The breeding biology of Cory's Shearwater *Calonectris diomedea borealis* on Berlenga Island, Portugal

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INTRODUCTION

The Berlengas Islands (39°24'N, 9°30'W) are a small group of granitic islands located off the western coast of Portugal and include the Estelas and Farilhões, both uninhabited, and Berlenga itself where some fishermen live permanently and which many tourist visit in July and August. The island has the only colony of Cory's Shearwater *Calonectris diomedea borealis* reported from the Atlantic coast of Iberia and it also has a small colony of Guillemots *Uria aalge*, on the southernmost limit of the species current breeding range (Cramp 1985). Most of the area was declared a Nature Reserve in 1981.

Following recent census of seabirds (Araujo & Luis 1982, Teixeira 1983, Teixeira & Moore 1983, Teixeira 1984, Vicente 1987), a study of the Cory's Shearwater population was initiated in 1987 to establish baseline information for a subsequent annual monitoring programme. This paper describes the chronology of major events in the breeding cycle, including the growth sequence of nestlings, breeding success and population size. Morphometry of adult birds is also presented and compared with the colony of Selvagem Grande (Madeira).

METHODS

In 1987 the island was visited regularly between February and October. During the breeding season adult birds were counted at sea in late afternoon. After the onset of the reproduction period in March, all nests that could be inspected throughout the entire island were individually mapped. During the laying and hatching periods, all the nest-sites were visited once a day. Eggs were measured to the nearest 0.05 mm with Vernier callipers and weighed using a Pesola spring balance (readable to 2g) if less than three days after laying. After hatching, all chicks of known age were weighed and measured every day for six days, followed by a six days "resting" period. This routine was repeated throughout the breeding season until the young fledged. The following characters were measured on the chicks (in mm): tarsus-length, wing-length (from carpal joint to the tip of the longest feather), head+bill length, culmen-length (from tip of bill to the first head feathers) and bill-height (measured to the foremost head feathering).

One hundred and five adult birds were also caught ashore (mainly before laying), measured, ringed and marked with a three-colour code painted onto the breast feathers, using various combinations of eight different colours, which allowed visual recognition of individual birds, thus avoiding the need for any further handling of the breeding birds in their burrows. When possible birds were sexed according to their vocalization (Cramp & Simmons 1977, Ristow & Wink 1980) or by their position during copulation. Measurements of birds from Selvagem Grande were obtained during a 20 days visit in June/July 1988. All mean values are given ± 1 standard deviation, except where otherwise stated.

RESULTS

Biometrics of adult birds

Comparison of the measurements made on Berlenga and Selvagem Grande colonies showed the existence of differences between all characters studied except wing-length, the birds of Berlenga being significantly smaller than those of Selvagem Grande (Table I). Morphological separation of

subspecies have already been reported (Jouanin 1976, Massa & Valvo 1986), but no references were found for such differences within the Atlantic subspecies *C.diomedea borealis.*

TABLE I. ADULT MEASUREMENTS (mm) AND WEIGHT (g) OF CORY'S SHEARWATERS BREEDING AT BERLENGA AND SELVAGEM GRANDE.

	BERLENGA			*SELVAGEM*			*t-TEST*	
	Mean (Range)	*sd*	*N*	*Mean (Range)*	*sd*	*N*	*t Value (d.f.)*	*P*
Weight	813.2 (620-1070)	90.27	194	907.6 (730-1030)	79.33	33	5.65 (225)	<0.001
Wing	365.9 (345-389)	9.02	195	362.2 (346-389)	9.57	33	1.93 (224)	ns
Tarsus	57.93 (53.15-65.35)	1.87	93	60.4 (57.85-63.5)	1.74	33	6.64 (124)	<0.001
Culmen	54.8 (48.10-61.50)	2.49	189	56.3 (51.70-61.70)	2.58	33	3.20 (220)	<0.005
Bill-Height	20.6 (17.80-23.65)	1.36	195	21.7 (19.40-23.65)	1.40	33	4.15 (224)	<0.001
Head+Bill	115.1 (106.95-125.30)	4.05	91	118.1 (110.75-126.55)	3.99	33	3.74 (122)	<0.001

Arrival and laying dates

Cory's Shearwater were first seen on the island and in the surrounding sea area on 5 March, when four birds were observed at sea and two captured ashore at their breeding sites at night. No birds were seen in the area between 21 February and 1 March. Until the laying of the first eggs birds were found ashore only at night, except just prior to laying when they were occasionally found in their burrows during the day. The nests on Berlenga were located mainly in rock crevices and burrows. Some were in holes, on platforms of loose soil on the floor of small caves and in deep rabbit holes, sometimes quite difficult to detect.

The first eggs were found on 26 May (Fig.1), the mean laying date was 1 June, a value showing no statistical differences from the results obtained by Zino *et al.* (1987) for the Selvagem Grande colony in 1984 (see Table III).

No significant correlation was found between laying date and either the weight, length or width of the eggs (r=0.05, r=0.05 and r=0.21 respectively, all n=31, ns). The measurements and weight of the eggs on Berlenga were significantly smaller than those from Selvagem Grande (Table II), although both populations belong to the Atlantic subspecies *C.d.borealis.* Most probably, this merely reflects differences observed in the overall size of the birds from the two colonies. These observations are consistent with the biometrical cline observed in birds from the eastern Mediterranean colonies to the NE Atlantic (Iapichino *et al.* 1983).

Incubation and hatching

The mean incubation period was 55 days, close to the value obtained on Selvagem Grande (Table III). In most cases (68% of total, n=16) the male took the first spell in incubation. Incubation stints of both sexes averaged 4.25 days, calculated from the number of times that a brooding bird was replaced by its mate (Mougin *et al.* 1988). This value is rather low when compared with the 8.4 days obtained by Mougin *et al.* (1988) on Selvagem Grande and it was due to the irregular

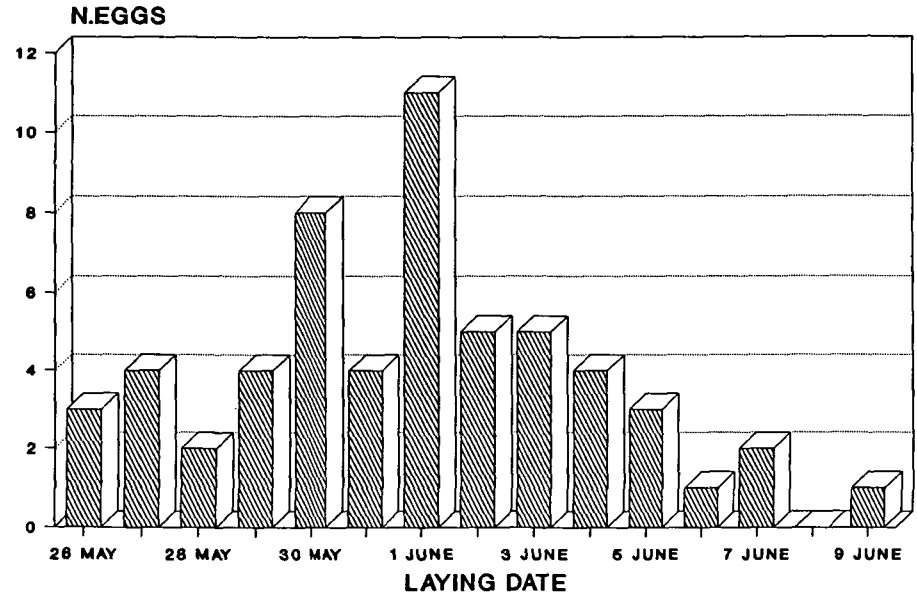


Figure 1. Laying dates of Cory's Shearwater at Berlenga in 1987 (n=57).

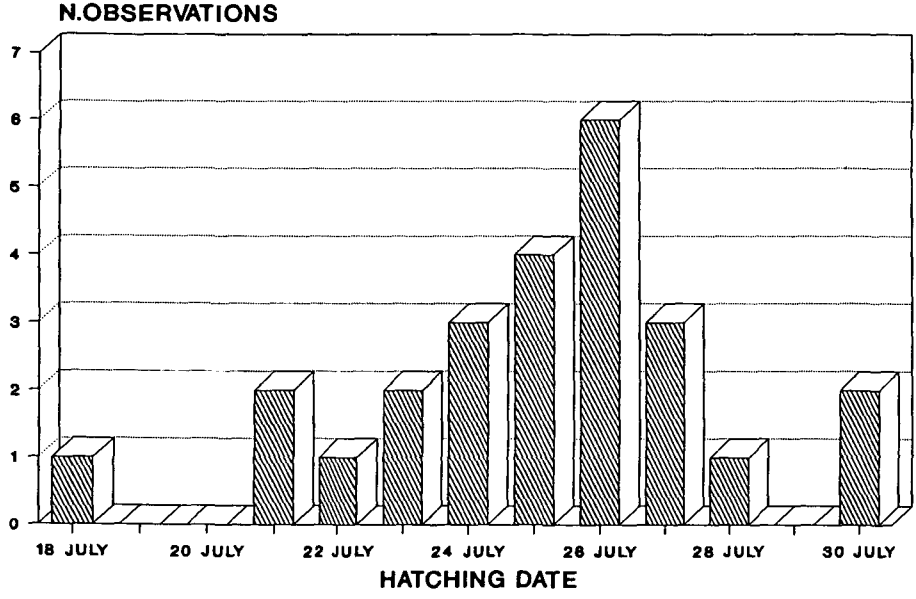


Figure 2. Hatching dates of Cory's Shearwater chicks observed at Berlenga (n=25).

TABLE II. EGG MEASUREMENTS (mm) AND WEIGHT (g) OF CORY'S SHEARWATERS BREEDING AT BERLENGA AND SELVAGEM GRANDE.

	BERLENGA			*SELVAGEM*[1]			*t-TEST*	
	Mean (Range)	*sd*	*N*	*Mean (Range)*	*sd*	*N*	*t Value (d.f.)*	*P*
Length	73.55 (67.25-79.45)	2.99	37	75.3 (70.6-82.3)	2.65	46	2.82 (81)	<0.01
Width	48.41 (45.15-51.45)	1.58	37	52.5 (47.8-54.0)	1.45	46	5.37 (81)	<0.01
Weight	93.5 (82-114)	15.8	31	104.3 (95-115)	5.38	46	3.97[2] (45/36)	<0.01

(1) – data from Zino (1971)

(2) – t-Test for heterogeneous variances (Sokal & Rohlf 1981)

incubation patterns of some breeding pairs at Berlenga, that exhibited periods of highly frequent changes between the brooding individuals. This irregular pattern had marked effects on the reproductive performance of the pairs involved, most of these situations resulting in abandoned eggs.

Most eggs hatched between 21 and 27 July (Fig 2) which was later than the range observed in some colonies of the Mediterranean (e.g. Round & Swann 1977, Ristow & Wink 1980, Thibault 1985, Massa & Valvo 1986). For example, significant differences were found in time of laying between Lavezzi colony, in Corsica (Thibault 1985) and Berlenga (Mann-Whitney U-test: U=234, $n_1 = 59$, $n_2 = 57$, $P<0.001$).

Growth of the chicks

As reported for other colonies, one of the parents usually spent the first few days after hatching with the chick (Zino 1971, Round & Swann 1977, Fernandez 1985, Thibault 1985). At around nine days after hatching the chicks were left alone in the nests (Figure 3), and feeds occurred only during the night. The mean fledging period was 95 days (Table III).

TABLE III. DETAILS OF THE BREEDING BIOLOGY OF CORY'S SHEARWATER OF BERLENGA AND SELVAGEM GRANDE (Test type: MW – Mann-Whitney U-test, t– Student's t-test)

	BERLENGA			*SELVAGEM*[1]			*STAT. TEST*		
	Mean (Range)	*sd*	*N*	*Mean (Range)*	*sd*	*N*	*Test type*	*Value*	*P*
Laying dates	1 June (26 May-9 June)	3.2	57	1 June (26 May-15 June)	3.6	277	MW	U=7227	ns
Incubation (Days)	55.1 (53-60)	1.65	20	54.46 (52-58)	1.12	88	MW	U=707	ns
Fledging period (Days)	94.9 (91-100)	2.96	10	96.76 (91-105)	2.66	78	MW	U=252	ns
Fledging weight (g)	887.0 (790-1010)	74.24	10	854.7 (510-1080)	109.92	68	t	t=0.899	ns

(1) Data from Zino *et al.* (1987)

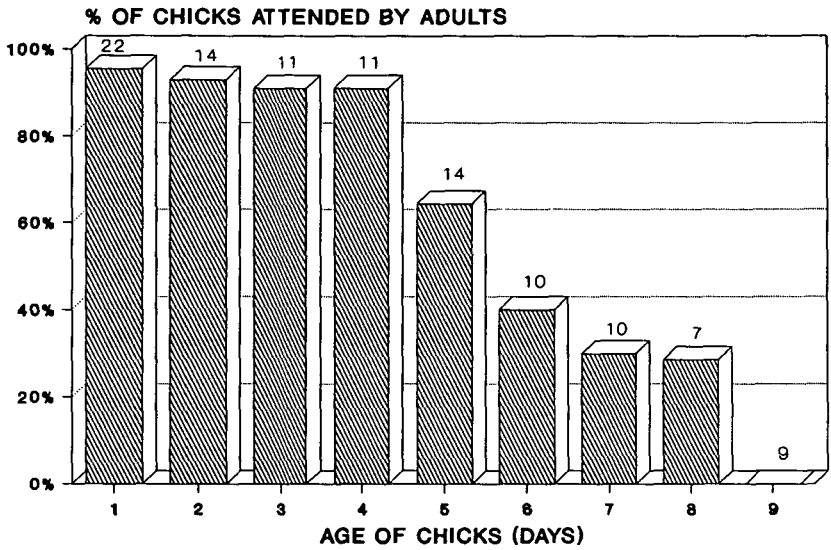


Figure 3. Proportions of chicks of different ages attended by adults. Sample sizes are indicated.

The mean weight of a chick at hatching was 69.2g (sd=8.75g, n=14, range 54-81g). This value probably overestimates the true mean, since some chicks could have been fed between hatching and the first measurements.

The weight growth curve (Fig. 4) was similar to that of other procellariiforms (e.g. Harris 1966, Perrins *et al.* 1973, Round & Swann 1977, Brooke 1990, Cruz & Cruz 1990). The chicks reached mean adult weight about 34 days after hatching and remained above that value for about 45 days. Mean peak weight, calculated from chicks 55 to 79 days old, was 1071.4g (sd=121.9g, n=182, range 790-1330). Body weight began to decrease when the birds were about 80 days old, and then progressively converged to the values recorded for adults. The growth curve for the wing-length (Fig. 5) shows two distinct phases, one from hatching date up to 35-40 days, and another from that age to fledging. The first phase, with a linear growth rate of 2.19mm.day^{-1}, represents the development of the osteological and epidermal structures. The second phase included also the process of feather growth, initiated at c.40 days after hatching, resulting in a linear growth rate of 4.23mm.day^{-1}. Due to the small standard errors and the continuous growth rate throughout the rearing period, the wing-length appears to be the most useful predictor of chick's age.

If the chick growth curves are expressed as a percentage of the corresponding adult values (Figs. 4, 5, 6A and B), it becomes obvious that horny and skeletal structures, like tarsus, culmen, bill and skull are fairly well developed at hatching, reaching up to 40% of the corresponding adult values. While these structures achieve sizes near those of adults rather early, the wing shows a different pattern, with a comparatively slow growth rate, reaching adult length only a few days before fledging (Fig. 5), which suggests an important role in the extension of the dependence period.

The first departure from the colony in 1987 was observed on 23 October and by 27 October 10 more birds had fledged. However, the fledging period could not be fully investigated, since 11 of the 21 chicks controlled were still present at the time of our last visit on 27 October. The mean weight at fledging was 887g (Table III).

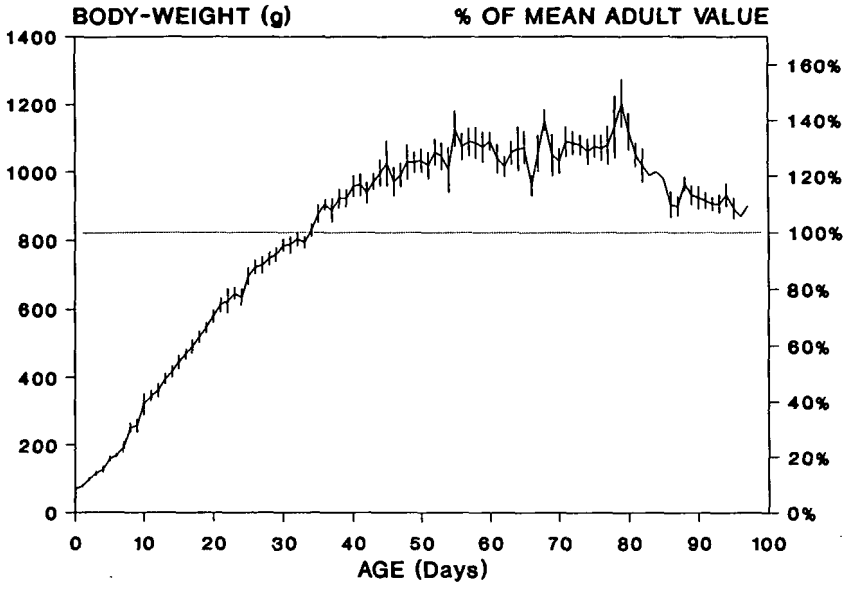


Figure 4. Growth curve for the body of Cory's Shearwater chicks at Berlenga in 1987 (given also as percentage of adult weight - dotted line). Sample size varied between 2 and 18 chicks, according to the day. Points represent mean ± s.e.

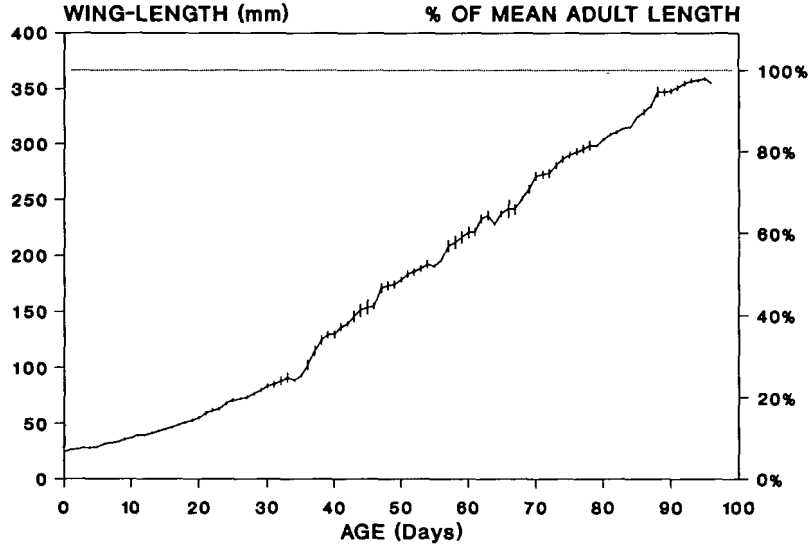
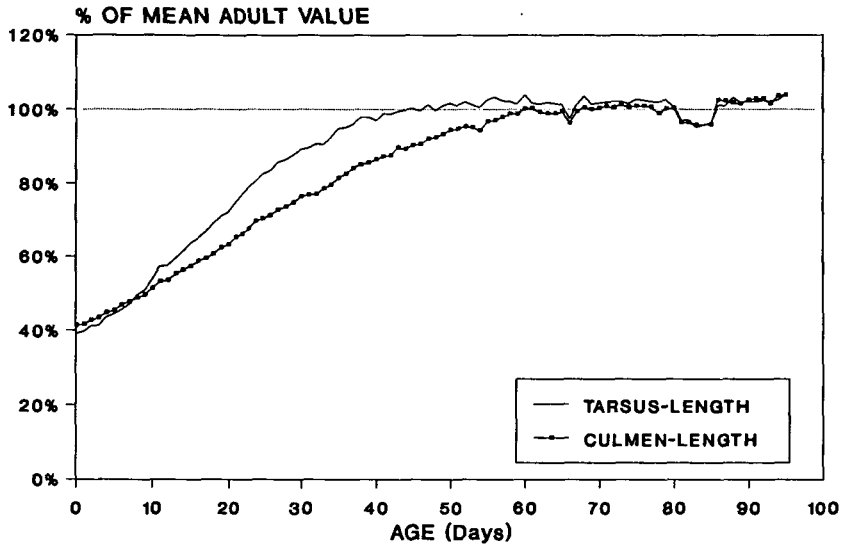


Figure 5. Growth curve for the wing-length of Cory's Shearwater chicks at Berlenga in 1987 (given also as percentage of adult weight – dotted line). Sample size varied between 2 and 18 chicks, according to the day. Points represent mean ± s.e.

a)



b)

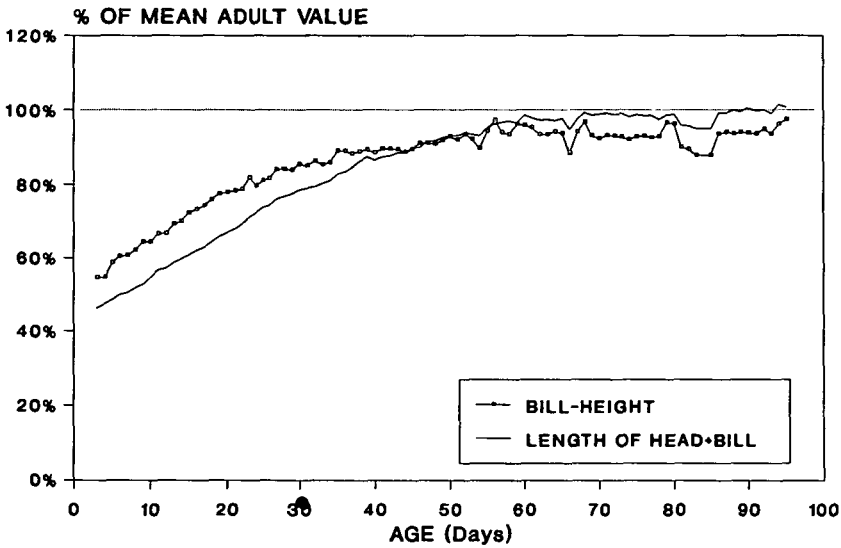


Figure 6. Growth curves of Cory's Shearwater expressed as percentage of mean adult values: (a) – Tarsus and culmen-length; (b) – Height of bill and length of head+bill.

Breeding success

The most striking feature of the breeding parameters in 1987, was the comparatively high number of abandoned eggs in the colony, resulting in a very low overall hatching success. In fact, from 59 individually marked eggs, 34 (57.6%) did not hatch, most of them being deserted in the early stages of the incubation period. This might have been due to our disturbance as some species of shearwaters are rather intolerant to disturbance during incubation (Warham 1990) and we had no control against which to assess our influence. In contrast, only 3 chicks (12%) died after hatching. One was found dead the day after hatching, the second apparently died from starvation at about 20 days old, while the third disappeared from the nest aged 6 days although no signs of predation could be found.

Population size

Census work in 1981, suggested 60-80 breeding pairs of Cory's Shearwater in the whole group (Barcena *et al.* 1984) but further census in 1982 and 1983, increased the estimate to 100-200 breeding pairs (Teixeira 1984). Our study, which included counts at sea and a fairly exhaustive search for suitable nesting habitat all over the island, suggested 100-120 pairs breeding on Berlenga island itself and 80-100 elsewhere.

DISCUSSION

Comparison of the morphometric data collected on adult birds from Berlenga and Selvagem Grande showed that there were significant differences between all characters measured except for the wing-length, although both populations belong to the subspecies *C.diomedea borealis* and these differences are also reflected in the dimensions of the eggs. These findings suggest some sort of reproductive isolation between these colonies which may be explained by the strong mate and nest-site fidelity reported for this species (e.g. Mougin *et al.* 1987, Zammit & Borg 1987). In addition, environmental variables such as food availability could play an important role in maintaining the observed differences.

The details of Cory's Shearwater breeding biology were generally quite similar to those reported from the Atlantic. Minor differences observed probably reflect only different methodological approaches. The differences for the Mediterranean colonies agree with the genetic differences found between subspecies (Randi *et al.* 1989).

The results obtained on the laying and hatching sequences seem to support the currently held ideas about laying synchrony (temporal compression) for this species (Jouanin & Roux 1966, Zino 1971, Zammit & Borg 1987). Furthermore, they seem to reflect also a very high degree of geographical conformity in the breeding behaviour of this species within its range.

The mortality factors affecting this population were difficult to assess. The Black Rat *Rattus rattus* usually described as a predator of seabird eggs and chicks (Moors & Atkinson 1984, Fernandez 1985, Guyot 1985, Thibault 1985, Vidal 1985, Furness & Monaghan 1987) can hardly account for the extent of the egg losses observed at Berlenga. In fact, we had no evidence of predation either of eggs or chicks of Cory's Shearwater, although rats did eat some long-deserted eggs. Similarly, we did not detect any predation of eggs or chicks by the Yellow-legged Herring Gull *Larus argentatus*, despite the recent increases in the population of that species breeding at Berlenga (Vicente 1987, pers.obs.).

The presence of Cory's Shearwater in Berlenga was first recorded by Daveau & Girard (1883) and following a visit to these islands in June 1939, Lockley (1952) estimated the breeding population as 100 pairs. The results obtained in this study suggest a stable condition for this population although it is important to ensure strict control of the most vulnerable breeding areas on the island. In fact, the disturbance by tourists and fishermen at the nest sites during the breeding season seem to play an important role in the overall success of Cory's Shearwater at Berlenga.

Although direct persecution of the birds and their eggs as reported by Lockley (1952) has markedly decreased in recent years, the island now has many summer visitors coming from the mainland and effective protection of some breeding sites is sometimes difficult.

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SUMMARY

In 1987 a biological study of Cory's Shearwater at Berlenga Nature Reserve (Portugal) was initiated in order to establish baseline information for a monitoring scheme for the population. Adult morphometry is presented and compared with data from the colony of Selvagem Grande. The chronology of the major events of the breeding cycle is described and growth of chicks documented. The breeding success in 1987 was very low, mainly because of the high number of abandoned eggs. More work should be carried out to ensure strict control of the most vulnerable sites, avoiding undue disturbance to the breeding birds.

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