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Original Investigation

Can pinewoods provide habitat for a deciduous forest specialist? A two-scale approach to the habitat selection of Bechstein's bat

Aitor Arrizabalaga-Escudero, Maria Napal, Joxerra Aihartza, Inazio Garin, Antton Alberdi, Egoitz Salsamendi*

Department of Zoology and Animal Cell Biology, Faculty of Science and Technology, University of the Basque Country UPV/EHU, Sarriena z/g, Leioa E-48940, The Basque Country

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ABSTRACT

Populations of *Myotis bechsteinii* in Sierra de Cazorla, Segura y Las Villas Natural Park (southwestern Spain) survive in a large, old-growth coniferous woodland, which is in contrast with known ecological preferences of the species. We tracked ten lactating females and studied patterns of habitat selection by Bechstein's bat (*Myotis bechsteinii*) at two spatial scales: macrohabitat and microhabitat, regarding forest essence (coniferous *vs.* deciduous). The tracked individuals always foraged within forested areas and did not use areas devoid of trees. At the macrohabitat level, no positive selection of deciduous stands was apparent, suggesting selection studies of coarse resolution may not be able to capture subtle selection patterns. At the microhabitat level *Myotis bechsteinii* selected deciduous patches within the coniferous matrix, therefore, our results corroborate the perception of this species as dependent of services provided by deciduous woodlands. Larger foraging home ranges and commuting distances as compared with other Mediterranean localities suggest that our studied population inhabits a marginal or suboptimal environment in terms of habitat quality. We argue that this population of Bechstein's bat has survived as a relict one probably as a consequence of fragmentation and transformation of deciduous forest ecosystems in the Mediterranean range.

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Introduction

It is increasingly recognized that the conservation of temperate bat fauna is associated to the well being of woodland areas. A major portion of bat species in temperate areas depends on woodlands whether for roosting, foraging, or both. For instance, of the 45 bat species currently known in North America, 25 use woodlands at least at some time of their life cycles (Brigham, 2007), whereas in Europe, 30 out of 41 species are somewhat linked to forests (Dietz et al., 2009). The degree of association between a given bat species and woodlands is pointed somewhere along a continuum, whose low end may be represented by synanthropic species like the little brown bat *Myotis lucifugus* (Coleman and Barclay, 2011); and top end may be represented by specialist forest dwellers such as the Bechstein's bat *Myotis bechsteinii* (Schofield and Morris, 2000; Kaňuch et al., 2008; Dietz and Pir, 2009; Napal et al., 2013).

The Bechstein's bat (*Myotis bechsteinii* Kuhl, 1817) is considered one of the rarest and most endangered European bat species. The species is widely distributed within the temperate forest zone of Europe, ranging from the Iberian Peninsula to southern Scandinavia and eastward to Iran and the Caucasus (Fig. 1; Schlapp, 1999), but considered rare everywhere, attaining only locally high densities. However, its faint frequency-modulated echolocation signals, which are suitable for detecting weak echoes from prey in cluttered environments (Schnitzler et al., 2003), may be difficult to detect during acoustic surveys (Ahlén, 1990) and easily confounded with other *Myotis* species (Dietz et al., 2009). This could lead to a posible underestimation of the species presence. Moreover, its comparatively broad and short wings, with a medium wingspan and low wing loading, enable a slow and maneuverable flight (Norberg and Rayner, 1987) and are well suited for foraging in structurally complex spaces. Accordingly, *M. bechsteinii* is dependent on deciduous woodlands; it prefers mature-to-aged lowland oak forests (Schofield and Morris, 2000; Kaňuch et al., 2008; Dietz and Pir, 2009), although it has been also reported in beech and mixed forests (Baagøe, 2001; Kusch et al., 2004). The species may roost in trunk and branch crevices and beneath loose bark, but it prefers holes carved by woodpeckers (Schofield and Morris, 2000; Dietz and Pir, 2009; Napal et al., 2009).

Its current distribution, mostly centered in deciduous woodlands of Central and Western Europe, has been related to the historical loss and decay of deciduous woodlands over the Mediterranean Basin (Postawa, 2004; Blant et al., 2010; Napal et al., 2013). Indeed, its strict habitat requirements, low population density, and

* Corresponding author. Tel.: +34 94 601 5331; fax: +34 94 601 4500.
E-mail address: egoitz.salsamendi@ehu.es (E. Salsamendi).

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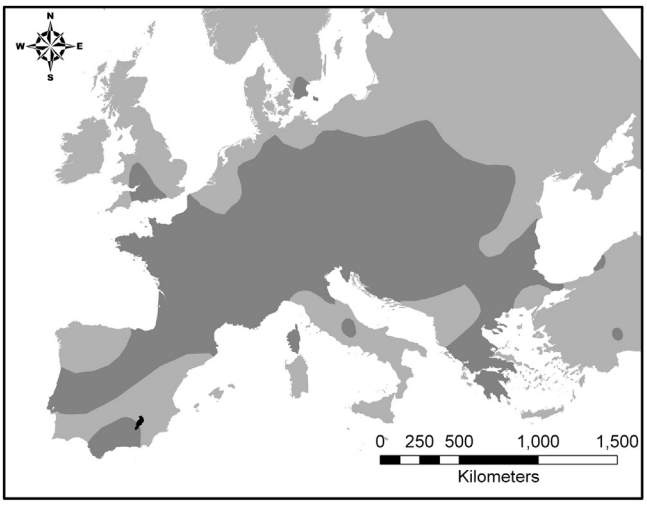

Fig. 1. Distribution range of *Myotis bechsteinii* in Europe (dark grey; redrawn from IUCN, 2012) and location of the study area in southeast Iberian Peninsula, Sierra de Cazorla, Segura y Las Villas Natural Park (black polygon).

low reproduction rate (Baagøe, 2001), together with limited dispersal ability (Safi and Kerth, 2004), make *M. bechsteinii* highly vulnerable to habitat loss and fragmentation (Napal et al., 2013).

A recent survey detected a breeding population of *M. bechsteinii* in Sierra de Cazorla, Segura y Las Villas Natural Park, southeast Iberian Peninsula (Benzal et al., 1990; Carlos Ibañez, *Pers. Com.*). Two main features make this population worth investigating: (1) its location in the southeastern margin of the species' distribution (Fig. 1; Carro, 2007; IUCN, 2012), and (2) its striking occurrence in a large coniferous woodland, where pines can compose 90% of the total forest biomass (Tiscar and Linares, 2011), if we consider that *M. bechsteinii* is regarded as a strict forest-dweller dependent on mature deciduous forests. The presence of *M. bechsteinii* in this large pinewood raises interesting questions about the bat's ecology and habitat preferences: Is *M. bechsteinii* restricted to deciduous woodlands as previously thought? What are its ultimate habitat requirements? The mechanisms underlying the association between deciduous forests and Bechstein's bats are known, but the attributes of the conifer woodlands that supposedly prevent the species to thrive have not been addressed so far. Experimental approaches at forest stand scale that include translocation of animals are not feasible for obvious reasons. However, the discovery of this population offers a natural chance to investigate the ultimate habitat requirements of Bechstein's bat.

Elucidating habitat requirement is one of the main objectives in studies of bat ecology and conservation, because the identification of key habitat features may be helpful in proposing conservation strategies (Racey and Entwistle, 2003). However, lack of accuracy could produce a misleading assessment of habitat requirements, and consequently, faulty conservation decisions (Thomas and Taylor, 2006). In habitat selection studies, habitat is often equated to a plant community or vegetative association and is defined as a homogeneous unit of land (Garshelis, 2000). However, this homogenizing classification may be misleading in the identification of key resources a certain species requires for survival (Tew et al., 2000). Moreover, a species may exert selection at a finer scale than represented in most coarse land use maps (Dussault et al. 2001)

Consequently, and to answer the questions above, we studied foraging habitat selection in this *M. bechsteinii* population at two scales: landscape (macrohabitat level) and forest patch (microhabitat level). Our main aims were (1) to identify which features *M. bechsteinii* selects for foraging in a large old-growth Mediterranean pinewood and (2) to demonstrate the importance of scale and accuracy at habitat selection studies.

Material and methods

Study area

The study was carried out in Sierra de Cazorla, Segura y Las Villas Natural Park (hereafter abbreviated as Cazorla), Andalusia, southeastern Iberian Peninsula (Fig. 1). The natural park has an area of 2099 km^2 and an elevation range of 470–2017 m a.s.l. The climate varies with altitude from continental Mediterranean to supra-Mediterranean. Local average annual temperature and precipitation are 11–12 °C and 450–550 mm, respectively. However, precipitation is distributed unevenly due to elevation gradients and localized rain shadow effects, and increases with altitude up to 1500 mm.

More precisely, the study area is located in a transitional area between pine woodlands and Mediterranean mountainous vegetation (elevation 1200–1600 m a.s.l.). European black pine (*Pinus nigra*) and maritime pine (*P. pinaster*) are the most abundant tree species in these woodlands, where black pine can make up 90% of the total forest biomass (Tiscar and Linares, 2011). Small patches of deciduous oak forest prevail on the west and northwest slopes of Cazorla, with Pyrenean and Portuguese oaks (*Quercus pyrenaica* and *Q. faginea*), the most common species in these stands, occasionally accompanied by maple (*Acer granatensis*) and rarely by rowan (*Sorbus domestica*), holly (*Ilex aquifolium*), and hawthorn (*Crataegus monogyna*). Relict hazel (*Coryllus avellana*) forests develop in Cazorla's shady valleys. Evergreen forests of Holm oak (*Q. rotundifolia*) are frequent below *c.* 1400 m a.s.l. Thermophilous understory communities of kermes oak (*Q. coccifera*), mastic (*Pistacea lentiscus*), and *Phillyrea angustifolia* characterize the lower, more xerophytic meso-Mediterranean climate belt (Gomez-Mercado, 2011). Pallinological records show that the area has been continuously covered with forests since the early Holocene, with alternating periods of black pine and mediterranean and deciduous vegetation (Carrión, 2001).

Bat trapping and tracking

Captures were conducted from 27 June to 18 July 2010, coinciding with the breeding season of *Myotis bechsteinii*. Trapping sites were established in water bodies considered suitable for bats to drink, such as small irrigation ponds and pools in narrow streams (Napal et al., 2010). We captured bats with mist nets intercepting access to water surfaces. Captured bats were immediately removed from the nets to be sexed, measured and aged. In total, we captured 39 *M. bechsteinii*. Radio-tracking was restricted to lactating females, identified by visual inspection (swelled nipples surrounded by bare skin) and gentle pressure on teats, because lactating females are well suited for habitat selection study due to their higher energy demands (Barclay, 1989; Kurta et al., 1989).

We tagged 12 lactating females with 0.35-g radio-transmitters (Pip II, Biotrac Ltd., Dorset, UK) attached to the bats with surgical adhesive (Skindbond®, Smith and Nephew, Florida, USA) after we cut the fur between the scapulae with scissors. Transmitter mass never exceeded 5% of body mass (Aldridge and Brigham, 1998). The transmitter eventually fell off after 12–22 days. Two of the transmitters fell prematurely, or the battery failed or the animals managed to cut-off the antenna, thus interrupting prematurely tracking. These individuals were excluded from further analyses. Captures were performed under license issued by the Junta de Andalucía (Regional Council of Andalusia). Trapping and handling protocols met guidelines proposed for the instrumentation of wild

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