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IMPROVED DECISION MAKING BY MIGRATING DIURNAL RAPTORS DURING MORE INTENSE MIGRATION

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The possibility that decisions made by flocks of animals, including birds, might be the product of a concensus was first stated explicitly by Lorenz (1952), but his comment did not elicit any research effort, although Condorcet (1785 ; see also Grofman *et al.* 1982) had shown that majority decision making should lead to distinct statistical advantages. There is every reason to believe that majority decision making could evolve in natural populations (Thake 1984-1985b).

In this paper, positive correlation is demonstrated between the accuracy of a decision to migrate made by certain raptors, and the total number of raptors on migration at the time.

Methods

The data used in this paper were obtained during visual watches maintained at Buskett during the autumns of 1976-78. For details of the observation methods, the reader is referred to earlier papers (Thake 1977, 1980). Although the period and duration of observations varied slightly from year to year, coverage during September was very uniform, and data for this month alone were used in the calculations.

Details of local weather were recorded at hourly intervals. Additional data were obtained from the records of the meteorological stations at Luqa and Qrendi. Regional weather maps were supplied by the Deutscher Wetterdienst and by the Hellenic National Meteorological Service.

Results

All calculations were performed on a Casio Fx 801P programmable calculator, using *ad hoc* computer programs devised and tested by the present author.

Wind strength data recorded at hourly intervals at Buskett were used to calculate the mean wind strength during a given watch. Watches were scored for suitability of migration conditions on the basis of wind strength alone. 'Good' conditions were considered to have prevailed on days when mean wind strength during a watch was less than 10 knots, while 'Bad' conditions were characterised by a mean wind strength of more than 10 knots. Data for September of each year were tabulated by date, forming the raw data for the analyses which followed.

Data for each date were grouped, and the fraction of individual birds of each species migrating during 'Bad' conditions calculated as a fraction of the total number of individuals migrating over Buskett on that date over the three years. The correlation of this fraction with the total number of individuals migrating on this date was investigated graphically, and by calculating a correlation coefficient. Data for the three species were then combined, and the analyses performed for all three species together. The results of these analyses are tabulated in Table 1.

TABLE 1 : Correlation of the fraction of individuals migrating during 'Bad' conditions with the total number of individuals sighted. Data for single dates analysed individually.

Species	Correlation Coefficient	Sample Size
Honey Buzzard	-.3172**	30
Hobby	-.3535**	25
Marsh Harrier	-.2341*	25
All species	-.5256***	30

*** p < .01
** .05 < p < .10
* .01 < p

The data were next grouped in periods spanning five dates (e.g. 1st to 5th September; a total of 15 days over three years), and the proportion of birds migrating under each of the two weather categories was calculated for all three years together. The total number of birds seen during this period was also calculated. Linear correlation coefficients were determined for the variation of the fraction of individual birds migrating during 'Bad' conditions with the total number migrating during the period in question. In addition, the mean number of birds migrating during both types of condition, and the ratio of the means sighted per day for each weather category were calculated. Correlation coefficients were calculated for variation of this quantity with the total number of birds migrating during the period in question. The results of these analyses are presented in Table 2.

TABLE 2 : Correlation of the fraction of individuals migrating during 'Bad' conditions with the total number of individuals sighted. Data grouped in intervals spanning five dates (see text).

	Fraction in 'Bad'		Mean no. in 'Bad' / Mean no. in 'Good'	
Species	Correlation Coefficients			
	simple	rank	simple	rank
Honey Buzzard	-.8939**	-.8857**	-.8116**	-.7143
Hobby	-.6715	-.7	-.3882	-.7
Marsh Harrier	-.5069	-.3	-.5877	-.3
All species	-.9108***	-.8857**	-.8696**	-.8857**

** .01 < p < .05
*** p < .01

A further analyses was performed using the same data. The total proportion of birds seen during 'Bad' conditions during the first n date periods to produce a 'n date moving proportion'. The calculation was performed for n= 1 to n= 23. Correlation between this quantity and the total number of birds seen during the period in question, was investigated for each value of n. Again the analyses were performed for each species in turn, and on all three species combined to produce Figure 1.

Sightings of flocks of Honey Buzzard *Pernis apivorus* were analysed for randomness as follows. Only data collected between 1200 and 1800 CET were used in the analyses. The number of Honey Buzzards migrating over Buskett during this period varied little with time of day during the study period (Thake 1981). Data for the last ten days in September 1976, when weather over Malta was anticyclonic and varied little from day to day, were stored on computer tape. These data were sampled using intervals of variable duration to deter-

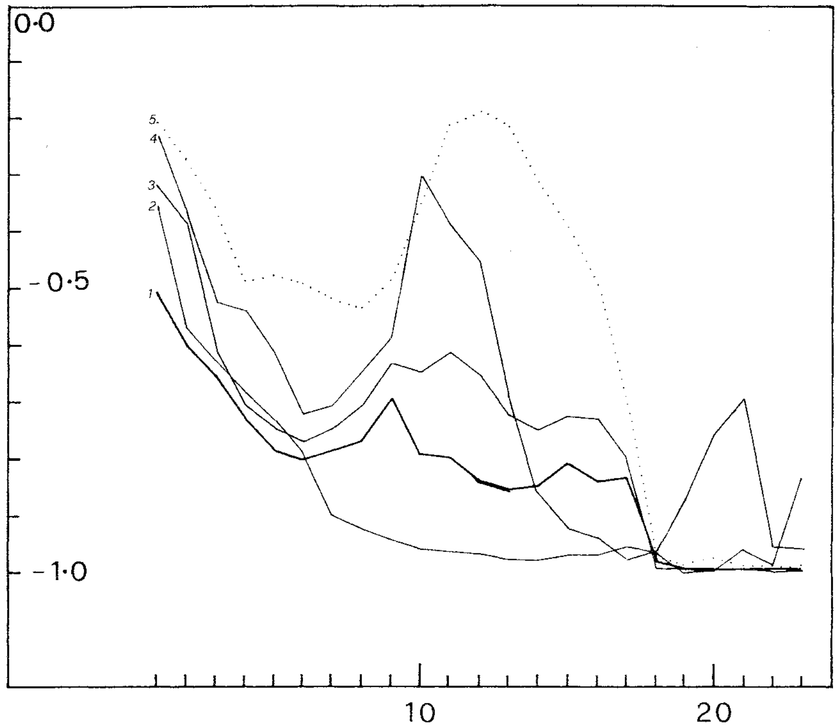

Fig. 1. Correlation of an 'n date moving proportion' of individuals migrating during 'Bad' conditions, with the total number of individuals sighted during the n date interval, plotted against the length of the interval (n) (see text for explanation). At low values of n, all five graphs show a pronounced tendency to become more negative with increasing n. This suggests that a source of variance is being removed by combining data for contiguous dates.

Key
1 All three species totals combined
2 Honey Buzzard
3 Hobby
4 Marsh Harrier
5 Honey Buzzard flocks consisting of one or two individuals.

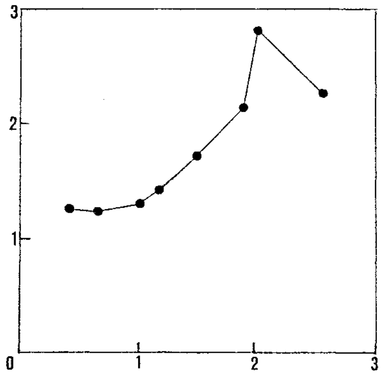

Fig. 2. Coefficient of dispersion (variance/mean) of the number of sightings per interval plotted against Log_{10} of the length of the sampling interval in minutes.

mine the most suitable sampling interval for detecting patchiness (see Figure 2). A sampling interval having a high coefficient of dispersion (the sixty minute interval) was selected (for rationale, see Sokal & Rohlf 1969). Data for the entire study period were then used to extract two sets of data for low and for high migration intensity (3 - 6 flocks sighted during each six hour period versus 24 - 37 during high migration intensity). These two sets of data were then analysed separately using a sixty minute sampling interval. The results are tabulated in Table 3.

Table 4 lists the numbers of flocks of various sizes which were seen during 'Bad' and 'Good' conditions respectively.

TABLE 3 : Analysis of Honey Buzzard sightings for randomness.

Number of flocks per interval	Intensity of migration High	Low
0	7	30
1	6	20
2	12	7
3	8	2
4	10	1
5	9	0
6	9	0
7	4	0
8	4	0
9	4	0
10	1	0
11	1	0
12	1	0
13	0	0
14	0	0
15	1	0
16	1	0

Poisson fit : Chi squared =	21.59	.1095
G =	19.22	.1099
	$p < .005$ significantly non random	$.5 < p < .75$ not significantly different from random

TABLE 4 : Sightings of flocks of various sizes during weather belonging to each of the two classes.

Flock size	1	2	3	4	5	6	7
Number in 'Bad' weather	33	9	3	2	3	1	1
Number in 'Good' weather	298	100	65	31	36	12	6

None of the proportions differ significantly ($p > .10$). Various combinations of flock size were tested for significant differences. No significant differences were found.

Discussion

Il-Wejba, Buskett, has been used as a watch point for studying raptor migration since 1966 (Galea 1969, Beaman and Galea 1974), and the general features of raptor migration through the islands are well known. Honey Buzzards (Thake 1977, 1981), Marsh Harriers *Circus aeruginosus* (Thake 1983a) and Hobbys *Falco subbuteo* (Thake 1978a) leave Sicily during anticyclonic weather when wind strength at low levels in the early morning is low. Hobbys converge on Buskett throughout the day, apparently to hunt small passerines (Thake 1978a, 1978b). Both Honey Buzzards and Marsh Harriers converge on Buskett in the late afternoon, and Honey Buzzards usually attempt to roost there (Beaman & Galea 1974). A leading line effect due to southeastwards trend of the southern coast of Malta operates to a variable extent depending on wind strength (Thake 1981, 1983b, 1984-85a). High totals of Honey Buzzards coincide with light southerly winds even if these are only sea breezes. The three species discussed in this paper thus decide to make the crossing to Malta on the basis of much the same criteria. Migration of the Kestrels *Falco naumanni* and *Falco tinnunculus* through the islands follows a rather different pattern (Thake 1982), and these species are not considered in this paper.

Consider the following hypothetical situation. On a given day, there are a number of raptors in Sicily deciding whether or not to cross the central Mediterranean on that day. Weather conditions are 'Bad' but some cross nevertheless. The ones which remain are reinforced by new arrivals and decide again on the following day. In such a situation, the number of birds on migration provides an index of the degree of socialisation which the birds may experience before deciding whether to migrate. The various analyses summarised in Table 1 and 2 utilise modifications of this index.

The correlations reported in Tables 1 and 2 clearly indicate a relationship between the accuracy of decision making and the number of birds on migration at the time. The relationship was present in all species examined but only reached significance in the Honey Buzzard (the most numerous species), and when the totals of all three species were combined.

The correlation coefficients calculated for the 'n date moving proportion' show a strong tendency to become more negative as the length of the moving interval employed increases (Figure 1). This suggests that a source of variance is being removed when data from contiguous dates are combined.

The graphs for flocks of size 1 and 2 in figure 1 (line 5), and the results listed in Table 4 strongly suggest that the accuracy of decision making is not being influenced principally by flock size as recorded at Buskett. Previous studies (Thake 1980) had shown that flocks are labile and could not represent the unit which had originally made the decision to migrate.

Besides decision making in flocks, another plausible way in which raptors might interact is by observing one another's migratory behaviour at a distance. This could be done most effectively if the birds showed a clumped distribution in space, and hence in time as recorded at Buskett. Table 3 shows clearly that Honey Buzzards flock sightings were clumped temporally during high intensity of migration, but were not clumped when migration intensity was low. There was thus more scope for visual interaction between birds on days of intense migration.

There are three principal ways in which social decision making might occur. (1) The behaviour of superior decision makers might serve as a model for other birds. Experienced adults should be superior decision makers to first autumn birds and a hierarchy based on plumage discrimination might occur. (2) Birds might pool information about their environment with other flock members, and then decide individually on the basis of an improved knowledge. (3) Birds might evaluate the intentions of other birds and decide on a simple majority basis.

The data available do not allow one to decide confidently which of these methods is being employed by the birds. Indeed, they are not mutually exclusive, and various combinations of the principal methods are conceivable. Nevertheless, it is clear from the data and the analyses that decision making of better quality was produced when many birds were on migration together. The occurrence of some form of social decision making is thus strongly indicated.

Although there are no clear records to date which show that social decision making is advantageous, animals have frequently been observed performing some types of behaviour simultaneously (Birke 1974, Colgan *et al.* 1979, Dauphine & McClure 1974, Deputte 1979, Kisimoto *et al.* 1982, Kramer & Graham 1976, Mathieu 1970, Meixner & Shaw 1979, Richman 1978, Sambraus 1973, Siegfried *et al.* 1975, Voisin 1976, Weidmann & Darley 1971), and there is evidence that communication is taking place in at least some such instances (e.g. Clifton 1979, Orcutt 1974, Siegfried *et al.* 1975, Walker 1969). Much of the extensive literature on socially facilitated behaviour is relevant to this topic. Clayton (1978) provides a recent review of this subject. The investigation of social decision making in animals remains a promising and virgin field of research.

Summary

Previous studies had shown that Honey Buzzards ***Pernis apivorus***, Marsh Harrier ***Circus aeruginosus***, and Hobbys ***Falco subbuteo*** make the sea crossing from Sicily to North Africa via Malta during anticyclonic weather. Such behaviour minimises the risk of encountering bad weather while over the sea. Low wind strength is the weather factor which allows the best prediction of daily totals. Data for three years (1976 - 1978) were analysed to determine the relationship between the accuracy of decision making and the number of individuals migrating on migration. The fraction of individuals migrating during bad weather (winds stronger than 10 knots) during intervals of 3 and 15 days (over 3 years)

was negatively correlated with the total number of birds seen during that interval. This relationship was present in all three species, but only reached significance ($r = -.8939$; $p < .05$) in the Honey Buzzard, and when data for all three species were combined ($r = -.9108$; $p < .01$). There was no relationship between the accuracy of decision making and flock size, but flocks are labile, and do not necessarily represent the units which made the decision to migrate. The raptors might have observed one another's migratory behaviour at a distance. The observed clumped distribution of flocks during high migration intensity would facilitate this. The occurrence of decision making of better quality when many birds were on migration simultaneously is a strong indication that some form of social decision making was taking place.

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SHORT NOTES

ARRIVAL DATES OF MANX SHEARWATERS AT COLONIES IN MALTA

The Manx Shearwater *Puffinus puffinus* is the commonest shearwater in the western palearctic, with two sub-species being found in the Mediterranean. The *Puffinus p. mauretanicus* of the Balearics, and the *Puffinus p. yelkouan* of the eastern Mediterranean, including the Maltese Islands. The Manx Shearwater is a common breeding visitor to the Maltese Islands.

Sultana & Gauci (1982) record that birds start arriving at their colonies from February. Manx Shearwaters had never been recorded locally in the months of November and December, until five were seen off the east coast on 31 December 1974 (Gauci & Sultana, 1975). Prior to this date there had been only one sighting between August and February. This dearth of records was probably due to the lack of sea watching. Forty-three birds were counted in one afternoon off the northern tip of Malta on the 24 November 1976 (Sultana & Gauci 1982). Single birds were noted flying off the south coast of Malta, near Filfla, during December and January in recent years (pers.obs.). As sightings of this shearwater increased during the early winter months, various visits were conducted to the largest breeding colony, situated in the northern part of Malta, to determine whether adult birds started visiting the colonies before January.

The first visit was made on 25 November 1983, when no signs of birds visiting colonies were found. On the second visit on 12 December, birds had already been ashore, as footprints were seen in front of many burrows. Waiting until after dark, we managed to catch one bird which had been ringed in previous years, another was seen, while one was heard calling out at sea. In the following year we again went to the colony on 12 December when two were trapped. In 1985 we visited the colony on an earlier date, on 8 December. Footprints were seen in front of several nest holes. Remaining until after dark we managed to catch one, while another was seen flying close to the cliff. During these visits the weather was calm with clear skies and no moon, except for the night of 12 December 1983 which was calm but with an overcast sky and a light drizzle. A morning visit on 3 December 1986 revealed that birds had already been ashore as fresh footprints were found in front of some burrows.

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