Spring habitat selection by the Mediterranean Horseshoe Bat *(Rhinolophus euryale)* in the Urdaibai Biosphere Reserve (Basque Country)

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SUMMARY

We have carried out a first research on habitat selection in *Rhinolophus euryale* with the aim of assessing if landscape changes may be involved in the current decline of this species. During May 2000 nine bats were tagged with small radio-transmitters, in a spring colony in Urdaibai Biosphere Reserve (Basque Country). We gathered a total of 133 locations in 23 tracking nights. Every night each bat moved to an individual feeding area, travelling as far as 10 km from the roost. Meadows were avoided. Forests were used extensively, where bats flew both along forest edges or within the canopy. Pine plantations were negatively selected with 25 % of fixes gathered in pine wood. Native deciduous forests and eucalyptus plantations were selected positively. The scarcity of deciduous woods, the intense use of exotic plantations, and the extremely large foraging radius suggest that the studied area is a suboptimal landscape for the species.

KEY WORDS
Mediterranean Horseshoe Bat
Rinolophus euryale, habitat selection, foraging, range, landscape changes.

RÉSUMÉ
Nous avons réalisé une étude préliminaire de la sélection d'habitat par *Rhinolophus euryale*, afin de voir si les évolutions du paysage pouvaient expliquer la diminution des populations de cette espèce. Pendant le mois de mai 2000, neuf chauves-souris on été capturées et marquées avec de petits radio-émetteurs dans une colonie de la Réserve de la Biosphère de Urdaibai (Pays Basque). Elles ont été suivies pendant 23 nuits et 133 localisations ont été réalisées. Chaque nuit, les chauves-souris se déplaçaient parfois à 10 km de la colonie vers une aire de nourriture individuelle, évitant les pâturages. Les chauves-souris ont par contre fortement utilisé la forêt, autant sous les arbres qu'en lisière, à l'exception des plantations de pins, dans lesquelles seulement 25 % des localisations ont été réalisées, malgré l'abondance de ce type de végétation. Les forêts caducifoliées d'origine et les plantations d'eucalyptus ont été positivement sélectionnées. La rareté des forêts d'origine, la forte utilisation des plantations exotiques et la distance parcourue vers les zones d'alimentation suggèrent que l'aire étudiée ne présente pas un paysage optimal pour cette espèce.

INTRODUCTION

Rhinolophus euryale is one of the most endangered bat species in Europe (Stebbings 1988 ; Council of the European Communities 1992 ; Ibáñez 1999 ; Hutson *et al.* 2001 ; Urcun 2002). Some authors have reported a strong population decline, for example in Slovakia, France or the Basque Country (Rybár 1981 *in* Stebbings and Griffith 1986 ; Brosset *et al.* 1988 ; Aihartza 2001). Disturbance and loss of roost places, uncontrolled ringing, intensive use of organochlorine insecticides, and transformation of natural habitats have been stressed as the most important causes of decline (Benzal *et al.* 1988 ; Brosset *et al.* 1988 ; Makin 1989 ; Palmeirim and Rodrigues 1992). Little is known about its ecology and only few works dealt with its roosting requirements (Brosset and Caubère 1959 ; Dulic 1963), activity pattern (Masson 1990) or roosting behaviour (Masson 1999). Recent diet analyses show that *R. euryale* feed predominantly on Lepidoptera, Diptera (mainly Tipulidae) and Neuroptera (Koselj and Krystufek 1999 ; but see Grabovac *et al.* 1999). Brosset *et al.* (1988) described the landscape surrounding 83 roosts in France, but did not determine any key habitat for the species. Barataud (*in* Roué and Barataud 1999) combined ultrasound detectors and light tags to investigate the hunting habitat of a breeding colony, but the scarcity of data prevented him from any conclusion, and the requirements of the hunting grounds of *R. euryale* remain unknown.

The loss or degradation of foraging habitats are considered among the most important causes for the declining of bats (see i.e. Entwistle *et al.* 1996 ; Racey 1998 ; Sierro 1999). The aim of this work is to determine the spring habitat selection of *R. euryale* in an Atlantic environment, as a first step to explore whether landscape changes may be involved in its decline.

MATERIAL AND METHODS

This study was conducted in the Urdaibai Biosphere Reserve (43°29'N, 2°40'W) Basque Country, Southwestern Europe (Fig. 1). It is a 230 km² area with an altitude range of 0-900 m that encompasses the catchments of the river Oka. Climate is typically oceanic, January and July mean temperatures being 6 °C and 18 °C respectively and average annual rainfall 1400 mm. Winters are mild and there is not effective snow cover.

The landscape is hilly, rugged and patchy. Although there are some small limestone massifs, there are not many caves in the area, and some of them are closed to protect archaeological

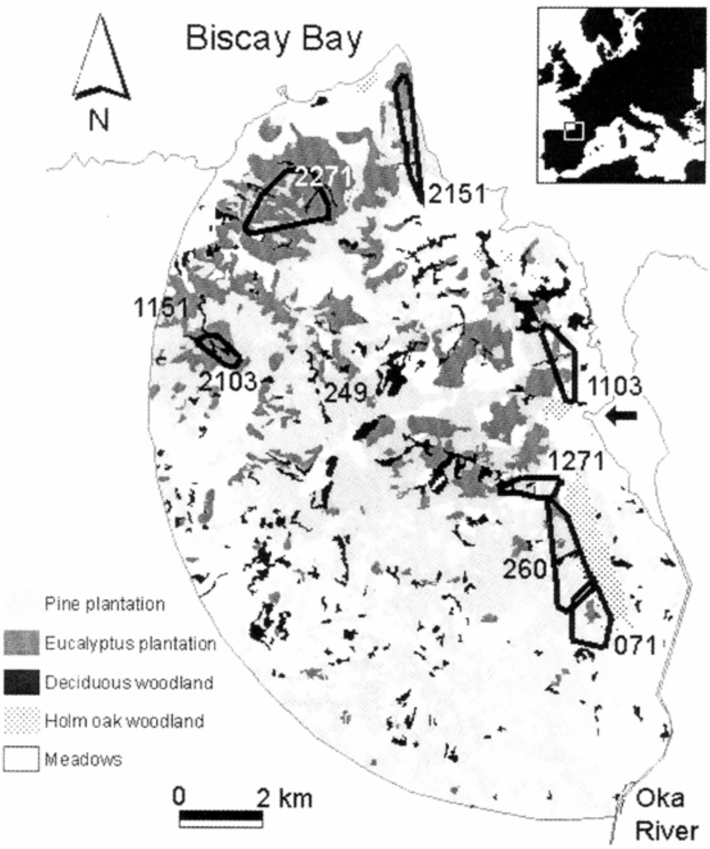

Fig. 1. – Foraging areas (Minimum Convex Polygons) of R. euryale in May 2000 in Urdaibai Biosphere Reserve. Each foraging area is identified by individual code number ; as sample size is too small to calculate feeding areas for bats No. 249 and 1151, their locations are showed by numbers only. Available habitats in a radius of 10 km from day roost are pine plantations (light grey), eucalyptus plantations (dark grey), deciduous woodland (black), holm oak woodland (dotted), and meadows (white). The black arrow points to the day roost.

remains. Major landscape units are forest (54 % of the land surface), most of them plantations of exotic species (Monterey pine *Pinus radiata* and eucalyptus *Eucalyptus globulus*). Deciduous woods are scarce and fragmented, and holm oak *Quercus ilex* woodlands occupy limestone areas. Meadows and cultivated fields cover 29 % of the area, estuarine mudflats and saltmarshes 5 %, and the remaining 5 % is urban area (Arrieta *et al.* 1993 ; Aldai and Ormaetxea 1998). The human population of ca. 44,000 clump in the towns of Gernika and Bermeo.

Under licence from the Regional Council of Biscay, on 12th, 19th and 22th May 2000, 9 *R. euryale* were captured in a spring colony with a harp-trap during emergence from a cave : 3 males of unknown age, 5 adult females, and one young nuliparous female. Females did not still show pregnancy symptoms. They were tagged with small glue-on radiotransmitters (Pip, 0.5 g, Biotrack, Dorset, UK), attached mid-dorsally with epoxy glue (Pérez-Jordá 1994). The transmitter mass did not exceed 5 % of the body mass (Table, 1), according to the suggestions for transmitter mass (Aldridge and Brigham 1988). Tagged bats were released in the same place. No locations were recorded the first night to avoid possible abnormal behaviour due to stress.

Bats were located preferably by " homing in " (White and Garrott 1990), and by triangulation when the first option was not possible. Triangulation was performed with two or more bearings taken simultaneously by observers coordinated by transceivers and mobile phones. Locations were obtained both by car and on foot by four observers equipped with radio-receivers (1000-XRS, Wildlife Materials, Carbondale, USA ; and FT-290RII, Andreas Wagener Telemetrieanlagen, Cologne, Germany) and hand-held 3-elements Yagi antennas. Tracking lasted from emergence until bats returned to the roost before sunrise. Time between successive locations elapsed more than 15 minutes to avoid temporal autocorrelation. Number of locations and tracking days per individual varied remarkably due to topographical constraints and premature loosening of transmitters from bats (Table 1). No fixes were taken during commuting, and consequently all the locations were considered as enclosed in feeding areas. Individual feeding areas were calculated by Minimum Convex Polygons enclosing all the fixes for each active bat. Animals were considered as active or inactive according to the level of variations in radio signal strength (Kenward 1987).

TABLE 1. – Tracking survey data, feeding areas and distance ranges from roost of individual *R. euryale*.

Code	Sex and age	Forearm length (mm)	Weight (g)	Tracking period	Tracked nights	Location number	Feeding area (ha)	Distance from roost (km)
1271	Male	47,4	10,0	14-16th May	3	29	50.8	1.9 - 2.7
249	Female, adult	47,1	11,0	14th May	1	3	*	5.6
2103	Female, adult	47,1	10,0	15-17th May	3	14	32.0	7.9 - 8.9
1151	Female, adult	47,4	11,5	15th May	1	2	*	9.8 - 9.9
071	Male	46,5	10,5	16-21th May	4	19	102.5	4.2 - 5.9
260	Female, adult	47,3	12,0	18-21th May	3	9	138.8	2.4 - 5.0
1103	Female, young	49,2	10,5	21-24th May	4	23	81.9	0.1 - 1.7
2151	Female, adult	48,1	12,5	23-24th May	2	21	64.1	5.6 - 8.6
2271	Male	47,6	12,5	25-26th May	2	13	194.1	7.1 - 8.7

* Too small sample size for calculation.

Locations were transferred to a Geographic Information System (Arcview 3.2. ESRI. California. USA). Individual feeding areas were estimated performing the minimum convex polygon (Hooge and Eichenlaub 1998). A habitat category was attached to each location. Five habitat categories were defined as : meadow, pine plantation, holm oak wood, deciduous wood and eucalyptus plantation. Meadows included small orchards, pastures and garden fruit trees. Deciduous woods included several small patches of mainly oak (*Quercus robur*), but also willow (*Salix atrocinerea*) and poplar (*Populus nigra*). Eucalyptus and pine plantations were monospecific. We considered as available habitat the circle of land included within a radius equal to the farthest location from the roost, and excluding the area beyond the main river, which was never crossed by any tagged animal (Fig. 1).

The independence of used and available habitat categories was tested by Chi square goodness of fit test, and Bonferroni's inequality was applied to test statistical significance of the selection in each category (Manly *et al.* 1993). Selection level was measured by Jacob's electivity index (E_i, *in* Manly *et al.* 1993), based on available and used habitat percentages. This index is independent from relative abundance of each habitat, and reaches values ranging from –1 to 1 reflecting negative to positive selection level.

RESULTS

A total of 133 locations were gathered for the nine bats (average : 14.8 locations per bat, S.D. = 9.12) in 23 tracking nights (average : 2.6 nights per bat, S.D. = 1.13) (Table 1). The radio-tagged individuals returned to the same roost daily, and none was lost during the work. However, five bats lost their transmitters between the 4th and 11th day of follow-up and before the battery life expired.

Each bat moved every night to the same individual feeding area, travelling as far as nearly 10 km from the roost (Table 1). They spent 15 minutes commuting to the most distant places. Individual feeding areas showed different size (average : 94.9 ha per bat, S.D. = 56.04, n = 7) and shape (Table 1, Fig. 1). Only individuals 071 and 269 overlapped in hunting areas, but in less than 10 % (Fig. 1).

Available habitat was mainly made up by meadows and pine plantations, while deciduous and holm oak woods were the scarcest (Table 2). Use of habitats did not depend on their availability ($X^2 = 276,2$; $p < 0.001$; $df = 4$) : deciduous forests and eucalyptus plantations were positively selected whereas meadows and pine plantations negatively. Jacob's electivity index was very similar for deciduous forests and eucalyptus plantations (Table 2).

TABLE 2. – Availability, number of locations, *Bonferroni's* confidence intervals, and Jacob's electivity index by habitat category. Positive and negative selections are indicated with symbols (+) and (–) respectively. Jacob's index is only indicated for significantly selected habitats.

Habitat type	Availability (%)	Locations	Bonferroni confidence interval	Jacob's index
Meadows	41	2	0.0 - 4.2 (–)	– 0.97
Pine plantations	39	30	13.2 - 31.9 (–)	– 0.37
Holm Oak	2	6	0.0 - 9.1	–
Eucalyptus plantations	13	61	34.7 - 57.0 (+)	0.70
Deciduous forest	6	34	15.8 - 35.3 (+)	0.71
Total	15 481 (ha)	133	–	–

Several visual contacts and short distance radiotracking showed that *R. euryale* flew both along forest edges or within the canopy in plantations of different ages of pine and eucalyptus, ranging from near ground level up to the highest branches, even in very cluttered environment. The foraging flight was butterfly-like, fluttering and highly manoeuvrable, and they fed hovering very close to or between branches and leaves. Individuals were observed twice resting for more than one hour perching in tree branches during the night. Only female 1103 returned (once) to the day roost during night.

DISCUSSION

R. euryale was found using different forest units. This fact is in accordance with the high proportion of forest found around their roosts (Brosset *et al.* 1988). Norberg and Rayner (1987) predicted that rhinolophids are well adapted to hover within cluttered environments due to low wing loading and low aspect ratio. Moreover, the structure of their long-duration echolocating signals, dominated by constant frequency pulses at a high frequency range, and produced at high duty cycles (sound on 40-70 % of the time), allows them detecting fluttering targets in dense clutter (see i.e. Schnitzler and Oswald 1983 ; Vogler and Neuweiler 1983 ; Schnitzler *et al.* 1985 ; Neuweiler 1989). Values of wing-span, wing loading and aspect ratio in *R. euryale* are intermediate between the larger *R. ferrumequinum* and the smaller *R. hipposideros* (Norberg and Rayner 1987). Consequently, *R. euryale* should be better adapted to foraging in cluttered environments than *R. ferrumequinum*, but not than *R. hipposideros*. Our field observations proved that *R. euryale* forages intensively within cluttered woodland.

The selection for deciduous woods observed in our study is analogous to the preference shown by *R. ferrumequinum* for seminatural woodland in spring (Jones and Morton 1992 ; Duvergé and Jones 1994 ; Jones *et al.* 1995). A similar selection pattern was inferred for *R. hipposideros* (Schofield 1996, 1999).

The strong positive selection of eucalyptus plantations is remarkable, and in contrast the negative selection of pine plantations, as both of them are exotic forests, which only became common in the Basque Country from the sixties on (Ruiz-Urrestarazu 1992). These differences could be due to the continued use of diflubenzuron to control the pest moth *Thaumatopoea pytiocampa* in pine plantations, that reduces prey availability for bats (Guillén *et al.* 1991). Despite being negatively selected, near 25 % of the total radiolocations were made in pine plantations, showing its relative importance for the species in the area.

Foraging ranges of *R. euryale* appear to be noticeable far from their roosts, as only two individuals ranged closer than 3 km, whereas four bats flew farther than 8 km (Table 1). Following the relation between flight performance and wing morphology stated by Norberg and Rayner (1987), Jones *et al.* (1995) found positive correlation between wing aspect ratio and foraging range of 18 species of microchiropteran bats, and the aspect ratio calculated for *R. euryale* (6.2 in Norberg and Rayner 1987) would correspond with a foraging range close to 1.5 km.

Factors other than wing shape, such as colony size, reproductive status, or age of bats have been described as influencing foraging range in bats (Jones *et al.* 1995). As our research was carried out in a spring colony rising to a maximum of 40 individuals in late May, which is a medium or low size for *R. euryale* standards (i.e. Brosset and Caubère 1959 ; Masson and Sagot 1987 ; Palmeirim and Rodrigues 1992 ; Ibáñez 1998), we can reject the size of the colony as a valid causal factor for our observations. In *R. ferrumequinum* reproductive status and age were observed constraining the foraging range during breeding and post-breeding seasons respectively (Jones and Morton 1992, Jones *et al.* 1995), but these factors do not seem applicable during spring, in an early pre-breeding stage. Finally, large ranges could also be explained by the unavailability of suitable roosts near good feeding areas. In our case, however, habitats positively selected and feeding areas are scattered all over the area surrounding the roost, which does not support this explanation.

According to the optimal foraging models (see i.e. Krebs and Davies 1984 ; Stephens and Krebs 1986), a poor habitat quality would imply that each bat would spend longer foraging time and/or use larger foraging areas, without or with little overlap between them, as well as a larger total foraging range for the colony. Our observations fitted this predictions, and therefore we suggest that the landscape in Urdaibai Biosphere Reserve is a suboptimal habitat for the species. The positive selection of eucalyptus and the strong use but negative selection of pine plantations, both of them recently introduced in the area, and the scarcity of deciduous woods, unique native habitat positively selected, reinforce this hypothesis.

Nevertheless, further research is required to determine its foraging behaviour in suitable conditions, i.e., in a less altered landscape or in a breeding colony, in order to test the conclusions drawn from the present study and to develop appropriate conservation measures against its decline. Equally, research on its trophic ecology is also needed to determine possible risks of some management techniques such as use of unspecific pesticides in forestry.

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