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HABITAT PREFERENCES OF BATS IN A RURAL AREA OF SICILY DETERMINED BY ACOUSTIC SURVEYS

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ABSTRACT - The bat fauna of a 60 km^2 wide area representing the typical rural landscape of inland Sicily and including the small “Rocche di Entella” karstic plateau (Natural Reserve and SAC) was surveyed between May 2006 and September 2007. Sampling was carried out at 95 sites, distributed proportionally in six main habitats. Bat calls were time-expanded with a D980 bat detector and then identified to species level by a Discriminant Function Analysis. We recorded 305 bat passes and identified 96.4% of recorded calls. Moon phase, cloud cover and their interaction did not affect total bat activity, nor did the sampling period. Aquatic and riparian habitats were preferred, whilst *Eucalyptus* plantations and vineyards were avoided. At species level, all bats selected the former habitats, except *H. savii*, and avoided field crops, except *Myotis* sp. Thermo-Mediterranean shrub formations showed the highest species richness, whereas vineyards had the lowest. Our study emphasizes the value of riparian habitats and low-intensity farming for bat conservation.

Key words: Chiroptera, species richness, rural ecosystems, SAC, southern Italy

RIASSUNTO - ***Preferenze ambientali dei chirotteri in un’area rurale della Sicilia***. Il presente lavoro espone i risultati di un’analisi di selezione del habitat da parte della chirotterofauna in un’area di 60 km^2 rappresentativa del tipico paesaggio rurale dell’entroterra siciliano e comprensiva del plateau carsico “Rocche di Entella (Riserva Naturale e SIC). Da maggio a settembre 2006 e 2007, abbiamo effettuato campionamenti mediante bat detector (Pettersson D980) in 95 stazioni distribuite proporzionalmente alla disponibilità di habitat. I segnali sono stati identificati mediante Analisi della Funzione Discriminante. Abbiamo registrato 305 passaggi, identificandone il 96,4% a livello di specie. Né la fase lunare, né la nuvolosità o l’interazione tra queste hanno influenzato significativamente l’attività di foraggiamento; nessuna influenza è stata inoltre rilevata rispetto al periodo di campionamento. Nel complesso la chirotterofauna ha evidenziato una preferenza per gli habitat acquatici e ripari, mentre le piantagioni di eucalipto e i vigneti sono stati evitati. A livello di singole specie, tutte hanno selezionato il primo habitat, con l’eccezione di *H. savii*, ed evitato i coltivi, con l’eccezione di *Myotis* sp. La più elevata ricchezza in specie è stata registrata nelle formazioni arbustive termo-mediterranee, la più bassa nei vigneti. Il nostro studio rimarca l’importanza della tutela degli habitat ripari e di un’agricoltura condotta a bassa intensità per la conservazione della chirotterofauna.

Parole chiave: chirotteri, ricchezza in specie, agro-ecosistemi, SIC, Italia meridionale

INTRODUCTION

Because of their peculiar characteristics (i.e. degree of isolation from mainland populations, simplified species assemblages and limited resource availability), islands offer ideal scenarios to set studies on bat natural history, including richness patterns, gene flow, evolution of acoustic behavioural traits and habitat use, with important implications for conservation (e.g. Findley, 1993; Davy *et al.*, 2007; Russo *et al.*, 2007; 2009; Salgueiro *et al.*, 2008; Echenique-Díaz *et al.*, 2009). Because island populations are usually small and habitat availability is inevitably limited, island-dwelling bats deserve special conservation attention and studies on their ecological requirements are therefore especially important to implement effective conservation strategies.

Despite its geographic and naturalistic importance, Sicily has received little attention as far as bat distribution and ecology are concerned. For this island, Agnelli *et al*. (2004) mentioned only 14 out of 33 species currently present in Italy, whilst, more recently, Agnelli *et al*. (2008) listed 20 species. Most available data refer to partial checklists and preliminary surveys or consist of single records from caves or protected areas mainly located in Palermo (NW Sicily), Siracusa and Catania (E Sicily) provinces.

Very little is known about the habitat use, community composition and life history of Sicilian bats. To help fill this gap, a research project aimed to investigate bat habitat preference in a typical rural landscape of inland Sicily was undertaken. The study represents the only quantitative assessment of bat habitat selection carried out in Sicily up to today.

A rural area was selected because conservation in this landscape is a priority on the island and, generally, throughout Mediterranean Europe. Such landscapes can be home to several species of conservation importance and are currently threatened by land use changes such as the intensification of agricultural activities or land abandonment (e.g. Moreira and Russo, 2007).

STUDY AREA

The study area was located between latitudes 41° 79’ N and 41° 86’ N and covered about 60 km^2. It includes the natural reserve RNI “Grotta di Entella” and the SAC ITA 020042 “Rocche di Entella”, a small karsts plateau (Fig. 1) which is considered an important roosting area for bats. The borders of the area were set along main roads and watercourses so as to include all representative rural habitat types.

METHODS

1. Sampling design

From May to September 2006 and 2007, acoustic sampling was carried out in six habitats types; the number of selected recording points was proportional to the area of each habitat (Tab. 1). Sampling points were preferred to transects (Russo and Jones, 2003) because the former allowed better control for the small-scale habitat variation in this heterogeneous study landscape.

The position and altitude of sampling sites were recorded with a Garmin Geko 201 GPS; habitat availability and the habitat type occurring at each sampling site were assessed from a 1:50,000 land use map of the area by the software Quantum GIS.

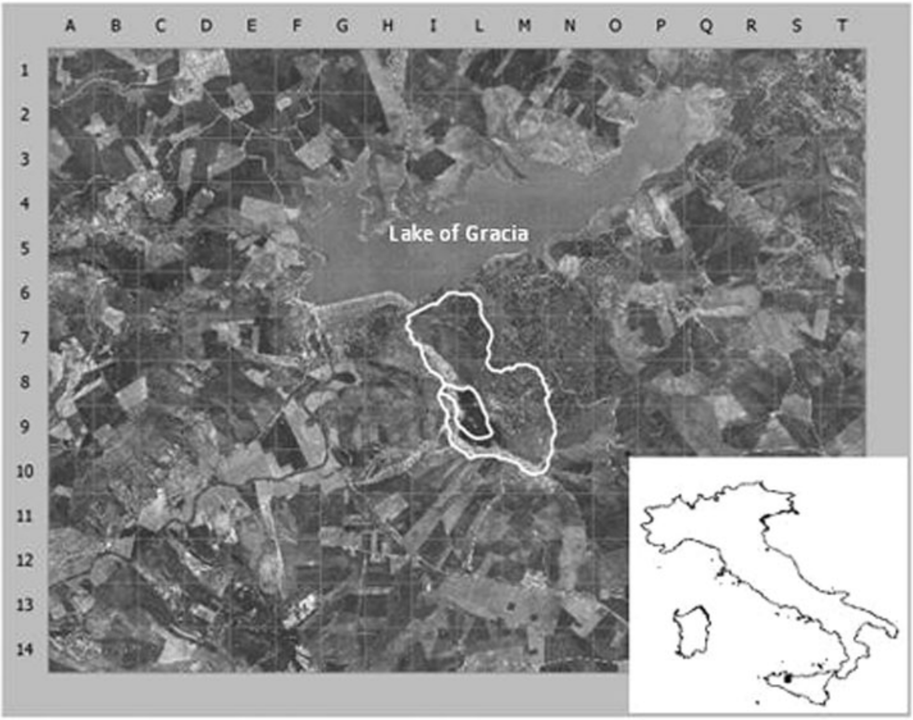

Figure 1 - Map of the study area embedded in the UTM grid European Datum 1950. The inner line encompasses the Nature Reserve, the outer includes the SAC (scale 1:50,000).

Each sampling lasted 10 min at each site, between 30 min after sunset and 1.00 a.m. (Russo, 2004), excluding both windy and rainy nights. We noted the moon phase and cloud cover to account for the possible influence of these factors (Russo and Jones, 2003). Sites were visited at random. Bat calls were detected with a D980 bat detector (Pettersson Elektronik, Uppsala) switched on frequency division. Whenever a bat pass was detected, we triggered the time expansion (10 x) and sampled a 3s sequence of each call. The corresponding sample of 30s was then downloaded and recorded on a Sony Metal XR cassette with a Sony Professional Walkman WM-D6C. Because it is not possible to time-expand continuously while downloading we could not expand any further incoming signal. Additional bat passes were counted on frequency division, but such calls were not recorded.

2. Sound analysis and species identification

We analyzed one echolocation call from each bat pass by Bat Sound 1.0 (Pettersson Elektronic, Uppsala), using a sampling frequency of 44.1 kHz, with 16 bits/sample and applied a 512 pt FFT with a Hamming window. A 112 Hz frequency resolution was obtained for spectrograms and power spectra.

Following Russo and Jones (2002), bats in flight were identified by their echolocation calls by a Discriminant Function Analysis (DFA). We applied two separate quadratic functions with cross-validation, one for bats emitting FM calls (*Myotis* spp. and *Plecotus* spp.), the other for those producing FM/QCF calls (genera *Pipistrellus*, *Hypsugo*, *Eptesicus*, *Nyctalus* and *Miniopterus*).

The model function for bats emitting FM calls

Table 1 - Habitat types and number of sampling sites (N) in the study area.

Habitat type	CORINE code	Area (ha)	% area	N	%
Water habitats and riparian vegetation	22.1 and 53	518.227	8.48	8	8.42
Thermo-Mediterranean shrub formations	32.2	468.962	7.67	7	7.37
Mediterranean xeric grasslands	34.5	846.009	13.84	13	13.68
Field crops	82.11	3381.706	55.32	53	55.79
Vineyards	83.21	557.618	9.12	9	9.47
Eucalyptus plantations	83.322	340.671	5.57	5	5.26
Total sampled area		6113.193		95	

relied on start frequency (SF), end frequency (EF), frequency of maximum energy (FMAXE) and duration (D) of the calls. That for bats emitting FM/QCF calls relied on end frequency (EF), centre frequency (CF), duration (D) and inter-pulse interval (IPI) (Russo and Jones, 2002).
Tadarida teniotis, *Rhinolophus ferrumequinum*, *R. hipposideros* and *R euryale* were easily identified by measuring only FMAXE (Russo and Jones, 2002). For each response the analysis provides a value expressing the probability of correct classification: we rejected all the responses scoring P < 80%. Because the functions we used were developed for bats of peninsular Italy, the geographic variation of echolocation signals might affect the identification performance (Russo, 2004; Russo *et al.*, 2007). Therefore, in some cases we preferred to be more conservative and classify the calls to the genus level (e.g. *Myotis* spp. or *Plecotus* spp.) or to assign them to the most likely pair of species (e.g. *N. leisleri* / *E. serotinus* or *P. pygmaeus* / *M. schreibersii*).

3. Data analysis

The number of passes recorded at species level and for the overall bat community in each habitat was considered as an index of foraging activity. ANOVA, followed by HSD post-hoc Tukey's test, were used to test the influence of cloud cover, moon phase, sampling period and habitat type on the number of bat passes and species richness. To meet ANOVA's assumptions, data were $\log_e$ transformed.
In addition, we used chi-square tests (χ^2) with Bonferroni's confidence intervals (BCI) to compare the observed and expected frequencies of habitat use by *H. savii*, *M. schreibersii*, *P. kuhlii*, *P. pipistrellus*, *Myotis* spp. and by all species lumped together (community level).
We performed all analyses with STATISTICA 6.0, setting the significance level at $\alpha = 0.05$.

RESULTS

A total of 95 sampling sites, on average 7.3 ± 2.1 (range: 5-15) sites per night, were surveyed. We recorded 305 bat passes, and identified 296 (96.4%) calls: 241 (81.4%) to species level, 29 (9.5%) to genus (27 of which attributed to *Myotis* sp. and two to *Plecotus* sp.), 18 (5.9%) as belonging to *N. leisleri* / *E. serotinus* and 8 (2.62%) to *P. pygmaeus* / *M. schreibersii* (Tab. 2).
Moon phase ($F_{1, 91} = 3.38$, N.S.), cloud cover ($F_{1, 91} = 0.82$, N.S.) and their interaction ($F_{1, 91} = 0.14$, N.S.) did not af-

Table 2 - Numbers of bat passes recorded at the 95 sampling sites.

	N total passes	%
Nyctalus leisleri/Eptesicus serotinus	18	5.9
Hypsugo savii	51	16.7
Miniopterus schreibersii	16	5.2
Myotis spp.	27	8.9
Pipistrellus kuhlii	123	40.3
Pipistrellus pipistrellus	27	8.9
Pipistrellus pygmaeus/M. schreibersii	8	2.6
Plecotus spp.	2	0.7
Rhinolophus euryale	4	1.3
Rhinolophus ferrumequinum	3	1.0
Rhinolophus hipposideros	5	1.6
Tadarida teniotis	12	3.9
Unidentified	9	3.0
Total	305	100.0

fect total bat activity, nor did the sampling period ($F_{2, 83} = 3.176$, N.S.). In contrast, total bat activity differed markedly between habitat types ($F_{5, 89} = 8.2$; $P < 0.001$) and Tukey's tests accounted for the highest level of total bat activity in "water habitats and riparian vegetation" and the lowest in "field crops" and "vineyards". Foraging activity in the different habitat categories proved non-random at both bat community ($\chi^2_{(5)} = 232.9$, $P < 0.01$) and species/group (*P. kuhlii*: $\chi^2_{(5)} = 35.4$, $P < 0.01$; *H. savii*: $\chi^2_{(5)} = 17.3$, $P < 0.01$; *P. pipistrellus*: $\chi^2_{(5)} = 152.5$, $P< 0.01$; *M. schreibersii*: $\chi^2_{(5)} = 110.8$, $P< 0.01$; and *Myotis* spp.: $\chi^2_{(5)} = 53.3$, $P< 0.01$) levels (Fig. 2). The whole bat community selected positively "water habitats and riparian vegetation" and avoided eucalyptus plantations and vineyards (Fig. 2). When the species were considered separately, all species selected "water habitats and riparian vegetation", except *H. savii*, and avoided field crops, except *Myotis* sp. Vineyards were avoided by *P. pipistrellus*, which also avoided Mediterranean xeric grasslands; *M. schreibersii* and *Myotis* spp. also avoided eucalyptus plantations (Fig. 2).

The number of passes recorded for the other species was too low for quantitative analysis; *T. teniotis* foraged in all habitats except vineyards, while rhinolophids were recorded in Mediterranean scrubland and crops.

Thermo-Mediterranean shrub formations showed the highest species richness, whereas vineyards had the lowest (Tab. 3). The mean number of foraging species detected per sampling point varied significantly between habitats ($F = 4.85$, $p < 0.001$), "water habitats and riparian vegetation" showing the highest value (mean 3.13 ± 2.23 SD) and "field crops" and "vineyards" the lowest (Tab. 3).

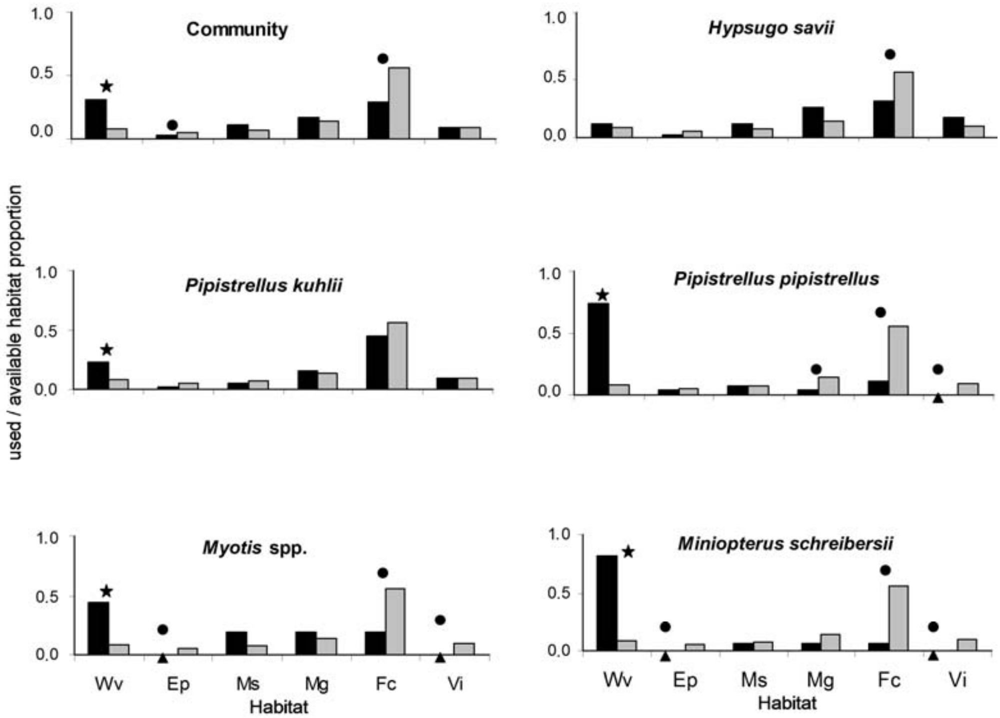

Figure 2 - Habitat use *vs* availability at both community and species levels. Grey bars: proportion of available habitat; black bars: proportion of habitat use; black triangles: no passes; black stars: preferred habitats (P<0.05); black dots: avoided habitats (P<0.05). Wv = water habitats and riparian vegetation; Ep = *Eucalyptus* plantations; Ms = Thermo-Mediterranean shrub formations; Mg = Mediterranean xeric grasslands; Fc = Field crops; Vi = Vineyards.

DISCUSSION

This study confirmed the importance of water bodies and riparian vegetation as foraging habitats for several bat species (Vaughan *et al*., 1997; Glendell and Vaughan, 2002; Russo and Jones, 2003). In xeric landscapes such as those of southern Italy, such habitats are also crucial for drinking (Russo and Jones, 2003).

The preference shown by *M. schreibersii* for riparian habitats is well-known from previous studies; this bat uses such habitats both for foraging and as navigation landmarks (Sierra-Cobo, 2000). The selection for such habitats recorded for *Myotis* bats may depend on the presence of species strictly related to this habitat type, i.e. *M. daubentonii* and *M. capaccinii* (e.g. Russo and Jones, 2003). The latter is known to roost in local caves (Di Salvo, pers. obs.). Interestingly, even generalist species such as *P. kuhlii* and *P. pipistrellus* selected aquatic habitats, most probably because of the disproportionately larger prey availability offered by them.

Not surprisingly, vineyards were the po-

Table 3 - Distribution and total species richness (S) in the available habitat types; Ep = *Eucalyptus* plantations; Ms = thermo-Mediterranean shrub formations; Wv = water habitats and riparian vegetation; Mg = Mediterranean xeric grasslands; Fc = field crops; Vi = vineyards.

	Ep	Ms	Wv	Mg	Fc	Vi
N. leisleri/E. serotinus	x	x	x	x	x	
Hypsugo savii	x	x	x	x	x	x
Miniopterus schreibersii		x	x	x		
Myotis spp.		x	x	x		
Pipistrellus kuhlii	x	x	x	x	x	x
Pipistrellus pipistrellus	x	x	x	x	x	
P. pygmaeus/M. schreibersii	x		x			
Plecotus spp.		x	x			
Rhinolophus euryale		x		x	x	
Rhinolophus ferrumequinum		x				
Rhinolophus hipposideros		x		x	x	
Tadarida teniotis	x	x	x	x	x	
S	6	11	9	9	7	2
Mean S ± SD	1.80±1.10	2.43±1.90	3.13±2.23	1.92±1.44	1.06±0.91	1.00±0.87
Range	1-3	1-6	1-7	0-5	0-4	0-2

orest habitat in terms of bat species, being periodically and massively sprayed with pesticides and fungicides, which presumably decrease the quantity and diversity of insects available to bats. *T. teniotis* is known to forage over field crops, especially if bordered by lit roads (Ahlén, 1990; Russo and Mastrobuoni, 1998), while the record of *R. ferrumequinum* in thermo-Mediterranean shrub formations, grazed by sheep and cattle, may depend on the high density of dung-beetles, a staple food item for this species (Duvergè, 1996; Ransome and Hutson, 2000). A broad-scale comparison of bat foraging activity in a variety of habitats found in peninsular Italy (Russo and Jones, 2003) showed that Mediterranean scrublands had little importance for bat foraging, perhaps as a consequence of water scarcity. Our results indirectly confirm that outcome, outlining the importance of water availability, which in our study area is granted by the presence of an artificial dam and the River Belice.

Although our work mainly focused on habitat selection and may have overlooked some rare species, we found that the small karstic plateau “Rocche di Entella” supports a relatively high species richness. Further investigations will probably increase the total number of species, allowing a more precise identification of *Myotis* species occurring in the area. We argue that the *Myotis* group may in fact include five or more species, i.e. the two cryptic species *M. myotis* / *M. blyhtii* and *M.*

capaccinii / *M. daubentonii* / *M. emarginatus*. For the unambiguous identification of *Myotis* bats, capture is recommended, especially for poorly investigated areas, where the geographic variation of bat calls may be significant. Likewise, although acoustic surveys left little doubt, captures should be carried out to confirm the occurrence of *P. pygmaeus* and *N. leisleri*.

The overall value of our study area for bats is certainly emphasized by its karstic nature, providing roosting opportunities for bats. Although our study area is mostly protected, intensive farming and the consequent loss of semi-natural habitats occurring in the immediate surroundings may adversely affect the bat community and, more generally, animal diversity (Benton *et al*., 2003). A landscape approach is thus required to preserve those features which may play a main role in sustaining bat diversity: promoting low-intensity farming is necessary to preserve landscape complexity and improve corridors (such as hedgerows and tree lines) between suitable habitat patches; moreover, as our study and others (Russo *et al*., 2002; Mattison and Norris, 2005) showed, the expansion of vineyard monocultures should also be limited.

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