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ACTIVITY AND FORAGING HABITATS OF *MINIOPTERUS SCHREIBERSII* (CHIROPTERA, MINIOPTERIDAE) IN SOUTHERN FRANCE: IMPLICATIONS FOR ITS CONSERVATION

STEPHANE VINCENT[1], MELANIE NEMOZ[2], STEPHANE AULAGNIER[3]*

[1]Ligue pour la Protection des Oiseaux - Drôme, pôle Chiroptères, 10 rue Roch Grivel, 26400 Crest, France
[2]Société Française pour l'Etude et la Protection des Mammifères / Conservatoire Régional des Espaces Naturels de Midi-Pyrénées, B.P. 43053, 31025 Toulouse cedex 03, France
[3]Société Française pour l'Etude et la Protection des Mammifères / Comportement et Ecologie de la Faune Sauvage, Institut National de Recherche Agronomique, B.P. 52627, 31326 Castanet Tolosan cedex, France;
*Corresponding author, E-mail: Stephane.Aulagnier@toulouse.inra.fr

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ABSTRACT - Comprehensive knowledge of roosting and foraging ecology is essential for conserving bats. Therefore, the four-year LIFE Nature programme "Conservation of three cave-dwelling bats in Southern France" included an autoecological study of *Miniopterus schreibersii*, a highly gregarious cave-dwelling species. In a colony of 3-5,000 adults, 21 females were radio-tracked during pregnancy and lactating periods, when some of them switched roosts within a 30 km radius around the maternity colony. Every night, for about 6 hours, each bat flew far from the roost (4.1 to 29.2 km) to forage on several small feeding areas (1 to 9 over a few nights). Mean individual home-range estimation averaged 10837 ha for pregnant females, 22318 ha for lactating females. Urban areas lighted by white street lamps were used extensively. Some bats also foraged selectively in deciduous or mixed woodlands and in orchards and parks. The importance of hedgerows was confirmed. Conservation of *M. schreibersii* must be planned at a large scale, protecting a network of roosts and promoting nature-friendly agricultural practices.

Key words: hunting activity, roosting behaviour, home range, urban areas, hedgerows, Schreibers' bat, France

RIASSUNTO - ***Attività e habitat di caccia di* Miniopterus schreibersii *(Chiroptera, Miniopteridae) nel sud della Francia: implicazioni per la sua conservazione***. Conoscere dell'ecologia comportamentale dei pipistrelli è essenziale per la loro conservazione. Il programma LIFE-Natura "Conservazione dei pipistrelli troglofili del sud della Francia", della durata di quattro anni, ha incluso lo studio auto ecologico di *Miniopterus schreibersii*, una specie altamente gregaria. In una colonia di 3-5000 adulti, 21 femmine sono state seguite con la radiotelemetria durante la gestazione e l'allattamento,quando alcune di esse hanno utilizzato diversi roost nel raggio di 30 km dal sito riproduttivo. Ogni notte, per circa 6 ore, ciascun individuo ha utilizzato da 1 a 9 piccole aree di caccia a una distanza di 4,1 – 29,2 km dal roost. Le dimensioni medie del home range sono variate da 10837 ha per le femmine in gestazione a 22318 ha per quelle in allattamento. Le aree urbane illuminate da lampioni con luce bianca sono state selezionate come aree di foraggiamento, secondariamente anche le aree boschive frammentate e i frutteti delimitati da siepi. I progetti di conservazione del pipistrello di Schreibers devono essere pianificati su larga scala, proteggendo una rete sufficiente di rifugi e favorendo pratiche agricole con minor impatto sulla diversità ambientale.

Parole chiave: attività di caccia, uso dei rifugi, area vitale, aree urbane, siepi, pipistrello di Schreibers, Francia

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INTRODUCTION

Schreibers' bat (*Miniopterus schreibersii* Kuhl, 1817), a western Palaearctic species (Appleton et al. 2004; Tian et al. 2004; Bilgin et al. 2006), is listed as "near threatened" in IUCN red lists, at the global (IUCN 2010), European (Temple and Terry 2007) and Mediterranean levels (Temple and Cuttelod 2009). Due to the mass mortality recorded in 2002 in its south-western range (Roué and Némoz 2002; Barataud and Précigout 2003; De Lucas 2007; Boléat et al. 2008), it has been listed as "vulnerable" in France (UICN Comité Français 2009), Spain (De Lucas 2007) and Portugal (Cabral et al. 2005). For example, in France, from 211,100 hibernating bats in 1995 (Roué and Groupe Chiroptères SFEPM 1997), only 70,950 were registered in 2004 (Groupe Chiroptères SFEPM 2010). Therefore, this cave-dwelling species deserves a high priority for conservation measures, including legal and physical roost protection and also friendly management for foraging areas.

While Schreibers' bats gather in large colonies in underground roosts that are then quite easy to locate, both their habitat use and spatial ecology are very poorly known. As far back as 1957, commuting routes and flight speed have been studied by Constant and Cannonge, then Serra-Cobo et al. (2000) confirmed the role of rivers as possible landmarks in the orientation flight of the species. Using chemiluminescent tags, Barataud (1992) reported the first data on hunting behaviour in a wooded valley of central France. Schreibers' bats foraged in the upper part of the valley, at the edge of the forest, at the canopy level.

In contrast, radio-telemetry revealed intense foraging activity in urban areas as well as in broad-leaved woodlands, as far as 30 km from the roost (Lugon et al. 2004). As sample size was small, these findings needed to be confirmed and tentatively related to the hunting of Schreibers' bats for preferred prey items in eastern France, namely Lepidoptera (73 to 96 % of volume through the seasons; Lugon 1998).

For this purpose and for developing management guidelines for the foraging areas, the four-year LIFE Nature programme "Conservation of three cave-dwelling bats in Southern France" included an autoecological study of Schreibers' bat. By associating the radio-tracking of some females with diet analysis, we investigated the habitat choice of *M. schreibersii* from one maternity colony in southeastern

France, at the edge of the Mediterranean region. We studied the pattern of nocturnal activity of bats and their use of space at both the individual and population levels, by identifying the commuting routes, assessing home range areas, measuring distances from the roost to foraging sites and roost fidelity. Finally, we tried to identify the preferred foraging habitats after mapping their availability in the colony home range and analysing the diet of the colony through the activity season. Radio-tracking was conducted during pregnancy and lactating periods, which are the seasons of maximum energy demand for females (Racey and Speakman 1987, Kurta et al. 1990).

MATERIALS AND METHODS

From March to October a maternity colony of Schreibers' bats (2500-3000 adults in 2005, 4000-5000 in 2006) roosts in the tunnel of Borie castle, located at Suze-la-Rousse (Drôme) in the south of the Rhône-Alpes region (44°17'17"N, 4°50'17"E). They share the roost with about 600 greater and lesser mouse-eared bats (*Myotis myotis* and *M. bythii*), and some Geoffroy's, Bechstein's and Natterer's bats (*M. emarginatus*, *M. bechsteinii* and *M. nattereri*, respectively), as well as some lesser horseshoe bats (*Rhinolophus hipposideros*). This tunnel, part of the Natura 2000 site FR 8201676 "Sables du Tricastin", is burrowed in clayey limestone and sandstone, and drains a swamp; water flows throughout the year.

The surrounding area (named Tricastin) is an alluvial plain (rivers Rhône, Lez, Ouvèze and Eygues) and low hills. The climate is Mediterranean, rainfall (750 mm per year) occurring irregularly through the year and rarely in summer, when the Mistral wind accentuates the drought. Cultivations dominate the landscape, including mainly orchards and crops in the River Rhône valley, and vineyards in the southern hills and the River Eygues valley. Hills are covered with Mediterranean vegetation of the holm-oak (*Quercus ilex*) and downy oak (*Q. pubescens*) series.

1. Bat trapping, tagging and tracking

To reduce the impact on the colony and on the individuals which rested during the following diurnal period, bats were captured using a mistnet or a harp-trap as they entered the roost. Each bat was identified and sexed, and both its forearm length and body mass were measured. Adult females were fitted with 0.64g, 0.80g or 0.86g (< 6% body mass; Kenward, 1987) radio-transmitters (Holohil™, Biotrack™ and Titley™), using surgical (Skinbond™) or cosmetic adhesive (Duo Professional™), and released in the tunnel after the adhesive got dry. We tagged 9 pregnant females in May 2005 (3 the 14th, 1 the 19th, 3 the 22nd and 2 the 25th), and 12 lactating females in June 2006 (3 the 15th, 1 the 18th, 2 the 19th, 3 the 22nd and 3 the 25th). Transmitters detached after a few days. All procedures were approved by the Ministry in charge of the Environment.

Radio-tracking was carried out during two weeks after the first captures by car and on foot using 6 receivers (LA12Q AVM™; Australis 26K Titley™) and either hand held three-element Titley™ antennas or four-element Televilt™ antennas. Each night, from 21.00 to 7.00 (CEST - Central European Summer Time), two to three stationary teams located the bats every 5 min by triangulation from vantage points (sometimes using a Null Peak AVM™ antenna to improve the accuracy of the direction of the signal), while the mobile operators determined bat locations mainly with the "homing in" method (White and Garott 1990). All teams were co-ordinated by walkie-talkie to ensure simultaneous bearings. In the field, bearings or locations were mapped on a 1/25.000© IGN map implemented with a GPS grid. Only fixes of active bats were used in habitat use analyses. Emergence and return times were also recorded.

2. Habitat categories

In the area used by the colony, we identified 12 main habitat categories by field surveys after both radio-tracking sessions:

1. Deciduous or mixed woodlands fragmented by rivers, trails, roads or recently managed plots, which provide heterogeneity and borders.
2. Closed and homogeneous deciduous or mixed woodlands.
3. Heterogeneous pine woodlands including clearings and/or different storeys.
4. Dense pine woodlands.
5. Traditional orchards, parks or tree-planted fallows.
6. Pastures, meadows and scrublands delimited by hedgerows or next to a woodland area.
7. Pastures, meadows and scrublands in an open area.
8. Crops and vineyards delimited by hedgerows or next to a woodland area.
9. Crops and vineyards in an open area.
10. Urban areas with street lamps.
11. Urban areas without street lamps.
12. Lakes, swamps and rivers.

Due to the very low occurrence of some habitats (e.g. pine woods) or the difficulty in identifying them at the home range scale (e.g. the presence of street lamps), to analyse habitat selection they were grouped into five supra-categories: woodlands (1-4), orchards and parks, open areas (6-9), urban areas (10-11), and water bodies.

3. Data analysis

Locations from triangulation and 95 % error polygons were calculated using the Maximum Likelihood Estimator (Lenth 1981) of LOCATE II (NAMS, NSAC Canada, 2000) and LOAS IV (Ecological Software Solutions, 2005) software. By this method locations are calculated using, for each bearing, a fixed angular error, the distance between the animal and the receiver, and the angle between bearings. This method provides a polygon when two bearings are available for one fix, and an ellipse when three bearings have been recorded.

These locations and the homing in fixes were stored in a Geographic Information System (Arcview 3.2, ESRI California) and superimposed to the SCAN25©IGN. Individual and colony home ranges were estimated by the Minimum Convex Polygon (Mohr 1947) using the extension Animal Movement (Hooge and Eichenlaub 2000) of Arcview. Following Odum and Kuenzler (1955), the minimum number of locations for estimating the individual home range size was identified by calculating the mean of 100 bootstraps. Variation in home range size between pregnant and lactating females was tested by a Mann-Whitney ranked test.

Foraging areas were identified by only the homing in fixes. Habitat categories within a 50 m radius circle were quantified (number of occurrences and percent area). Habitat selection relied on the comparison between used habitats (overall percent area of each habitat category within the circles) and available habitats (percent area of each habitat category within the colony home range) using compositional analysis (Aebischer et al. 1993). The unit of statistical independence was the individual tracked bat. Following Almenar et al. (2006), to assess the selection or rejection of each habitat category, Bonferroni confidence intervals were additionally calculated according to Neu et al. (1974). Analyses were computed with the animal movement extension (Hooge and Eichenlaub 2000) of Arcview.

The height of hedgerows was classified in four categories (0: no hedgerow, 1: hedgerow < 2 m, 2: hedgerow between 2 and 10 m, 3: hedgerow > 10 m). The light colour (white or orange) of street lamps at homing in fixes was also recorded. An equal number of locations, randomly sampled in the same proportion of habitat categories, were described for subsequent comparisons. Significance of differences between the two sets was checked by χ^2 tests whenever applicable. Significance for all tests, computed by Minitab 12.2, was set at $p < 0.05$.

RESULTS

1. Radio-tracking data

The 21 females were tracked during only 2.4 ± 0.8 nights (maximum 4 nights) due to the quick loss or breakdown of transmitters (Tab. 1). The mean number of locations per female was 64.0 ± 61.3 (SD), the maximum number was 201, including 83 homing in fixes. The minimum number of locations for estimating individual home range size was obtained for 6 pregnant and 6 lactating females. For this sample, the mean number of locations was 103.1 ± 50.3 (with no significant difference between pregnant and lactating females; Mann-Whitney W = 45.5, p = 0.337).

Out of 17 bats tracked for more than one night, 6 pregnant and 1 lactating females were located resting in diurnal roosts different from the Borie tunnel. Two roosts were identified (underground transit roosts 15 and 19 km distant from the colony, hosting maternity colonies of greater and lesser mouse-eared bats), and at least two other roosts were only located in a favourable area at a distance of 23 and 30 km from the colony.

2. Nocturnal activity

Pregnant females (14-28 May) emerged 59 ± 32 min after sunset and returned 140 ± 45 min before sunrise. Lactating females (15-28 June) emerged 42 ± 17 min after sunset and returned 113 ± 47 min before sunrise. During all nights, no female returned temporarily to the roost. One lactating female even spent one day in a secondary roost, 19 km distant from the colony, and came back early on the following night. Total duration of activity was 333 ± 57 min for pregnant females, and 366 ± 38 min for lactating females (Fig. 1), the difference being significant (Mann Whitney W = 356, p = 0.029).

3. Home ranges and foraging areas

Individual home ranges (Fig. 2) were significantly larger for lactating females (22318 ± 7141 ha, n = 6) than for pregnant females (10837 ± 5399 ha, n = 6 Mann-Whitney W = 25 ; p = 0.031). The smallest home range was 4465 ha for a pregnant female, and the largest was 29840 ha for a lactating female (Fig. 3).

Commuting routes were very difficult to identify due to the flight speed of the bats and the large distance covered every night. The use of woodland borders, hedgerows; and riverine forests as landmarks suffered many exceptions, including crossing a small mountain area. During windy nights, it was even more difficult to locate the bats when commuting. Luckily they were very faithful to their foraging areas, as revealed by the small number of distinct homing in fixes (Tab. 1), and it was then possible to find them after their

Table 1 - Tracking data and spatial use data of 21 female Schreibers' bats from the maternity colony of Suze-la-Rousse (France). * individuals reaching the minimum number of locations for estimating the home range size. Mean ± standard deviation.

Code	No of nights tracked	No of locations	No of homing-in	No of distinct homing-in	Maximum distance (km)	Maximum Convex Polygon (ha)
5-01 *	3	68	25	3	19.3	10550
5-02	2	11	0	0	-	4420
5-03	1	24	12	1	11.2	-
5-04 *	3	184	78	1	12.7	6009
5-05 *	3	91	30	3	18.5	4465
5-06 *	4	130	43	5	22.4	18000
5-07 *	2	54	22	9	15.9	9751
5-08 *	3	201	83	3	14.7	16250
5-09	2	29	12	1	16.6	2864
Pregnant	2.6 ± 0.9	88.0 ± 69.7	33.9 ± 29.1	2.9 ± 2.8	16.4 ± 3.6	9038.6 ± 5665.1
6-01 *	4	63	20	2	29.2	29840
6-02	2	2	0	0	-	358
6-03	3	15	0	0	-	3344
6-04 *	3	110	24	3	21.5	25330
6-05 *	3	78	0	0	-	24410
6-06	1	10	9	2	6.4	97
6-07 *	3	137	29	4	26.2	22230
6-08	2	1	0	0	-	-
6-09 *	3	68	5	4	21.2	23340
6-10 *	1	53	5	2	20.8	8758
6-11	1	5	0	0	-	5987
6-12	2	10	0	0	-	6700
Lactating	2.3 ± 1.0	46.0 ± 46.1	7.7 ± 10.6	1.4 ± 1.6	20.9 ± 7.8	13672.1 ± 11310.9

outward journey which was usually longer than the return journey. A flight speed of 40-50 km/h was then recorded.

Foraging areas were identified for 8 pregnant and 6 lactating females. The number of foraging areas (2.0 ± 2.3) ranged from 1 (during 3 nights for a pregnant female) to 9 (during two nights for another pregnant female). Mean distance between two foraging areas was 2896 ± 2834 m. The distance between the maternity roost and foraging areas (16.4 ± 5.7 km, N = 43, Fig. 4) was significantly larger for lactating females than for pregnant females (Mann Whitney W = 550, p = 0.008). The maximum was 29.2 km and the minimum was 4.1 km for two lactating females.

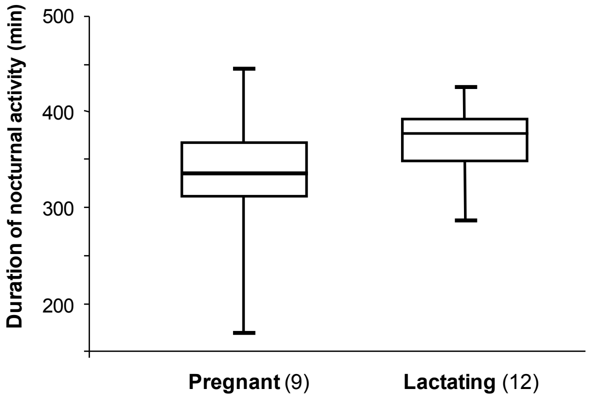

Figure 1 - Nocturnal activity (total duration) of pregnant and lactating Schreibers' bat females from the maternity colony of Suze-la-Rousse (France).

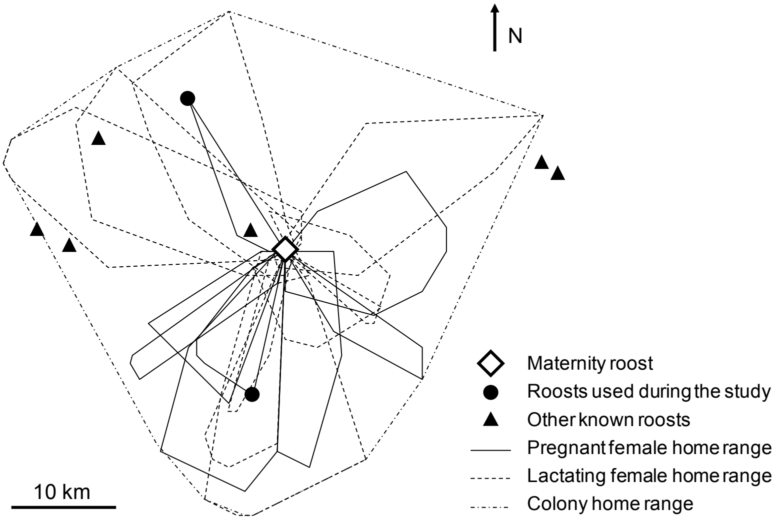

Figure 2 - Roosts and home ranges (individual and colony) of pregnant and lactating Schreibers' bat females from the maternity colony of Suze-la-Rousse (France).

The colony home range, evaluated by all radio-tracking data, was smaller for pregnant females (89359 ha) than for lactating females (162997 ha). The maximum home range over the two periods was 168438 ha. The longest distance precisely recorded from the roost was 29.7 km for a lactating female (24.7 km for a pregnant female). However some bats flew out of this range and probably reached a distance of 32-35 km from the roost (according to imprecise locations).

4. Habitat selection

Urban areas were by far the most used habitat category (54.0 %), followed

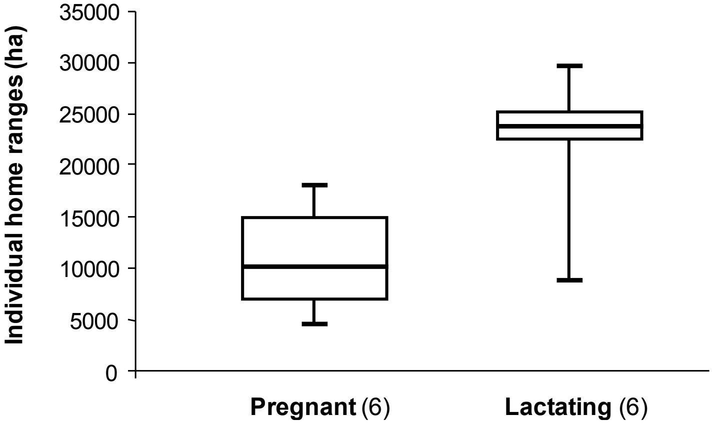

Figure 3 - Home range areas of pregnant and lactating Schreibers' bat females from the maternity colony of Suze-la-Rousse (France).

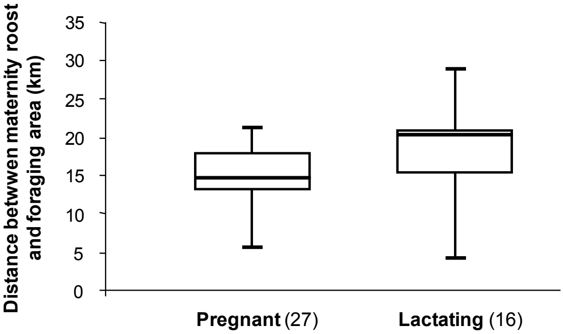

Figure 4 - Flight distances between the roost and foraging areas of pregnant and lactating Schreibers' bat females from the maternity colony of Suze-la-Rousse (France).

Table 2 - Selection of habitats classified according to the main landscape categories by 14 female Schreibers' bats from the maternity colony of Suze-la-Rousse (France): compositional analysis (signs indicate whether the habitat placed in the corresponding row was more (+) or less (-) preferred than that in the corresponding column; + or -: non significant trends, +++ or ---: significant differences, $p < 0.05$).

	Woodlands	Orchards and parks	Open areas	Urban areas	Water bodies	Rank
Woodlands		+	+	---	+	3
Orchards and parks	-		+	---	+++	2
Open areas	-	-		---	+	1
Urban areas	+++	+++	+++		+++	4
Water bodies	-	---	-	---		0

Table 3 - Selection of habitats classified according to the main landscape categories by 14 female Schreibers' bats from the maternity colony of Suze-la-Rousse: Bonferroni confidence intervals.

	Used proportion	Available proportion	Bonferroni confidence intervals		Selection	p-value
			Lower	Upper		
Woodlands	0.155	0.286	0.1394	0.1906	Negative	$p < 0.0001$
Orchards and parks	0.091	0.023	0.0718	0.1105	Positive	$p < 0.0001$
Open areas	0.198	0.626	0.1769	0.2331	Negative	$p < 0.0001$
Urban areas	0.540	0.032	0.4898	0.5592	Positive	$p < 0.0001$
Water bodies	0.015	0.017	0.0077	0.0253	None	

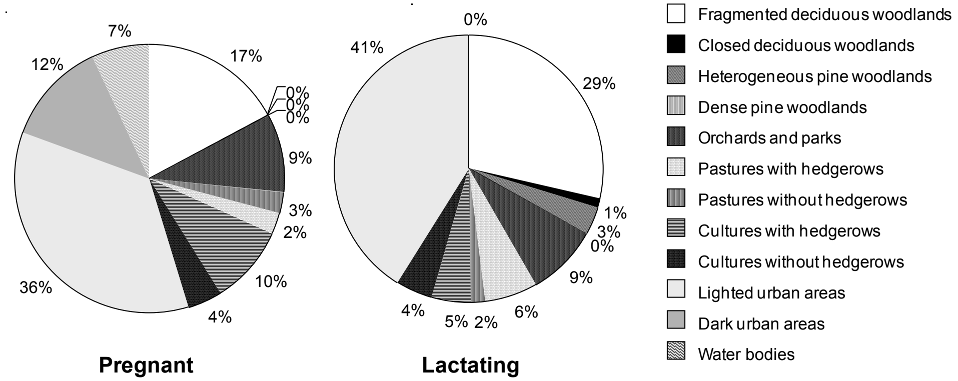

Figure 5 - Habitat use of pregnant and lactating Schreibers' bat females from the maternity colony of Suze-la-Rousse (France): percentages of homing in areas in each habitat category.

by open areas (19.8 %), woodlands (15.5 %), orchards and parks (9.1 %), and water bodies (1.5 %). According to compositional analysis, habitats were not used according to their availability ($\Lambda = 0.1318$, $\chi^2 = 28.37$, df = 4, $p < 0.0001$). Schreibers' bat used urban areas >>> woodlands >>> orchards and parks > open areas > water bodies (Tab. 2). Bonferroni confidence intervals ($\chi^2 = 6.64$, df = 1, p = 0.0012) confirmed the selection for urban areas and outlined a preference for orchards and parks (Tab. 3). Open areas, as well as woodlands, were negatively selected, while the use of water bodies was opportunistic.

At a finer scale, foraging areas were mainly urban areas (with and without street lamps; number of occurrences = 31; percent area = 46) and (heterogeneous) deciduous or mixed woodlands (n = 19; %area = 22), followed by crops and vineyards (n = 11; %area = 8), pastures, meadows and scrublands (n = 8; %area = 4), delimited by hedgerows or next to woodland, orchards and parks (n = 7; %area = 9) and water bodies (n = 6; %area = 4). By contrast, no fix was recorded in dense pine woods, and very few were recorded in closed and homogeneous deciduous or mixed woodlands (n =1; %area = 1). Most foraging areas included more than two habitat categories (81%), with one dominant habitat category (75%), except for those in (heterogeneous) deciduous or mixed woodlands and urban areas with street lamps.

Urban areas without street lamps and water bodies were used only by pregnant females; (heterogeneous) deciduous or mixed woodlands were more used by lactating females, while crops and vineyards delimited by hedgerows or next to woodland were more used by pregnant females (Fig. 5).

Homing in fixes included significantly more and higher hedgerows than those randomly sampled in the colony home range (97 % *vs.* 70 %, and 94 % *vs.* 60 % respectively, $\chi^2 = 22.43$; df = 3; $p < 0.0001$; Fig. 6).

Finally, in urban areas, Schreibers' bats foraged preferably in lighted areas ($\chi^2 = 17.19$; df = 1; $p < 0.0001$), and exclusively in areas lit by white street lamps (Fig. 7), whereas orange lamps prevail in the region (63%).

DISCUSSION

Whether the duration of nocturnal activity had been already recorded by direct observation at the entrance of roosts, and foraging areas described by the detection of echolocation calls, tele-

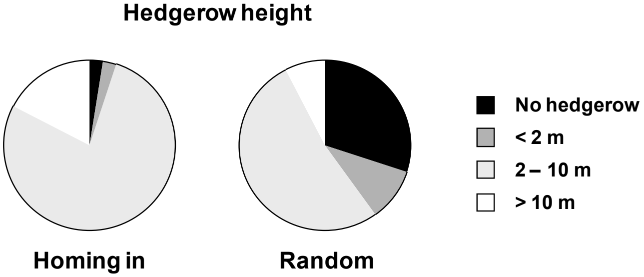

Figure 6 - Habitat use of Schreibers' bat females from the maternity colony of Suze-la-Rousse (France): comparison of hedgerow height between random sites and homing in areas.

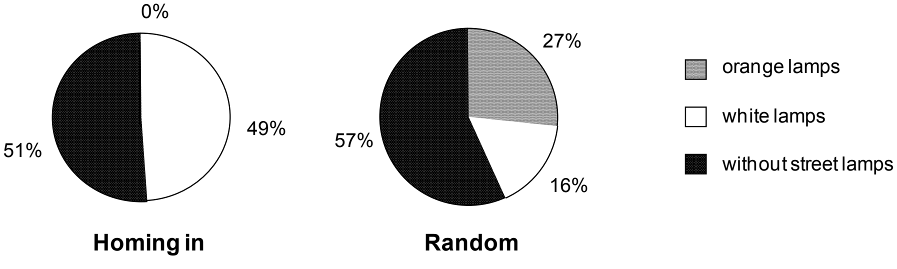

Figure 7 - Habitat use of Schreibers' bat females from the maternity colony of Suze-la-Rousse (France): comparison of lighting between random and homing in urban areas.

metry revealed innovative results on the behaviour of Schreibers' bats. However, radio-tracking of Schreibers' bats proved to be tricky. First, radio-transmitters were quickly lost or broke down, the maximum number of tracking nights (N = 4) being much shorter than those reported for two other cave-dwelling species, such as the Mediterranean horseshoe bat *Rhinolophus euryale* (N = 9; Goiti et al. 2003), and long-fingered bat *Myotis capaccinii* (N = 15; Biscardi et al. 2007). Their loss was probably due to the highly gregarious behaviour of the species, including intense rubbings and mutual grooming, and possible interactions with the mouse-eared bats sharing the roost, as most recovered radiotransmitters were nibbled. Second, some females switched roost, even during the maternity period, although they are known for their attachment to the maternity roost (Rodrigues et al. 2010). Third, the high speed of the flight of this species, already recorded by Constant and Cannonge (1957) was confirmed. Schreibers' bats were reported to fly usually between 5 and 10 m above ground, up to the tree top level, but, mainly during windy nights, they may shelter close to woodland borders and hedgerows, where they are more difficult to locate (Weid and Von Helversen 1987; Lugon 1999; Lugon and Roué 2002). Fourth, the distances between diurnal roosts, as well as those between the maternity roost and foraging areas reached more than 30 km, while the maximum recorded distance was 15 km for the long-fingered bat (Biscardi et al. 2007) and 9 km for the Mediterranean horseshoe bat (Goiti et al. 2006). A preliminary four-night study conducted with Schreibers' bat in eastern France (Guillaume and Roué, 2006) revealed a maximum distance of only 10 km. In contrast, with 11 tracked bats Lugon et al. (2004) recorded a maximum distance between roost and foraging areas of 29 km in a nearby area. This huge dispersal around the roost, recorded in two very different French regions, may reduce intra-specific competition among the large number of bats in the colony. As suggested by Goiti et al. (2006) for the Mediterranean horseshoe bat, this hypothesis is supported by the longer distances and larger home ranges recorded for lactating females, whose energetic demand is maximum (Racey and Speakman 1987) and flight ability cleared of the embryo's body mass (Norberg and Rayner 1987).

Mean time of emergence (ca. 50 min after sunset) was in agreement with previous records for this time of the year (Topál in Boye 2004), however Schreibers' bats started to emerge sooner than reported by Constant and Cannonge (1957). Contrary to most species (Racey 1982; Henry et al. 2002; Russo et al. 2002), maternal care does not occur during the night, and hardly any resting period was recorded. A similar result was obtained in eastern France (Lugon et al. 2004) for 10 females. The total duration of activity was even longer during the lactating period, when the night is shorter. So females probably balance the need for feeding far away from the roost and reproduction constraints, reaching the maximum during lactation (Racey and Speakman 1987). At the end of July, when the young-of-the-year are already flying, Barataud (1992) recorded some returns to the roost after two hours, without distinguishing between adults and young.

Defining home ranges for such a long-distance moving species is quite confusing as Schreibers' bats usually forage on very small areas (e.g. 50 m of a street or hedgerow). Variation in the size of Minimum Convex Polygon mainly depended on both the distance between foraging areas and the roost, and the number of foraging areas. Defining home range sizes using the Kernel method (Worton 1989) would not provide a good estimate of the spatial ecology of a species which uses such a small part of its range as foraging areas. So we analysed habitat use by Schreibers' bats by the field description of homing in fixes.

Confirming the results of Lugon et al. (2004), urban areas were the main foraging habitats, and lactating females preferred lii areas, as numerous bat species do in Europe and North America (Rydell and Racey 1995). Furthermore, Schreibers' bats only foraged in areas lit by white street lamps. After Rydell (1992), it is now well known that the bluish-white light of mercury-vapour street lamps, which emit ultraviolet radiation, attracts insects, including moths, optimising energy gains by bats. In contrast, low-pressure sodium lamps, which emit monochromatic orange light, do not attract insects (Racey 1998). For northern bats, Rydell (1992) reported a gross energy intake more than twice higher for bats foraging around street lamps (0.5 kJ / min) than in woodland (0.2 kJ / min). Arlettaz et al. (1998) suggested that this foraging strategy could influence reproduction success, and then be selected for.

The importance of woodland borders and hedgerows (Constant and Cannonge 1957; Barataud 1992; Lugon and Roué 2002) was confirmed by our results. In open areas (crops, vineyards, pastures, meadows and scrublands), hedgerows or woodland borders over 2 m high were significantly chosen by bats for foraging. The vertical structure of vegetation was also a determinant in woodlands, where Schreibers' bats favoured fragmented deciduous plots. In eastern France, 74.6 % of locations in forests were recorded along roads and trails (Lugon et al. 2004). Deciduous woodlands were negatively selected in our study, a result mainly due to pregnant females which possibly did not find substantial food supply there in May 2005. In June 2006, lactating females benefited from an outbreak of Asian gypsy moth (*Lymantria dispar*) in holm-oak woodlands, and were probably attracted by this abundant resource. Contrary to pregnant females in May 2005, they neglected riverine forests, a habitat used in southern Italy (Russo and Jones 2003) and possibly offering an earlier availability of prey.

CONCLUSIONS

The foraging behaviour of Schreibers' bat proved to be different from most of insectivorous bat species. Although the common pipistrelle (*Pipistrellus pipistrellus*), Kuhl's pipistrelle (*P. kuhlii*), as well as the northern bat and the common serotine (*Eptesicus serotinus*), were reported to preferably forage in urban areas lighted by white street lamps (Haffner and Stutz 1985-1986; Rydell 1992; Blake et al. 1994; Catto et al. 1995), none of these species forage 30 km away from their daily roost. Another unlikely feature, according to Henry et al. (2002), was the continuous overnight foraging activity, even during lactating period, and the roost switches. Long-distance foraging flights imply that conservation measures for Schreibers' bat must be planned at a large scale. Efforts should focus on the protection of a network of roosts, keeping in mind that this species is reluctant to enter grilled sites (Moeschler 1995), and also the improvement of hedgerows, so as to assist commuting and foraging areas and connectivity between favourable habitats and the promotion of nature-friendly agricultural practices instead of massive pesticide spread. The tendency to replace mercury vapour lamps with sodium lamps, which use less energy but do not attract insects, is unfavourable to Schreibers' bat. On the other hand, the former attract moths, that then become unavailable to gleaning bat species (Racey 1998), and possibly concentrate bats into relatively small risky areas. Due to its high speed flight, Schreibers' bat might suffer from the impact of wind farms (Alcalde 2003). Mitigation and / or avoidance measures should be a priority for stakeholders.

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