

Habitat selection by the Mediterranean horseshoe bat, *Rhinolophus euryale* (Chiroptera: Rhinolophidae) in a rural area of southern Italy and implications for conservation

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Abstract

We studied habitat selection by *Rhinolophus euryale* in a rural area of southern Italy in 1998–2000 by radio-tracking. Two comparisons were carried out, one between habitat occurrence within individual home ranges and within the study area, the other between time spent in each foraging habitat and habitat occurrence within the home range. The first analysis showed that olive groves and conifer plantations were, respectively, the most and the least important habitats. The second analysis highlighted the importance of woodland for *R. euryale*, while urban sites, open areas and conifer plantations were avoided. We recommend that clearing of continuous, large areas of woodland for tree harvesting should be avoided. Conifers should not be used for reforestation. Urbanisation should be limited in the areas of greatest importance for the species, and linear landscape elements such as tree lines and hedgerows should be maintained. © 2002 Elsevier Science Ltd. All rights reserved.

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1. Introduction

The Mediterranean horseshoe bat (*Rhinolophus euryale* Blasius, 1853) is one of five rhinolophid species occurring in Europe (Mitchell-Jones et al., 1999). It is a medium-sized bat (forearm length = 43–51 mm, body mass = 8–17.5 g; Schober and Grimmberger, 1997), and its European range mainly covers the southern part of the continent (Ibáñez, 1999), particularly the Mediterranean region, as the vernacular name suggests. Although its status is merely classified as ‘Vulnerable’ in the IUCN Red List (2000), data are scarce and populations may be more threatened than this classification indicates: a worrying decline (ca. 70%) occurred in France between 1940 and 1980 and a serious population decrease has occurred in Slovakia (Brosset et al., 1988; Schober and Grimmberger, 1997; Ibáñez, 1999).

All five European rhinolophids feature in the Italian bat fauna (Lanza, 1959). *Rhinolophus blasii*, however, is

probably extinct (Bulgarini et al., 1998), and *Rhinolophus mehelyi* is mainly confined to Sardinia (Mucedda et al., 1994–1995). Of the remaining three species, *R. euryale* seems to be the rarest, and it appears to be less common than the greater (*Rhinolophus ferrumequinum*) and the lesser (*Rhinolophus hipposideros*) horseshoe bats (D. Russo, personal observation).

The species appears to be particularly sensitive to human disturbance, and because it mainly roosts in underground shelters, protection of such sites is undoubtedly a key conservation strategy (Stebbing, 1988; Schober and Grimmberger, 1997; Ibáñez, 1999).

However, besides protecting roosts, bat conservation actions should also address the preservation, correct management and enhancement of foraging sites, because these are fundamental to bats (e.g. Stebbing, 1988; Ransome, 1997; Hutson et al., 2001). Among rhinolophids, in particular, especially valuable information on the selection of foraging habitats has been gathered for *R. ferrumequinum* (Jones and Morton, 1992; Duvergé and Jones, 1994; Jones et al., 1995; Duvergé, 1996; Ransome, 1997; Bontadina et al., 1999a; Duvergé and Jones, in press). Such knowledge has been used to

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implement conservation measures in Great Britain (Ransome, 1997) and to formulate an Action Plan (Ransome and Hutson, 2000). Countryside Stewardship Schemes were also developed to grant-aid farmers for the conservation of habitat features important for this species (Mitchell-Jones, 1998).

Although habitat protection has been emphasised for the conservation of *R. euryale* (Schober and Grimberger, 1997), the only reports on foraging habitats by this species are largely anecdotal (Schober and Grimberger, 1997). Our project aimed to fill this gap. We studied habitat selection in a *R. euryale* colony from a rural area of southern Italy by radio-tracking. We did not apply acoustic survey methods because the chance of detecting this species with a bat detector was low. In fact, like all rhinolophids, *R. euryale* emits high-frequency (Russo et al., 2001), highly directional echolocation calls, much affected by atmospheric attenuation (e.g. Griffin, 1971; Lawrence and Simmons, 1982). Furthermore, the species was uncommon in the study area and thus unlikely to be encountered on foraging grounds. We paid special attention to the following questions: (1) which habitats are most preferred by the species?; (2) can the species adapt to habitats created or substantially modified by man?

We also provide some qualitative observations on commuting, foraging and roosting behaviour of this little known species. The ultimate aim was to collect basic information which may contribute to the development of a conservation plan for *R. euryale*, as recommended by Hutson et al. (2001) for bats in the Mediterranean region.

2. Material and methods

2.1. Study area and land use mapping

The study was conducted in June–July 1998–2000 in the Titerno valley (Lat. 41°17' N, Long. 14°30' E) and its surroundings, a rural area of Campania (southern Italy). The Titerno is a stream which largely dries up in summer. The highest elevation of the mountains occurring in the area is 1332 m.a.s.l. The 'study area' considered for habitat selection analyses covered 3397 ha. It was determined by mapping all locations where the bats tracked were observed and tracing a Minimum Convex Polygon (MCP; Mohr, 1947) around them (Fig. 1). Disturbance factors occurring in the area were farming practices, conifer plantations, urbanisation, non-native plant species, alteration of river structural features and water pollution. The study area landscape was therefore a rapidly changing mosaic of natural and transformed habitats.

The following eight habitat types were recognised by field surveys and analysis of aerial photographs:

1. Broadleaved woodland. This was mainly constituted by evergreen *Quercus ilex* coppice in some areas, or by a complex association of several tree species in others, for example *Quercus pubescens*, *Alnus cordata*, *Ostrya carpinifolia*, *Castanea sativa* and frequent aliens such as *Robinia pseudoacacia* and *Ailanthus altissima*. Large hedgerows consisting of trees were included.
2. Riparian woodland. This occurred along the shores of the Titerno stream and the Volturno river (the latter occurred only within the west sector of the study area). Riparian woodland bordering the Titerno had been altered considerably, and in several riparian areas native tree species such as willows and poplars had been substituted by invasive trees such as *R. pseudoacacia* and *A. altissima*. Large strips of woodland bordering canals in farmland were also included.
3. Riparian scrubland. Riparian low vegetation, dominated by shrubs and herbaceous species, with a few trees.
4. Scrubland, grassland and clearings. This category included open sites, i.e. sites with shrubs (excluding riparian scrublands), grass and bare ground. Clearings produced by logging and fire were included.
5. Olive groves. These were generally patchy and interspersed with small woodland tracts, constituting a complex mosaic. Olive groves were generally managed in a traditional and not intensive way, and some undergrowth occurred in a number of them.
6. Farmland. Arable land, including fields with herbaceous species, vineyards, small and isolated olive groves and orchards, often arranged in a complex mosaic.
7. Conifer plantations of *Pinus halepensis*.
8. Urban. Small towns; patchy built-up sites surrounded by farmland.

The landscape appeared quite patchy, particularly in the east sector of the study area. Simpson's diversity index value (McGarigal and Marks, 1994) calculated from raster maps with the software Fragstats version 2.0 was 0.67 for the whole area, and reached 0.75 in the east portion.

A land-use map was generated with the GIS software Arcview 3.1 (ESRI inc.). Mapping was accomplished by photo interpretation of 1:10,000 orthophotos. Screen digitisation of photographs was integrated and corrected with data from field surveys. Topology was verified with Ilwis 2.23 (ITC© The Netherlands). The map was referred to the Gauss-Boaga coordinate system projection for Italy (Zone 2).

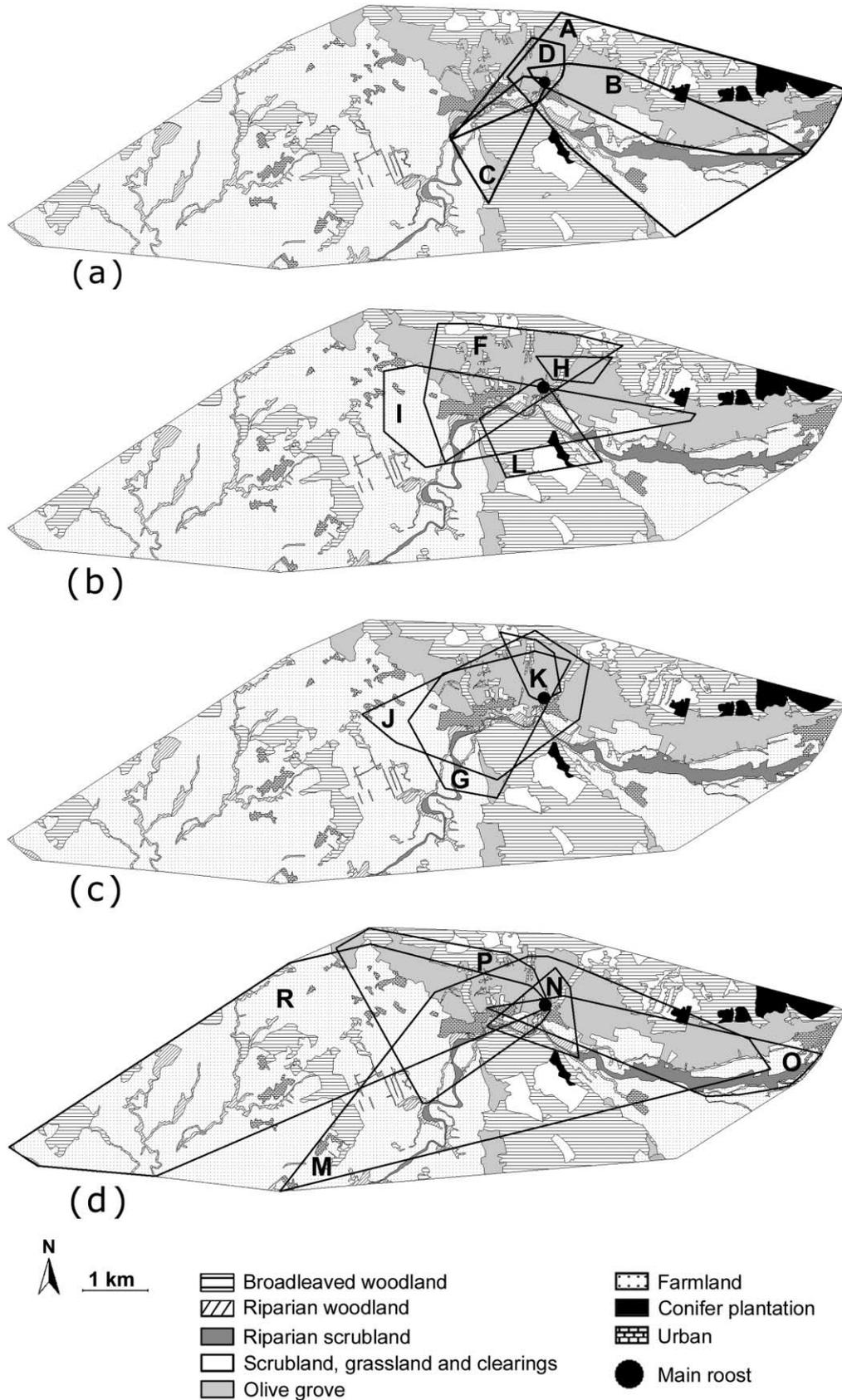


Fig. 1. Individual home ranges (Minimum Convex Polygons) of 16 *Rhinolophus euryale* tracked in (a) 1998, (b,c) 1999 and (d) 2000. Letters correspond to bats as in Table 1. The study area is delimited by a Minimum Convex Polygon enclosing all locations of the bats followed during the entire study.

2.2. The bat colony

The bats roosted in an artificial underground shelter about 1-km long located at an elevation of ca. 200 m.a.s.l. and comprising four branches. These were characterised by different ambient temperatures: the branch used in summer by *R. euryale* was the warmest, with a mean winter temperature of ca. 12 °C (about 3 °C higher than that measured in the others; D. Russo, unpublished data). Although temperature was not measured in summer, we noticed that the thermal difference clearly persisted, and perhaps even increased because of the heat produced by the larger congregation of bats.

In summer, *R. euryale* roosted together with *Miniopterus schreibersii*, *Myotis emarginatus*, *Myotis capaccinii* and a few non-breeding *R. ferrumequinum*. In summer 1997, the overall colony size was estimated to be ca. 500 bats, about 200 of which were *R. euryale*. Although counts were not carried out on a regular basis, occasional observations on emergence and repeated captures in order to tag bats showed a large seasonal fluctuation in the number of individuals from all species frequenting the roost. This varied from a few hundred in May to only 20–40 from mid-July to the beginning of August. Bats probably moved to different sites soon after breeding, as some of our results suggested (see later). The reproduction of *R. euryale* was ascertained in all 3 years of study. It was not clear whether the other species (apart from the non-breeding *R. ferrumequinum*) regularly bred at the site over the

study period. *R. euryale* newborns and females in late pregnancy were observed from mid-June to mid-July.

2.3. Tagging procedure and data collection

Our methods followed those used for similar studies on the closely related *R. ferrumequinum* (Jones and Morton, 1992; Jones et al., 1995; Duvergé, 1996). Bats were captured while leaving the roost with a harp-trap and fitted with a radio-transmitter, attached between the shoulder blades with Skinbond[®] adhesive after clipping the fur. In 1998, we used Holohil (Carp, Canada) BD-2 0.72 g tags. These slightly exceeded 5% of body mass (Aldridge and Brigham, 1988)—a condition that did not affect bats in other radio-telemetry studies (e.g. Entwistle et al., 1996; Sedgely and O'Donnell, 1999)—but, in order to avoid all risk of influencing the bats, we used Holohil LB-2 tags weighing 0.5 g in the following years (Table 1).

A Lotek (Newmarket, Canada) Suretrack STR1000 receiver connected to a three-element Yagi antenna was used in the field. Each night, one individual was tracked (focal subject) and the presence of other bats was checked repeatedly. Whenever contact was lost with the focal subject for more than ca. 15 min, another bat in contact was followed.

Continuous tracking was adopted (e.g. Jones and Morton, 1992; Duvergé, 1996): once a bat was detected, several bearings were taken in rapid sequence. To locate a bat, the 'homing in' method was applied (e.g. White

Table 1

Date of capture, sex, biometry (FAL = forearm length, BM = body mass), percentage ratio tag/body mass and tracking details of the bats studied^a

Bat code	Date of capture	Sex	FAL (mm)	BM (g)	100× (tag mass /BM)	Days tracked	<i>n</i> fixes	Time tracked (min)	Max distance (m)	Max elevation (m)
A	5 July 1998	F	47.9	10.7	6.7	4	41	221	4618	580
B	5 July 1998	F	48.2	11.2	6.4	4	33	406	4156	393
C	17 July 1998	F	49.4	11.2	6.4	3	39	255	1946	344
D	17 July 1998	F	48.5	11.2	6.4	3	41	238	865	368
E	5 July 1998	F	48.2	11.1	6.5	2	4	38	–	236
F	5 July 1999	F	49.0	11.1	4.5	8	59	471	1840	525
G	5 July 1999	F	47.0	10.5	4.8	4	31	156	2077	382
H	5 July 1999	F	47.0	11.2	4.5	3	21	301	–	408
I	5 July 1999	F	47.8	11.2	4.5	3	23	155	2503	320
J	15 July 1999	M	48.5	11.1	4.5	5	87	927	1129	492
K	15 July 1999	M	45.2	10.7	4.7	3	21	137	446	565
L	15 July 1999	F	49.7	13.8	3.6	4	34	201	–	290
M	27 June 2000	F	48.9	10.8	4.6	6	68	445	2656	393
N	27 June 2000	F	48.5	10.6	4.7	3	22	87	694	323
O	27 June 2000	F	48.5	10.6	4.7	3	27	142	879	272
P	10 July 2000	F	47.7	10.5	4.8	7	61	345	2253	456
Q	27 June 2000	M	48.4	11.4	4.4	–	–	–	–	–
R	13 July 2000	M	47.5	10.3	4.8	6	52	1120	5035	300
	Mean (S.D.)		48.1 (1.0)	11.1 (0.8)	5.1 (0.9)	4.2 (1.7)	39.1 (20.8)	332 (289.5)	2221 (1474)	391 (102.4)

^a Days tracked include all nights when at least one contact with the bat was obtained. M = male, F = female. Tags used in 1998 weighed 0.72 g, all others 0.5 g. Max. distance and Max. elevation are the maximum distance flown from the roost and the highest elevation reached by each bat. Distance for bat 'R' was measured from the second roost discovered during the study.

and Garrott, 1990; Entwistle et al., 1996): the observer established the bat's position by approaching the subject tracked as close as possible by car or on foot. Signals that were very strong and almost or completely non-directional—even when the receiver gain was lowered to 'zero'—were attributed to close proximity of the bat tracked. The bat position (hereafter termed fix; Table 1) was noted on a 1:25,000 map (Istituto Geografico Militare, Firenze) and the activity performed by the bat was recorded. Rapid, directional movements between distant sites were classified as commuting; the behaviour of a bat which kept flying in a defined area of variable size (i.e. a foraging area) was interpreted as foraging. Foraging and commuting times were recorded; when activity was unclear, the corresponding time was attributed to an 'undetermined behaviour' category, and not considered for analysis. On rare occasions, in woodland, a bat appeared to be completely motionless for > 20 min (up to 78 min); it was thought to be night-roosting hanging from a tree, and such a period was excluded from foraging time budget and not used for analysis.

In 1998, field work was limited by the difficulty of receiving signals from bats within the roost. To solve this problem, two aerials fitted with about 200 m of BNC cable were set up within the roost. Sometimes the aerials made it possible to verify the presence of the bats within the roost.

2.4. Data analysis

A point vector map of all bat positions was obtained with Ilwis, and fixes were associated to a database including subject code, activity performed, time of observation (start–end) and duration of the behaviour observed (in minutes).

Minimum Convex Polygons (MCPs) delimiting respectively all fixes (i.e. the study area) and those corresponding to each bat (individual home ranges) were digitised with Arcview, and percentage habitat composition within MCPs was calculated. Habitats corresponding to each bat location were determined through overlay operations carried out with the Arcview 3.1 geoprocessing extension (Spatial Join). Point- and land-use maps were rasterised to perform overlay procedures. The time spent by each bat in each habitat type was then calculated. Two different analyses comparing habitat use with habitat availability were performed:

1. Percentage habitat composition within each bat's MCP was compared with that of the study area to determine whether habitat occurrence within individual home-ranges was non-random (i.e. differing significantly from that of the study area).
2. Percentage foraging time spent by bats in each habitat was compared with percentage habitat

proportion occurring within individual home-ranges to see whether the bats selected habitats or used them according to availability.

Hence while analysis (1) concerned all observations (i.e. regardless of whether they corresponded to foraging or other behaviours), analysis (2) focused on foraging time and foraging sites. In analysis (1), a MCP including all bat positions to define habitat availability was adopted because this was independent from the roost position. In fact, a few days after tagging, several bats moved to different roosts (apparently located in the same general area) only one of which could be exactly located; some of these roosts may have been underground shelters, from which radio-signals could not be detected. The reason for this behaviour in lactating females may have been that the bats left the nursery soon after weaning the young. In this situation, it was impossible to define the area potentially available to the bats as a circle around the roost with a radius equal to the maximum distance travelled from the roost (maximum range circle, MRC) as done in other studies (e.g. Waters et al., 1999). In this paper, we call 'main roost' the one where all study subjects were captured.

In 1999 and 2000, two adjoining woodland areas of ca. 12 ha each were cleared (one in each year). The resulting clearings were classified as 'scrubland, grassland and clearings'. The proportions of woodland and 'scrubland, grassland and clearings' occurring in the study area in the corresponding years were therefore corrected for, and adjustments were made on habitat percentages relative to one individual MCP whose area partly included the cleared site.

Both comparisons were carried out using Compositional Analysis (Aebischer et al., 1993). To overcome problems determined by departure from multivariate normality of log-ratio difference distribution, we calculated the significance of Wilk's Λ and t statistics by randomisation tests (Aebischer et al., 1993). When availability was zero, the missing values in a given residual log-ratio were replaced by the mean of all non-missing values for that log-ratio. A mean Λ was then obtained as a weighted mean (Aebischer et al., 1993), and 1000 iterations were employed in randomisation tests (Manly, 1997). Where proportions of 'used' were zero, these were substituted by 0.001 (Aebischer et al., 1993). Habitats were ranked according to their relative importance, those written before '>' symbols being preferred to those following the sign. The symbol '»' separates habitats that differed significantly, while '>' is placed between those that did not. Preliminary data exploration (ANOVA, Kruskal–Wallis tests) showed that neither the percentage foraging time spent in each habitat nor the percentage habitat composition of home ranges differed significantly across years. Therefore the effect of year on habitat selection was not considered in

the final analysis. Sexual differences in habitat selection could not be analysed because sample size of males was too small (three out of 16 bats). Analyses were performed with the software Compositional Analysis Excel tool 3.1 written by Peter Smith (University of Aberdeen). All statistics, matrices and rank orders were provided automatically by this software. In all statistical tests, significance was set at $P < 0.05$.

The bats could rarely be tracked continuously over most or all of one night. Possible reasons for frequent interruptions in signal reception were landscape complexity (presence of obstacles such as mountains and canyons which obscured the signal), the bats' low flight (as noticed on occasional sights of the subjects tracked) and maybe the use of underground night roosts (potential cave roosts were largely available in the area) from which radio signals could not be detected. We determined with Arcview the furthest distance travelled by the bats on nights when they left a known roost. The value range obtained may be regarded as a descriptor of maximum nightly movement from roost of the bats tracked. We used Ilwis to determine the highest elevations of the sites frequented by the bats by overlaying all bat locations with a digital elevation model (DEM) calculated by point interpolation.

3. Results

3.1. Habitat selection

Eighteen adult bats were tagged, five (all females) in 1998, seven (five females, two males) in 1999 and six

(four females, two males) in 2000 (Table 1). All females were lactating or in early post-lactation when they were captured. A female tagged in 1998 (E; Table 1) was tracked for <40 min, so that data were not considered for analysis, and a male tagged in June 2000 was never detected after release. Data from 16 bats were used to determine habitat selection. Data collection ended when contact with the bats was lost in all cases except two, when the tag fell off.

Percentage habitat composition of individual MCP areas (used; Table 2, Fig. 1), compared with that of the study area (available; Table 3) was non-random (weighted mean Wilk's $\Lambda = 0.1504$, $\chi^2 = 30.3076$, $df = 7$, $P < 0.0001$, randomisation $P < 0.008$). Comparison between habitats (Table 4) provided the following simplified rank order (from 7 to 0): olive groves \gg broadleaved woodland $>$ urban $>$ riparian scrubland $>$ riparian woodland $>$ scrubland, grassland and clearings $>$ farmland \gg conifer plantations.

The comparison between time spent foraging by bats in each habitat and habitat proportions occurring in their MCPs (Tables 2 and 5, Fig. 1) provided more information: a larger number of significant differences between habitats emerged. Again, habitat use departed significantly from random when compared with habitat availability (weighted mean Wilk's $\Lambda = 0.0044$, $\chi^2 = 86.6707$, $df = 7$, $P < 0.0001$, randomisation $P < 0.001$). The rank order (from 7 to 0; Table 6) was: broadleaved woodland \gg olive groves $>$ riparian woodland $>$ riparian scrubland $>$ farmland \gg conifer plantations $>$ scrubland, grassland and clearings \gg urban. No bat was ever observed foraging in conifer plantations and urban areas, and only one showed activity (albeit limited) in

Table 2
Percentage habitat composition of Minimum Convex Polygons (MCP) of 16 *Rhinolophus euryale*

Bat	MCP area (ha)	Broadleaved woodland	Riparian woodland	Riparian scrubland	Scrubland, grassland and clearings	Olive groves	Farmland	Conifer plantations	Urban
A	936.8	19.23	1.65	6.76	5.29	29.43	30.06	4.41	3.17
B	215.4	12.80	0	2.97	2.20	68.98	11.70	0.89	0.46
C	126.0	38.90	9.41	2.84	0.06	18.66	28.57	0	1.56
D	102.6	14.83	9.41	2.15	0.45	52.38	12.20	0	8.58
F	345.4	21.04	4.07	1.84	4.26	48.27	13.36	0	7.16
G	333.8	18.87	5.68	2.71	0.37	36.85	28.25	0	7.27
H	33.9	11.26	0	0	0	88.74	0	0	0
I	418.9	17.34	6.73	3.03	0.44	21.01	43.60	0.60	7.25
J	439.6	20.83	4.91	1.70	0.59	37.86	27.07	0	7.04
K	54.5	14.55	0	0	6.50	78.95	0	0	0
L	163.0	48.27	11.74	2.97	10.14	5.55	14.86	3.86	2.61
M	1229.4	17.98	3.77	4.57	5.27	24.38	39.95	0.85	3.23
N	99.9	13.62	17.34	3.18	0.24	40.66	16.44	0.01	8.51
O	350.5	7.12	1.17	13.59	0.06	42.30	31.97	0.10	3.69
P	504.0	14.76	3.69	1.57	1.11	33.09	39.10	0	6.68
R	1281.3	10.53	4.74	0.24	0.08	9.23	71.23	0	3.95
Mean (S.D.)	414.7 (397.4)	18.87 (10.52)	5.27 (4.79)	3.13 (3.27)	2.32 (3.06)	39.77 (23.56)	25.52 (18.08)	0.67 (1.39)	4.45 (3.05)

Table 3

Size and percentage habitat composition of the study area (determined as the Minimum Convex Polygon including all bat positions recorded over 1998–2000)^a

Year	Total area (ha)	Broadleaved woodland	Riparian woodland	Riparian scrubland	Scrubland, grassland and clearings	Olive groves	Farmland	Conifer plantations	Urban
1998	3397.1	21.75	3.25	2.43	3.23	13.85	51.33	1.55	2.61
1999	3397.1	21.39	3.25	2.43	3.59	13.85	51.33	1.55	2.61
2000	3397.1	21.04	3.25	2.43	3.94	13.85	51.33	1.55	2.61

^a In 1999 and 2000, woodland decreased by 12 ha in each year, and clearings (included in scrubland, grassland and clearings) increased accordingly.

Table 4

Ranking matrix for *Rhinolophus euryale* based on comparing proportions of habitats occurring within individual Minimum Convex Polygons and those in the study area^a

	Broadleaved woodland	Riparian woodland	Riparian scrubland	Scrubland, grassland and clearings	Olive groves	Farmland	Conifer plantations	Urban	Rank
Broadleaved woodland		+	+	+++	---	+++	+++	+	6
Riparian woodland	-		-	+	-	+	+++	-	3
Riparian scrubland	-	+		+	---	+++	+++	-	4
Scrubland, grassland and clearings	---	-	-		---	+	+++	-	2
Olive groves	+++	+	+++	+++		+++	+++	+	7
Farmland	---	-	---	-	---		+++	---	1
Conifer plantations	---	---	---	---	---	---		---	0
Urban	-	+	+	+	-	+++	+++		5

^a The signs show whether the habitat placed in the corresponding row was more or less (sign + or -) important than that in the corresponding column. A triple sign (+++, ---) indicates occurrence of significant ($P < 0.05$) differences, one sign shows non-significant trends. Habitat relative importance (rank) was determined by the number of +, +++ signs occurring in the corresponding row. Habitats were ranked according to their importance from zero (the least important habitat) to seven (the most important one).

scrubland, grassland and clearings (Table 5). All bats observed foraging in farmland actually used tree lines and hedgerows rather than flying over open fields.

3.2. Activity patterns and behaviour observed

The maximum distance travelled from the roost on one night by a bat ($n=14$) averaged about 2.2 km (Table 1); the furthest recorded was about 5 km. The maximum elevation of sites frequented by individual bats ($n=17$) ranged between 236 and 580 m.a.s.l. (Table 1). In this study, the bats often followed linear landscape elements such as stretches of riparian vegetation bordering the dried up stream (Fig. 2), large hedgerows and woodland strips. Nine bats commuted along the riparian vegetation. One of the bats tracked (bat 'R') reached a previously unknown roost 8.4 km away from the main one. On its way to the roost, bat 'R' crossed several kilometres of farmland following large hedgerows and woodland strips. These landscape elements were also used to forage, and probably to night-roost. Bat 'R' roosted together with other conspecifics under a river bridge, near a water conduit which provided suitable dark, humid conditions. Other

species observed at the roost included *M. schreibersii*, *M. capaccinii* and *M. emarginatus* (i.e. the same species association found in the main roost).

Direct observation was difficult because the bats mostly selected wooded sites. Only one bat was seen foraging (aerial hawking). In that case, the signal varied rapidly in direction and intensity within the foraging site, as was often noticed for foraging bats tracked but not observed. Another typical signal variation was associated with bats foraging in wooded sites; here, rapid changes in signal strength and direction within a very limited woodland spot (i.e. very short-range movements) alternating with a stationary condition suggested that the bats may have been perch-feeding.

4. Discussion

4.1. Habitat selection

The two analyses made to determine habitat selection by *R. euryale* showed some discrepancies in habitat ranking according to the relative importance of habitats. In spite of some significant differences, the comparison

Table 5
Overall foraging time (minutes) and percentage foraging time per habitat for 16 *Rhinolophus euryale*

Bat	Foraging time	Broadleaved woodland	Riparian woodland	Riparian scrubland	Scrubland, grassland and clearings	Olive groves	Farmland	Conifer plantations	Urban
A	186	73.12	0	0	0	18.82	8.06	0	0
B	219	85.84	0	2.74	0	11.42	0	0	0
C	223	33.19	30.49	2.24	0	27.35	6.73	0	0
D	196	58.17	12.24	3.06	0	26.53	0	0	0
F	137	83.08	1.99	0	0	14.43	0.50	0	0
G	120	29.17	0	0	0	38.33	32.5	0	0
H	266	57.14	0	0	0	42.86	0	0	0
I	102	32.05	2.91	0	0	15.53	49.51	0	0
J	807	64.13	3.94	0	0	19.43	12.50	0	0
K	122	61.48	0	0	0	38.52	0	0	0
L	186	15.59	74.73	4.84	0	3.23	1.61	0	0
M	342	61.11	10.82	2.05	0	25.15	0.87	0	0
N	80	63.75	17.50	3.75	0	7.50	7.50	0	0
O	101	70.30	0	12.87	0	11.88	4.95	0	0
P	282	38.66	18.09	2.13	0.35	40.42	0.35	0	0
R	474	23.21	70.04	0	0	6.75	0	0	0

Table 6
Ranking matrix for *Rhinolophus euryale* based on comparing percentage of time spent foraging in each habitat with the proportions of habitats occurring within individual Minimum Convex Polygons^a

	Broadleaved woodland	Riparian woodland	Riparian scrubland	Scrubland, grassland and clearings	Olive groves	Farmland	Conifer plantations	Urban	Rank
Broadleaved woodland		+	+++	+++	+++	+++	+++	+++	7
Riparian woodland	–		+	+++	–	+	+	+++	5
Riparian scrubland	----	–		+++	----	+	+++	+++	4
Scrubland, grassland and clearings	----	----	----		----	–	–	+++	1
Olive groves	----	+	+++	+++		+++	+++	+++	6
Farmland	----	–	–	+	----		+++	+++	3
Conifer plantations	----	–	----	+	----	----		+	2
Urban	----	----	----	----	----	----	–		0

^a Habitats were ranked according to their importance from zero (the least important habitat) to seven (the most important one). Symbols as in Table 4.

between habitat occurrence within individual home ranges and within the study area cannot determine habitat selection by this species in detail. Indeed, the bats often commuted within the home range to reach favourable, and quite often small hunting sites located far apart where most foraging occurred. The highly patchy landscape may have exaggerated this behaviour as suitable foraging sites were scattered over home ranges. For example, among the preferred hunting sites were several narrow wooded canyons surrounded by olive groves on the flank of a mountain. Despite their limited size, these canyons were used frequently and foraging time spent there had an important effect on the final time budget. The same considerations apply to fragments of broadleaved woodland in farmland and to restricted riparian

woodland spots. Therefore, the analysis of foraging time provided a more effective picture of habitat selection.

The high importance of broadleaved woodland for foraging was revealed by both analyses, and particularly by that based on foraging time. The fact that the bats followed wooded strips when commuting, and the probable night-roosting in trees, further highlights the importance of broadleaved woodland for *R. euryale*. It is unclear why riparian woodland was less important than broadleaved woodland found elsewhere, but this might be due to the higher fragmentation of woodland along water-courses. Although riparian woodland occurred in smaller patches (mean 8.4 ha) and with longer distances between neighbouring patches (mean 673 m) compared with broadleaved woodland (20.5 ha

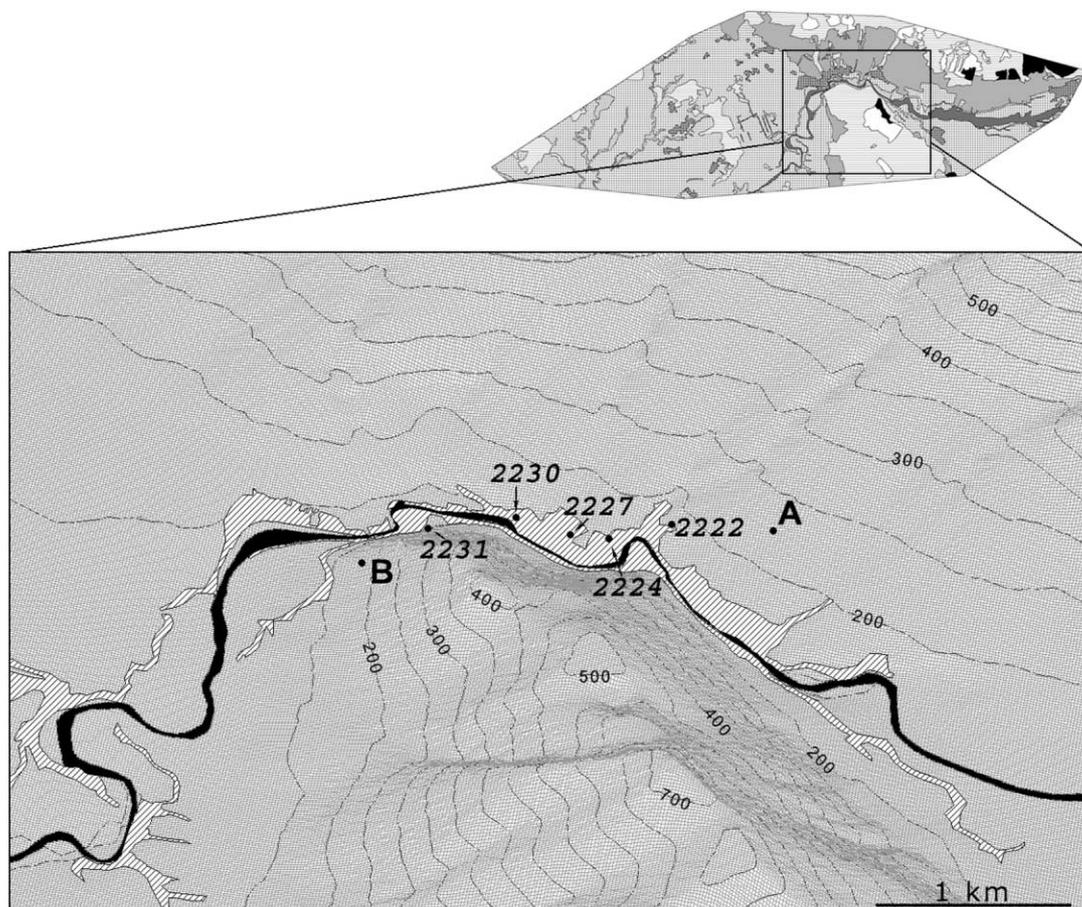


Fig. 2. A typical navigation pattern of *Rhinolophus euryale* following the riparian vegetation. On 16 July 1999, bat J left the olive grove foraging site 'A' at 2220 and moved west to a woodland foraging site ('B'), which was reached after ca. 15 min. Dots illustrate consecutive bat locations; the corresponding time (local time) is also shown. The box shows the section of the study area (illustrated as in Fig. 1) that has been zoomed. Only riparian habitats are highlighted: riparian scrubland is marked in black; dashed areas correspond to riparian broadleaved woodland.

and 143 m, respectively), there was so much variability in the sample that these differences were not significant.

A preference for olive groves emerged from both habitat selection analyses. However, the importance of this habitat may have been overestimated in the comparison between habitat occurrence in MCPs and in the study area, because olive groves were mostly concentrated around the main roost (Fig. 1). The area around the main roost was included in all home ranges, and this emphasised the 'weight' of olive groves in the analysis. Furthermore, it should be noted that olive groves were generally adjacent to major woodland areas and were often interspersed with broadleaved woodland patches. Hence, their value for foraging was probably influenced by the frequent proximity of broadleaved woodland.

A significant proportion of urban areas featured in most individual MCPs because one of the few large urban sites in the study area was close to the roost (Fig. 1). This is why this habitat obtained a high rank in

the analysis that considered habitat composition of home ranges, while the analysis of foraging time revealed that built-up sites had no importance for foraging. Although some more adaptable bat species may take advantage of roosting and foraging opportunities offered by urban areas (e.g. Kunz, 1982), in general urbanisation is harmful to insectivorous bat communities (Kurta and Teramino, 1992; Gaisler et al., 1998).

Although conifer plantations mainly occurred quite close to the roost (see areas shown in black in Fig. 1) and could therefore be reached easily, a negative selection for them emerged from both analyses. Altitude played no role in determining the rank difference between conifer and broadleaved woodlands: the former habitat occurred at 175–613 m.a.s.l., i.e. mostly within the altitude range covered by the bats (Table 1). The highest broadleaved woodland site where a bat was recorded was at 580 m.a.s.l. The probable reason for avoiding conifer woodlands is that they support fewer prey insects than broadleaved ones (Waring, 1988, 1989;

Entwistle et al., 1996), including Lepidoptera—an important component in the diet of *R. euryale* (Koselj and Krystufek, 1999). Whether conifer plantations could be more important in areas where broadleaved woodland is absent is difficult to predict as no data are available. Conifer plantations are avoided by other bat species that forage in broadleaved woodlands, such as *Plecotus auritus* (Entwistle et al., 1996) and *Myotis nattereri* (Smith, 2000). Acoustic surveys (D. Russo and G. Jones, unpublished data) showed that in southern Italy conifer plantations were also avoided by *Hypsugo savii*.

In the rank order provided by the analysis of foraging time (Table 6), conifer plantations (rank 2) followed ‘scrubland, grassland and clearings’ (rank 1) because the latter habitat was commoner than the former in most home ranges (Table 2). For the same reason, ‘scrubland, grassland and clearings’ was apparently preferred to urban areas (rank 0). In reality, because all of these habitats were not used (Table 5), they should be considered as equally undesirable for *R. euryale*.

Studies on the closely related *R. hipposideros* (Schofield, 1996; Bontadina et al., 1999b) in Wales gave results very similar to ours. Like *R. euryale*, *R. hipposideros* mainly selected broadleaved woodland, riparian vegetation, hedgerows and tree lines, whilst conifer plantations, low vegetation, settlements and open areas were avoided. Also, *R. hipposideros* commuted along hedgerows, tree lines and stretches of riparian vegetation. The presence of woodland is also important for *R. ferrumequinum*, whose preferred foraging habitats are grazed pastures interspersed with blocks or strips of deciduous woodland and significant hedgerows (e.g. Duvergé, 1996; Ransome and Hutson, 2000). This species commonly follows linear landscape features (Ransome and Hutson, 2000).

4.2. Implications in habitat protection and management

Because *R. euryale* clearly favours lower altitudes for roosting and foraging (see also Schober and Grimmberger, 1997; Ibáñez, 1999), the correct management of woodlands below ca. 800 m.a.s.l. appears important to preserve this bat species. An especially careful logging protocol should be applied in managing coppice within areas of major importance for *R. euryale*: the logging of large areas should be avoided, minimising the size of single clearings, but leaving a system of woodland corridors and patches to connect areas of undisturbed woodland. Grindal and Brigham (1998) showed that small forest openings may lead to an increase in bat activity. Riparian vegetation, hedgerows and tree lines should be scrupulously protected and encouraged. Reforestation with non-native conifers, as widely practised until recently in Italy, should be discouraged where it is possible to plant broadleaved forests.

Urbanisation is a major threat to *R. euryale*, which avoids urban sites. Since towns generally occupy low altitudes, they are likely to alter habitats used by this rhinolophid. Reforestation with broadleaved trees of areas close to built-up sites might be a viable strategy to contrast the negative effect of urbanisation.

Our data on distances between roosts and foraging areas should be considered as preliminary and treated with prudence until further, more complete information on the commuting range of *R. euryale* is gathered. However, they are similar to those obtained in several studies on other rhinolophids (Jones and Morton, 1992; Duvergé and Jones, 1994; Bontadina et al., 1999b). A conservative approach would require protection of foraging habitats within a range of not less than 5 km from nurseries. Frequent roost switching by this species may necessitate the protection of even larger areas around maternity roosts however.

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