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Rivers as possible landmarks in the orientation flight of *Miniopterus schreibersii*

Jordi SERRA-COBO, Marc LÓPEZ-ROIG, Tomás MARQUÈS-BONET and Eva LAHUERTA

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This study examines the initial orientation of *Miniopterus schreibersii* (Kuhl, 1817) when released from their roosts and analyses the significance of rivers as landmarks in bat navigation. Two orientation tests were carried out in which the bats were released in areas familiar to them and two further tests were carried out in unfamiliar areas. In both types of areas one of the tests was performed close to a river and the other away from a river. Initial orientation capability of *M. schreibersii* was verified in all tests except in unfamiliar area away from a river. The test performed in unfamiliar area with river showed higher mean angular deviation and lower directionality than the two tests performed in familiar areas. Most of the bats released near a river both in a familiar area and in an unfamiliar one turned towards the watercourse. The results obtained in these two last tests proved that the bats tended to turn towards the river. There were no significant differences between the directions taken by males and females in each of the four tests. Rivers seem to be landmarks in the navigation of the species and also paths to be followed in migratory flights.

Instituto Pirenaico de Ecología (C.S.I.C.), avenida Montañana 177, Apartado 202, 50080 Zaragoza and Universidad de Barcelona, Barcelona, Spain (JS-C); Departamento de Biología Animal. Universidad de Barcelona, avenida Diagonal 645, 08028 Barcelona, Spain (ML-R, TM-B, EL)

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Introduction

The study of orientation in bats, especially in migratory species, and their capability to find roosts has stimulated the interest of zoologists and ethologists for years. By using banding or radio-tracking techniques, several authors have proved that bats return to their original roosts after release (eg Cockrum 1956, Gifford and Griffin 1960, Mueller 1966, Williams and Williams 1967, Griffin 1970). Avery *et al.* (1984) observed that *Myotis lucifugus* finds the roost entrance by detecting the ultra-sonic signals from the bats already inside. Griffin (1970) suggested that bats recognize landmarks by echolocation. In certain situations passive auditory signals, like the sound of river water or sea waves, could also be useful. The same author also suggests the contribution of vision in long distance orientation. Buchler and

Child (1982) established that post-sunset glow is significant in the orientation of *Eptesicus fuscus*.

Miniopterus schreibersii (Kuhl, 1817) is a migratory bat with a relatively high and quick flight. It performs seasonal movements between summer roosts – with surroundings usually rich in trophic resources – and winter quarter, characterized by high humidity and relatively low temperatures. Between both types of localities the species uses spring and autumn roosts (Serra-Cobo *et al.* 1998). This study examines the initial orientation capability of *M. schreibersii* after release from its roosts and analyses the importance of rivers as landmarks for the navigation of the species.

Material and methods

Four tests were carried out by using bats from the spring shelter of Castanya mines, located in Montseny, a massif in the province of Barcelona (Serra-Cobo *et al.* 1987). Around 2500 bats coming from the winter quarter of Daví pothole after the winter period take shelter in these mines. Even though there is a lack of knowledge of the exact size of the foraging area of *M. schreibersii* from Castanya mines, the banding of bats carried out since 1985 has allowed us to know that the area is not bigger than 15 km (Serra-Cobo 1989). For each test a random sample with a similar number of *M. schreibersii* individuals was captured by hand and sexed. The bats were individually released in the following way: each bat was released to one cardinal point following the order north, east, south and west. They were tracked with binoculars until they disappeared from the observer's visual area; at that point their orientation was recorded with the aid of a magnetic compass. The directions of the roost R and the river – where appropriate – were also recorded.

The tests were designed to analyse the initial orientation capability of *M. schreibersii* when released inside and outside an area familiar to the species and also to determine the importance of rivers as landmarks during orientation. By familiar area we mean an area known by bats, either because it is part of a migratory path or a foraging area. For the first test 32 individuals were used. They were released at a site called Pujada de la Mel (41°47'27"N, 2°20'18"E), a place known by *M. schreibersii* as a foraging area (J. Serra-Cobo, pers. comm.) located at 1200 m height a.s.l. and about 2 km away in a straight line from their home roost. The second test (n = 37) was carried out in an area unknown by the species, 2 km away from Gurb village (41°58'34"N, 2°12'36"E) and about 24 km away in a straight line from Castanya mines. The third test (n = 38) took place in Santa Maria de Palautordera (41°14'25"N, 21°26'33"E), in an area familiar to the bats (a migratory path, Serra-Cobo *et al.* 1998) about 14 km away from the roost and about 100 m away from Tordera river. The fourth test was carried out in La Gleva (42°00'04"N, 2°14'50"E), in an area unfamiliar to the bats and near Ter river. The test was performed 26 km away from the mines and 34 individuals of *M. schreibersii* were used. In order to obtain accurate and reliable results all tests were performed in open areas, with no obstacles, thus allowing a successful tracking of the bats by the observers (which, in our case, always consisted minimum of four people). The tests were carried out in windless mornings (so that the flight path of the bats released was not altered) during springtime. As for the tests performed near a river we took into account that the direction of the river and the roost were different. This way it was easy to determine which direction the bat was travelling.

Mathematical processing of data

The directions obtained in each test were represented around a circumference. The mean direction was obtained as:

$$\tan\alpha = \frac{\Sigma \sin\alpha_i}{\Sigma \cos\alpha_i}, \text{ where } \alpha = \arctan\alpha$$

The Rayleigh-test (Schmidt-Koenig 1975, Batschelet 1981) was used to prove whether a sample was drawn from a uniform (H_0) or from some unimodal population (H_1). The length of the mean vector r is calculated according to the following expression:

$$r = R/n$$

where $R = [(\Sigma \sin\alpha_i)^2 + (\Sigma \cos\alpha_i)^2]^{1/2}$ and n is the sample size.

The length r is a measure of concentration and is restricted to the interval from 0 (when data are distributed in an ideal random way) to 1 (if all data of the sample are recorded in the same direction). Critical level p, in relation to the sample size n and to the mean vector length r, was obtained from the tables given by Batschelet (1981). The mean angular deviation SD is calculated by using the following formula:

$$SD = \frac{180^\circ}{\pi}[2(1-r)]^{1/2}$$

The V-test was used to show whether the sample was uniformly distributed (H_0) or clustered around the roost direction (H_1) (Schmidt-Koenig 1975, Batschelet 1981). If the angle to the roost direction is β, V is obtained from the formula:

$$V = R \cdot \cos(\alpha - \beta)$$

For practical purposes it is easier to use

$$u = [(2/n)^{1/2} \cdot V]$$

In the third and fourth tests we also used χ^2-test with Yates correction for continuity to verify whether the bats flew in the direction of the river, meaning those that flew towards the stretch of river within the observer's field of vision, that is to say, between 10° and 140° for the third test and between 20° and 190° for the fourth one. In each test the directions taken by males and females were compared by using Mann-Whitney test (Siegel 1985).

Results

Out of the two tests performed in areas far away from a river, directionality occured only in the one carried out at Pujada de la Mel, an area familiar to *M. schreibersii* because it is located in a foraging area (Serra-Cobo *et al.* 1998)

Table 1. Results of the statistical analyses of the four orientation tests. SD – mean angular deviation, n – sample size, R – roost direction.

Statistics	Familiar area		Unfamiliar area	
River absent	1st test		2nd test	
	SD = 46.12°		SD = 76.22°	
	n = 32		n = 37	
	R = 210°		R = 150°	
Rayleigh-test	$r = 0.676$	$p < 0.001$	$r = 0.115$	$p > 0.565$
V-test	$u = 5.12$	$p < 0.0001$	$u = 0.98$	$p > 0.10$
Mann-Whitney test	$U = 5.12$	$p > 0.10$	$U = 112.5$	$p > 0.10$
River present	3th test		4th test	
	SD = 49.95°		SD = 66.82°	
	n = 38		n = 34	
	R = 320°		R = 160°	
Rayleigh-test	$r = 0.620$	$p < 0.001$	$r = 0.320$	$p < 0.045$
V-test	$u = 0.43$	$p > 0.10$	$u = -0.08$	$p > 0.10$
χ^2-test	$\chi^2 = 23.78$	$p < 0.001$	$\chi^2 = 13.02$	$p < 0.001$
Mann-Whitney test	$U = 152.5$	$p > 0.10$	$U = 94$	$p > 0.05$

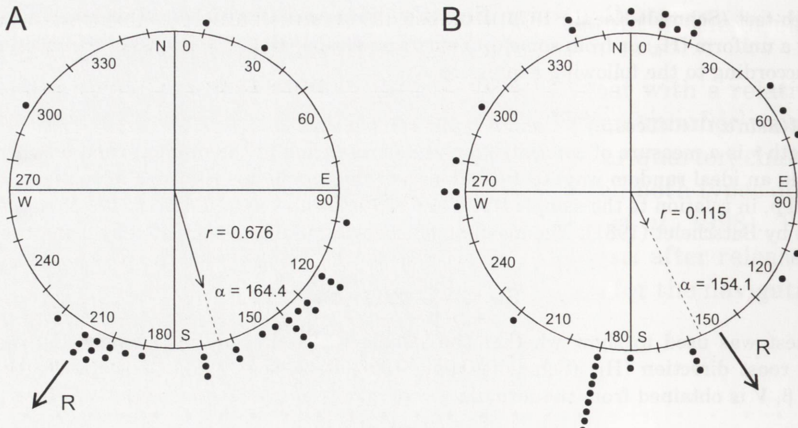

Fig. 1. Representation of the directions obtained in the 1st (A – area familiar to bats, river absent) and in the 2nd tests (B – area unfamiliar to bats, river absent). R – roost direction, α – mean direction, *r* – mean vector.

(Table 1, Fig. 1). However, directionality of flight was apparent in the two tests performed near the river, although in the one carried out in an area unfamiliar to the bats there was higher mean angular deviation and lower directionality (Table 1, Fig. 2).

Critical values of *u* for the *V* test show that mean direction α and roost direction R obtained in the first test are significantly similar ($u = 5.12, p < 0.0001$). In the

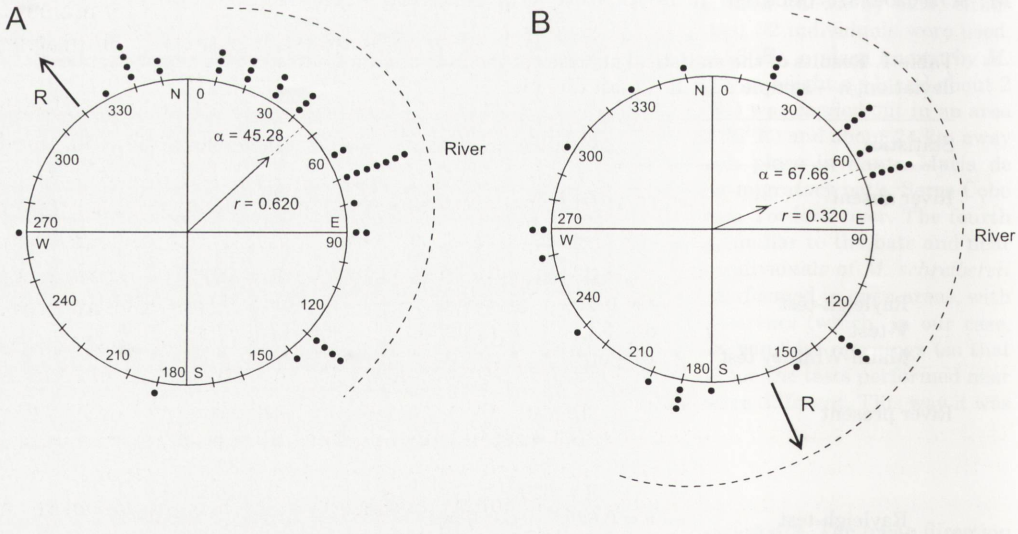

Fig. 2. Representation of the directions obtained in the 3rd (A – area familiar to bats, river present) and in the 4th tests (B – area unfamiliar to bats, river present). R – roost direction, α – mean direction, *r* – mean vector.

rest of the tests α and R are significantly different (Table 1). The results of χ^2-test show that bats released near a river tend to turn towards it (Table 1, Fig. 2). There are no significant differences between the directions taken by males and females in each of the four tests (Table 1).

Discussion

M. schreibersii become orientated shortly after being released, provided they are released in a familiar area, for instance a migratory path, or near a river, as inferred by the results obtained from the four experiments (Table 1, Figs 1 and 2). This capability must be very useful to *M. schreibersii* when carrying out its seasonal displacements successfully. The mean flight direction found in each test may or may not coincide with the home roost location R, depending on the physiographic characteristics of the region and the distance of the bats release in relation to the roost. Thus, in the first test, in which *M. schreibersii* was released far from a river, in an area familiar to the colony of Castanya mines and with no geographical obstacles between the site of testing and the roost, the bats showed marked directionality of flight towards the mines (Table 1). The results seem to confirm the observations carried out by other authors (Casteret 1938, Lanza 1958, Heymer 1964, Kuramoto *et al.* 1979) about the tendency of bats to return to the home roost.

As already suggested by Griffin in 1970, it is likely that bats recognize landmarks by echolocation to be used as cues in their migrations. The remarkable development of brain cortex in *M. schreibersii* (Ferrer 1987, 1989) probably provides these bats with a good memory, so they are capable of remembering landmarks in the migratory paths. This would explain the good orientation capability observed in the tests performed in areas familiar to the bats.

The results of the tests carried out near the rivers show that *M. schreibersii* tends to turn towards them, even though that direction is not the shortest and most straight way to the roost. Such behaviour is especially reflected in the third test, in which bats were released in a familiar area and, in spite of this, showed a tendency to turn towards the river instead of heading directly for the roost. Rivers seem to be landmarks for the species' navigation and also paths to be followed during the migratory movements. The presence of rivers would be detected by passive auditory signals, as suggested by Griffin (1970) and Griffin and Buchler (1978). To travel by following watercourses may be beneficial for the species, not only as reference cues easy to follow during navigation, without serious geographical incidents to overcome that would represent a high energetic cost, but also because they provide the species with abundant trophic resources and high atmospheric humidity. Evaporation of water from body surface occurs continuously and represents the major route of water loss in small mammals. The extremely large surface area to volume ratio of bats increases water loss by evaporation. High atmospherical humidity contributes to decrease water loss (Basset and Studier 1988).

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