HIBERNATION OF BATS IN NAVARRE (NORTHERN SPAIN)

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Abstract

During the winters of 1990 to 1994 the fauna of Chiroptera was sampled in Navarra and a total of 12 species was found: *Rhinolophus ferrumequinum, Rhinolophus hipposideros, Rhinolophus euryale, Myotis myotis, Myotis blythii, Myotis daubentonii, Myotis emarginatus, Pipistrellus pipistrellus, Barbastella barbastellus, Plecotus auritus, Plecotus austriacus,* and *Miniopterus schreibersii*. The present work describes the main characteristics of the roost sites found (temperature, relative humidity, altitude, habitat) and shows distribution on Mercator projection maps with 10 Km-sided squares.

Resumen

Durante los inviernos entre 1990 y 1994 se han muestreado los Chiroptera de Navarra, encontrándose 12 especies: *Rhinolophus ferrumequinum, Rhinolophus hipposideros, Rhinolophus euryale, Myoti myotis, Myotis blythii, Myotis emarginatus, Pipistrellus pipistrellus, Barbastella barbastellus, Plecotus auritus, Plecotus austriacus y Miniopterus schreibersii.* En el presente trabajo se describen las características más importantes (temperatura, humedad relativa, altitud s/m, hábitat) de los refugios hallados y se muestra su distribución en mapas UTM de cuadrícula de 10 Km de lado.

Key words: Hibernation, Chiroptera, Navarra, Spain

Palabras clave: Hibernación, Quirópteros, Navarra, España

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Introduction

The majority of studies undertaken on the hibernation of bats in Europe have centred on very few species, generally those which roost in caves and are easy to observe (Dulic 1963, Ransome 1968 and 1990, Harmata 1969 & 1973, Racey 1974, Kokurewicz & Kovats 1989, Urbanczyk 1991). However, the data available on the hibernation of species roosting in crevices are very sparse.

In the Iberian Peninsula, data on the hibernation of this group of mammals are available for only very few areas and come from more general studies (Balcells 1965, 1967 and 1968, Serra-Cobo 1989, Romero 1990). As far as Navarre is concerned, extremely few observations have been carried out (Balcells 1963, Balcells & Gracia 1963, Galán 1970). The aim of the present study is to provide data on the roost sites, distribution and hibernating conditions of bats in Navarre.

Navarre is a region located in the north of Spain between the Pyrenees and the Ebro basin. The northern half of the region is mountainous, being made up of a series of mountain chains (Codés, Lóquiz, Andía, Urbasa, Aralar, Velate, Pyrenees) running from west to east. The northern sides of these mountain chains are very steep and lead onto low valleys almost at sea level. Towards the south, they extend to the basins of Pamplona and Aoiz-Lumbier which are surrounded by the mountains of Perdón, Alaiz and Leyre. The south of Navarre corresponds to the low-lying areas of the Ebro basin.

In the northern half of the region there are important limestone massifs with a great number of caves and chasms. The climate is maritime and the most frequent habitats are beech, oak and wild pine woodlands. The southern half is a more level area where many rivers flow into each other and where there are few caves. Human activity is widespread. The climate is mediterranean and submediterranean and the land is fundamentally used for irrigation and non-irrigation crops although some limited areas of Portuguese oak and evergreen oak woodlands are also found (Floristán et al. 1986). In the centre of the region there is a gradual transition between both tendencies.

Material and methods

Sampling was carried out in the winter months (November to March inclusive) from 1990 to 1994 during which time visits were made to different roost sites (buildings, tunnels, mines, caves and chasms). The temperature and relative humidity of the bats' hibernating sites were measured. For this purpose a digital thermo-hygrometer (Lutron HT-3001-C) with an accuracy of 0.5° C and 3% was used. The type of roost site used, the habitat in which it was found, and the number of specimens from each species present were also noted.

Results and discussion

Results are shown in tables 1 and 2 and figures 1, 2 and 3. Table 1 shows the roost sites in which each species was found hibernating; table 2 shows the conditions (altitude, temperature and relative humidity of the roost site) in which the species found were hibernating.

Rhinolophidae

Rhinolophus ferrumequinum (Schreber, 1774)
Of the 34 hibernating sites found 79.4% were in caves in the limestone massifs in the north of the province (fig 1, table 1). 23 sites comprised only one specimen, 9 small groups of less than 10 specimens and 2 housed colonies of 40 and 172 specimens respectively. The sites were situated mainly in forest areas, with a predominance of oak woods (42.9%) over beech woods (25.7%) and evergreen oak woods (14.3%). They were situated at an altitude of between 120 and 970 m (table 2). The average temperatures of the sites (range = 4.0 - 14.6° C) were similar to those reported by Balcells (1968) and Galán (1970) for the Cantabrian mountain range, by Ransome (1968) for Great Britain and Saint Girons et al. (1969) for France (table 3).

Dulic (1963) and Brosset & Poillet (1985) found lower temperatures (4 - 7° C) in Croatia and western France respectively. Both cases dealt with colonies in which individual specimens could attain greater thermoregulation than when they hibernated as isolated individuals and were thus less dependent on ambient temperature (Ransome 1968, Saint Girons et al. 1969).

The relative humidity varied from site to site, which is consistent with observations made by Dulic (1963). Ransome (1968), however, always found conditions to be near saturation. The sex ratio in the colonies was 9 males to 1 female, a fact which is also in agreement with Ransome (1968).

Rhinolophus hipposideros (Bechstein, 1880)
33 hibernating sites were identified. 24 (72.7%) contained only one bat whilst the remaining 9 included 2 to 10 specimens, all of which were found as isolated individuals. The markedly solitary character of this species has already been pointed out by other authors (Balcells 1963, Palmeirim 1990, Galán 1993).
This species is found mainly during winter in caves (84.8% of the hibernating sites were limestone caves) in the northern part of the province (fig. 1, table 1). The temperature of the sites (range = 1.8 - 14.7° C) was similar to the data obtained by other authors for Europe (Dulic 1963, Balcells 1968, Harmata 1969 and 1973, Galán 1970,

Kokurewicz & Kovats 1989) (table 3). *R. hipposideros* hibernates in sites which are significantly colder than those *R. ferrumequinum* prefers ($t = 2.38$, $p < 0.05$). These differences could be due to the larger size of the latter species which allows it to store greater amounts of fat and thus hibernate in warmer sites. The relative humidity of the sites was generally high although variable (range = 69.2 - 100%). This same fact was attested to by Dulic (1963) in Croatia (table 3).

Rhinolophus euryale (Blasius, 1853)
The three sites found were caves close to rivers containing only one specimen of the species. This contrasts with the data from other authors (Romero1990, Palmeirim & Rodrigues 1992) who found hibernating colonies in the Iberian Peninsula. We therefore believe that these sites may be isolated cases of hibernation rather than characteristic of the species.

The caves were located at two quite separate sites in the north of the province and one in the south (fig. 1). The northernmost cave was limestone whilst those further south were small and formed by clays and mud. The sites found were at an altitude of between 200 and 400 m ($x = 323.3$ m). The hibernating temperature was relatively high ($x = 12.9°$ C) (table 2) as was found by Dulic (1963). Balcells (1967) found individual bats hibernating in warmer caves (15° C) in the southern half of the Iberian Peninsula with few individuals (table 3).

The relative humidity was very variable: in the large limestone cave it was high (93.4%) whilst in the two small clay caves it was, as a result of external environmental influences, very variable (60.0 - 86.4%). Dulic (1963) found specimens hibernating in conditions close to saturation (90 - 100% rH) in limestone caves in Croatia (table 3).

Vespertilionidae

Groups of hibernating individuals were only found for the species *Pipistrellus pipistrellus* and *Miniopterus schreibersii*. In the remaining species only solitary specimens frequently located in narrow and inaccessible crevices were found.

Myotis myotis (Borkhausen, 1797)
Only one specimen was found in a hibernating site; this was located in the interior of a cavity in the roof of a limestone cave situated in an evergreen oak wood in the centre of the region (fig. 2).

The altitude of the cave was 940 m. The temperature was 5.9° C and relative humidity was near saturation (98.9%) (table 2). These data are consistent with those reported by Harmata (1969) (table 3).

Myotis blythii (Thomes, 1857)
Two hibernation sites were located in the central area of Navarre (fig. 2) with one specimen in each. In both cases the specimen was found in a crevice in the roof of a cave. One of the caves was limestone with stable conditions situated in an oak wood whilst the other was small and unstable, being made up of clay sediments, and situ-

ated on a river bank. The temperature of the sites was low (1.9 - 7.1° C) and the relative humidity high (77.8 - 98.6%)(table 2).

Myotis daubentonii (Kuhl, 1819)
Only one hibernating specimen was found in a crevice in the wall of a large cave situated in an evergreen oak wood in a limestone massif in the west of the region (Lóquiz mountains) in which ambient conditions were stable throughout the winter (fig. 2). The temperature of the site was slightly below 10° C and the relative humi-dity was close to saturation (table 2). This temperature is somewhat higher than those measured by Jooris & Goosens (1980) in warehouses in Belgium (3 - 9° C)(table 3).

Myotis emarginatus (Geoffroy, 1806)
The only hibernating specimen observed was found in a crevice at the back of a cave. This was limestone, medium-sized and with stable ambient conditions. It was located in an evergreen oak wood in the centre of the region (fig. 2). The temperature of the site was 8.3° C and relative humidity was very high (95.9%) (table 2). These data support the observations made by Brosset & Caubère (1959) and are within the range established by Harmata (1969) (table 3).

Pipistrellus pipistrellus (Schreber, 1774)
7 hibernating sites were located. 4 were in buildings, which confirms the marked tendency of the species to use man-made structures. In all cases the specimens were found inside very narrow crevices and as a result it was not possible to count all the individuals. However, further study confirmed the presence of several bats at each site. The crevices in the buildings were located in the roof and were formed, at least in some cases, by wooden beams. In the caves, the crevices were in rocks in the walls or roof near the entrance. These sites were found both in areas of human activity (villages, cities, croplands) and varying natural habitats (river banks, oak and evergreen oak woods) in the centre and south of Navarre (fig. 3).

The temperatures ranged from 2.8 to 10.7° C (table 2). These values are in the middle of the range as established by Racey (1974) for Scotland (from -5 to 12° C; x = 3.4° C) although they are slightly higher. It is necessary to point out that the temperatures were measured around midday, when the sun was at its hottest and the roosts were warmest. Indeed, in the crevices at the entrance of two caves it was possible to hear specimens that were awake. This same phenomenon was observed by Avery (1985) who frequently found active specimens in winter. The relative humidity was slightly lower than that measured by Racey (1974), who also reported wide variations (tables 2 and 3).

Barbastella barbastellus (Schreber, 1774)
4 hibernation sites were located: caves, mines and buildings in ruins. All were relatively open to the exterior. The bats were always found as individual specimens, even in those sites where several specimens were present. This contrasts with the

observations of Rybar (1975) and Urbanczyk (1991) who found large groups of up to one hundred hibernating specimens.

The four sites were situated in mountain and forest areas (beech and oak woodlands) in the north of the region (fig. 3). Relative humidity was high and the average temperatures were generally low (x = 4.8° C) (table 2), which is consistent with the data provided by Harmata (1969) for Poland.

Table 1: Sites at which hibernating specimens were found. (Rf: *Rhinolophus ferrum-equinum*; Rh: *R. hipposideros*; Re: *R. euryale*; Mm: *Myotis myotis*; Mb: *M. blythii*; Md: *M. daubentonii*; Me: *M. emarginatus*; Pp: *Pipistrellus pipistrellus*; Bb: *Barbastella barbastellus*; Paur: *Plecotus auritus*; Paus: *P. austriacus*; Ms: *Miniopterus schreibersii*).

Species	n	Type of site				
		Cave-chasm	Mine-tunnel	Church	Ruins	House
Rf	34	27	5	2	-	-
Rh	33	28	3	-	1	1
Re	3	3	-	-	-	-
Mm	1	1	-	-	-	-
Mb	2	2	-	-	-	-
Md	1	1	-	-	-	-
Me	1	1	-	-	-	-
Pp	7	3	-	3	1	-
Bb	4	2	1	-	1	-
Paur	2	2	-	-	-	-
Paus	4	1	1	2	-	-
Ms	5	4	1	-	-	-

Plecotus auritus (Linnaeus, 1758)

The two hibernation sites found were limestone caves located in wooded (oak and beechwood) mountainous areas in the north of the region (fig. 3). In each cave, one specimen was found in the interior of small crevices in the wall.

The average temperatures varied greatly (table 2), as was found by Balcells (1968) and Harmata (1973) (table 3). Relative humidity was very high, close to saturation (range = 93.3 - 100%; x = 96.7%).

Plecotus austriacus (Fischer, 1829)

Four hibernation sites were found in the northern half of the region (fig. 3). Two were hermitages, which is evidence of the species' greater dependence on man-made constructions in comparison with *P. auritus*. The other two sites were a limestone cave and some abandoned mines. Only one specimen was found at each site, always occupying the interior of very narrow crevices.

Average temperatures varied widely (table 2), as was found by Harmata (1973), who reported temperatures of between –3 and 11° C (table 3). Relative humidity was

low (range = 65.4 - 77.0%; x = 72.1%) probably as a result of the influence of exterior environmental factors on the sites, which were small in size (table 2).

Table 2: Altitude, temperature and relative humidity of the hibernation sites of the species found; x : mean value; s: standard deviation; n: number of measurements taken. The symbols for the different species as in Table 1.

		Altitude			*Temperature*			*Relative Humidity*		
Species	*n*	range	x	s	range	x	s	range	x	s
Rf	30	120-970	588.4	244.0	4.0-14.6	9.1	2.5	66.9-100	86.0	10.9
Rh	30	120-1000	687.5	208.3	1.8-14.7	7.4	3.1	69.2-100	89.4	8.8
Re	3	200-400	323.3	107.9	11.2-14.3	12.9	1.6	60.9-93.4	80.2	17.1
Mm	1	-	940	-	-	5.9	-	-	98.9	-
Mb	2	370-970	670	424.3	1.9-7.1	4.5	3.7	77.8-98.6	88.2	14.7
Md	1	-	530	-	-	9.1	-	-	96.2	-
Me	1	-	660	-	-	8.3	-	-	95.9	-
Pp	7	340-830	552	188.2	2.8-10.7	7.5	2.8	62.7-92.2	77.4	9.5
Bb	4	400-1060	822.5	293.3	2.1-8.8	4.8	3.2	76.1-93.3	85.5	7.2
Paur	2	605-970	878.5	258.1	2.4-9.6	6	5.1	93.3-100	96.7	4.7
Paus	4	340-950	665	330.7	2.6-12.0	7.4	4.6	65.4-77.0	72.1	5.3
Ms	22	200-760	484	210.8	4.3-12.1	7.63	2.1	66.1-100	80.1	10.1

Miniopterus schreibersii (Kuhl, 1819)

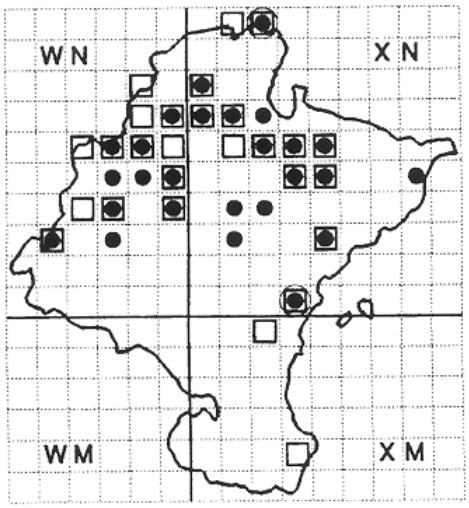
Of the five hibernation sites located, 4 were caves, as is characteristic of this species (Balcells 1968, Serra-Cobo 1989, Benzal & Paz 1991, Palmeirim & Rodrigues 1992). The specimens were always found hanging from the roof in full view. The number of specimens per site ranged from 1 to 100, the number varying throughout the course of the winter. This leads us to believe that the bats are still active in this period.

The sites were located mainly in the limestone massifs of the north of the region, always in wooded areas (evergreen oak and oak woodlands, and river banks) and at an altitude of between 200 and 760 m (fig. 3, table 2). Several colonies of this species are present in Navarre which migrate to other (as yet unknown) areas during November. Only a few specimens (generally less than 10) remain at the sites. This behaviour is widespread and on the basis of this we conclude that the animals found in the winter are incapable of travelling large distances.

The temperature at the hibernating sites was measured in different months and years and we found that in three caves the bats avoided the warmest chambers (11 - 12° C) in spite of the fact that they had higher humidity, were less well protected (being closer to the outside) and were cooler.

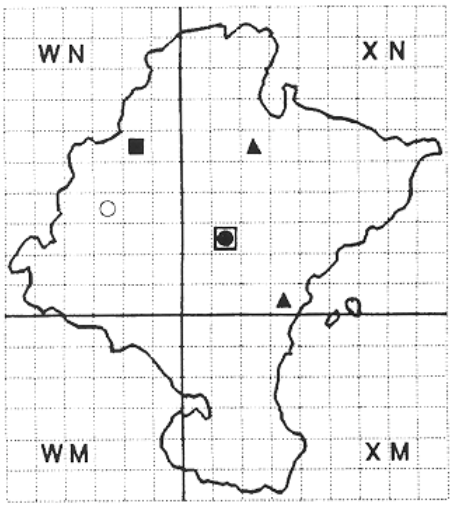
The temperature of the sites was relatively low (x = 7.6° C), as was found by Serra-Cobo & Montori (1986) and Serra-Cobo (1989) in the north-west of the Iberian Peninsula. However, Romero (1990) found colonies hibernating at warmer sites in the south of the Iberian Peninsula (table 3). These authors indicated that relative

humidity at the sites was close to saturation. However, the observations made in our study have shown values to be very variable.



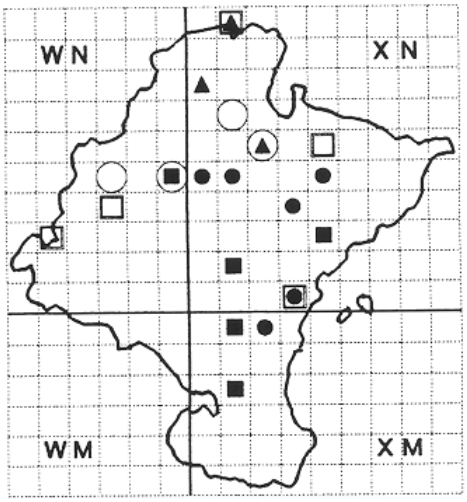
□ *Rhinolophus ferrumequinum*
● *Rhinolophus hipposideros*
O *Rhinolophus euryale*

Fig. 1: Hibernal records of bats in Navarra.



□ *Myotis myotis*
▲ *Myotis blythii*
● *Myotis emarginatus*
O *Myotis daubentonii*
■ *Myotis nattereri*

Fig. 2: Hibernal records of bats in Navarra.



● *Pipistrellus pipistrellus*
▲ *Plecotus auritus*
■ *Plecotus austriacus*
O *Barbastella barbastellus*
□ *Miniopterus schreibersii*

Fig. 3: Hibernal records of bats in Navarra.

Table 3: Bibliographic data on the temperature and relative humidity of the hibernation sites of the species under study. Mean values are given in brackets. B: Belgium; C: Czech Republic; E: Spain; F: France; GB: Great Britain; P: Poland; species as in Table 1.

Authors	Rf		Rh		Re		Mm	Md	Me		Pp		Bb	Paur	Paus	Ms	
	T [°C]	rH[%]	T [°C]	rH[%]	T [°C]	rH[%]	T [°C]	T [°C]	T [°C]	rH[%]	T [°C]	rH[%]	T [°C]	T [°C]	T [°C]	T [°C]	rH[%]
Brosset & Caubere, 1959 (F)	--	--	--	--	--	--	--	--	7/8.8	70/100	--	--	--	--	--	--	--
Dulic, 1963 (C)	4.5/7	--	5/11	70/100	11/13	90/100	--	--	--	--	--	--	--	--	--	--	--
Balcells, 1965 & 1967 (E)	--	--	--	--	(15)	--	--	--	--	--	--	--	--	--	--	--	--
Balcells, 1968 (E)	4.5/14	--	3/14	--	--	--	--	--	--	--	--	--	--	4/9.2	--	--	--
Ransome, 1968 (GB)	7/11	>96	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Harmata, 1969 (P)	--	--	2/14	--	--	--	-4/15	--	1/10	--	--	--	-3/9	-3/11	--	--	--
Saint Girons et al., 1969 (F)	(8)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Galán, 1970 (E)	9/14.5	--	5.5/10.5	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Harmata, 1973 (P)	--	--	2/14	--	--	--	--	--	--	--	--	--	--	--	-3/11	--	--
Racey, 1974 (GB)	--	--	--	--	--	--	--	--	--	--	-5/12	70/96	--	--	--	--	--
Rybar, 1975 (C)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Jooris & Goosens, 1980 (B)	--	--	--	--	--	--	--	3/9	--	--	--	--	--	--	--	--	--
Paz, 1984 (E)	--	--	--	--	(12)	--	2/15	--	--	--	--	--	--	--	--	--	--
Brosset & Poillet, 1985 (F)	5/7	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Kokurewicz & Kovats, 1989 (P)	--	--	(5.99/8.44)	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Serra-Cobo, 1989 (E)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	7/9	90/100
Romero, 1990 (E)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	(13.5)	90/100

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