THE RELATIONSHIP OF CHICK-SIZE AND NEST SITE OCCUPANCY WITH NEST TYPE AND NESTING DENSITY IN CORY'S SHEARWATER

CALONECTRIS DIOMEDEA ON SELVAGEM GRANDE.

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With 4 tables and 1 figure

SUMMARY. Data were collected on Selvagem Grande over a three week period in August 1984. Tarsus-length was used as a measure of chick size. Rate of tarsus growth appeared to be linear through the period.

The tarsus lengths of chicks from a variety of nest types and nesting densities were measured. Density of nests had more effect on chick size than did nest type or nesting area. Chicks were larger in the denser nesting areas and as a group, were more synchronized in size than those in sparser areas.

Cliffs and walls provided more nesting opportunities than the plateau areas. An active preference for the former areas was suggested by the larger proportion of unused nest sites on the island plateau.

SUMÁRIO. Durante um período de três semanas em Agosto de 1984 foram colhidos dados na Selvagem Grande. O comprimento do tarso foi usado como medida do tamanho do juvenil. A taxa de crescimento do tarso foi linear durante este período.

Foram tomadas medidas dos tarsos em juvenis de vários tipos de ninhos e em áreas com diferentes densidades de ninhos. A densidade dos ninhos teve mais efeito no tamanho dos juvenis do que o tipo de ninho ou área de nidificação. Os juvenis eram maiores nas áreas de maior densidade de ninhos e no conjunto mais sincronizados em tamanho do que nas áreas em que os ninhos eram mais dispersos.

Falésias e muros proporcionaram mais oportunidades de nidificação do que as áreas planálticas. Uma preferência activa pelas primeiras foi sugerida dada a proporção de ninhos não utilizados no planalto da ilha.

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Bol.Mus.Mun.Funchal,38(177):110-119.

INTRODUCTION

This study assesses some of the effects of nest type and density on chick size and nest site occupancy in Cory's Shearwater.

Data were collected on Selvagem Grande which lies 175 km to the north of the Canary Islands. The island is 160 hectares in area and has steep cliffs rising to a plateau 80 m above sea level. Selvagem Grande is home to Cory's Shearwater and a number of other seabird species. Further details may be found in Hartog *et al.* (1984).

I visited the island with an expedition from the University of Manchester and stayed for a three week period between 7th and 30th August 1984. Comparisons of size were made between chicks in different types of nests and at different densities. Any differences in chick sizes or in nest types prefered could then be related to what is known about breeding success in similar species under similar conditions.

METHODS

Tarsus-length was used as a measure of chick size. Wing-length may perhaps have been a more sensitive measure, but the emerging primary feathers could have been easily damaged. Tarsus-length is probably a good indicator of overall size (see Brooke 1978a).

Three distinct nesting areas were chosen: 1) the cliffs around Ponta dos Moinhos and in Enseada das Cagarras; 2) stone walls running across the island plateau and 3) sites on the plateau itself at the southern half of the island. Within the cliff area, nests were separated into cave and cleft sites. The caves were all very large cavities in the rock. More than one nest site was present in each cave. Clefts were small cavities in the rock or under boulders, which always contained only one nest. Nests in walls were all very similar, and were found where stones had been removed from the walls by man. On the plateau itself, there were two types of nest, natural sites where nests were found in rabbit burrows or cavities under large stones, and man-made sites. The latter consisted of two or three large stones laid against each other, forming a cavity between them (see Hartog *et al.*, 1984 for more details).

Chick tarsus measurements were made at cliff sites on 10th, 15th and 19th August, at wall sites on 11th, 16th and 20th August and at plateau sites on 12th, 17th and 20th August. Fifteen nests, as closely grouped as possible, were selected on each day. The distance from each nest to the nearest three occupied nests was also recorded. On 26th August, a further three cliff areas in Enseada das Cagarras were sampled and 71 chicks measured.

The «popularity» of the different nest types and areas was assessed in the following way: large, representative, areas of cliff, wall and plateau were surveyed and the nest sites recorded as: 1) occupied; 2) not occupied but some signs of activity eg. addled egg, dead chick or fresh droppings; and 3) occupied and with no sign of recent activity. In this way 526 cliff, 198 wall and 191 plateau nests were surveyed.

Individual nest sites could be easily recognised, even when there had been no recent activity, owing to the presence of piles of stones and nesting material.

RESULTS

In Figure 1, tarsus-length is plotted against date. Tarsi were obviously growing through the period and there appears to be no levelling off at the end of the graph. This indicates that, in this period, tarsus length was a useful measurement for making size comparisons between chicks. The longest tarsus measured was 59mm and this is still 10mm less than the average adult tarsus.

Looking at the data from the largest sample of chicks measured on one day from one nest type (56 from nests in clefts on cliffs), it was obvious that tarsus lengths were not normally distributed. The logarithm of tarsus length does however produce a normal distribution, and for all further analysis the log of the tarsus length is used.

Initially, tarsi were compared between caves and clefts and between the two types of plateau sites; natural and man-made. Each day's data were analysed separately (analysis of variance (f) test, Table 1). There was no significant difference between cave and cleft chicks within any of the day's data. No chicks from man-made nests were measured on the first 'plateau' day but there were no differences between chicks from man-made and natural nest sites on the other two days.

To compare tarsus lengths between nesting areas (and in effect between days) allowance had to be made for growth of chicks through the study period. Multiple Linear Regression (MLR) was used to control for this growth. The first step was to regress the log of tarsus length against date. Any other effects could then be assessed in terms of the variation in tarsus lengths from this regression line. In Table 2 the differences between the nesting areas were investigated in this way. Initially, cliff nests were assigned a score of 1 and wall and plateau nests a score of 0 to form a new variable X1. When this variable was used in the MLR there was no significant increase in the R^2 value. This suggested that cliff chicks could not be separated in size from a combination of wall and plateau chicks. The only significant effect was obtained when cliff and wall nests were combined and compared with plateau nests (variable X3); the associated negative sign in the table indicated that plateau chicks had smaller tarsi.

When mean distance to the three nearest occupied nests was included in MLR with date, this also had a significant effect (Table 2). Nests which were isolated had smaller chicks. This density effect seemed

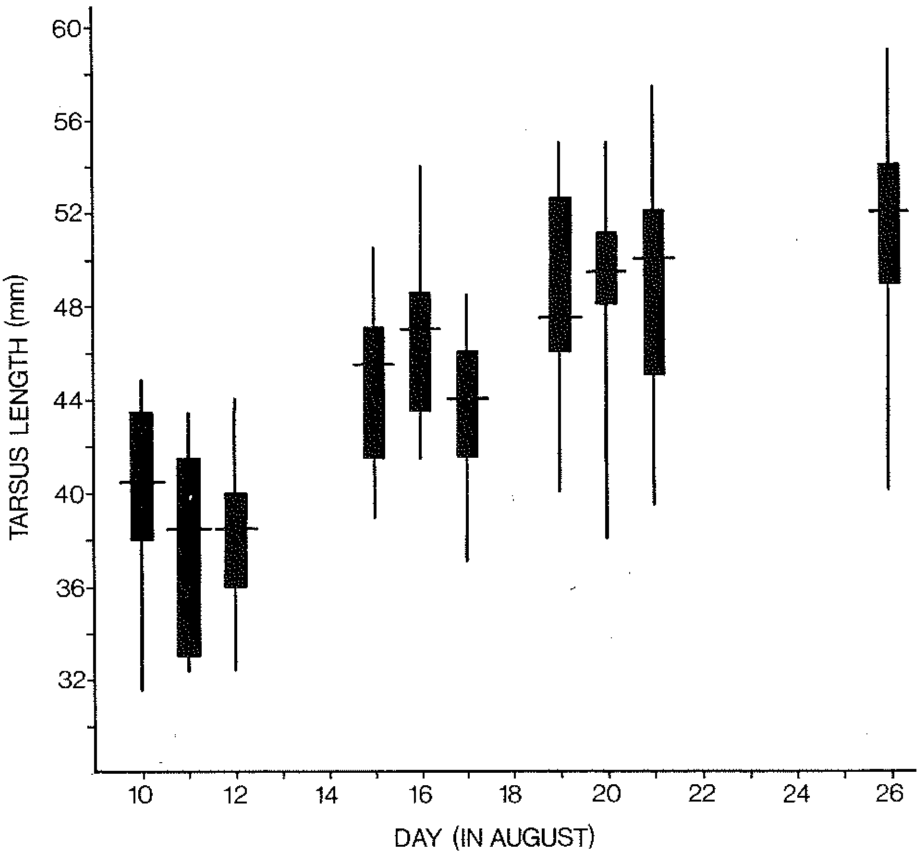

Figure 1. — Changes in length of tarsus with date in Cory's Shearwaters.

The thin bars show the range of measurements on each day and the thick bars the interquartile ranges. The horizontal lines show the median value for each day.

to be largely responsible for the difference between the plateau and other nesting areas. In Table 2 when mean distance was included in the regression with variable X3 (Plateau = 1, cliff and walls = 0), the effect of X3 became insignificant. It appears that chicks on the plateau are not smaller because they have different types of nest site, but because their nests are further from other nests. The mean distances from each chick to its three nearest neighbours were 3.89m for cliff nests, 4.42m for wall sites and 13.05m for plateau sites. These means are significantly different ($F = 80.562$, $P < 0.001$).

(i) caves and clefts

day in August	tarsus lengths: caves $\bar{x}$	n	clefts $\bar{x}$	n	analysis of variance: f	P
10	1.59	5	1.61	10	0.276	0.608
15	1.66	9	1.63	6	2.043	0.176
19	1.68	4	1.68	11	0.013	0.910
26	1.72	14	1.71	57	0.088	0.767

(ii) man-made and natural

day in August	tarsus lengths: man-made $\bar{x}$	n	natural $\bar{x}$	n	analysis of variance: f	P
12	1.63	10	1.65	5	0.584	0.458
17	1.68	10	1.70	5	0.363	0.557

$\bar{x}$=mean values, n=number of chicks measured.

Table 1. — Comparison of log. tarsus lengths between (i) cave and cleft sites and (ii) man-made and natural sites.

variable	R^2	F	signif. of F	R^2 change	signif. of change	sign
date	0.578	279.5	>0.001	0.578	>0.001	+
X1	0.580	140.7	>0.001	0.002	0.317	+
X2	0.581	140.9	>0.001	0.003	0.216	+
X3	0.585	145.5	>0.001	0.011	0.021	-
D	0.588	147.8	>0.001	0.015	0.007	-

variables X1, X2 and X3 were generated by assigning a value of 1 in turn to each nest type and a value of 0 to the other two nest types. X1: cliffs=1; walls and plateau=0. X2: walls=1; cliffs and plateau=0. X3: plateau=1; cliffs and walls=0. The variable 'D' is the mean distance of each nest to its three nearest neighbours. As a result of tarsus growth through the study period 'date' was used first in each regression. Each of the other variables was then used in one of four separate regressions with date already introduced into the equation. X3 and D were the two variables which had significant effects after log. tarsus had been regressed with 'date'. When X3 and D were included together, the values for D remained the same, but for X3 the R^2 change (0.001) was insignificant (P=0.454).

Table 2. — Multiple linear regression analysis of log. tarsus length on date, nest-type and nesting density.

Differences in absolute size may not be the most important consideration when comparing nesting sites and densities. Jones (1986) has shown that Cory's Shearwater on Selvagem Grande synchronise their

cliffs		walls		plateau	
day in August	variance (x100)	day in August	variance (x100)	day in August	variance (x100)
10	19	11	21	12	14
15	13	16	11	17	13
19	17	20	19	21	19
26	10				

Table 3. — Variance in log. tarsus length of Cory's Shearwater chicks in different nesting areas.

breeding with their near neighbours. In such a situation the variability of size of chicks in an area may be as important as the absolute sizes of those

nesting area	nest type	number occupied	number unoccupied (recent activity)	number unoccupied (no activity)
cliffs	caves	92	17	31
cliffs	clefts	217	59	110
walls	holes	120	33	45
plateau	natural	60	22	31
plateau	man-made	19	8	51

tests of independence	G	df	P
between: caves and clefts	3.880	2	0.142
natural and man-made sites	27.626	2	2.191x10
all cliff sites and walls	5.379	4	0.250
cliff wall and natural plateau sites	7.286	6	0.295

Table 4. — Numbers of nests in censuses of different nest types and nesting areas that were: a) occupied; b) unoccupied but with signs of recent activity; and c) unoccupied with no signs of activity.

chicks. The variances in tarsus measurements for each nesting area on each day are shown in Table 3. The chicks in one nesting area were not consistantly more or less variable than those in any other area.

The analysis of absolute tarsus length (rather than variance in lengths) suggested that density was important, and that nesting areas were only different because they had different densities of nests (Table 2). To test for a direct effect of density on variance of tarsus lengths, the absolute difference between each tarsus length and the mean daily length was correlated with the mean distance to the three nearest neighbours. The correlation is just significant at the 5% level ($r=0.116$, $n=206$, $p=0.049$) which suggests that isolated chicks, as a group, may be more variable in size than chicks from the denser areas.

The numbers of nests: a) occupied; b) unoccupied with signs of activity; and c) unoccupied with no signs of activity are shown in Table 4. Tests of independence using the G statistic were used to assess the differences between nest types and areas in terms of their level of occupancy. Both of the cliff nest types, all the wall nests and the natural nest sites on the plateau have similar proportions of occupied and unoccupied nests. Taking all these nests together 50.4% had chicks, 15.7% had no chicks but showed signs of activity and 25.9% had no chicks and showed no signs of activity. It was only the man-made sites on the plateau which had different proportions; 24.4%, 10.3% and 65.4% respectively.

DISCUSSION

The results suggest that chick-size was significantly related to the distance between nests. Chicks in different types of nest (cliffs, walls and plateau) vary in size because they occur at different densities and not because the nest sites themselves are different.

A number of studies have illustrated the close relationships between breeding success and nesting density and age and experience of parents (eg. Coulson & White 1958, 1960; Coulson 1966; Nelson 1966). Pairs which nest at high densities are likely to be more successful (Patterson 1965, Parsons 1976), one reason being that predation is less likely in dense areas (Kruuk 1964, Patterson 1965, Birkhead 1977).

Older and more experienced birds may be able to compete more successfully for nests in the densely populated areas of colonies (Chabrzyk & Coulson 1976) and perhaps as a consequence of the 'quality' of these birds, eggs are often laid earlier in such areas (Marshall & Servanty 1956, Coulson 1966, 1968, Nelson 1966, Chabrzyk & Coulson 1976, Brooke 1978b). The 'need' to occupy contested sites early may also encourage early breeding, although only the more experienced birds may be in a condition to do so (Coulson & White 1958, Perrins 1970).

The effects of density on chick size in Cory's Shearwater would seem to conform to the pattern of earlier breeding in the favoured denser breeding areas. The stimulus for Cory's Shearwater to compete for nests at high densities is likely to be related to predation. Herring Gulls (*Larus argentatus*) take many shearwater eggs (Zino 1971) and isolated nests may be more vulnerable to predation.

The reason why cliff and wall areas have the highest densities of nests is that opportunities for nesting are much greater in these areas than on the rather bare plateau. Birds on the plateau rely, to a large extent, on the provision of nest sites by man.

The greater preference for nests in dense areas is reflected in the levels of occupancy of the different nest types. The man-made nests upon the plateau have a much greater proportion unused. The large number of nest sites with no signs of activity suggests that predation at some time in the breeding cycle is not solely responsible for the low proportions.

Many seabird species show localised breeding synchrony (Gochfeld 1980). This phenomenon has been demonstrated for Cory's Shearwater on Selvagem Grande (Jones, 1986). The tendency to breed earlier at high densities may be constrained by the advantage of breeding synchronously. Coulson & White (1960) suggest that one of the consequences of nesting in dense areas is that there is a greater variation in laying dates. The opposite may be true in Cory's Shearwater. At the time of our visit, breeding at high densities was at least as synchronous as that at low densities, a similar situation to that found for Black-headed Gulls *Larus ridibundus* (Patterson 1965), Gannets *Sula bassana* (Nelson 1966) and Guillimots *Uria aalge* (Birkhead 1977).

I should like to thank Dr R. R. Baker, J. Hill and K. Hamer for comments upon the manuscript and H. R. Read, L. Parker, C. P. Wheater, K. Hamer, Almada, Filipe and especially L. A. Lace for their help on Selvagem Grande. I am indebted to Mr P. A. Zino, Dr M. Biscoito and Mr G. E. Maul for there invaluable assistance and hospitality. The Portuguese Navy very kindly provided transport to and from the island and I am also grateful to Arq. José Manuel Vasconcelos of the Serviço Nacional de Parques e Reservas for supplying a permit to visit the island. I should also like to thank Mr A Araujo of CEMPA for his cooperation and for the provision of rings. Generous financial support was provided by a Zochonis Special Enterprise Award from the University of Manchester.

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