Factors Influencing the Distribution and Abundance of Seven Cliff-nesting Ratpors: A Multivariate Study

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INTRODUCTION

In order to provide better conservation and management for raptor populations, it is necessary to determine both their ecological needs and the impact that human activities have upon them. A first step is the use of census data for describing their trophic and nesting requirements, etc.

Quantitative habitat descriptions for different species are generally scarce (Titus & Mosher 1981; Reynolds *et al.* 1982). In the present paper we try to quantify the ecological needs of seven cliff-nesting raptors in the northern Iberian Peninsula. We describe the distribution of each species, compare the interspecific differences in nest-site habitat selection and investigate whether interspecific and intraspecific competition influences this selection.

STUDY AREA

The study area spreads from the Pyrenees to the Iberian mountains, including the Ebro Plain (30TN8 - 30 TM5 north and 30TW4 - 30TX7 west). It is a region with considerable orographic and climatic variation, as a consequence of the union of the Cantabric mountains with the Pyrenees and the Iberian mountains. The northern half is placed in the Euro-Siberian bioclimatic region, with a transition W-E from the Colino-Hyperhumid stage (Atlantic Province) to the Alpine-Hyperhumid stage (Pyrenean Province). Altitude varies from 10 to 2,400 m. The southern half is included in the Mediterranean region, the Ebro Plain reaching the MesoMediterranean-Semiarid stage (Rivas 1983); its average altitude is between 300 and 500 m.

MATERIAL AND METHODS

Density and distribution data come mainly from censuses in 1980-81 (Donazar & Fernandez 1982) and 1984-85 (Lopo & Ceballos 1985), with subsequent updates (Donazar 1986; Fernandez & Leoz 1986; Ceballos & Donazar 1986; Insausti 1986).

The first analysis, of general distribution and densities, was based on a 11,000 km^2 area divided into 29 U.T.M. squares of 20 x 20 km. Each square was characterised by 13 variables: ANP = total annual precipitation (1/m^2); NRD = annual number of rainy days; NFD = annual number of foggy days; ATP = annual average temperature (°C); DQT = annual range of temperatures (average of 4 squares of 10 x 10 km); PTC = percentage of 1 x 1 km squares with cliffs; PTW = percentage of woodland; PTP = percentage of pastureland; RBT = number of rabbits shot/km^2; HOV = head of sheep/km^2; HCT = head of livestock/km^2 (calculated as the product of the following indices: 1 sheep = 1, 1 horse = 3, 1 head of cattle = 5 and 1 pig = 5). NIH = number of inhabitants (1982); NPC = number of population centres.

In the whole area there were 149 pairs of *Neophron percnopterus*, 572 of *Gyps fulvus*, 3 of *Gypaetus barbatus*, 30 of *Aquila chrysaetos*, 6 of *Hieraaetus fasciatus*, 66 of *Falco peregrinus* and 42 of *Bubo bubo*. Principal Component Analysis was used to detect correlations between the number of pairs inhabiting each square and the values of the 13 variables (Fernandez *et al.* 1977; Cuadras 1981).

The second analysis, of nest site selection, was confined to 6 adjacent 20 x 20 km squares in the SupraMediterranean stage. Thirty-four selected cliffs, of which 27 were occupied by studied raptors, were described by means of 10 variables: ORI = an orientation index (NNW = 1, NNE = 1, WNW = 2, WSW and ENE = 3, SSW and ESE = 4, SSE = 5); ALT = altitude (metres above sea level); CFH = cliff height (in metres); MDL = range of altitude in a radius of 500 m (in metres); PTW = percentage of woodland within a radius of 500 m; NIR = number of inhabitants within a radius of 2,000 m; DNV = distance to the nearest village (in metres); DNR = distance to the nearest road (in metres); DQR = range of distances between cliff and nearest road (in metres); RKM = kilometres of road within a radius of 2 km.

Competition was evaluated in the area used for the nest site selection analysis. The distance to neighbouring pairs of all species except *Gypaetus barbatus* was measured from each cliff, scoring 0 for species on the same cliff. The data included 6 species on 34 cliffs. Principal Component Analysis was used to study the interspecific nest site distances and t-tests to compare the average distances to cliffs occupied and non-occupied by the same species.

RESULTS

The first two PCA axes absorbed 61.47% of the variance in habitat variables. The first vector accumulated 42.94% and correlated with a north-south climatic axis on which rainfall (ANP, NRD) and temperature range (DQT) were negative, with positive contributions from high temperatures (ATP), woodland (PTW) and rabbits (RBT). The second vector was negatively influenced by human presence (NIH) and cattle (HCT), with positive contributions from cliffs (PTC) and fog (NFD).

Figure 1 shows the species composition of the 29 squares projected on these two vectors. Thus *Aquila chrysaetos* avoids the area with most human activity, *Gypaetus barbatus* lives in northern zones with abundant cliffs and scarce human population, *Hieraaetus fasciatus* appears in the squares with intermediate characteristics, *Gyps fulvus* avoids the Ebro Plain MesoMediterranean squares, *Neophron percnopterus* is distributed all over the area, *Bubo bubo* is absent from the northern regions and from the excessively developed areas and *Falco peregrinus* is absent from the more populated southern regions.

There were significant simple positive correlations ($p < 0.01$) for the number of pairs per square with cliff abundance (PTC) for *Neophron percnopterus*, *Gyps fulvus*, *Aquila chrysaetos* and *Falco peregrinus* with temperature range (DQT) for *Gyps fulvus*, and negative correlations ($p < 0.01$) with fog (NFD) and human presence (NIH) for *Aquila chrysaetos*.

Since there was a negative correlation ($p < 0.01$) between cliff abundance and human presence, we tested for partial correlation between these variables and Golden Eagle densities. Eagle densities remained significantly correlated with cliff abundance ($r = 0.494$, $p\ 0.01$) but not with NIH ($r = -0.317$, $p > 0.05$).

NEST SITE SELECTION

The first three axes from the Principal Component Analysis explained 61.46% of the variance. The first axis (21.41% of the variance) is characterised by cliffs (MDL, ALT) and roads (DNR),

which probably represent cliff accessibility. The second vector accounted for 20.95% of the variance, with negative contributions from human presence and roads (NIR, RKM) and positive contributions from orientation (ORI) and distance from settlements (DNV). The third axis explained 19.10% of the variance with increase in the variables cliff height (CFH, MDL) and woodland (PTW).

The projection of the 34 sample points on the planes formed by the three axes (Figs. 2 & 3) shows the following tendencies: *Bubo bubo* and, to a lesser degree, *Neophron percnopterus* occupied small cliffs with some human presence. *Aquila chrysaetos* together with *Gypaetus barbatus* seemed to be the most sensitive to human presence: they used the least accessible cliffs. The remaining species fit no particular pattern.

INTERSPECIFIC AND INTRASPECIFIC COMPETITION

The first two PCA axes account for 55.27% of the variance in interspecific spacing and show (Fig. 4) a contrast between two groups of species, *Falco-Aquila* and *Bubo-Hieraaetus*, whose nests are separated by long distances. The Golden Eagle seems to be especially intolerant with regard to other species, and was the only species that showed a significant difference between the distances of occupied and non-occupied cliffs from the nearest occupied cliffs (t = 2.45, p ‹ 0.01), which indicates strong intraspecific competition.

DISCUSSION

Both the size and the distribution of raptor populations may be limited by the availability of suitable nest sites, the existence of trophic resources, climatic factors and human pressures (Newton 1979). In species with either territorial or colonial tendencies, intra- and interspecific competition may exclude some cliffs which are otherwise suitable (Ratcliffe 1980; Fernandez & Insausti 1986; Donazar 1986).

The densities of *Aquila chrysaetos* seemed to be correlated with absence of humans and abundance of cliffs. Although partial correlation analysis indicated that the last factor was more determinant, this species clearly avoids populous zones in other regions (Brown 1969; Mosher *et al.* 1978). The presence of clear intraspecific competition in this species, and not in the other raptors which hunt live prey (Bonelli's Eagle, Peregrine Falcon, Eagle Owl), may be due to the relatively smaller home ranges of the latter together with the irregular distribution of the cliffs in the study area. Only the species with the largest home range, the Golden Eagle, has the possibility of frequent contact between neighbouring pairs.

Gypaetus barbatus is confined to the most precipitous region and to the most inaccessible cliffs. This may be due to the ecological needs of the species or to intolerance of human activities. Possibly the last reason is the most plausible, taking into consideration its wide original distribution and subsequent confinement to the high mountain zones (Hiraldo *et al.* 1977).

Hieraaetus fasciatus occupies the SupraMediterranean stage in our region (Insausti 1986). Its abundance was uncorrelated with any of the environmental variables studied, although the low number of pairs (5) prevent firm conclusions. *Hieraaetus fasciatus'* distribution and nest site selection may also have been strongly influenced by *Aquila chrysaetos*. These species do not occur together on the same cliff in our region (Fernandez & Insausti 1986), although they frequently alternate between years in the Mediterranean area (Real 1982; Parellada *et al.* 1984; Clouet & Goar 1984; Fernandez & Insausti 1986).

In the case of *Gyps fulvus*, the occupation of mountain cliffs in precipitous areas with little fog could result from a search for optimum gliding conditions. Food availability did not seem to be fundamental for determining nest density; the major colonies were where there were most cliffs.

Possibly the ability to travel long distances makes it easy to prospect throughout the study area, starting from stable settlements on the most favourable cliffs.

Neophron percnopterus was distributed all over the study area, its density correlating strongly with the abundance of cliffs. Its great tolerance of human activities, together with its tendency to use the nest sites which optimise foraging throughout its home range (Bergier & Cheylan 1980), lead it to occupy accessible cliffs and very populous areas.

The tendency of *Bubo bubo* to occupy cliffs at a low altitude in rabbit-rich areas explains the distribution of this raptor in the European Mediterranean area (Choussy 1971; Blondel & Badan 1979) and can be linked to the need for good hunting zones near the nest site (Donazar 1986). The lack of rabbits in the Pyrenean mountains may prevent the establishment of *Bubo bubo* there, since there are few large alternative prey (Choussy 1971; Donazar 1986).

Falco peregrinus appears to depend only on cliff availability. The nest site selection was apparently greatly influenced by interspecific competition from *Aquila chrysaetos* (Ratcliffe 1980) and *Bubo bubo* (Donazar 1986), and perhaps also from *Hieraaetus fasciatus* (Thiollay 1967).

ACKNOWLEDGEMENTS

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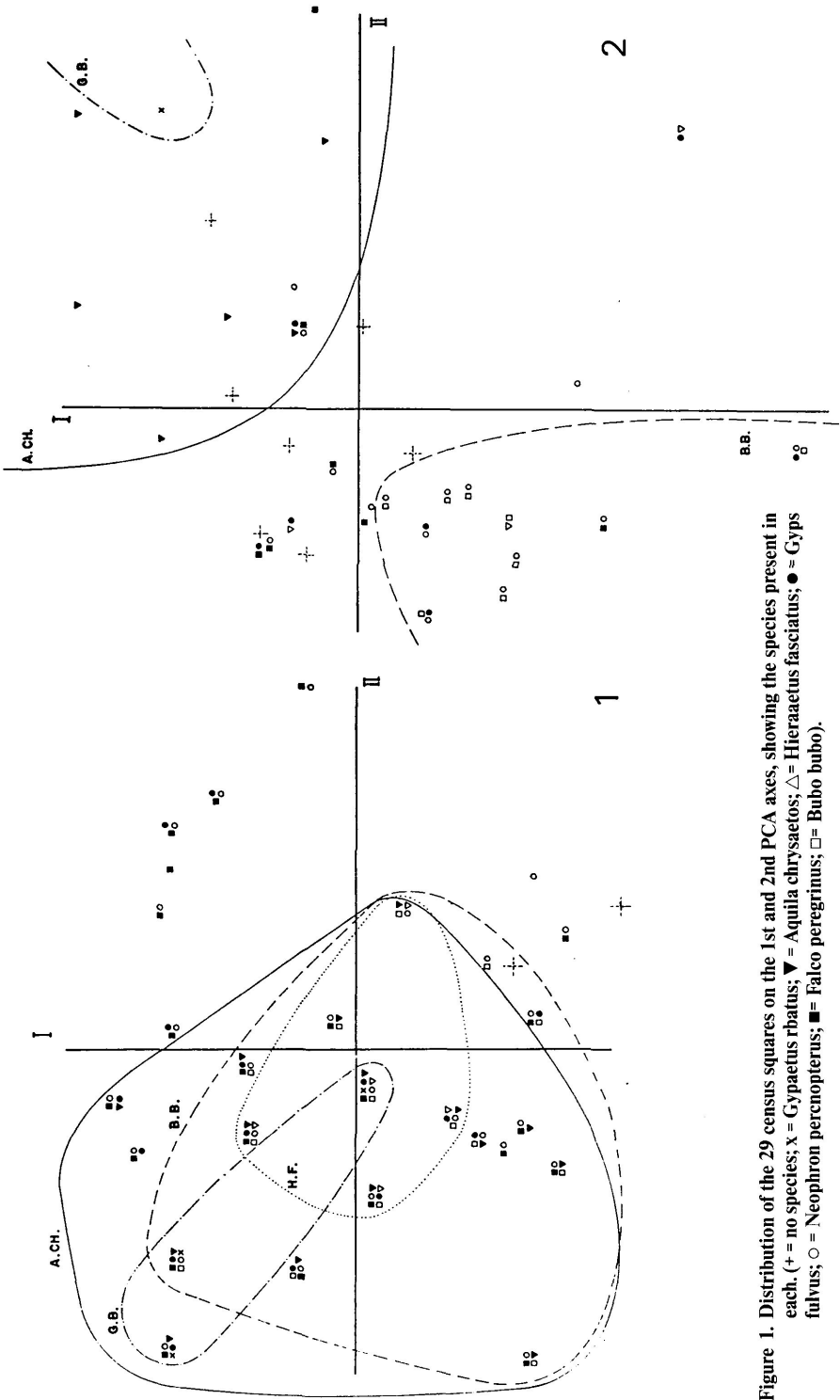Pedro I II
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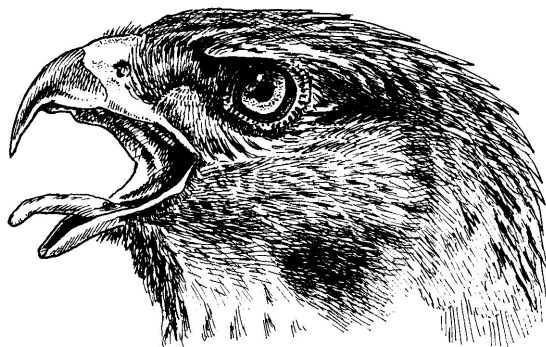
Figure 1. Distribution of the 29 census squares on the 1st and 2nd PCA axes, showing the species present in each. (+ = no species; x = Gypaetus rbatus; ▼ = Aquila chrysaetos; △ = Hieraaetus fasciatus; ● = Gyps fulvus; ○ = Neophron percnopterus; ■ = Falco peregrinus; □ = Bubo bubo).

Figure 2. Nest-site selection. Projection of the 34 census cliffs on the 1st and 2nd PCA axes. The species at each cliff are shown as in Fig. 1.

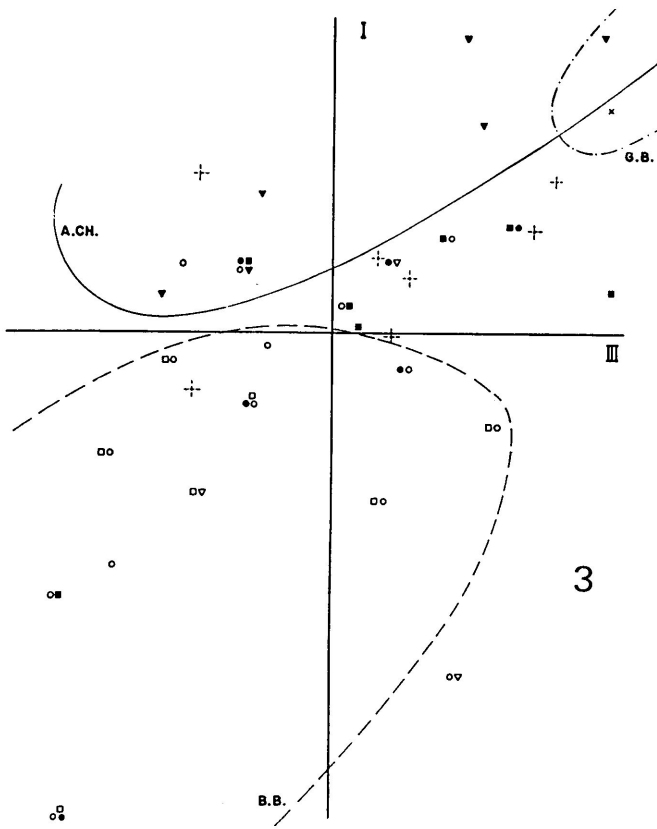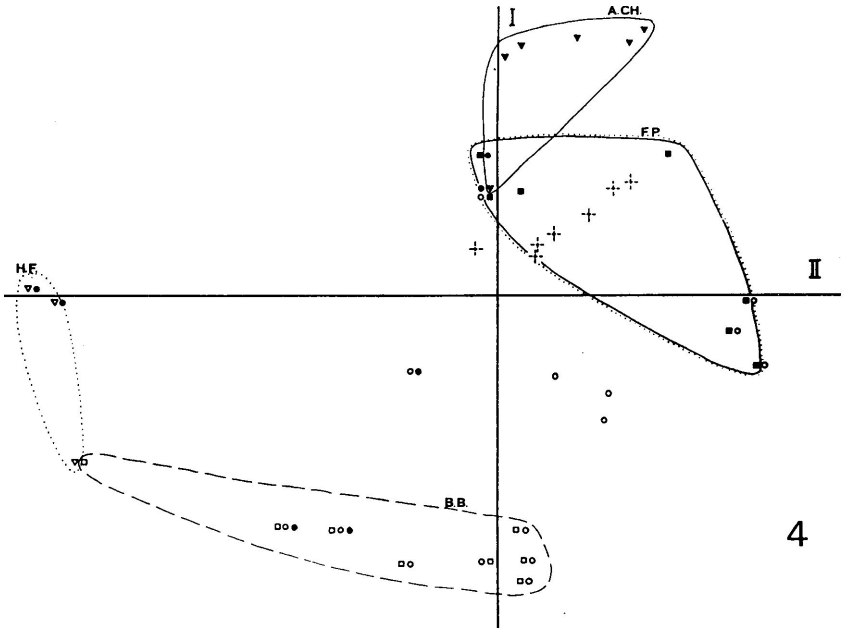Figure 3. Nest-site selection. Projection of the census cliffs on the 1st and 3rd PCA axes.

Figure 4. Interspecific competition. Projection of the 34 census cliffs on the 1st and 2nd PCA axes. The symbols for species at each cliff are shown in Fig. 1.