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NESTING HABITAT SELECTION OF BOOTED EAGLE *HIERAAETUS PENNATUS* IN CENTRAL CATALONIA

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SUMMARY.—*Nesting habitat selection of Booted Eagle* Hieraaetus pennatus *in central Catalonia.*
Aims: The Booted Eagle *Hieraaetus pennatus* is a poorly known raptor that has bred in Catalonia at least since 1989, when the first nest was found. Its confirmed breeding population has increased from 1 breeding pair in 1989 to 13 breeding pairs in 2001. The present study provides information about the population and the nesting habitat selection of the Booted Eagle in central Catalonia from 1990-2001.
Location: central Catalonia.
Methods: The data of presence of the Booted eagle in the studied area was obtained from April to August (1990-2001). The representation of the located nests has been made by means of a UTM projection square grid 10x10 km. To describe the characteristics of the nesting habitat, the occupied territories have been compared with equal number of random sites by means of 16 variables using the *t*-test and circular statistics.
Results: Of 41 UTM square 10x10 km prospected, reproduction has been verified in 9, with 11 located breeding pairs. Potentially breeding pairs have been detected in other 6 squares and the species has been detected during the breeding season in other 13 square. In central Catalonia, Booted Eagles breeds significantly in places away from country houses. However, this species tolerates a more significant presence of paved and unpaved roads near its nesting area than would occur at random points. Birds nest in big trees (preferably Black Pine) of extensive, closed and shady woods, significantly orientated between 315°N to 45°N.
Conclusions: In the area studied, the species settles down preferably far from the human settlement, although it perfectly tolerates the presence of highways and forest paths. Contrary to what happens in other Iberian areas, where the species breeds in solitary trees and in small groups of trees, in central Catalonia the Booted Eagle breeds in big trees of extensive, closed and shady forests of Black Pine, facing north. The orientation of the nest is probably influenced by the wind direction, the altitude and perhaps by the solar radiation.
Key words: Booted Eagle, forest management and nesting habitat.

RESUMEN.—*Selección del hábitat de nidificación del Aguililla Calzada* Hieraaetus pennatus *en Cataluña central.*
Objetivos: El Aguililla Calzada *Hieraaetus pennatus* es una rapaz poco conocida que cría en Cataluña desde al menos el año 1989, fecha en que se encontró el primer nido. La población reproductora se ha incrementado de una pareja en 1989 a 13 parejas en el 2001. En este artículo, los autores aportan información sobre la población y sobre la selección del hábitat de nidificación del Aguililla Calzada en la Cataluña central en el período 1990-2001, con el objetivo de aportar información clara sobre esta especie en Cataluña.
Localidad: Cataluña central.

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Métodos: Los datos de presencia de la especie en el área de estudio se han obtenido de abril a agosto durante el período 1990-2001. La representación gráfica de los nidos estudiados se hizo mediante un enrejado de cuadrículas UTM 10x10 km. Para describir las características del hábitat de nidificación, los territorios ocupados han sido comparados con el mismo número de territorios vacíos, mediante 16 variables usando el test de la *t* y estadística circular.
Resultados: De las 41 cuadrículas UTM. 10x10 km prospectadas, la reproducción ha sido comprobada en 9 de ellas, con 11 parejas localizadas. En 6 cuadrículas más se han detectado parejas potencialmente reproductoras y en otras 13 cuadrículas se han detectado individuos solos en época reproductora. En la Cataluña central las Aguililas Calzadas crían en lugares significativamente alejados de las casas de campo. Sin embargo, toleran perfectamente la presencia de carreteras asfaltadas y de pistas forestales cerca de sus nidos con respecto a los puntos al azar. Nidifican en grandes árboles (preferentemente Pino Negral) de bosques extensos, cerrados y umbríos, significativamente orientados entre 315°N y 45°N.
Conclusiones: En el área de estudio, se establece preferentemente alejada de los asentamientos humanos, aunque tolera perfectamente la presencia de carreteras y pistas forestales. Contrariamente a lo que sucede en otras zonas de la península Ibérica, dónde cría en árboles solitarios o en pequeños grupos de árboles, en la Cataluña central el Aguililla Calzada nidifica en grandes árboles de bosques de Pino Negral, extensos, cerrados, umbríos y orientados al norte. La orientación de los nidos está probablemente condicionada por la dirección del viento, la altura sobre el nivel del mar y posiblemente la radiación solar.

Palabras clave: Aguililla Calzada, gestión forestal, selección del hábitat de nidificación.

Introduction

In the Iberian Peninsula, raptor nesting habitat selection studies have focused on large diurnal raptors (González, 1991; Donázar *et al.*, 1993; Rico Alcázar *et al.*, 2001). These studies were basically associated with different projects to preserve threatened populations or to avoid habitat loss as has happened in other parts of the planet with other threatened raptors (González, 1991). Recently, several studies have been published that directly or indirectly deal with the selection of Booted Eagle habitat (Sánchez-Zapata, 1994; Sánchez-Zapata & Calvo, 1999; Suárez *et al.*, 2000; Martínez, 2002). However, these studies were conducted in the southeastern peninsular semi-arid Mediterranean areas and, one of them in the Doñana National Park (southwestern Spain), environments and habitats vary greatly from the ones in the Catalan study area.

The aim of this study is to study the nesting habitat selection of the Booted Eagle population in central Catalonia, comparing the occupied breeding areas with random but potentially appropriate sites in relation to variables related with to environmental humanisation, the topographic relief characteristics, the vegetable cover, the intra-specific competition and meteorological incidence.

Material and methods

Study area

The studied area has an extension of 4100 km^2 and it embraces through the districts of Bages, Solsonès, Anoia, Berguedà and Segarra (Fig. 1). 70% of the area is occupied by forests, except the Segarra where cereal crops prevail, and the forest area is only a 32% of the total surface. The forest is mainly Sub-Mediterranean, highlighting the extensive and uniform pinewoods of Black Pine *Pinus nigra*, with some patches of Scots Pine *Pinus sylvestris* on the shady slopes of the central and oriental area. The woods of Scots Pine are frequent in the northern and eastern areas, which are outside the study area. The masses of Black Pine are secondary communities

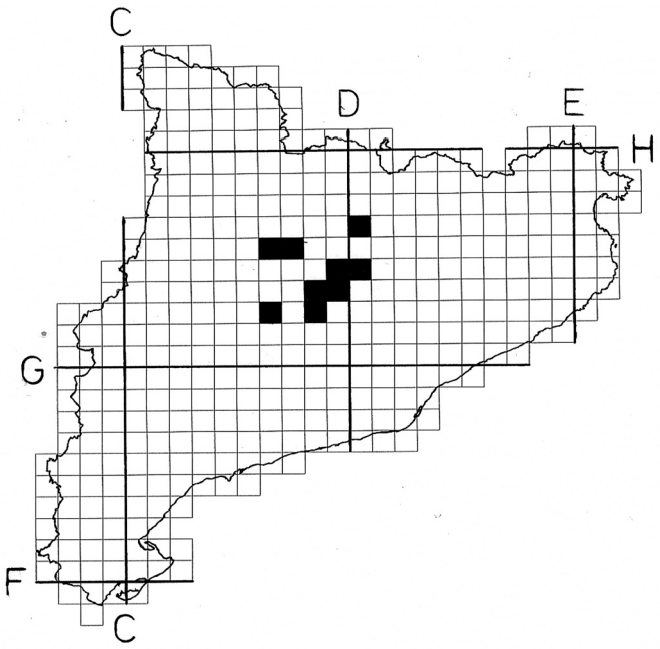

FIG. 1.—Representation of nests used in the nesting habitat selection study. Occupied square ruled 10 x 10 km UTM projection are coloured in black.
[Representación de los nidos usados en este estudio. Las cuadriculas ocupadas en un proyección 10 x 10 km (proyección UTM) se representan en negro.]

which grew from the historical breaking of new ground for cropping. So, the primitive dry and wet Sub-Mediterranean vegetation of oaks *Quercus faginea* and *Quercus pubescens* has decreased in the valleys and the shady hillsides, as well as the Holm Oak woods *Quercus ilex rotundifolia* in xerophil and sunny summits. The masses of oaks are limited to ecotone and patched and scarce areas, while the Holm Oak woods are found on the summits and drier and sunnier areas. Forest management has a turnover of 15-20 years and basically consists in thinning out the biggest and most mature trees.

Methods

The data of presence of the species in the study area were obtained during the months of April to August (1990-2001), with the participation of nine different observers. We prospected 41 UTM squares of 10x 10km in central Catalonia. The study of nesting habitat selection of ten out of eleven located nests was carried out. A 1 km radius of nest centred circular area has been adopted to quantify the nesting area, according to an approximate radius of territorial and nuptial flights observed. To describe the characteristics of the nesting habitat, the ten occupied territories have been compared with other ten random sites, generated in adjacent areas with the help of a computer, excluding open areas lacking potential nest sites (such as crops, urban areas or grasslands). For each nest site and random site points, we measured 16 variables in order to quantify the habitat (Table 1), similar to the ones made in previous studies referred to other Iberian raptors (González, 1991; Martínez & Calvo, 2000; Rico *et al.*, 2001). In this case, the selected variables were adapted from the species

TABLE 1

Abbreviations and description of the environmental variables used to characterise occupied or not occupied nest site areas by Booted Eagle in the study area.
[Abreviación y descripción de las variables ambientales usadas para caracterizar las áreas de nidificación ocupadas o no por el Aguililla Calzada.]

Abbreviation *[Abreviación]*	Definition *[Definición]*
DCH	Distance (km) to the nearest inhabited country house *[Distancia (km) a la casa habitada más cercana]*
DNH	Distance (km) to the nearest urban centre *[Distancia (km) al centro urbano más cercano]*
DCASF	Distance (km) to the nearest paved road *[Distancia (km) a la carretera asfaltada más cercana]*
DPF	Distance (km) to the nearest unpaved road *[Distancia (km) a la carretera no asfaltada más cercana]*
INTRA	Impassability index. Measure of difficulty of access by foot to the nest area in function of relief and scrublands surface according to INTRA = MAT + (2 ± ITP). *[Índice de intransitabilidad. Medida de la dificultad de acceso por pie al nido en función del relieve y la superficie arbustiva de acuerdo a INTRA = MAT + (2 ± ITP).]*
PEN	Mean slope in the nest location (%) *[Pendiente media en el nido (%)]*
ITP	Topographic irregularity index. Number of 20 m.-contours cut by 1 km line starting from the nest in directions N, S, E and W *[Índice de irregularidad topográfica. Número de líneas de contorno de 20 m a lo largo de 1 km desde el nido en dirección N, S, E y W]*
DA	Maximum altitude - minimum altitude in circles of 1 km radius around nests *[Altitud máxima – altitud mínima en circulos de 1 km alrededor del nido]*
ASM	Nests altitude (m.a.s.l.) *[Altitud del nido (m s.n.m.)]*
DCUL	Distance to the nearest crop *[Distancia al cultivo más cercano]*
DNMP	Distance to the nearest occupied nest *[Distancia al nido más cercano]*
PA	Habitat patch index. Number of different crop limits or different vegetation type limits cut by four 1 km lines starting from the nest in directions N, S, E and W *[Índice de fragmentación del hábitat. Número de diferentes limites de cultivo o tipos de vegetación cortados por una línea recta desde el nido de 1 km hacia el N, S, E y W]*
MAT	Area (%) covered by scrublands in a 1 km circle around the nest *[Área (%) cubierta por arbustos en un 1 km alrededor del nido]*
CUL	Area (%) covered by crops in a 1 km circle around the nest *[Área (%) cubierta por cultivos en un 1 km alrededor del nido]*
ARB	Area (%) covered by woodlands in a 1 km circle around the nest *[Área (%) cubierta por bosques en un 1 km alrededor del nido]*
ORI	Nest orientation *[Orientación del nido]*

TABLE 2

Means ± standard deviations of variables used to characterize the nest sites of Booted Eagle and random sites.
[Media ± desviación típca de las variables utilizadas para caracterizar los lugares de nidificación del Aguililla Calzada y los lugares escogidos al azar.]

	Occupied	*Unoccupied*	*t*-value	*P*-Value
DCH	0.94 ± 0.31	0.47 ± 0.23	3.63	0.002
DNH	4.02 ± 2.01	3.19 ± 2.24	0.90	0.378
DCASF	0.70 ± 0.48	1.34 ± 0.93	2.16	0.044
DPF	0.09 ± 0.09	0.18 ± 0.11	2.30	0.034
INTRA	31.10 ± 36.04	36.05 ± 33.69	0.32	0.755
PEN	38.56 ± 17.63	29.35 ± 11.26	1.39	0.181
ITP	36.00 ± 16.10	32.90 ± 7.29	0.55	0.590
DA	245.5 ± 139.6	232.2 ± 87.9	0.25	0.803
ASM	787.0 ± 142.0	669.0 ± 210.2	1.47	0.159
DCUL	0.32 ± 0.33	0.25 ± 0.29	0.21	0.833
DNMP	5.86 ± 6.10	3.56 ± 1.79	0.69	0.502
PA	7.50 ± 2.22	10.50 ± 5.82	1.52	0.156
MAT	29.10 ± 36.00	32.07 ± 34.04	0.23	0.822
CUL	23.90 ± 33.70	25.53 ± 24.00	0.40	0.695
ARB	47.00 ± 35.70	42.40 ± 33.37	0.19	0.849
	Williams-Watson test		*F*-value	*P*-value
ORI	8.94 ± 37.31	180.0 ± 52.0	4.38	<0.001

studied characteristics as geographical environment on which the study is centred.

The relative information at the distances from roads and highways, distances among the nests, topographical variables and land uses have been obtained from the Catalonian Cartography Service 1:50.000 regional maps and Army Geographical Service 1:50.000 maps. On the other hand, the meteorological data of the speed and wind direction in the period 1997-2001, were obtained from the automatic stations of Catalonian Meteorology Service of Sant Salvador de Guardiola (Bages), Cervera (Segarra), Clariana del Cardener (Solsonés) and La Quar (Berguedà).

Statistical analysis

To check the possible differences between the used habitat and the available one, all the defined variables have been compared among the used nests and the points selected at random, using *t*-tests with a Bonferroni correction. Circular statistic has been used for the circular variables (Zar, 1999). Previously to the statistical analysis the variables were checked for statistical normality using Kolmogorov-Smirnov test and variables were square root-transformed (distances) and arcsine-transformed (% circle area).

RESULTS

In 9 out of 41 UTM 10x10 km prospected squares in central Catalonia the reproduction was verified, with a total of 11 breeding pairs located (Fig. 1). In another 6 squares potentially breeding pairs were detected. In another 13 squares the presence of the species was detect-

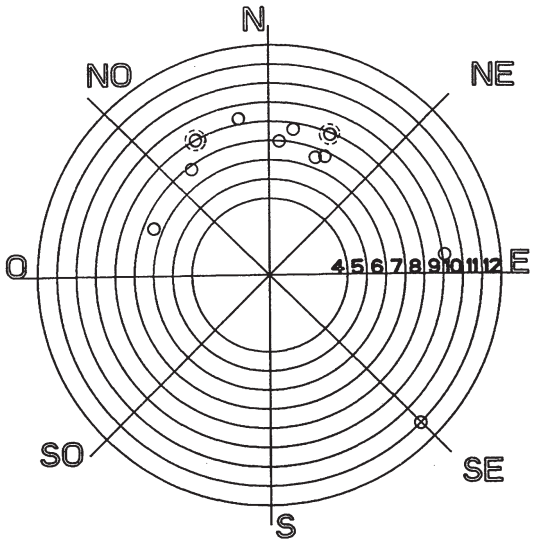

FIG. 2.—Nest orientations and altitude (100 x m a.s.l.). Several nests of the same couple with orientation difference are also represented into of pointed circle. Empty circle = nest site.
[Orientación de los nidos y altidud (100 x m s.n.m.). Los circulos punteados representan varios nidos de la misma pareja con orientaciones diferentes. Circulos vacios = lugar de nidificación.]

ed during the breeding season. In these last squares solitary individuals hunting or moving without denoting any reproductive behaviour were observed. Finally, in 13 remaining squares the species was never detected.

The nesting habitats differed from the random sites in three variables related with the degree of environmental humanisation. The distance from inhabited isolated country houses is significantly greater in nesting than in random sites ($t = 3.63$, $P = 0.002$). The distance from the nest to the nearest urban centre differed between nesting and random sites ($t = 0.90$, $P = 0.38$). The mean distance to roads or dirt roads did not differ between nesting and random sites ($t = 2.16$, $P = 0.044$ and $t = 2.30$, $P = 0.034$, respectively).

The habitats did not differ between nesting and random sites in the mean slope ($t = 1.39$, $P = 0.18$), topographic irregularity index ($t = 0.55$, $P = 0.59$), maximum-minimum altitude ($t = 0.25$, $P = 0.80$), impassability index ($t = 0.32$, $P = 0.75$), altitude ($t = 1.47$, $P = 0.16$), and the mean distance to the nearest crop field ($t = 0.21$, $P = 0.83$). The orientation of the nests, a variable that can condition the influence of the meteorology effects, differed significantly between nesting and random sites (Williams-Watson test: $F = 4.38$, $P < 0.001$). An angular-linear correlation analysis showed that there is a positive relationship between the orientation and altitude ($r = 0.83$; $X^2 = 5.99$, $P = 0.023$). Moreover, there is a significant relationship between the direction of the dominant winds for each nest and its orientation ($Z = 0.042$, $0.358 < L < 0.441$).

The structure and the three variables related to the vegetation cover did not differ between nesting and random sites (all P-values > 0.15). The Booted Eagle bred preferably in high trees, locating the nests in Black Pine woods between 6 and 25 meters above the ground (mean ± SD = 12.53 ± 4.79, $n = 15$). Nine out of ten territories were located in forests larger than 5 ha and one of them in a small forest of less than 5 ha. Thirteen out of the fourteen nests of the ten studied territories were lo-

cated in Black Pines and only that corresponding to the breeding pair located at 1100 m. a.s.l. was situated on a Scots Pine. Seven of those nests were located in lateral branches away from the trunk and the seven remaining next to the trunk, although at least one of these last ones was an old platform of Northern Goshawk *Accipiter gentilis*. All nests located in lateral branches were built by Booted Eagles. The distance from the neighbouring nest, variable related with the intra-specific potential competition, did not differ between nesting and random sites ($t = 0.69$, $P = 0.502$).

Discussion

The Booted Eagle settles down in a significant way in areas as far away as possible from inhabited housings, bending the distance of the random points, a common fact in other raptors such as the Iberian Imperial Eagle *Aquila adalberti* (González, 1991). On the other hand, the humanisation degree does not appear to affect this species with regard to the vicinity to paved or dirt roads, nesting significantly much nearer these communication roads than the distances given by the random points. This also occurs in Doñana National Park (Suárez *et al.*, 2000), where the Booted Eagle has even bred in trees located close to unpaved forest tracks ($n = 2$), probably because of a preference for open areas near the nests for surveillance or for hunting (I. S. García Dios, *pers. obs.*).

The orientation of the nests is significant with regard to random points, preferably facing North (9°N). In Fig. 2, all the platforms are represented with regard to their orientation and altitude above sea level. When relating the nest orientations with altitude, there is a significant correlation, straying more marked of the north the nests located to more height. The lower temperatures at greater heights could determine that the nests head S and E looking for milder temperatures. A correlation has been made between the orientation of the nests and the average wind direction the location of each nest giving a significant result. The average wind speed in the studied area from 1997-2001, during the reproductive cycle was of 2.39 m/s and the dominant direction was 165°N, diverging 156° from the nest orientations. It is possible that the low density and the great availability of adequate zones provide the Booted Eagles to elect the wind and atmospheric inclemency's less exposed places. Solar radiation is possibly another factor that influences the orientation of the nests and the situation of these in preferably shady areas. None of the four variables that define the covering and distribution of the vegetation has given rise to significant differences between the nests sites and the random points. Contrary to what happens in other areas (Suárez *et al.*, 2000), in the studied area the Booted Eagle settles preferably in extensive pinewoods (> 5 ha) of *Pinus nigra*. The variable that defines the intra-specific potential competition (neighbour pair distance) has not given rise to significant differences between the nests sites and the random points. An area with 4 nests exists where the mean distance from each other is 1,333 ± 354 m. (1000 m. to 1750 m.) and in another area with 2 nests with mean distance is 2050 ± 0 m. However, the distances between these groups of nests and the other isolated nests with their nearer neighbours, oscillate between 9,500 and 14,000 m. It seems that the population grows around the existent nests, having big empty areas between these small nuclei and nesting sites. The fact that the species breeds in big trees of calm and extensive woods, the tolerance with nesting neighbour pairs of its own species and of any other raptors (Garzón, 1974; Bosch, 1997; Bosch, 2000), its absence during maximum hunting pressure time, its varied food and its capacity to exploit diverse ecosystems, may indicate a progressive density increase in the inhabited areas (Bosch, 2000). According to this, in the studied area a great number of non-occupied areas potentially suitable for nesting

species are available, as shown in the study of nesting habitat selection of the Booted Eagle.

The main dangers for the reproduction of the species in the study area are without a doubt some: the forest burning, which in the period 1994-1998 razed some 75,000 hectares to the ground in central Catalonia districts. On the other hand, until now human disturbance and nesting habitat alteration caused by forest works in seasonal time have little affected the breeding success of this species (Malagarriga, *pers. obs.*). Contrarily, in other Iberian areas where an intense forest management exists the consequences are very negative (García Dios & Viñuela, 2000).

In conclusion, in the central regions of Catalonia the Booted Eagle settles down preferably far from the human establishments, although it tolerates the presence of highways and forest unpaved roads perfectly. Contrarily to what happens in other areas of the Iberian peninsula, where this species breeds in solitary trees, in small groups of trees or small woods (<5 ha) (Suárez *et al.*, 2000, Sánchez-Zapata & Calvo 1999, I. S. García Dios, *pers. obs.*), in central Catalonia the Booted Eagle spreads its nesting in the most abrupt areas, in big trees of extensive, closed and shady forests of Black Pine, headed North, possibly due to the temperature and wind. However, this species can also nest in forests of small extension, in areas where the cereal crops prevail. When nesting is tolerant with other couples of own species and of other raptors (Bosch, 1997, 2000; Garzón, 1974). The orientation of the nests is probably conditioned by the wind direction, the altitude and possibly by the solar radiation, being in the studied area, preferably headed in the quadrant understood between 315°N and 45°N (Fig. 2).

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