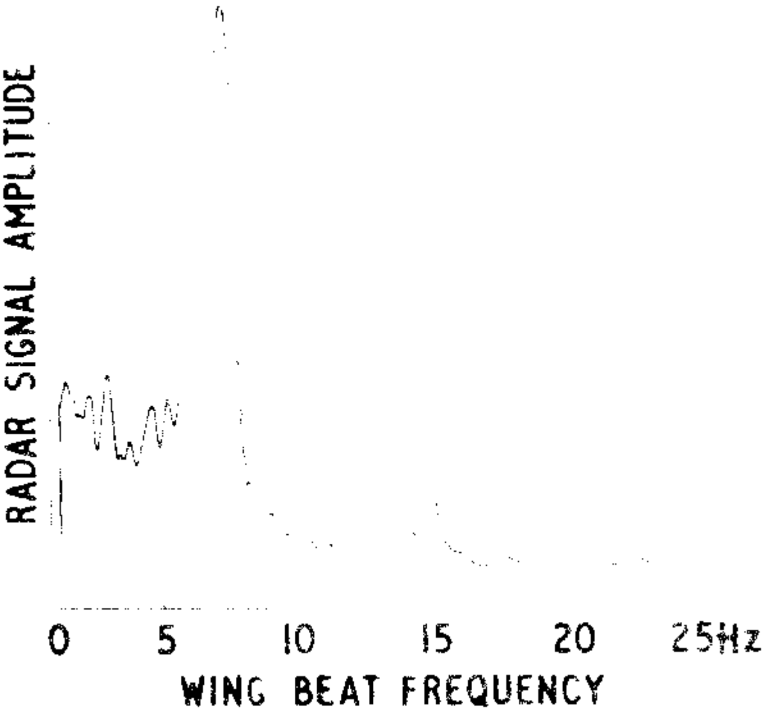


FIG. 1
BAM WAVEFORM AND SPECTRUM

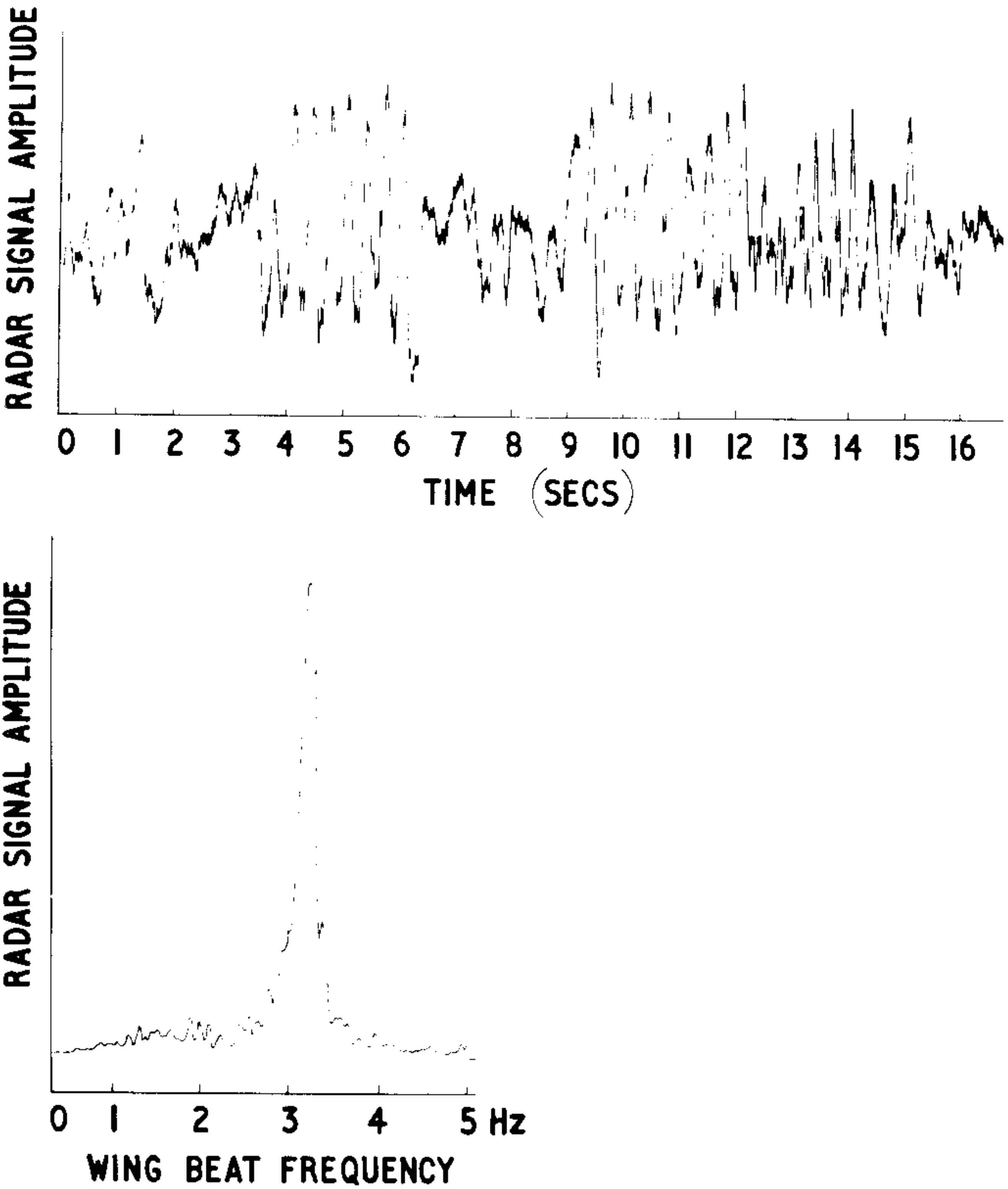
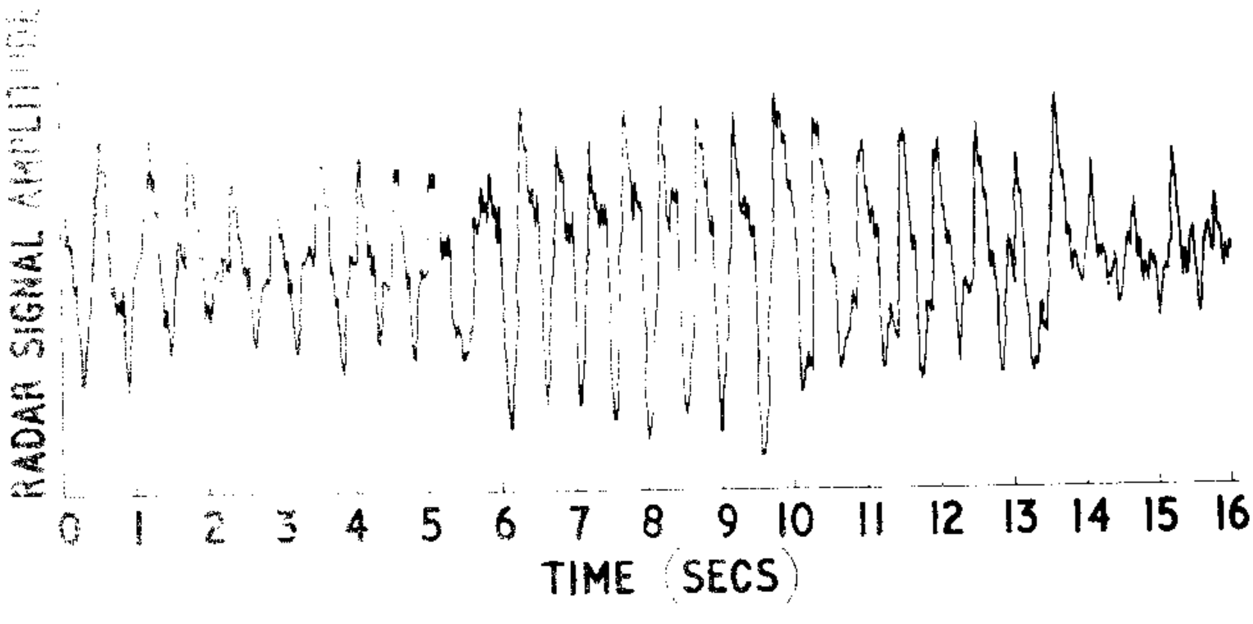


FIG. 2
BAM WAVEFORM AND SPECTRUM
OF MIGRATING BIRD



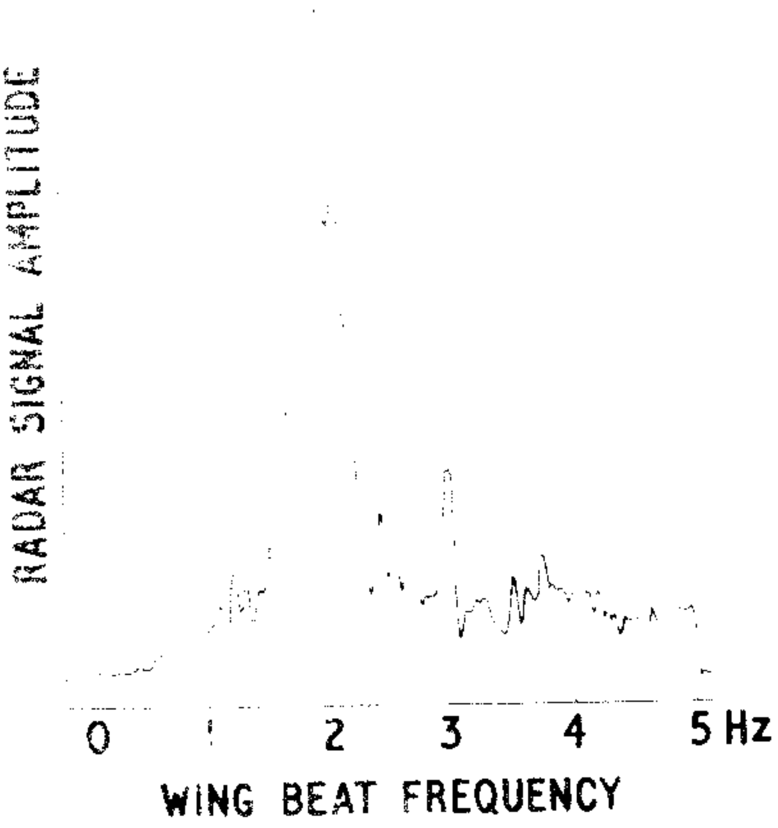


FIG. 3

BAM WAVEFORM AND SPECTRUM

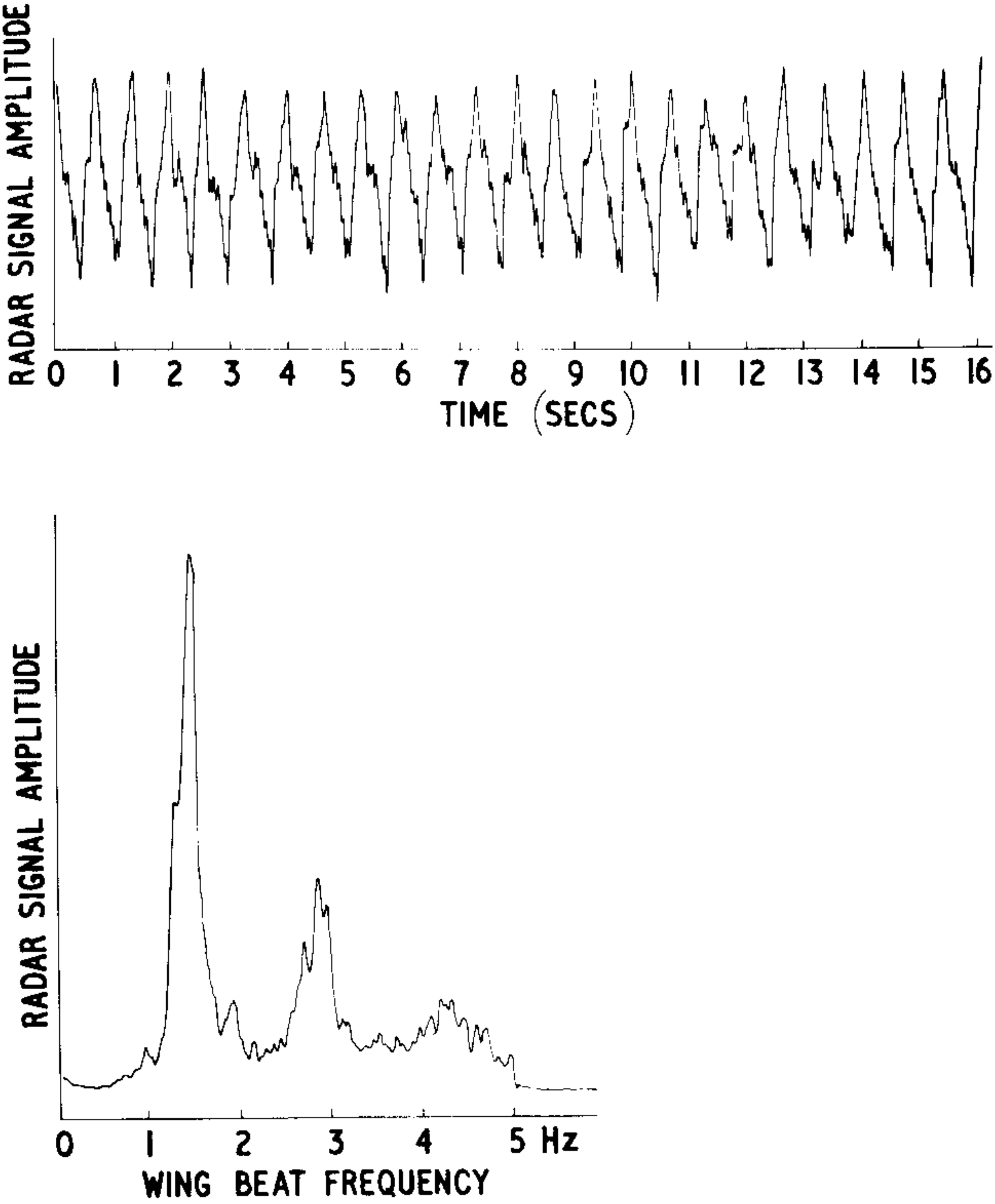


FIG. 4
BAM WAVEFORM AND SPECTRUM

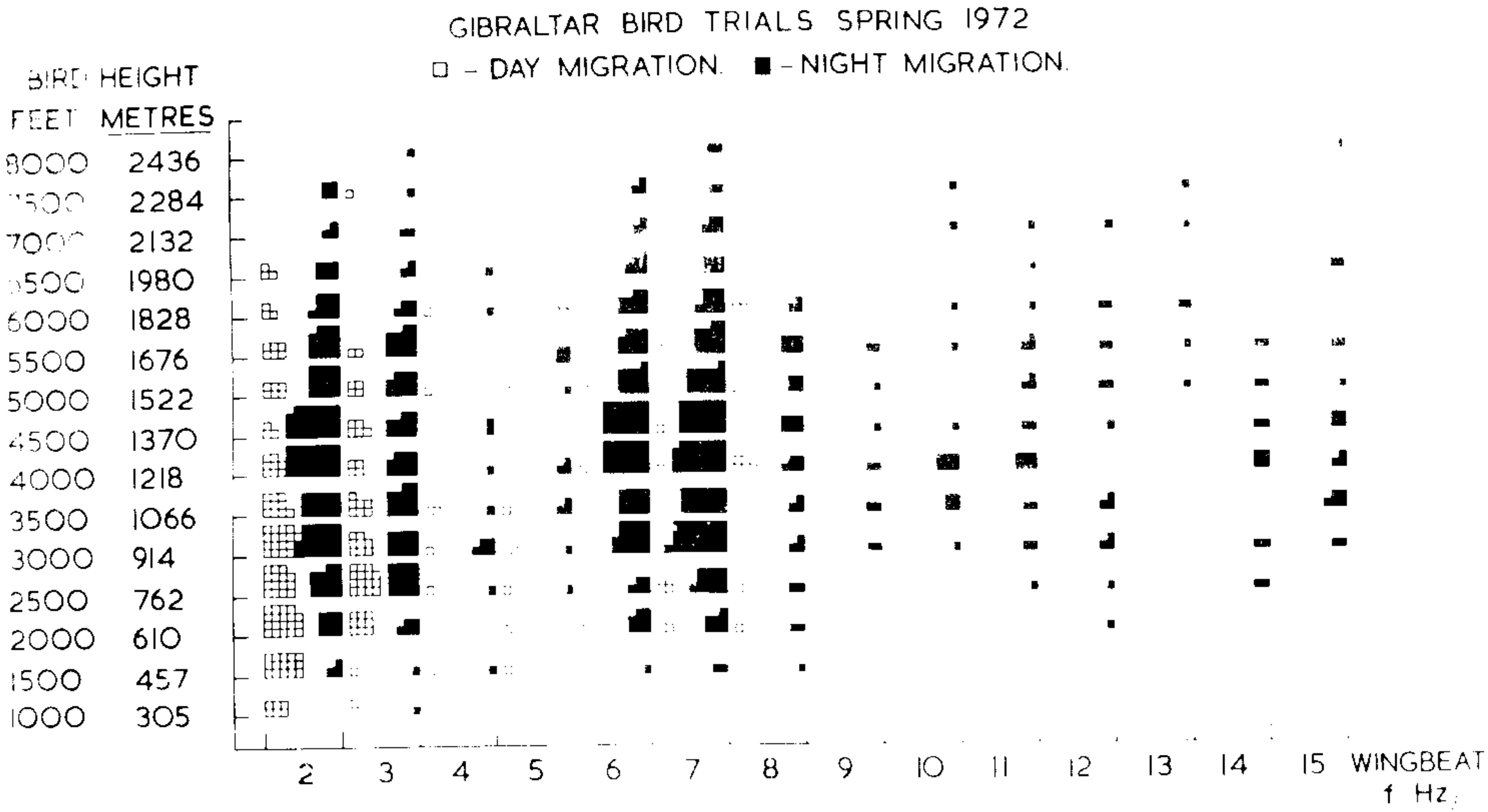


FIG. 5 HEIGHT VERSUS WINGBEAT FREQUENCY DISTRIBUTION

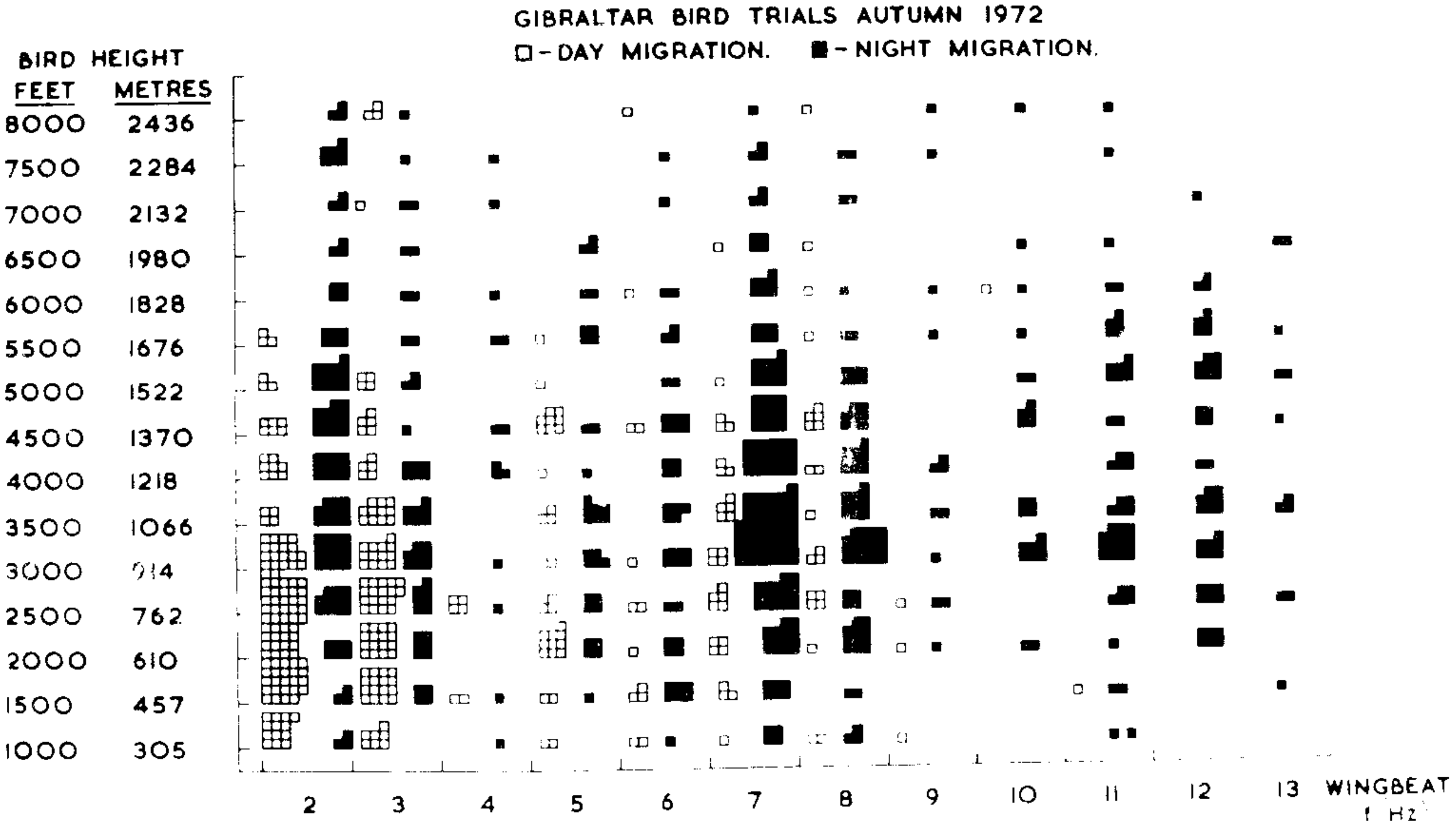


FIG. **6** HEIGHT VERSUS WINGBEAT FREQUENCY DISTRIBUTION