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ORIGINAL ARTICLE

The Mediterranean *Quercus pyrenaica* oak forest: a new habitat for the Capercaillie?

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Abstract We described an extension of the known distribution range of the Cantabrian Capercaillie *Tetrao urogallus cantabricus* into an atypical area and habitat for the species. Nine Capercaillie leks and 14 cocks were registered in Mediterranean *Quercus pyrenaica* forests in an area of 1,500 km^2, of which 4,500 forest hectares were surveyed. At present, this population represents both the southern-most distribution for Capercaillie and the only one inhabiting Mediterranean *Q. pyrenaica* forests, what suggests a wider adaptation of this (sub)species than previously thought. This population and its habitat need to be better studied, as well as to be considered in conservation planning for Cantabrian Capercaillie.

Keywords Conservation · Leks · *Quercus pyrenaica* · *Tetrao urogallus cantabricus* · Plasticity

Introduction

Populations across distribution ranges show different adaptations to local conditions from the core areas to the periphery of their distribution (Guo et al. 2005). In the case of the Capercaillie *Tetrao urogallus*, the vast majority of populations inhabit boreal and montane coniferous forests with abundant bilberry *Vaccinium myrtillus* understory (Storch 1993, 2000a, b, 2001). However, the Cantabrian subspecies *T. u. cantabricus* (Cantabrian Mountains, NW Spain) resides mainly in pure deciduous forests of beech *Fagus sylvatica*, birch *Betula pubescens* and sessile oak *Quercus petraea,* as well as mixed forests of beech and oaks (*Quercus robur*, *Q. petraea,* and *Q. pyrenaica*; Bañuelos and Quevedo 2008). In these forests, holly *Ilex aquifolium* provides a key, evergreen winter food resource for Cantabrian Capercaillie (Storch 2001; Blanco-Fontao et al. 2010), whereas it relies on bilberry in summer–autumn (Blanco-Fontao et al. 2010). Previous studies showed, however, a negative selection to *Quercus pyrenaica* forests by Cantabrian Capercaillie at the northern slope of the Cantabrian range (Quevedo et al. 2006b).

This endemic Capercaillie subspecies is isolated and separated by more than 300 km from the nearest Capercaillie population in the Pyrenees. After severe population decline in the last three decades (from 2,000 to 400 adults), only 108 leks remain occupied in the northern watershed and 85 leks in the southern, corresponding to an overall occupancy rate of 32% of all known leks (Bañuelos and Quevedo 2008). Consequently, the Cantabrian Capercaillie subspecies qualifies to be listed as "Endangered" according to the IUCN criteria (Storch et al. 2006).

Capercaillie populations have so far been generally considered to be distributed in the Eurosiberian biogeographic region, outside the Mediterranean region (but see Handrinos and Akriotis 1997; Storch 2001; and "Discussion"). Unlike the Eurosiberian region, the Mediterranean region is characterised by a period of drought during the hot summer which determines the existing vegetation (e.g. Penas 1995; Blondel

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and Aronson 1999; Rivas-Martínez et al. 2005). This Mediterranean environment is thought to be unsuitable for a species primarily adapted to boreal environments. However, there are historical records suggesting Capercaillie presence during seventeenth to nineteenth centuries in Mediterranean areas in Spain (Madoz 1848; Castroviejo 1975; Martínez 1993), but the first sighting in *Q. pyrenaica* forests in this Mediterranean area was unnoticed until May 1998 (Pollo et al. 2004; No. 1 in Fig. 1).

In this study, we present information on the number of cocks and characteristics of leks located in an atypical area and habitat for the Capercaillie, i.e. Mediterranean *Q. pyrenaica* forests with virtual lack of bilberry and holly. This study is the first showing Capercaillie to be widely present in this forest type, suggesting a wider ecological plasticity of this (sub)species than previously thought. We also discuss implications that this new Capercaillie site may have in the conservation of the Cantabrian Capercaillie.

Methods

Study area

The study area is located on the southern slope of the Cantabrian Mountains in León province (NW Spain). It is centred at 42°39′N and located in the Mediterranean biogeographical region bordering the Eurosiberian region (Atlantic; Rivas-Martínez et al. 2004; European Environment Agency 2008; Fig. 1). The study area covers approximately 1,500 km^2 below the putative line separating the two biogeographical regions in a landscape slightly mountainous (elevation ranges from 800 to 1,700 m a.s.l.). It belongs to the biogeographical unit Carpetan-Leonese Subprovince from the Mediterranean region with supramediterranean bioclimate (Penas 1995; Rivas-Martínez et al. 2005; del Rio et al. 2007). A meteorological station from our study area (Villameca) clearly shows two dry months ($P < 2T$; Blondel and Aronson 1999) in summer*:* July ($P = 26$; $T = 19.9$) and August ($P = 19$; $T = 19.1$; data based on 37 years data).

Dominant forests are supramediterranean natural (more than 50 years old), and post-fire *Q. pyrenaica* forests frequently occurring interspersed with Scots pine *Pinus sylvestris* plantations (less than 50 years old). Both forest types are largely mono-specific in the study area. *Q. pyrenaica* forests cover 27,000 ha (19% of the study area). Scots pine plantations occupy 11,000 ha (8%).

Q. pyrenaica (Willd.) is a marcescent oak tree distributed widely in Spain as well as the western part of France and the northwest of Morocco. This tree develops under siliceous soils in the Eurosiberian region as well as in the Mediterranean region with an extensive representation in this biogeographic region. In Spain, *Q. pyrenaica* represents the dominant species of different vegetation series (del Rio et al. 2007).

Forest fragments of the study area are embedded in a matrix mainly composed of heather *Erica australis* 1,560 ha (1%), brooms *Genista florida* and Cy*tisus scoparius* 3,640 ha (3%), meadows 3,460 ha (3%) and riparian lowland forest of *Populus nigra*, *Fraxinus excelsior* and *Alnus glutinosa* 5,340 ha (4%). Understory cover

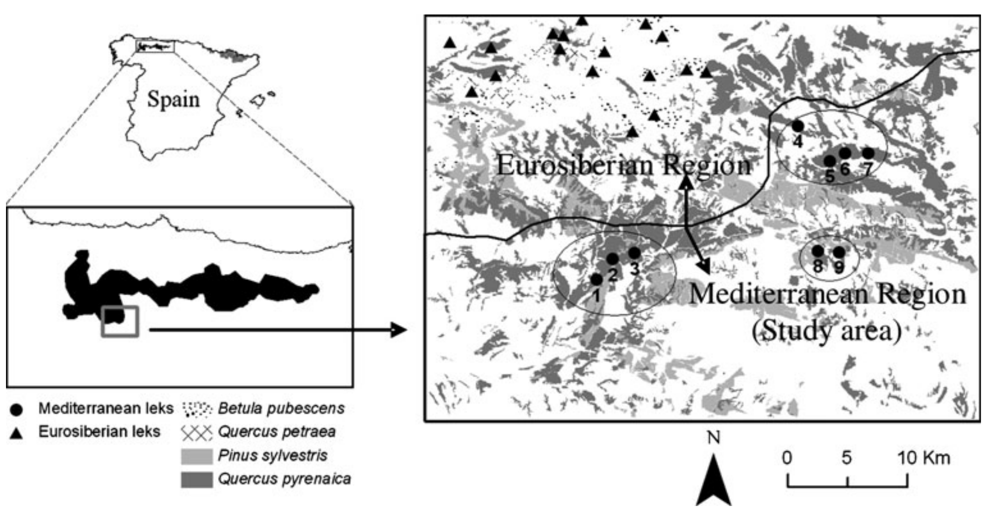

Fig. 1 Area of occupancy of Cantabrian Capercaillie *Tetrao urogallus cantabricus* in 1980 (Obeso and Bañuelos 2003; *black left*) and study area (*right*). *Numbers* correspond to the leks according to the discovery date. Lek *1* was the first Capercaillie breeding record in *Q. pyrenaica* forest in 1998. *Solid line* represents the border between the Eurosiberian and the Mediterranean biogeographical regions after European Environment Agency (EEA) (2008) and Rivas-Martínez et al. (2004). *Filled circles* represent the recently discovered Mediterranean leks while *filled triangles* represent the traditional Eurosiberian leks. According to government restrictions, lek locations are slightly moved for security. *Light* and *dark grey* areas represent *Pinus sylvestris* and *Q. pyrenaica* forests, respectively

is mainly dominated by heath *Erica arborea* and broom *C. scoparius*, while bilberry and holly is completely absent or very scarce (<0.5% of the forest ground cover) in the study area. The remaining 62% surface corresponds with anthropogenic landscapes such as villages, roads, opencast mines, valley bottoms, which are not suitable for Capercaillie habitat. Human population is approximately 1,000 people (0.6 people/km^2); it has declined by 80% since the 1950s. Livestock rearing is the main economic activity in the study area, followed by coal mining industry, agriculture, forestry and hunting.

Survey methods

No systematic sampling of the species was performed for the whole study area. We gathered information on Capercaillie presence from 2002 to 2009 from two sources: (1) questionnaires and reports sent by forest wardens, hunters and local people to the León environmental agency from the regional government (Consejería de Medio Ambiente of the Junta de Castilla y León), and (2) field surveys. Samples were recorded over the whole year. Data from the first source were validated within 2 weeks after receipt of the sample through field surveys carried out by an experienced observer (L. Robles). Field surveys consisted of a 3- to 4-h systematic zig-zag walk looking for presence signs of Capercaillie (e.g. direct sightings, footprints, droppings or feathers), especially focusing on sites known to be highly used by the species (e.g. forest paths, dead trunks, big stones, oldest forest sites, etc.).

In forest patches bigger than 1 km^2 (i.e. more than 3–4 h of sampling required), we conducted surveys over consecutive days until covering the whole forest patch (i.e. a continuous forest isolated by a non-forest matrix). Direct sightings, footprints, droppings or feathers recorded in a site were considered as signs of Capercaillie presence. Each forest patch was completely surveyed 6–10 times throughout 1 year, with 1–2 months between each. If no sign of Capercaillie presence was found, the forest patch was labelled unoccupied and no further surveys were conducted in that specific patch.

Additionally, we surveyed the occupied patches in order to find leks. Selected sites were locations where survey after survey we found Capercaillie signs. The visits were performed throughout April and May (i.e. the display season) after 1200 hours to avoid disturbing birds. A lek is defined as a site where one or more cocks consistently display for hens, plus the adjacent surrounding forest habitat. It has traditionally been used as a Capercaillie occurrence measure in the Cantabrian range (see Obeso and Bañuelos 2003).

During April–May, where fresh Capercaillie signs were found, 2–3 observers (forest wardens and L. Robles) visited the site at night as many as four times until the display finished, or until well past dawn. A site was considered as an occupied lek when at least one cock was heard calling or seen displaying.

Every detected lek was surveyed each year to label it as occupied or unoccupied just looking for presence signs after 1200 hours (see above). In April–May 2009, every occupied lek was surveyed at night to get the number of displaying cocks.

Nine forest structure variables (Appendix1) were measured in each lek consisting of 12 circular plots with 5-m radius. Three plots separated by 10 m were arranged in each cardinal direction from the lek centroid (i.e. the point where previously a cock was recorded displaying).

Results

A total of nine leks, including that discovered in 1998 (Pollo et al. 2004), were registered in the study area, seven of them remained occupied in 2009 (Fig. 2). The highest occupancy was in 2006 with eight occupied leks (Fig. 2). Since 2006, no new lek was found, despite an increase of around 2,000 additional hectares surveyed (60% of the total surveyed surface; Fig. 2). Leks were grouped into three sub-areas according to the watersheds: one sub-area had three leks, another had four and the last sub-area had two (Fig. 1). Mean nearest neighbour distance between leks was 2.07 ± 0.74 km (mean ± SE).

Leks were in *Q. pyrenaica* forests ranging from 1,132 to 1,398 m a.s.l. (mean ± SE: 1,275 ± 100.93, $n = 9$) and mainly faced in a northerly direction with two exceptions facing south (Appendix1). They showed heterogeneity in the forest structure, ranging from sites with young trees (perimeter 0.19 ± 0.005 m) with high canopy cover (0.81 ± 0.06%) to mature trees (perimeter 0.90 ± 0.62 m) with low canopy cover (0.28 ± 0.07%). The maximum tree height in leks varied from 7.75 ± 0.86 m to 16.50 ± 3.20 m (see Appendix 1).

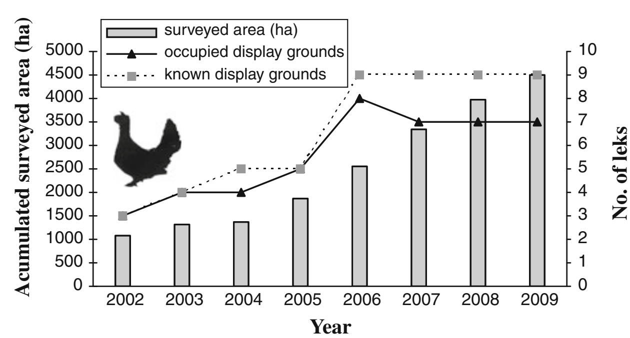

Fig. 2 Occurrence of the Mediterranean leks since 2002. *Bars* show the total accumulated forest surface surveyed (ha) through the study years. *Solid line* represents the occupied leks and *broken line* the known leks

Understory cover ranged from low (0.004 ± 0.86%) to high (0.62 ± 0.27%). In six of the nine leks, the dominant understory species was *E. arborea* while *C. scoparius* dominated the remaining one (Appendix1).

In 2009, 12 cocks were recorded at the seven occupied leks. Moreover, 2 additional cocks not referred to any lek were detected during the spring 2009 fieldwork. Two nests with five and seven eggs each (both in *Q. pyrenaica* forest) were found in early June 2009 (Fig. 1, nos. 5 and 8).

Discussion

So far, the Capercaillie always occurred in the Eurosiberian biogeographical region with the exceptions of the probably introduced birds of Mount Athos (Greece; Handrinos and Akriotis 1997), currently extinct (S. Xirouchakis, personal communication), and two other unclear records in the Mount Grammos and Lailias Forest Reserve in Greece (Storch 2001). Therefore, the Capercaillie population we described here represents both the southern-most distribution for Capercaillie and the only one inhabiting Mediterranean *Q. pyrenaica* forests. These forests are different from the nearest ones occupied by Capercaillie leks located north of the putative line separating Eurosiberian and Mediterranean regions (Fig. 1; Appendices 1 and 2). These northern leks are mainly located in birch and sessile oak forests with understory dominated by bilberry (see Appendix2) in a Eurosiberian bioclimatic environment (superior montane thermotype and inferior humid ombrotype) (Penas 1995). Nonetheless, lek 4, although in *Q. pyrenaica* forest, has a eurosiberian bioclimatic environment (Penas 1995), probably because of its most northerly relative position.

Despite an increase in the surveyed area, no new leks were found after 2006. However, the fact that we only surveyed 12% of the forest surface within our study area (Fig. 2) suggests new leks may be found in the future. Although the number of Capercaillie in the study area is small, it represents approximately 7% of the global Cantabrian population, highlighting the conservation value of this site.

All the nine leks were located in *Q. pyrenaica* forests. Conversely, no lek was located in pure Scots pine plantations, although these were available in the study area. In addition, two of four radio-tracked (one hen and one cock) Capercaillies used *Q. pyrenaica* forests of the studied area all year round (authors, unpublished data) and two Capercaillie nests were discovered in these forests. All this suggests that *Q. pyrenaica* forests are suitable year-round habitat for the Cantabrian Capercaillie. This is particularly important because the potential habitat for this endangered subspecies could thus be greatly increased, as *Q. pyrenaica* forests are highly represented with >100,000 ha at the southern slope of the Cantabrian Mountains (Gil-Sánchez and Torre-Antón 2007). Additionally, despite the idea that *Q. pyrenaica* forests are not considered as suitable habitat (Quevedo et al. 2006b), and neither are included in the recovery plans for the Cantabrian Capercaillie, our study highlights the need to take into account these forests for the conservation of this subspecies. Nonetheless, the role of the pine plantations for Capercaillie in the study area should be further assessed.

Finally, this study supports what is suggested by Quevedo et al. (2006a, b) and Blanco-Fontao et al. (2010), that many general considerations for the species overall are not fully useful for the Cantabrian Capercaillie, and suggests a wider adaptation and plasticity of this species than previously thought. For example, the near absence of bilberry and holly in the studied area suggests that Capercaillie can maintain viable populations without this important summer and winter food resource for the Cantabrian population and elsewhere (Storch 2001; Blanco-Fontao et al. 2010). Future research could address a detailed comparison of suitable Capercaillie habitat between the two different biogeographical regions. Studying the ecology and genetic variability of this local population living in this atypical habitat would be of a great value to further understand and conserve this subspecies in particular and *Tetrao urogallus* in general.

Zusammenfassung

Der Mediterrane Pyrenäen-Eichenwald: ein neuer Lebensraum für das Auerhuhn?

Wir beschreiben eine Ausdehnung des bekannten Verbreitungsgebietes des Auerhuhns in ein atypisches Gebiet und Habitat für diese Art. In einem 1,500 km^2 großen Pyrenäen-Eichenwald Gebiet, wovon 4,500 ha Wald untersucht wurden, konnten neun Balzarenen des Kantabrischen Auerhuhns *Tetrao urogallus cantabricus* und 14 Hähne festgestellt werden. Aktuell repräsentiert diese Population die sowohl südlichste Verbreitung von Auerhühnern als auch die einzige, die mediterrane Pyrenäen-Eichenwälder bewohnt. Dieses weist auf eine größere Anpassung dieser (Unter-)Art hin, als vorher vermutet. Diese Auerhuhn-Population und ihr Lebensraum müssen jedoch noch besser untersucht werden und sie sollte auch in Schutzstrategien für das Kantabrische Auerhuhn berücksichtigt werden.

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Appendix 1

Table 1.

Table 1 Description of the leks ($n = 9$) in the study area; see (*filled circle*) in the map of the study area (see Fig. 1)

Lek.	Year	Cocks	m a.s.l.	Exp.	Trees				Understory		
					Size (m)	Height (m)	Cover (%)	Species	Height (m)	Cover (%)	Species
1	1998	2	1,215	NW	0.45 ± 0.17	9.42 ± 1.38	0.57 ± 0.21	*Q. pyrenaica*	1.12 ± 0.38	0.39 ± 0.25	*C. scoparius*
2	2002	1	1,131	NW	0.90 ± 0.62	16.50 ± 3.20	0.58 ± 0.15	*Q. pyrenaica*	0.85 ± 0.07	0.25 ± 0.06	*C. scoparius*
3	2002	0	1,154	NW	0.32 ± 0.15	9.17 ± 1.75	0.54 ± 0.26	*Q. pyrenaica*	0.75 ± 0.50	0.16 ± 0.17	*E. arborea*
4	2003	2	1,230	NE	0.70 ± 0.13	7.75 ± 0.86	0.28 ± 0.07	*Q. pyrenaica*	1.33 ± 0.24	0.45 ± 0.25	*E. arborea*
5	2004	3	1,387	N	0.70 ± 0.15	14.08 ± 2.81	0.64 ± 0.22	*Q. pyrenaica*	0.03 ± 0.08	0.004 ± 0.01	*C. scoparius*
6	2006	1	1,253	N	0.20 ± 0.05	9.50 ± 0.42	0.60 ± 0.25	*Q. pyrenaica*	0.50 ± 0.42	0.51 ± 1.41	*E. arborea*
7	2006	0	1,356	N	0.23 ± 0.06	11.17 ± 0.38	0.47 ± 0.24	*Q. pyrenaica*	0.79 ± 0.25	0.39 ± 0.57	*E. arborea*
8	2006	2	1,351	SE	0.43 ± 0.10	10.33 ± 1.37	0.58 ± 0.15	*Q. pyrenaica*	1.37 ± 0.31	0.40 ± 0.17	*E. arborea*
9	2006	1	1,398	SW	0.19 ± 0.05	10.16 ± 0.57	0.81 ± 0.06	*Q. pyrenaica*	1.42 ± 0.45	0.62 ± 0.27	*E. arborea*

Mean ± SE are shown for forest structure variables of the leks

Lek Lek number by discovery date, *Year* when the lek was first-time recorded (April–May), *Cocks* number of Capercaillie cocks recorded in each lek in 2009, *m a.s.l.* elevation (meters above sea level), *Exp.* exposure of the slope. *Trees: Size* mean tree size measured in DBH (diameter at breast height), *Height* mean tree height, *Cover* mean canopy cover (%), *Species* dominant tree species. *Understory: Height* mean understory height (m), *Cover* mean understory cover (%), *Species* dominant understory species

Appendix 2

See Table 2.

Table 2 Description of the Eurosiberian leks ($n = 17$) north of the study area (see Fig. 1)

Lek	m a.s.l.	Exposure	Tree species	Understory species
1	1,440	N–W	*Q. petraea*	Vaccinium myrtillus
2	1,520	N–W	Mixed	*Vaccinium myrtillus*
3	1,450	N–W	Mixed	*Vaccinium myrtillus*
4	1,550	N–E	Mixed	*Vaccinium myrtillus*
5	1,490	N	*Q. petraea*	*Vaccinium myrtillus*
6	1,620	N	*Betula pubescens*	*Erica arborea*
7	1,650	N	*Betula pubescens*	*Erica arborea*
8	1,550	N	*Betula pubescens*	*Erica arborea*
9	1,680	N	*Betula pubescens*	*Erica arborea*
10	1,590	N–E	*Betula pubescens*	*Vaccinium myrtillus*
11	1,680	N	*Betula pubescens*	*Vaccinium myrtillus*
12	1,620	N–W	Mixed	*Vaccinium myrtillus*
13	1,540	N–W	Mixed	*Vaccinium myrtillus*
14	1,510	N–W	*Betula pubescens*	*Erica arborea*
15	1,590	N	*Betula pubescens*	*Erica arborea*
16	1,620	N–E	*Betula pubescens*	*Vaccinium myrtillus*
17	1,590	N–W	Mixed	*Vaccinium myrtillus*

Mixed No tree species was dominant, with the following occurring: *Betula pubescens*, *Q. petraea*, *Q. pyrenaica* and *Sorbus aucuparia*

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