Etología, 1:19-31 (1989)

Nest placement by azure-winged magpies (*Cyanopica cyana*)

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ABSTRACT. *Nest placement by azure-winged magpies (*Cyanopica cyana*).*- Nest position inside the tree was studied in 32 nests of azure-winged magpies (*Cyanopica cyana*) belonging to three colonies. All nests were found in holm oaks (*Quercus rotundifolia*). Differences between colonies were observed regarding nest-tree size but not between variables characterizing the position of the nest. Nest height above ground did not correlate with tree size, while nest distance to bole did. It is argued that birds maximized nest-bole distance in order to prevent predation by nocturnal mammals. At a given nest-bole distance, nest position (nest-bole angle) inside the canopy is thus aimed at minimizing total costs arising from terrestrial predation, (which increased as nests were placed closer to the lowest branches) and those arising from aerial predation and poor nest insulation against climatic conditions (both of which decreased as nests were placed closer to lowest branches). At a given nest height, partial correlation analyses showed that nests placed at created distances from the bole survived for longer periods of time. Also, nest height affected nest survival adversely at a given distance to bole. Predictions of such a tradeoff model are supported: nests in trees with large canopy radii (and, hence, less prone to predation at given nest-bole angle) were placed in lower branches and survived better than comparable nests placed at wider angles. Data on nest site features for other populations are reviewed.

KEY WORDS. *Cyanopica cyana*, Nest site, Breeding ecology

Introduction

Most bird species show clear nest site preferences. Adequate sites may be limited, especially for hole-nesting species (Lack, 1972) but also for birds that build open nests on vegetation, as indicated by instances of nest site reuse and take-overs (Mckenzie et al., 1982), their availability may influence habitat selection (Hilden, 1965). Differences in nest site features have been shown to affect breeding success of birds in the same population (Lack, 1972; Roëll, 1978; Loman, 1979). Consequently, habitat selection mechanisms are expected to be adaptive. In predictable or uniform environments, specialized optimal phenotypes will be favoured, while in habitats with unpredictable fluctuations, either a single phenotype capable of greater adjustments or temporally polymorphic populations will evolve depending on whether fluctuations are short or long in relation to generation time (Furrer, 1975).

Studies on nest-site selection usually reveal variations between individuals of a population, sometimes causing different species of the same community to overlap widely (Mckenzie et al., 1982). In predictable environments, where specialization is likely to occur, many ecological constraints (i.e. is intense intra- and interspecific competition, absence of preferred plant species, etc.)

may force some individuals away from the optimum. In this respect, comparisons between populations can be helpful in determining what is being actually selected. The variables more intensely affecting reproductive success are expected to remain conservative since deviations from the optimum are more costly. For colonial species, comparisons between colonies that breed in the same area may be even more valuable since a variety of ecological factors (food and vegetation type, climate, interspecific competitors and predators) can be assumed to remain fairly constant.

The azure-winged magpie (*Cyanopica cyana*) is a small corvid which inhabits low, open woodland areas in the south-west of the Iberian Peninsula (Sacarrao, 1972). It breeds between April and June in loose colonies of three to 13 nests (Hosono, 1966; Pacheco et al., 1975), although larger colonies have been occasionally encountered (Cruz, 1988). Data on nest site selection in this species are scarce and partly contradictory (Sacarrao & Soares, 1976). On the other hand, the Iberian and Japanese populations bear amazing similarities regarding some aspects of their breeding biology (Hosono, 1966, 1971; Dos Santos, 1968; Alvarez, 1974; Araujo, 1975; Pacheco et al., 1975). In this paper we analyse the nest site features of this species by comparing nests belonging to different colonies of the same breeding population; we also discuss the potential adaptive implications of the results obtained.

Material and Methods

The study area was a ca. 8.5 km^2 holm oak (*Quercus rotundifolia*) open woodland lying 38°28'N, 5°21'W. It has long been managed as pastureland and the shrub layer has been removed throughout except on the steeper slopes. Other tree species were rare and all nests (32) were found in holm oaks. This limited the available range of nest-tree variables but, in turn, provided us with a uniform background for comparisons between nests. Weather conditions during spring 1984, when field data were collected, were extremely adverse and most nests failed to fledge any youngs. This prevented us from making comparisons between successful and failed nests with regard to nest-site features. Instead, we obtained an estimate of nest survival as the number of days over which a brood was found to be alive or being brooded by parents since clutch initiation. Nests were periodically revisited every two or three days.

After nests were found empty or deserted, we measured the following variables:

- NSO: North-South component of Nest Vector orientation.
- EWO: East-West component of Nest Vector orientation.
- CIRCUL: Bole circumference at 1 m above ground.
- TOP: Height above ground of the highest nest-tree leaves.
- LEAF: Height above ground of the lowest nest-tree leaves.
- STUMP: Height above ground of the point at which prime branches sprang.
- RADIUS: Distance between bole and canopy edge measured on the horizontal plane in the direction of the nest (Canopy Radius).
- HEIGHT: Nest height above ground.
- DISTANC: Distance between nest and bole end, measured on the horizontal plane.
- MODULE: Nest distance to the point at which prime branches sprang (Nest Vector Module).
- ANGV: Nest Vector inclination above the horizontal plane.
- BRDIA: Diameter of the nest branch 5 cm from the nest.
- BRANG: Inclination of the nest branch above (below) the horizontal plane.

Two nests belonging to the largest colony were found in the same tree 2 m apart and were included as separate cases for all analyses except the principal component analysis. The typical pattern of a holm oak tree includes a short bole from which two or three thick prime branches spring at about the same height and then ramify into the

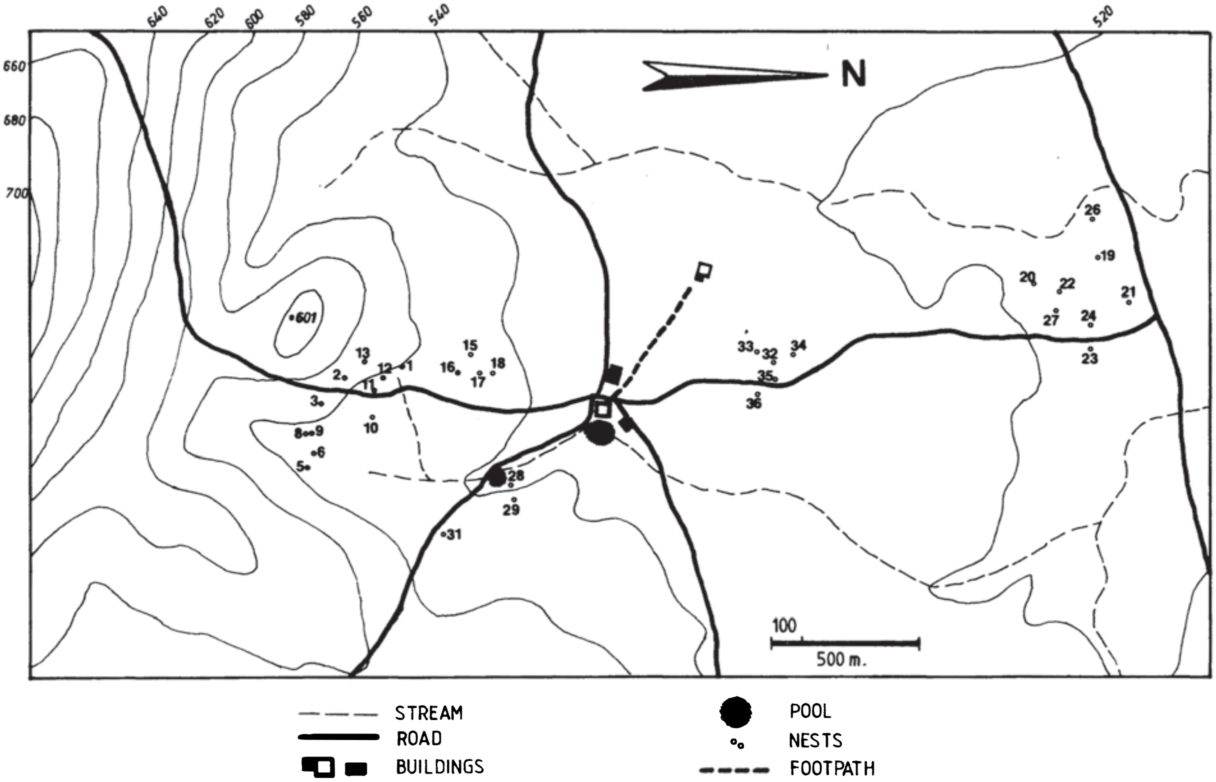

FIGURE 1. Map of the area studied. Figures refer to field labels of trees containing active nests.
[Mapa del área de estudio. Los números se refieren a identificadores para los árboles que contenían nidos activos.]

canopy. We can visualize a Nest Vector starting at the point prime branches spring (bole end) and pointing to the position of the nest inside the canopy. The orientation of this vector was divided into two components. High values of the NSO and the EWO components indicate, respectively, a South-facing and a West-facing position of the nest. Actual values of Nest Vector orientation, inclination (ANGV) and MODULE were taken *in situ* by holding a pole between the nest and the end of the bole which supported a compass and a clinometer. All nest trees were located on a 1:15000 map in order to measure inter-nest distances. We obtained a matrix of distances between nest-trees, which was subjected to principal component analysis (Foucart, 1985) with the aim of obtaining clusters of nests with a similar spatial distribution relative to the remaining nests. Once colonies were established according to this criterion, a factor discriminant analysis (Foucart, 1985) was carried out in order to determined if a nest's assignement to a colony was only a function of the nest-site variable values. Finally, correlation analysis, one-way variance analysis and chi-squared tests of independence for 2x2 contingency tables were made according to Sokal & Rohlf (1981). Partial correlation analyses

TABLE I. Matrix of correlation between nest-site variables. Non-significant correlations at $p<0.05$ are omitted.
[Matriz de correlaciones entre variables.]

	1	2	3	4	5	6	7	8	9	10	11	12
1.NSO	+											
2.EWO		+										
3.CIRCUL	-0.38		+									
4.TOP			0.85	+								
5.LEAF				0.47	+							
6.STUMP			0.56	0.52	0.48	+						
7.RADIUS			0.50	0.44			+					
8.HEIGHT								+				
9.DISTANC			0.50	0.45			0.78		+			
10.MODULE			0.44	0.40			0.45	0.40	0.55	+		
11.ANGV							-0.52	0.61	-0.69		+	
12.BRDIA												+
13.BRANG							-0.38	0.51	-0.54		0.77	0.39

(Zar, 1984) were made to search for associations between pairs of variables while controlling the effects due to a third one.

Results and Discussion

Differences between colonies.

Figure 1 shows the spatial distribution of nests over the area studied. They tend to be located both close to roads and water (ponds or streams), from which they obtain the mud used in nest building. Two colonies of eight and five nests (Colonies I and II, respectively) could be easily seen while nests in the third colony seemed to belong to two subgroups (nests 1-18 and 28-31). Our interest in assigning each nest to a colony, led us performe to a principal component analysis in order to determine if four, rather of three colonies should be considered. The analysis revealed only three nest clusters distributed over the plane defined by the two first components, only 2% of the total variance remaining unaccounted for.

Colonies I and II lay on flat ground (mean slope 4.9°±0.91 SE and 3.8°±1.2 SE, respectively) while Colony III was spread over the foot of a hill with higher slopes (10.3°±2.6 SE), though differences were not significant (one-way ANOVA, F=1.67, df=2.29, ns). Considering all nest-site variables at a time, each nest could be accurately assigned to its colony, showing that colonies represented, in some way, distinctive entities. A factor discriminant analysis correctly classified 31 out of 32 nests (97%). Nest 29, which was intuitively ascribed to Colony III, was assigned to Colony II according to the analysis.

While this multivariate technique takes into account interactive effects due to intercorrelations between variables, it does not provide us with a method for identifying those variables that cause differences between colonies. Consequently, we ran simple linear correlation analyses for the whole sample of nests (table I) and one-way ANOVAs (table II) in order to detect associations between variables and differences between colonies. Significant differences arose for a subset of highly intercorrelated variables (CIRCUL, TOP and STUMP). These variables are indicative of tree size, particularly CIRCUL and TOP. Birds in Colony III nested, on average, in larger trees than those in colonies I and II. Despite this, nest locations were quite similar with respect to height above ground

TABLE II. Mean (±SE) values of nest-site variables for colonies and comparison tests between colonies (One-Way ANOVA).
[Medias y errores típicos de las variables para cada una de las colonias y comparación entre colonias.]

Variable	Colony I	 II	 III	$F_{(2.29)}$	p
NSO (°)	89.6 ± 14.7	102.1 ± 26.2	87.9 ± 13.4	0.13	ns
EWO (°)	71.3 ± 21.2	98.5 ± 17.1	91.3 ± 10.8	0.61	ns
CIRCUL (cm)	123.0 ± 7.0	94.0 ± 9.0	143.0 ± 6.0	8.10	0.01
TOP (cm)	666.0 ± 25.0	550.0 ± 36.0	790.0 ± 24.0	14.54	0.001
LEAF (cm)	202.0 ± 16.0	233.0 ± 29.0	184.0 ± 16.0	1.15	ns
STUMP (cm)	260.0 ± 19.0	195.0 ± 13.0	234.0 ± 9.0	3.65	0.05
RADIUS (cm)	368.0 ± 26.0	308.0 ± 30.0	372.0 ± 25.0	0.51	ns
HEIGHT (cm)	451.0 ± 40.0	407.0 ± 26.0	447.0 ± 26.0	0.32	ns
DISTANC (cm)	151.0 ± 42.0	215.0 ± 41.0	232.0 ± 26.0	1.49	ns
MODULE (cm)	264.0 ± 41.0	284.0 ± 28.0	318.0 ± 28.0	0.67	ns
ANGV (°)	54.8 ± 10.6	48.1 ± 6.5	40.9 ± 5.3	1.01	ns
BRDIA (cm)	4.9 ± 0.9	3.3 ± 0.5	4.5 ± 0.6	0.77	ns
BRANG (°)	28.9 ± 10.6	24.0 ± 15.2	16.1 ± 12.0	0.23	ns

(HEIGHT), distance to bole (DISTANC) and Nest Vector module (MODULE). Nevertheless, both DISTANC and MODULE correlated positively with tree size, while HEIGHT did not. Such a lack of a correlation did by no means indicate that birds selected a narrow range of height values for placing their nests but, rather, that nest height was not maximized. At a given tree height, nests were found over a wide range of heights above ground (fig. 2). This is quite surprising since, for Japanese populations of *C. cyana* (Hosono, 1971: table II) and also in the Magpie *Pica pica* in Coto Doñana (Alvarez & Arias de Reyna, 1974), fledging success correlated positively with nest height (Spearman's rank correlation, r=0.81, N=8, p<0.05 for Hosono's data). Conversely, when trees were larger, both DISTANC and MODULE increased (table I), suggesting that what birds were actually maximizing was the distance to the bole. These two variables were highly correlated with canopy radius (RADIUS). No differences between colonies were detected in RADIUS mean values, although they were also correlated with tree size. Figure 3 shows that a large proportion of nests were placed close to the canopy edge.

MODULE values were also usually large; only two nests (6 and 23) were less than 2 m apart from the bole. This variable also correlated with space availability in the canopy in the Nest Vector direction. We illustrate this point in figure 4 by plotting MODULE values against the distance between the edge of the bole and the central point of the rectangle whose sides are the values of RADIUS and (TOP-LEAF), i.e. half the diagonal of this rectangle. As canopies are not rectangular, but rather elliptical in shape, these points are usually close to the canopy edge.

Why should a bird keep its nest away from the bole? Perhaps the most pausible answer is to avoid terrestrial predators. The most frequent nest predators in our study area were birds (raptors and other corvids) and, less important, lizards, both diurnal, and nocturnal mammals (rodents and carnivores). As a colonial breeder, *C. cyana* engages in vigorous communal defence of nests against intruders, but birds are inactive at night, just when mammalian predators are not. Unlike diurnal predators, mammals often prey upon both the brood and the adult birds in the nest, so they may become a more intense selective pressure acting on birds' behaviour to conceal the nest. By keeping their nests at a long enough distance from the bole,

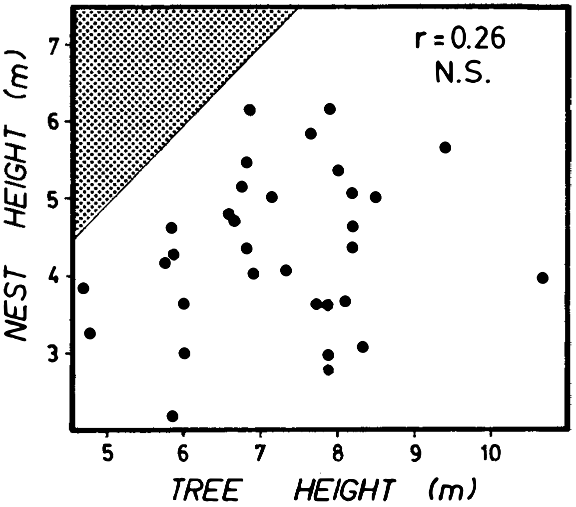

FIGURE 2. Plott of nest height above ground (HEIGHT) against nest-tree height (TOP). The shaded area corresponds to forbidden HEIGHT values (i.e. those cases in which Y should be greater than X).

[Altura del nido vs. altura del árbol.]

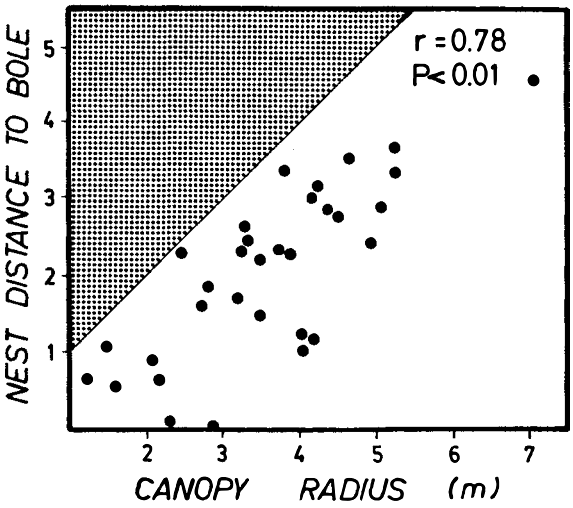

FIGURE 3. Plott of nest-bole distance (DISTANC) against the distance between bole and canopy edge (RADIUS), both measured on the horizontal plane. See FIGURE 2 for more detail.

[Distancia horizontal al tronco vs. radio de cobertura en la dirección del nido.]

birds probably reduce olfactory clues used by nocturnal predators in search for them.

Canopy shape and nest location

Most canopies (90%) were "vertical" in shape, with (TOP-LEAF) values usually exceeding those of RADIUS. For birds to maximize distance to bole under such conditions, nests should be placed near the tree top, since MODULE values can be maximized in this way. There was significant correlation between canopy "verticality", calculated as an index (TOP-LEAF)/RADIUS, and inclination of the Nest Vector above the horizontal (r=0.61, df=30, p<0.01), but about half of the nests were found in very low positions within the canopy, thereby suggesting that more complex relationships should exist between Nest Vector inclination and canopy shape. Although increasing the angular value of the vector may result in lower costs of nest destruction by terrestrial predators, it also probably facilitates nest taking by avian predators. Nests located by wide angles may also suffer from higher thermal fluctuations readily and be more exposed to rainfall than those covered by a larger amount of foliage. Perhaps it would be more realistic to see optimum angular values as a tradeoff between these two cost functions, preferred angles being those at which total costs are minimal (fig. 5). Birds using "vertical" canopies to position their nests should choose wide angles since this is the only way they can achieve a long distance to the bole. But, for birds having trees

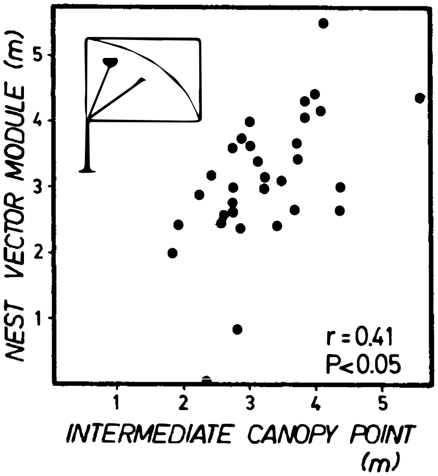

FIGURE 4. Actual nest-bole distance (MODULE) plotted against the distance between the bole and the intermediate canopy point. Such distances are half the diagonal of the rectangle whose sides are (horizontal) the bole-canopy edge distance (RADIUS) and (vertical) the canopy height (TOP-LEAF).

[Distancia del nido a la cruz del árbol frente a distancia a la cruz del centro geométrico de la sección de la copa en el plano radial que contiene el nido.]

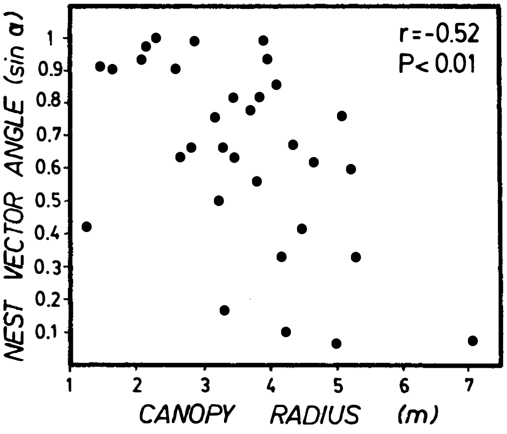

FIGURE 6. A prediction of the tradeoff model. Plotting of Nest Vector angle (ANGV) values against canopy radius (RADIUS): nests placed inside large canopies usually lie on the lowest branches.

[Inclinación del vector cruz-nido vs. radio de cobertura del árbol soporte.]

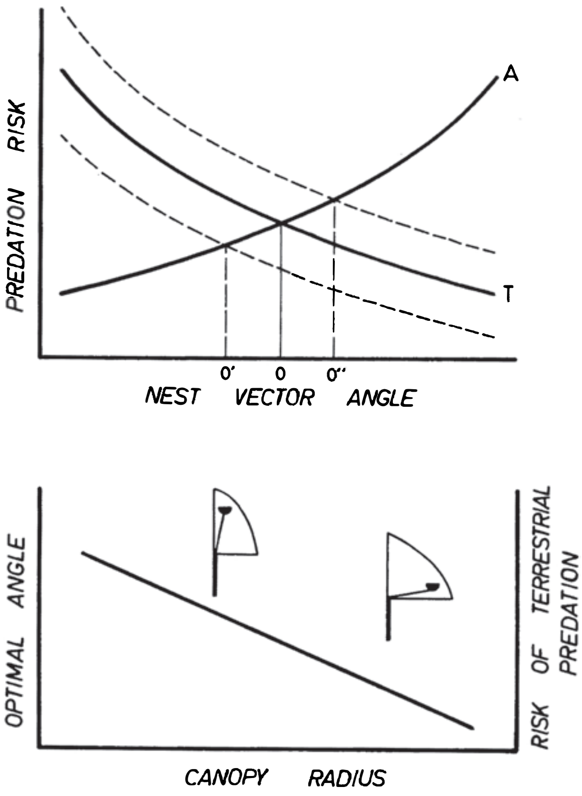

FIGURE 5. A tradeoff model of optimal Nest Vector angle. Costs due to terrestrial predation (T) were assumed to decrease, and costs due to aerial predation and poor nest insulation (A) to increase as a function of Nest Vector angle. The optimal nest angle was at which the sum of costs (A+T) was minimal. As T increase, so did the optimal angle it. Variations in canopy radius affect T predation risks: keeping Nest Vector angle constant, T costs can be reduced by enlarging nest-bole distance and so they should decrease as canopy radius increases. Otimal angle values should reflect indirectly such variations.

[Un modelo de optimización de la inclinación del vector cruz-nido. Se asume que los costos debidos a predación de origen terrestre (T) y a predación aérea junto con un deficiente aislamiento del nido (A) decrecen y aumentan, respectivamente, como una función de la inclinación. El ángulo de inclinación óptima es aquél para el que la suma (A+T) es mínima. Según aumenta la pendiente de T, el óptimo crece. Para una inclinación constante, los costos T pueden reducirse aumentando la distancia horizontal al tronco sin por ello aumentar A: los nidos situados en árboles con grandes radios de cobertura deberían situarse en las ramas inferiores.]

with large canopy radii, it should be better to choose lower branches because they can reduce the risks of being disturbed from the air (or other costs), while keeping an adequate distance to the bole. Variations in canopy radius then affect the expected risk of terrestrial predation in such a way that this prediction of the tradeoff model can be easily tested. Canopy radius and the angular value of the Nest Vector proved to be negatively correlated (fig. 6). Such a trend also holds on computing a partial correlation coefficient between ANGV and RADIUS by controlling the effects of MODULE (partial r=-0.50, df=29, p<0.01), i.e. when the actual distance to the trunk is kept constant. In fact, it was quite easy for us to predict in the field that trees of very large canopy radii should contain nests placed in the lowest branches. These branches were usually thinner (sometimes sprouts) and showed lower inclination angles than the higher branches, which accounts for the observed correlations between BRDIA and BRANG with ANGV (table I).

Nest location and brood survival

Breeding success in our study area was extremely low. Only one nest out of 32 fledged young successfully, 20 nests (62.5%) were deserted prior to or during incubation, and the remaining 11 were found empty during the incubation or nestling stages. No evidence of nestling abandonment was found, so we attributed whole-brood losses entirely to the action of predators. It is possible that adverse weather conditions, which caused insect occurrence to be smaller, stressed predation pressure because of youngs being hungrier and parents spending longer periods away from the nest (Yom-Tov, 1974).

Since nests that are easy to find by predators are destroyed more rapidly, the maximum age recorded for a brood can be used as an indicator of the difficulty in locating it (Ricklefs, 1969). We found that, for non-deserted clutches, maximum brood age increased with increasing DISTANC values (r=0.56, df=10, p=0.0596), i. e. in the direction assumed by the model. In addition, brood age showed significant partial correlation with ANGV values when controlling MODULE effects (partial r=-0.75, df=9, p<0.01; simple r=-0.70, df=10, p<0.02), as predicted by the model. Surprisingly, we obtained a negative correlation between brood age and HEIGHT values (r=-0.62, df=10, p<0.05) which, in turn, could be used as evidence for excess mortality of nests placed on the highest branches under unfavourable weather conditions. When HEIGHT effects were controlled by means of partial correlation analysis, brood age and DISTANC proved to be positively correlated (partial r=0.70, df=9, p<0.02). Also, when DISTANC was kept constant, brood age showed a higher partial correlation with HEIGHT values (partial r=-0.74, df=9, p<0.01). Contrary to expectations, brood age did not correlate with MODULE values (r=-0.10, df=10, ns) though this could be partly an effect of MODULE and HEIGHT being positively correlated to each other (table I). In fact, when HEIGHT effects were controlled, brood age increased with increasing MODULE values (partial r=0.58, df=9, p=0.059). Correlation between brood age and HEIGHT also improved when MODULE was held constant (partial r=-0.77, df=9, p<0.01).

In summary, the distance to bole and height above ground affected nest survival in the direction assumed by the model. Also, as predicted, for a given MODULE value, nests placed in trees with large canopy radii lay on the lowest branches and survived better than those placed at wide angles.

Comparison with previous studies

Information on the nest site features of the azure-winged magpie is scarce. The only two features studied in relative depth are nest height above ground and the preferred plant species for placing the nest. Regarding the latter, Sacarrao & Soares (1976) pointed out that great differences exist about the recorded number of nest-tree species cited by different authors and claimed that *C. cyana* behaves as highly eclectic regarding plant selection.

TABLE III. Data on nest-tree species selection and nest height above ground obtained in previous studies.
[Datos sobre especies de árboles empleadas como soporte y altura del nido sobre el suelo obtenidos en estudios previos.]

					Nest height (m)			t test[b]	
Reference	Nº tree species	Diversity[a]		Sample Size	Mean	SE	Range	t	p
Alvarez, 1974	1	0.00		14	5.5	0.16	5.5 - 6.8	3.6[c]	0.001
Araujo, 1975	13	0.83	(45%)	61	6.6	e	2.5 - 18.0	-	—
Cruz, 1988	5	0.13	(94%)	184[d]	4.5	0.18	1.5 - 6.6	0.3	ns
Hosono, 1966	16	1.12	(17%)	46	4.4	0.31	2.0 - 10.0	0.0	ns
Hosono, 1971	23	0.59[f]	(38%)[f]	76	4.6	0.23	2.0 - 10.0	0.5	ns
Pacheco et al, 1975	1 (5[g])	0.00	(?)	19	6.6	0.53	2.6 - 11.7	4.5	0.001
This study	1	0.00		32	4.4	0.18	2.2 - 6.3	-	—

a: $H=-\Sigma p \log p$ (Shannon & Weaver, 1975). Percentages are the proportion of nests found in the most preferred species.
b: comparison tests with mean values obtained in this study.
c: comparison with Hosono (1971) is not significant (t=1.56, ns).
d: sample size for nest-height measurements. For tree selection, N=368.
e: not stated.
f: values for 50 nests placed in six tree species.
g: qualitative data, not included in the study.

However, the small diversity values obtained in most studies (table III) suggest that birds may actively select certain tree species for placing their nests.

Differences have also been reported in relation to the preferred position of the nest in the canopy. Alvarez (1974) agrees with us in stating that nests are usually placed near the canopy edge, while Araujo (1975) and Pacheco et al. (1975) found a marked tendency for nests to be placed close to the bole. The latter of these two papers includes no quantitative data on this subject, while that of Araujo (1975, fig. 2) shows a discrete frequency distribution from which the average distance to bole can be roughly estimated (mean=173 cm). Should both populations differ from that of this study regarding nest position relative to the bole, differences could be accounted for in terms of differences in nest height. It follows from table III that both populations nested in pine trees, nests being placed 2 m higher, on average, than those observed by us in holm oaks. Consequently, they might have suffered less from terrestrial predation. The population studied by Cruz (1988), for which most nests were also placed in holm oaks, also showed high values of nest-bole distance (mean=366 cm±18 SE, range 110-650), which is significantly larger to the average DISTANC value found by us (t=5.82, df=214, p<0.001). This author also reports a tendency for birds to select trees with large canopy radii.

Both Araujo (1975) and Hosono (1971) agree when stating that nests are more frequently placed on the lowest, horizontal branches or on the leading branches near the tree top, "this last almost exclusively in pine trees less than 8 m high " (Araujo, 1975). The percentage of nests located on the first (51%, Araujo) or on a horizontal branch (50%, Hosono) was similar in both cases and also similar to that obtained by us for nests placed on branches less than 10° above the horizontal (43.7%) (χ^2=0.5 and 0.15, respectively, df=1, ns). No such tendency towards bimodality was evident from our distribution of ANGV and BRANG values, as judged by visual inspection. However, in a highly diverse plant community like that studied by these two authors, bimodality is expected to occur if canopy shapes are polarized between two extremes: a "vertical" pattern like that of coniferous trees and a "horizontal" one like that of many fruit trees. In fact, most nests observed by them were found in one of these two types of tree.

Evidence for differential reprodutive success relative to nest location comes from two studies. Hosono (1971) found that fledging success of nests placed on a horizontal branch was twice that of nests placed on a leader, though differences were not significant (Chi-square calculated on Hosono's (1971) data, χ^2=1.13, df=1, p<0.25). In a more illustrative way, Cruz (1988) found that reproductive performance of nests located at the very edge of the canopy, hung on sprouts, was significantly higher than that of nests placed on thick, horizontal branches. These two types of nest differed mainly in their DISTANC values since both of them were located near the lowest positions of the canopy. Differences in reproductive success reported by Cruz were apparent when considering total chick losses (i.e. nests which failed in fledging any young), but not partial losses. Typically, total losses are the result of predation (Ricklefs, 1969). Consequently, in the sample analysed by Cruz (54 nests), birds nesting at the edge of the canopy suffered less from predation than those nesting closer to the bole.

Final comments

The azure-winged magpie inhabits almost exclusively areas of well-stocked forest, perhaps as a result of its frugivory (Consul & Alvarez, 1978). In fact, its patchy distribution within the Iberian Peninsula is thought to reflect rather rigid habitat and/or temperature requirements (Goodwin, 1975; Sacarrao, 1982). In predictable environments like the lowland Mediterranean forests, with tree communities often dominated by a single species (mainly *Quercus* spp. or *Pinus pinea*), specialization is likely to be adaptive (Maynard Smith, 1966). Data on *C. cyana* nest site features suggest that birds maximize nest distance to bole in order to avoid terrestrial predators and that nest position inside the canopy may follow rules for diminishing total predation risk. Large trees should provide birds with the highest benefits but some nests which do not conform to this pattern have also been found in this and other populations [see Araujo (1975) for nests placed in bushes]. Nest-site optimization does not necessarily imply specialization since multiple nest-site types can coexist provided that they are (i) equally successful or (ii) in advantage when rare because they counteract nest-searching specializations of predators (Furrer, 1975). Neither possibility can be ruled out for the azure-winged magpie. Particularly, the latter may be relevant to colonial species since assessment of others' reproductive decisions is favoured under communal breeding conditions and they also may suffer from higher risks of search-image specialized predation. A variety of ecological constraints may spread the range of optimal decisions in a way that nest-placing rules can become obscured. For example, tips of holm oak branches are rigid and resistant enough to support a medium-sized nest, while pine-tree twigs are not. Nest-bole distance maximization may be a good rule in the former case, but bole length maximization may be better in the latter.

This model offers an adaptive explanation for the observed patterns of nest placement from a cost-benefit approach. It is simple because many factors related to nest placement which probably affect breeding success are neglected. For instance, some nest positions may be energetically cheaper for a bird to enter the nest and parents would save an important amount of energy while feeding the brood by selecting for them. Also, some favourable positions may be unsuitable owing to mechanical constraints. However, predation pressures may have been strong enough to allow us to account for a great amount of variance in nest-placement patterns by invoking them as the only selective force acting on birds' nesting tactics. Economic models have shed much light over many ethological topics (Krebs & Davies, 1987) and may also prove to be helpful in the domain of nest-site selection studies in the future.

Acknowledgements

We wish to thank N.E. Collias, A. Brosset and two anonymous referees for improving earlier drafts of the manuscript and Alicia Toledo for her invaluable assistance in field work. Diego and Josefina, while in charge of the property 'Los Bermejos', kindly offered us their hospitality and friendiliness during the study period.

Resumen

Emplazamiento de los nidos de rabilargo (Cyanopica cyana).

Uno de los factores que pueden resultar determinantes del éxito de un nido es su localización. Se espera, por tanto, que las aves tomen decisio- nes acerca de dónde colocar el nido sobre una base adaptativa. Las diferentes estrategias de emplazamiento pueden determinarse comparando diversas poblaciones o colonias dentro de la misma población a fin de precisar qué características se eligen dentro del rango de posibilidades disponibles. Se asume que aquellas variables que afectan más intensamente al éxito reproductivo deben permanecer conservativas, ya que las desviaciones del óptimo resultan más costosas.

En este trabajo se analiza la posición del nido dentro del árbol en tres colonias de rabilargo (*Cyanopica cyana*) situadas en un encinar al Norte de la provincia de Córdoba. Para un total de 32 nidos, se midieron 13 variables una vez que el nido era encontrado vacío. La asignación de un nido a cada colonia se realizó mediante un análisis en componentes principales calculado sobre la matriz de distancias de cada nido a todos los demás.

Para describir cuantitativamente la posición de un nido dentro del entorno arbóreo, se define un vector nido originado en la cruz del árbol y apuntando a la posición del nido dentro de la copa. La orientación, inclinación y módulo de dicho vector son tomadas como variables que pueden ser relacionadas con la disponibilidad de espacio en el plano radial de la copa que contiene al vector nido. Un análisis factorial discriminante reveló que cada nido podía ser asignado a la colonia a la que pertenecía únicamente como función de las variables del árbol soporte y del vector nido, mostrando así que las colonias representaban, en cierto sentido, entidades distinguibles. La comparación de los valores de cada variable entre colonias puso de manifiesto que tales diferencias se debían, principalmente, al tamaño de los árboles (tabla II). Las aves de la colonia III eligieron, en promedio, árboles de mayor porte. A pesar de ello, las variables relativas a la posición del nido dentro del árbol no mostraron diferencias. Mientras que el módulo del vector nido y la distancia horizontal al tronco se correlacionaban positivamente con el radio de cobertura del árbol, la distancia sobre el suelo no aumentaba para árboles más altos (tabla I). Las aves no maximizaron la distancia del nido al suelo (fig. 2) pero sí la distancia a la cruz (fig. 3). El módulo del vector nido también se correlacionaba positivamente con la disponibilidad de espacio dentro de la copa (fig. 4).

Es probable que la predación por parte de mamíferos (que alcanzan el nido a través del tronco y predan sobre los padres en incubación a la vez que sobre la puesta) haya constituído una presión selectiva importante para que las aves maximicen la distancia al tronco a fin de reducir los estímulos olfativos. Un estudio reciente (Cruz, 1988) presenta evidencias de un menor riesgo de predación para los nidos situados en el borde de la copa del árbol.

Para la mayor parte de los árboles, maximizar el módulo del vector nido implica a la vez valores altos de inclinación del vector sobre la horizontal, ya que el eje vertical de la copa suele ser mayor que el horizontal. Sin embargo, una alta proporción de nidos

se localizaron en ramas muy bajas, con escasos valores de inclinación. Se sugiere que, aunque elevar la inclinación del nido puede reducir el riesgo de predación terrestre, también aumenta el riesgo de mortalidad por predación aérea y un deficiente aislamiento del nido contra factores climáticos. La posición del nido óptima debería ser aquella para la que la suma total de costos fuese mínima (fig. 5). Se comprueba que, efectivamente, cuando el árbol soporte posee un gran radio de cobertura, los nidos se sitúan en las ramas más bajas (fig. 6), posición que permite a la vez maximizar la distancia al tronco y minimizar los costos asociados a valores altos de inclinación sobre la horizontal. Utilizando el tiempo de supervivencia del nido como una estima del riesgo de predación a que se ve expuesto, se pone de manifiesto que los nidos situados a mayores distancias del tronco, para una altura dada, sobreviven más tiempo y que la altura sobre el suelo afecta negativamente a la supervivencia del nido para una distancia al tronco constante. Además, los nidos situados en ramas más bajas presentan un mayor tiempo de supervivencia cuando el efecto de la distancia real a la cruz se mantiene constante.

Estudios previos realizados en otras poblaciones (tabla III) sugieren una preferencia por determinadas especies de soporte en zonas de elevada diversidad de árboles. Para poblaciones que anidan en pinos, la regla de decisión parece ser maximizar la altura sobre el suelo. A diferencia de las ramas de encina, cuyos brotes apicales son resistentes y permiten colocar el nido junto al borde de la copa, la menor rigidez de los brotes de pino limita las posiciones utilizables cerca del borde, lo que probablemente no permite valores elevados de distancia a la cruz. En tales condiciones, seleccionar árboles de mayor altura puede ser la única estrategia disponible a fin de eludir a los depredadores terrestres.

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(Recibido: 26 octubre 1988)