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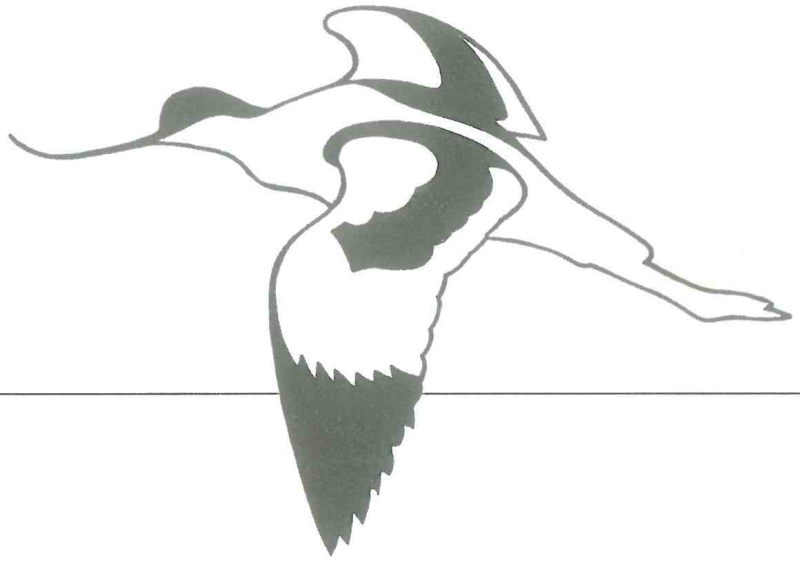

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The influence of nest site characteristics on frequency of use and breeding success in the Cory's Shearwater *Calonectris diomedea*

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Abstract - In the Cory's Shearwater *Calonectris diomedea borealis* of Selvagem Grande (30°09'N, 15°52'W), information was collected for 15 consecutive years on frequency of use and breeding success at 529 nest sites, the physical characteristics of which were measured or coded as ranked variables. Nest type and presence of material outside the nest site were found to have significant effects on both parameters but there were no effects of location, density, vegetation cover or type of floor. Cory's Shearwaters being faithful to their mate and nest site, the frequency of use of a nest site is likely to be more dependant on the length of pairings and on the hazards of repairings than on nest qualities. Breeding success is also likely to depend on the qualities of the breeders more than on those of the sites.

Introduction

Among various parameters affecting the frequency of use of the nest sites by seabirds and breeding success, those related to the nest site itself (location in the colony, orientation, density, depth, material collected,..) have been taken into account less often than those concerning the birds (age, experience and so on), and mostly among epigeous species – auks (Cairns 1980, Harris *et al.* 1997, Hatchwell 1991, Hudson 1982), penguins (Davis and Mc Caffrey 1986, Emslie *et al.* 1995, Stokes and Boersma 1988, Tenaza 1971), gulls (Burger, 1984, Coulson 1988, Jehl 1994) and shags (Shaw 1986). Their influence is in no way obvious and often contradictory, some of them showing, according to the species studied, positive, negative or no perceptible effects : breeding success is thus higher at high density in Guillemots (Harris *et al.* 1997, Hatchwell 1991), though no effect is apparent in the Black Guillemot *Cepphus grylle* (Cairns 1980) and in the California Gull *Larus californicus* (Jehl 1994). In the Herring Gull *L. argentatus* (Burger 1984, Kilpi 1989, Parsons 1976), too high and too low densities reduce egg survival.

Here we present results concerning the Cory's Shearwater *Calonectris diomedea borealis* of Selvagem Grande (30°09'N, 15°52'W), a Portuguese island in the Atlantic Ocean, between Madeira and the Canaries, where about 36,000 birds breed (Mougin *et al.* 1996). Nine nest characteristics have been selected, and their possible effects on the frequency of use of the nests and on breeding success have been studied.

Material and methods

Data were collected from 529 nest sites in three colonies of Cory's Shearwaters of Selvagem Grande, for 15 consecutive years, from 1983 to 1997.

The three colonies are all in the southern part of the island, one on the central plateau, one on the eastern coast and one on the western coast. Both coastal colonies are found on a gentle slope, just above the coastal cliffs. Most nest sites are well or moderately sheltered and only a few are open. The eastern colony is permanently swept by the prevailing winds whereas the western colony is more sheltered. The plateau colony is located on level ground inland, in a stone wall. Nidification is always hypogeous, all the breeding cavities are open to the north and sheltered from the prevailing winds.

Like the whole population of the island (Mougin *et al.* 1996), the breeding birds of the study colonies have increased in numbers, from nearly 400 pairs in the early eighties to nearly 500 pairs at the end of the decade, a value which has remained stable during the nineties.

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The choice of the nest site characteristics depends on the breeding habits of the birds and is therefore locality specific. Table 1 summarizes the 9 characteristics which have been recorded on Selvagem Grande as they seemed likely to influence locally the frequency of use of the nest sites and breeding success. Because some of the birds of that locality nest in the open, the length of nest cavities was not measured. Instead, nest types are described by means of a shelter index (Tab. 1) ranging from 1 (no roof, single wall) to 6 (deep cavity).

All nest sites and breeding adults were marked – if used or breeding for the first time – or checked – if already in use or known – and all the eggs laid were recorded during yearly visits, at the end of the laying period, in the second decade of June. The frequency of use of nests is known as well as the year of first breeding of the birds which enable us to compute their breeding experience as the number of breeding years. Chick survival was recorded in September-October, shortly before they fledge, in order to obtain an estimate of breeding success (number of chicks fledged per number of eggs laid). Chicks were also ringed. The three colonies were mapped, thus allowing the calculation of nest density, distance to nearest neighbour and also, for central nests, shortest distance to the periphery of the colony. Vegetation cover has been estimated during the last year of study – no appreciable differences being apparent between years, at least in the study colonies. Only some nest-sites have been used since the beginning of the study. With an increasing population, sub-optimal new nest sites should have been added in subsequent years to the sites previously in use, with a lower breeding success, and thus nest sites should have shown different breeding success according to their year of first occupation. However this was not the case. For the same frequencies of use, the differences between both types of nest sites for the breeding success are non significant - 0.589 (n = 3228 breeding years) *vs* 0.581 (n = 718 breeding years), $\chi^2_1 = 0.17$, n.s.

The statistical work is mostly based on various types of regressions, linear for continuous variables and logistic for categorical variables. Nine independant variables, collected in the colonies (orientation, vegetation cover, nest type, floor of site, nest material, stones at entrance) or on a map (location, density, nearest neighbour), and two dependant variables, successively frequency of use (number of years of occupation in the 15-year period studied) and breeding success, have been used for the logistic regressions. Frequency of use and breeding success have been used as variables for a linear regression The χ^2 test has also been used when necessary.

Results

Nest site characteristics

More than half (51.4%) of the 529 nest sites studied were peripheral. Colonies being generally elongated along contour lines, no central nest was more than 10 m distant from periphery. Nest sites faced any direction and their density was comparatively low (0.1-0.8 nest/m^2, with 84% < 0.4 nest/m^2). The distance to the nearest nest site varied between 0.2 and 6.3 m - 51% being less than 1 m. Vegetation cover was generally absent (91%). Nest type varied from nests without roof sheltered by one wall to deep individual cavity. The nests without roof were rare (4.2%), as were deep individual cavities (6.5%). 41.3% of the nests were found in a simple niche and 29.4% in a short individual cavity. 18.6% of the pairs nested in a cave, with

Tab. 1. Variables recorded for each nest cavity.

Nest site variables	Description
Location	Shortest distance to the periphery of the colony (m).
Orientation	(1) north, (2) east, (3) south, (4) west.
Density	Number of nest / m^2 in the 10 m^2 surrounding the entrance of the nest considered.
Nearest neighbour	Distance to nearest neighbour of the same species (m)
Vegetation cover	(1) absent, (2) rare, (3) plentiful.
Nest type	No roof: (1) one wall, (2) 2-3 walls. Roof present: (3) niche (1-3 walls and a roof), (4) cave (more than one pair breeding), (5) short individual cavity, (6) deep individual cavity.
Floor of site	(1) rough rock, (2) smooth rock, (3) sand, earth, guano.
Nest material	(1) absent, (2) stones, (3) plants, (4) others and mixed.
Stones at entrance	(1) none, (2) few (<70), (3) many (>70).

one or several other pairs. The floor was generally loose (78.5%), made usually of sand, earth or guano, seldom of rock. 28% of the pairs nested on the bare floor. When a nest was built, stones were used (21%), plants (38%) or various materials (13%). Many stones (13%) or a few (28%) may be gathered at the entrance of some sites. However most of them (59%) were completely devoid of ornamentation.

Frequency of use

The frequency of use was extremely variable. Less than a fifth (18.5%) of the nest sites studied were used during all 15 years while 59% were used in more than 10 years and 7% during one year only (Fig. 1). A logistic regression shows that only two of the parameters taken into account (Tab. 2), nest type and presence of material outside the nest site, affect the frequency of use (Fig. 2 and 3). The presence of material was important but the quantity ($\chi^2_1 = 0.12$, n.s.) or type of material gathered ($\chi^2_2 = 2.71$, n.s.) had no influence. Central nests did not prove to be more attractive than peripheral nests - respectively 0.658 (n = 257) *v* 0.699 (n = 272, $\chi^2_1 = 0.056$, n.s.).

Breeding success

Figure 4 shows that the best breeding success was obtained in the most frequently used nest sites, the survival rate being closely related to the frequency of use (by means of a linear regression: $R^2 = 0.7645$, $F_{1,13} = 42.2$, $P < 0.01$). There is a 2.5 fold increase in breeding success between sites used during 15 years (0.717) and those used during one year only (0.286).

With regards to the parameters more specifically related to nest sites, a logistic regression showed that only nest type, presence of material at the entrance of the nest site and orientation were significantly linked to breeding success (Fig. 5 and Tab. 2). A significant difference existed ($\chi^2_2 = 8.02$, $P < 0.05$) between caves (0.677, n = 97), nests with no roof and one wall only (0.323, n = 10), and all the other types (0.555, n = 414, $\chi^2_3 = 0.21$, n.s.). The presence or absence of stones at entrance - respectively 0.627, n = 217 and 0.534, n = 304 ($\chi^2_1 = 4.65$, $P < 0.05$) - was much more important than their number ($\chi^2_2 = 5.05$, n.s.). Breeding success was not affected by the presence or absence of material inside the nest site, the birds breeding on bare ground obtaining no worse results than those which had gathered some

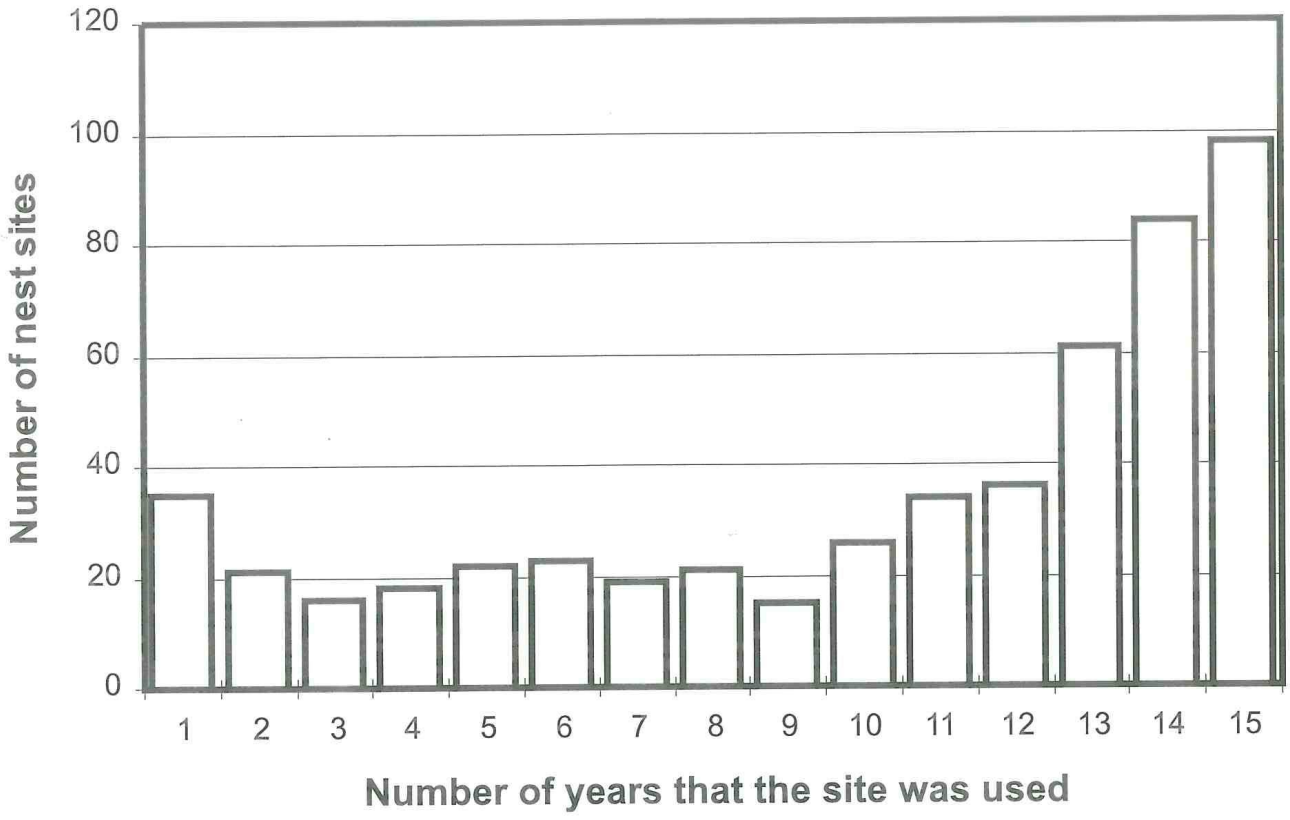

Fig. 1. Number of nest sites used during 1-15 years.

Tab. 2. Parameter estimates of the logistic regression model used to assess the contribution of nest cavity characteristics in explaining frequency of use and breeding success.* $P < 0.05$: ** $P < 0.01$; others $P > 0.05$.

Variable	Frequency of use	Breeding success
Location	-0.43	0.78
Orientation	-1.71	-2.36*
Density	1.91	-1.35
Nearest neighbour	1.88	1.26
Vegetation cover	-0.60	1.17
Nest type	-4.60**	-2.15*
Floor of site	0.15	-0.49
Nest material	1.91	0.60
Stones at entrance	-4.46**	-3.25**

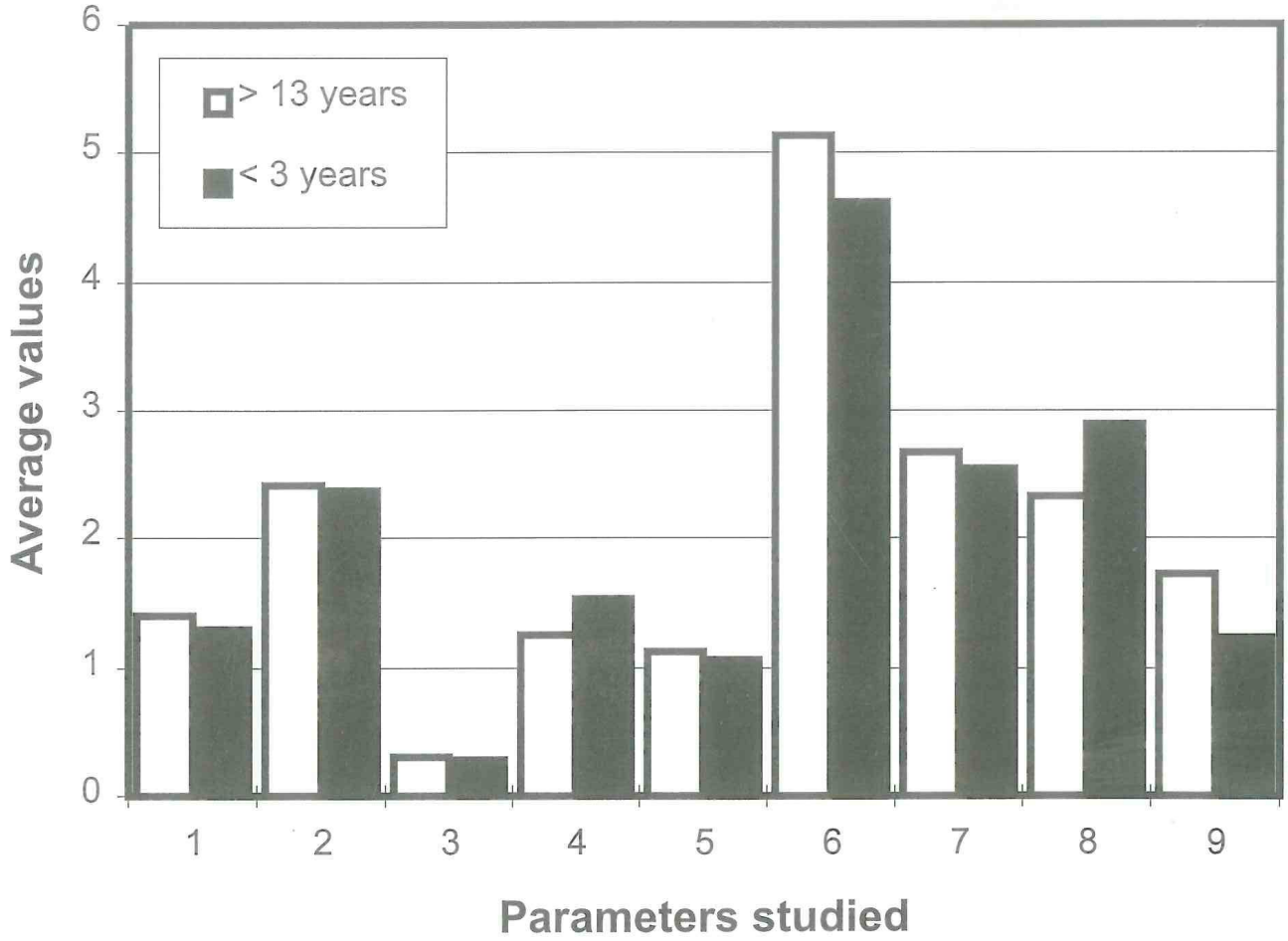

Fig. 2. Compared characteristics of the nest sites used during 1-2 and 14-15 years. 1. location ; 2. orientation ; 3. density ; 4. distance to nearest neighbour ; 5. vegetation cover ; 6. nest type ; 7. floor of site ; 8. nest material ; 9. stones at entrance.

stones or plants - respectively 0.517 (n = 146) *vs* 0.595 (n = 375, $\chi^2_1 = 2.82$, n.s.). It was not either affected by the location of the nest site in the colony, central sites (0.576, n = 257) giving no better results than peripheral ones (0.565, n = 272, $\chi^2_1 = 0.031$, n.s.) or by their density, nests densely grouped (0.5-0.8/m^2, n = 86) giving no better results than nests more sparsely dispersed (0.1-0.4/m^2, n = 443) - 0.594 *vs* 0.566, $\chi^2_1 = 0.23$, n.s.

Finally, on Selvagem Grande, the role of nest depth and imported material is not a secondary effect of the breeding experience of the birds, these parameters

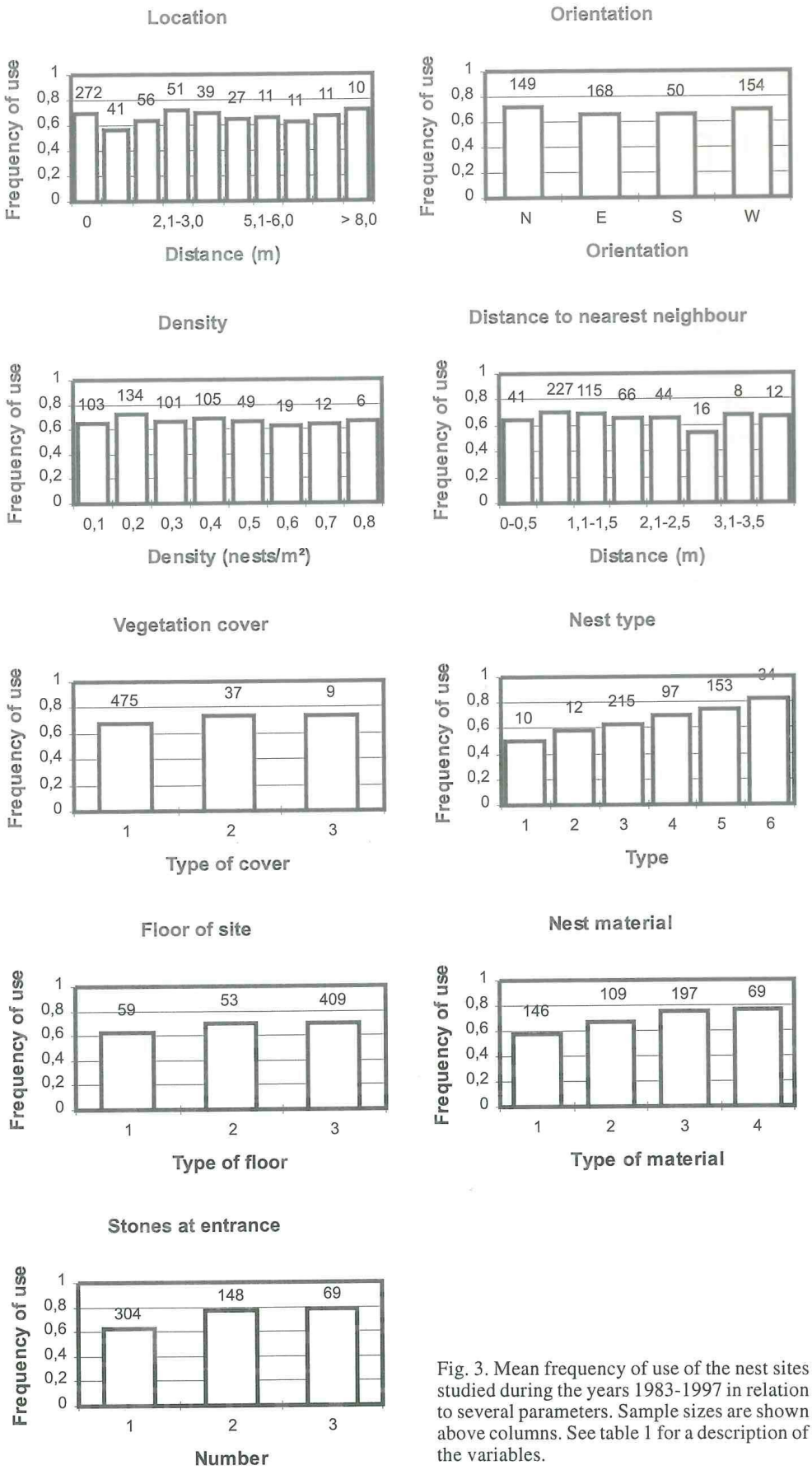

Fig. 3. Mean frequency of use of the nest sites studied during the years 1983-1997 in relation to several parameters. Sample sizes are shown above columns. See table 1 for a description of the variables.

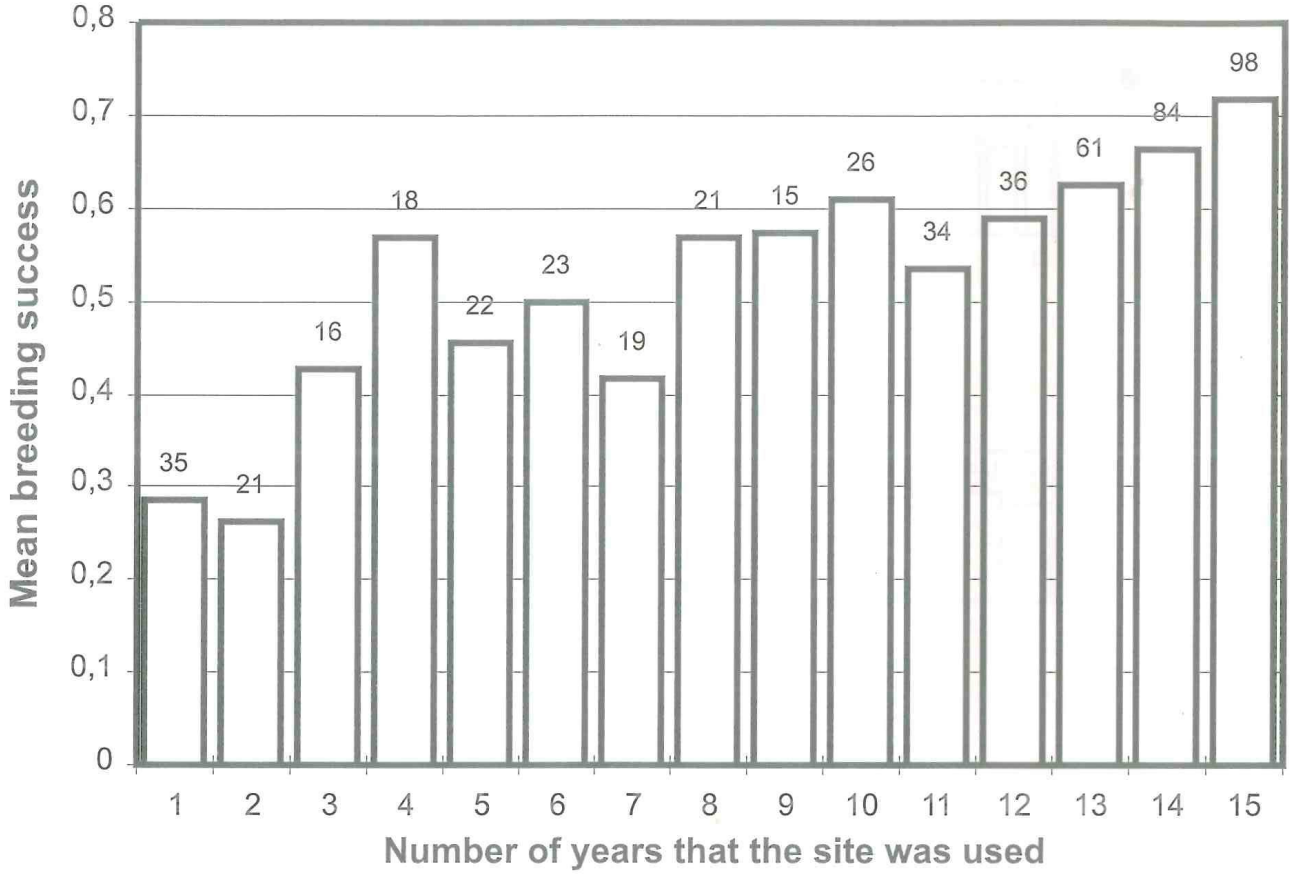

Fig. 4. Mean breeding success in the nest sites studied in relation to the frequency of use during the years 1983-1997. Sample sizes are shown above columns.

being not correlated - respectively $F_{1,159} = 0.072$, n.s. and $F_{2,518} = 2.76$, n.s. Deep nests with many stones are not a characteristic of the most experienced birds.

Discussion

In the Cory's Shearwater of Selvagem Grande, few among the characteristics of the nest sites taken into account were found to affect either frequency of use or breeding success, only the nest type and the presence of material (stones or plants) around the site and perhaps orientation but neither location in the colony nor density, vegetation cover or floor of site. Other studies conducted amongst various species of seabirds have led to frequently inconsistent results. The protection of the nest can play an important part in breeding success - a deep nest site gives better results than a more open one in the Guillemot *Uria aalge* (Harris *et al.* 1997), the Razorbill *Alca torda* (Hudson 1982) and the Magellanic Penguin *Spheniscus magellanicus* (Stokes and Boersma 1998) as in the Cory's Shearwater. But if the Kelp Gull *Larus dominicanus* shows preferences for covered nest sites, the effects of this choice on breeding success are not significant in all cases (Yorio *et al.* 1995). The location within the colony can also be important - central sites give better results than peripheral ones in penguins, Adélie *Pygoscelis adeliae*, and Gentoo *P. papua* (Davis and McCaffrey 1986, Emslie *et al.* 1995, Tenaza 1971), in the Kittiwake *Rissa tridactyla* (Coulson 1988) and in the Guillemot (Harris *et al.* 1997), but neither in the Antarctic Blue-eyed Shag *Phalacrocorax atriceps* (Shaw 1986) nor in the Cory's Shearwater. Breeding success is higher at high density in Guillemots (Harris *et al.* 1997, Hatchwell 1991), though no effect is apparent in the Black Guillemot *Cepphus grylle* (Cairns 1980), the California Gull *Larus californicus* (Jehl 1994) and the Cory's Shearwater. In the Herring Gull *L. argentatus* (Burger 1984, Kilpi 1989, Parsons 1976), too high and too low densities reduce egg survival. These results are difficult to generalise, the parameters under control being possibly affected by conflicting factors. Thus, predation and disturbance, lowering egg survival, are more likely to occur in peripheral than in central nest sites and in low densi-

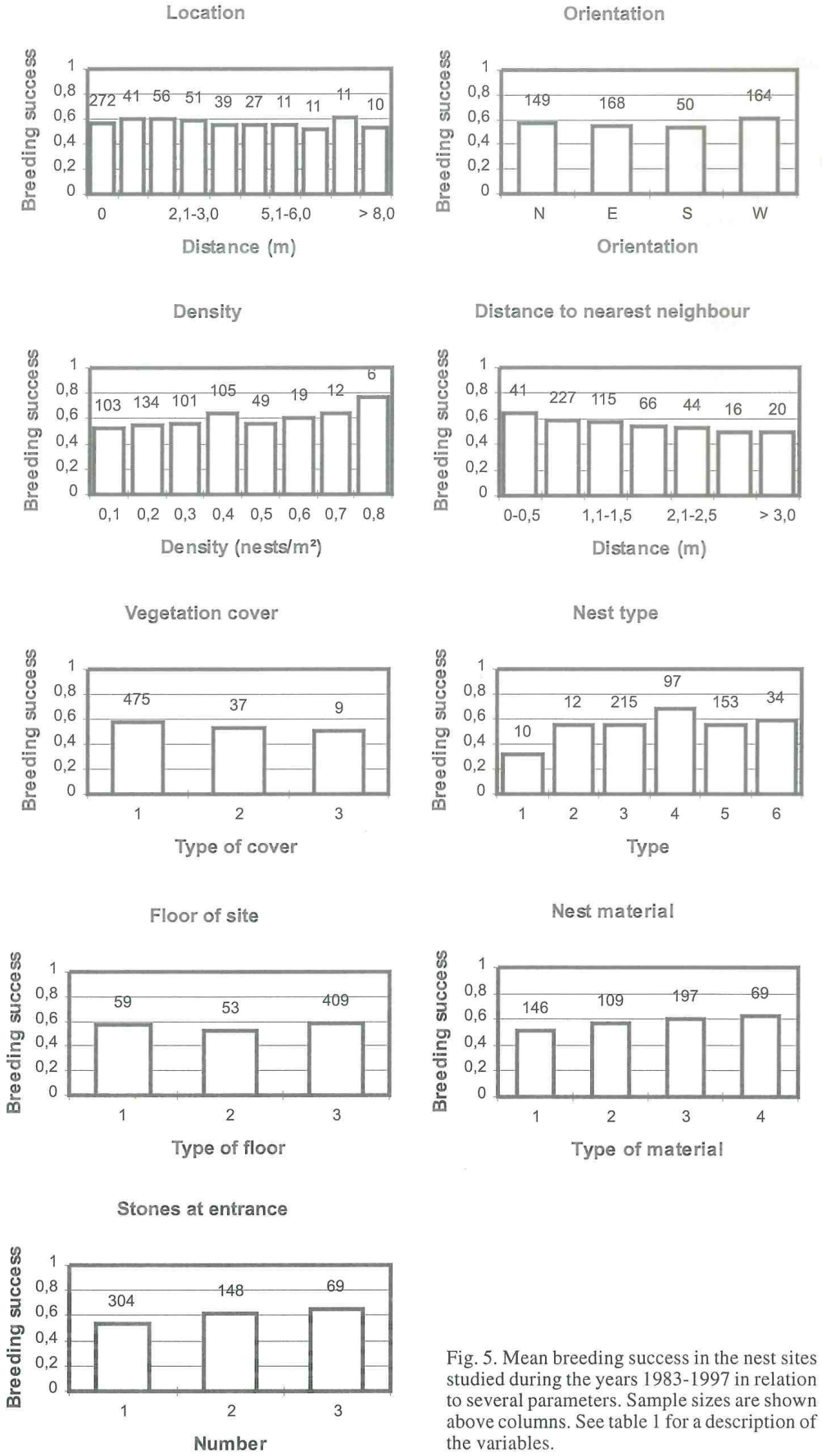

Fig. 5. Mean breeding success in the nest sites studied during the years 1983-1997 in relation to several parameters. Sample sizes are shown above columns. See table 1 for a description of the variables.

ty than in the most crowded colonies. But no effect of the location in the colony is apparent among the cormorants studied by Shaw (1986) : central nests have less access to open water than peripheral nests, but they are exposed to rain and snow to a lesser extent and the degree of social contact is higher.

A study, dealing partly with the Cory's Shearwater, has examined the same problems in Azorean seabirds (Ramos *et al.* 1997) with somewhat different results. As in Selvagem Grande, the depth of the breeding cavity affected breeding success, but not nest density, vegetal cover or ground characteristics. The presence of stones at the entrance of the cavity had much more influence than on Selvagem Grande - the breeding success in the nests with such an accumulation was 2.5 times higher than in the nests without it, *vs* 1.2 times only on Selvagem Grande. The presence of nest material inside the cavity also had an influence, very few of the eggs brooded without material surviving until hatching, which appears not to be the case on Selvagem Grande. Are these cavities with nest material mostly used by experienced birds? The hypothesis has been presented by Ramos *et al.* (1997) for this locality where, furthermore, the Buzzard *Buteo buteo* exerts some predation on chicks. The accumulation of stones at the entrance of the cavities can thus offer some protection. Conditions are different on Selvagem Grande. Stone accumulation is not a characteristic of experienced birds but is linked to the frequency of use of the nests, the regular use of the same site by birds - whatever their experience may be - allowing, in the long run, such an accumulation. Predation is unknown - the Yellow-legged Gull *Larus cachinnans* is locally a scavenger, not a predator of the Cory's Shearwater - and climatic conditions not so rough as to endanger egg and chick survival. Cory's Shearwaters being essentially faithful to their mate and nest site (Mougin *et al.* 1993), the frequency of use of a site is likely to be affected by the length of pairings and the hazards of repairings much more than by the qualities of the sites. The same holds true for breeding success, affected by the experience of the birds (Mougin and Lufbéry, unpubl. data) - appearing in their ability to brood their egg and rear their chick and not in stone accumulation - much more than by nest sites characteristics, even if some nest site characteristics play a significant, but minor, part. Harris *et al.* (1997) have reached the same conclusion in their study of the Guillemot.

Finally, if deep individual cavities are the type of nest site the most regularly used by the birds of Selvagem Grande, caves show the highest breeding success. One should have thought that the presence of several pairs in the same relatively small cavity should have brought a disturbance reducing egg survival, but this does not hold true. The increase of social contacts resulting from several pairs standing close to each other can perhaps induce a higher efficiency of the mechanisms of breeding, and thus increase egg survival.

Résumé - Chez le Puffin cendré *Calonectris diomedea borealis* de Selvagem Grande (30°09'N, 15°52'W), des données concernant la fréquence d'utilisation et la réussite de la reproduction ont été collectées au cours de 15 années consécutives sur 529 nids dont les caractéristiques physiques ont été mesurées ou codées. Le type du nid et la présence de matériel à l'extérieur ont une influence significative sur les deux paramètres étudiés, mais la localisation du nid dans la colonie, la densité, la couverture végétale ou le type de sol n'en ont aucune. Le Puffin cendré étant fidèle à son partenaire et à son nid, la fréquence d'utilisation d'un nid dépend probablement plus de la durée des appariements et des hasards des réappariements que des qualités propres des nids. Il est également probable que la réussite de la reproduction dépend plus des qualités des oiseaux que de celles de leurs nids.

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