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EFFECT OF PREDATION BY THE BLACK RAT *RATTUS RATTUS* ON THE BREEDING SUCCESS OF CORY'S SHEARWATER *CALONECTRIS DIOMEDEA* IN CORSICA

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SUMMARY

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The breeding success of the Cory's Shearwater *Calonectris diomedea* was studied from 1979 to 1992 in a Mediterranean colony. Predation by the Black or Ship Rat *Rattus rattus* was the main reason for breeding failure as shown by the experimental control of rats by poisoning and trapping. Predation by rats induced several secondary effects on the behaviour of prospecting birds, and on nest and mate fidelity. Effect and intensity of rat predation are more marked on small islets where rat density is high than on larger islands where rat density is low and numbers fluctuate.

INTRODUCTION

Breeding success is an essential parameter of seabird population dynamics and it has been used to gain insight into many aspects of seabird biology acting outside the breeding sites (e.g. feeding resources: Dunn 1975, Anderson *et al.* 1982, Furness 1982, Monaghan *et al.* 1989), or at the breeding sites (e.g. predation: Uttley *et al.* 1989; parasitism: Danchin 1992; disturbance: Culik *et al.* 1990).

Several papers have described the predation of seabirds by introduced predators (review in Moors & Atkinson 1984) and its consequence on their breeding success, especially in Procellariiformes (Imber 1978). Petrels appear to be very sensitive to predators due to: (i) the total isolation of their breeding sites, mostly situated on islands from which mammal predators are naturally absent (Lack 1968); and (ii) their specific breeding biology traits, such as egg-neglect (Imber 1984) and precocious emancipation of the chick. Feral cats, dogs and pigs have eliminated petrels from many islands (Moors & Atkinson 1984). The impact of rats also can be dramatic, but it is less systematic, depending on petrel species and size (Imber 1978)

In the Mediterranean, the Black or Ship Rat *Rattus rattus* has reached numerous islands and islets (Cheylan 1984). Off Corsica it is known from 34 of the 125 islets covered with vegetation (Guyot *et al.* 1992). The Black Rat is mainly

vegetarian (Cheylan 1988), but rat predation of Mediterranean seabirds has been largely underestimated. Predation on Cory's Shearwater *Calonectris diomedea* chicks has been attested on several islands (Thibault 1985, Fernandez 1987). The aim of this paper is to examine the effect of predation by the Black Rat on the breeding success of Mediterranean Cory's Shearwaters.

STUDY AREA AND METHODS

A monospecific colony of Cory's Shearwater, whose number is estimated at 255-400 pairs, breeds on the Nature Reserve of Lavezzi (41 20N, 09 15E), an island of 66 ha situated between Corsica and Sardinia (western Mediterranean, Fig. 1). Shearwaters breed in distinct sub-colonies (Fig. 2).

Breeding success is based on the mean number of birds fledged per breeding attempt. It was measured each year between 1979 and 1992 in four of the six sub-colonies studied. Laying is highly synchronized within and between years (Thibault 1985, Thibault *et al.* in press a). Visits to check incubating birds were conducted each year from 2-26 June. Visits during incubation were made by a single observer. Incubating birds were not handled. Most young fledge at mid-October (Thibault 1985). Visits to check fledging birds were made after 20 September and before 6 October.

Two-door traps were set out each year, from 1985 to 1991 (except in 1987), in sub-colony 8, to obtain an index of presence. Two line transects with about 15 traps each were set out during two consecutive nights in September (see Cheylan & Granjon 1985 for methodology). Lavezzi Island has several habitats which are patchily distributed (Dubray 1982), but compared with other sub-colonies, sub-colony 8 is characterized by: (i) a relatively high vegetation cover and (ii) the greatest diversity of plants.

Comparison of breeding success between a sub-colony where rats were eliminated and the other sub-colonies was used to estimate the impact of predation by the Black Rat. Two experiments of partial elimination of rats were conducted. The first experiment was conducted in sub-colony 8 in 1989 from April to September. The second was conducted in sub-colony 5 in July and August 1992. In the two experiments, poison baits with Coumatetralyl were used, solid cubes being inserted in PVC tubes. Daycard & Thibault (1990) describe the method used to put out baits and to assess the elimination of rats. However, the size of Lavezzi Island has so far prevented the total eradication of rats which recolonized the sub-colonies the year after eradication.

RESULTS

Table 1 shows data on variations in the breeding success between years in the four sub-colonies studied. Omitting the two years of rat control, justifiable because the rat control effects do not carry over into succeeding years, it shows consistent differences in breeding success between years (Kendall's Coefficient of Concordance, N.S.). It also shows consistent differences in breeding success between sub-colonies (Kendall's Coefficient of Concordance, N.S.). Finally, there was no relationship between the size of the sub-colonies and the breeding success (Table 1; Spearman rank correlation, N.S.).

Data on rats' monitoring conducted in sub-colony 8 are presented on Table 2. The relationship between breeding success of Cory's Shearwaters and abundance of Black Rat is significant (r_S=-0.77, P=0.05). A low breeding success was associated with a high density of rats.

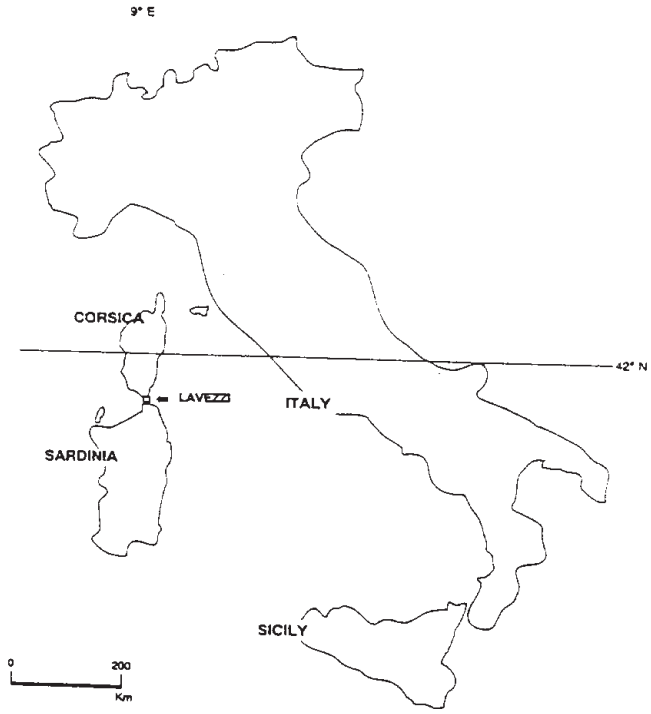

Figure 1

Location of Lavezzi Island.

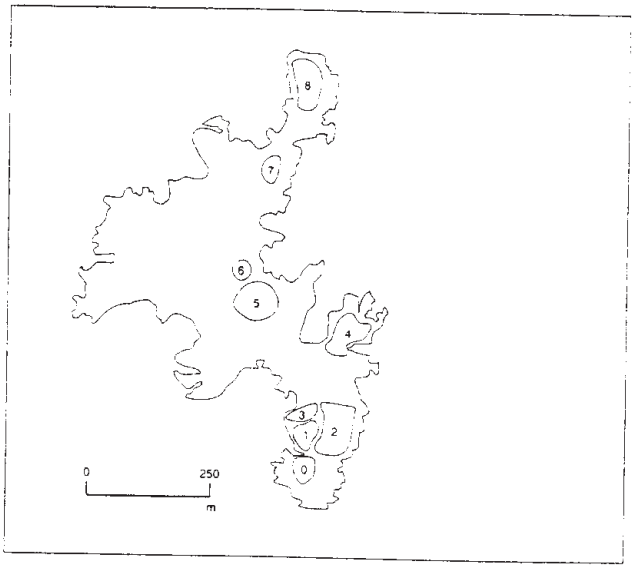

Figure 2

The different sub-colonies of Cory's Shearwaters on Lavezzi Island.

TABLE 1

COMPARISON OF BREEDING SUCCESS OF CORY'S SHEARWATERS IN FOUR SUB-COLONIES ON LAVEZZI ISLAND DURING 1979-1992

Years	Sub-colonies				
	1	3	5	8	Overall
1979	0.80 (25)	0.81 (11)	0.75 (44)	0.39 (31)	0.67 (111)
1980	0.83 (23)	0.78 (9)	0.76 (46)	0.19 (26)	0.63 (104)
1981	0.82 (22)	0.70 (10)	0.57 (47)	0.80 (30)	0.70 (109)
1982	0.45 (20)	0.10 (10)	0.49 (47)	0.0 (25)	0.32 (102)
1983	0.73 (26)	0.50 (10)	0.51 (49)	0.18 (27)	0.48 (112)
1984	0.90 (21)	0.70 (10)	0.52 (42)	0.06 (18)	0.54 (91)
1985	0.48 (21)	0.70 (10)	0.71 (45)	0.05 (21)	0.51 (97)
1986	0.23 (22)	0.0 (10)	0.02 (40)	0.06 (16)	0.08 (88)
1987	0.64 (25)	0.08 (13)	0.04 (44)	0.05 20)	0.20 (102)
1988	0.63 (27)	0.0 (14)	0.42 (45)	0.12 (25)	0.35 (111)
1989	0.48 (25)	0.15 (13)	0.24 (42)	0.85* (27)	0.44 (107)
1990	0.85 (27)	0.33 (12)	0.46 (39)	0.0 (22)	0.45 (100)
1991	0.65 (29)	0.69 (13)	0.62 (42)	0.19 (21)	0.55 (105)
1992	0.40 (30)	0.50 (11)	0.70* (44)	0.08 (26)	0.46 (111)
1979-92	0.64 (343)	0.41 (157)	0.49 (616)	0.24 (335)	0.46 (1451)

Each cell indicates breeding success (see methods) and sample size (in parentheses).
*rats eradicated.

In 1989 eradication of the Black Rat from sub-colony 8 was followed by a significantly higher breeding success than in other sub-colonies (data in Table 1; $Chi^2_1=7.32$, $P=0.007$). In 1992, eradication of rats from sub-colony 5 also resulted in a significantly higher breeding success than in other sub-colonies ($Chi^2_1=5.46$, $P=0.019$). In the two cases of eradication breeding success was high, respectively 0.85 and 0.70 (Table 1). So, predation by the Black Rat can account for 85% of the failure in some years.

Egg-neglect was rare in Cory's Shearwaters on Lavezzi island (pers. obs.). Most predation occurs on chicks soon after the end of the breeding stage, at five to nine days old. During two detailed monitoring periods (1980 and 1989), all but one of the 29 and 16 chicks, respectively, eaten by rats were less than 45 days old (Thibault 1985, Daycard & Thibault 1990).

TABLE 2

BREEDING SUCCESS OF CORY'S SHEARWATERS AND RAT INDEX OF PRESENCE ON LAVEZZI ISLAND, 1985-1991

Year	Breeding success	Rat index*
1985	0.05	0.62
1986	0.06	0.48
1988	0.12	0.20
1989	0.85	0.04
1990	0.00	0.35
1991	0.19	0.21

*see text for explanation

DISCUSSION

Causes of low breeding success

The main cause of breeding failure appeared to be due to predation by the Black Rat. Around sub-colony 8, due to abundant feeding resources, its density stayed generally very high and breeding success of Cory's Shearwaters low during the 15-year period. Elsewhere, mainly in sub-colony 1, rat density varied considerably from year to year, and breeding success of Cory's Shearwaters was higher. This sub-colony has less vegetation cover and less plant species, including species generally not eaten by rats, such as *Obione portulacoïdes* (see Cheylan 1988). In fact, the part of the island including sub-colony 8 constitutes a good and stable habitat for rats, whereas other sub-colonies, specially sub-colony 1, were mainly visited when their numbers increased.

At Lavezzi, as on other islets off Corsica, the breeding period of the Black Rat was shorter and more synchronized than on the larger islands (Cheylan 1986, Cheylan & Granjon 1987). Births occured in May and June (Cheylan & Granjon 1987), and the highest density was in July-September when plant biomass was the lowest of the year, due to the summer dryness (Gamisans 1991, J.-B. Casanova & M. Muracciole unpubl. data). In fact, the period of chick predation corresponds to a scarcity of vegetation productivity. Such a phenomenon has been noticed elsewhere (Moors *et al.* 1992).

The significant inter-annual variation in the breeding success indicates that the density of the Black Rat fluctuates. But we cannot exclude that another factor may be partly responsible for breeding failure, such as food shortage (e.g. Dunn 1975, Anderson *et al.* 1982, Furness 1982, Monaghan *et al.* 1989). In this case, annual variation in food supply may also induce variations in chick survival. However, our results suggest that its effect is amplified by rat predation in sub-colonies from which rats were not eliminated.

Secondary effects of Black Rat predation

On Lavezzi Island I observed a high turnover rate of breeders with a low breeding success at the

same nest-site. These birds tended to change mates after a failure and the turnover rate of breeders was higher in sub-colonies where breeding success was low (Thibault 1994); this is probably a serious handicap since breeding success is usually initially low after separation (Hunt 1980). In addition, colonies with low breeding success attracted fewer prospecting birds. For example, in sub-colonies 1 and 5, the ratio of immigrants/emigrants was different; sub-colony 1 attracted more prospectors than sub-colony 5 (Thibault 1993a). One reason might be that sub-colonies with high breeding success have more active birds in July and August, the period of intense visits by prospectors, compared with sub-colonies where only a few young were fledged.

Demographic impact of Black Rat predation

Introduction of the Black Rat to the Corsican mainland was recorded in the 6th Century (Vigne & Marinval-Vigne 1985). Archaeological excavation in Lavezzi Island showed that Black Rats and Cory's Shearwaters have coexisted at least since the 14th Century (Vigne *et al.* 1991). Such a long coexistence of the two species is probably common on Mediterranean islands, although little proof exists. Archaeological data from Zembra Island, Tunisia, the largest colony known of Cory's Shearwaters in the Mediterranean, indicates that the two species have coexisted there, at least, since the 5th or 6th Centuries (Vigne 1988).

No changes were noticed in numbers of occupied nests in the different sub-colonies from 1978 to 1992, and colony size was stable (Thibault *et al.* in press b). Although rat predation on Cory's Shearwaters was severe, it did not lead to a population decrease. The reason may be fluctuations in the rat population and their absence in some years from several sub-colonies.

Studies of the density of the Black Rat on Mediterranean islands show that: (i) rat numbers on medium-size islands show annual variation. On islets (<20 ha) numbers remain more stable during a long period of time (Cheylan 1986, Granjon 1987); and (ii) density is higher on small islands than on medium-sized islands (Cheylan 1986, Granjon 1987, Granjon *et al.* 1992). These observations corroborate general conclusions on rodents (Gliwicz 1980). For a sample of 11 islets around Corsica with an area of less than 20 ha, there is a significant difference in the density of Cory's Shearwaters between islets with and without rats (Table 3). Conversely, the presence of rats on medium-sized islands did not interfere with the density of Cory's Shearwaters. For a sample of eight Mediterranean islands with rats, the number of shearwater breeding pairs per ha varies from 0.04 to 66.2 (Table 4). On small islets, rats by their predation on chicks keep breeding population of shearwaters low; their persistence probably results from immigration. But, on medium-sized islands, fluctuation in rat numbers allows for an irregular predation with less interference with the population dynamics of shearwaters. Difference in population number, on these different islands, depends more on external factors, such as feeding resources, as shown by the concentration of the greatest colonies along the coast of Tunisia and in Sicily's channel on islands (Thibault 1993b) where rats are also present (Vigne 1988).

A study of the predation on petrels by rats in New Zealand suggested that the birds are at greatest risk when their mass is equal to or less than that one of the rats (Imber 1975, Moors & Atkinson 1984). Mean mass of Black Rats on islets off Corsica is 153 g (Cheylan 1986). Of the three breeding species of Procellariiformes in the Mediterranean (Cory's Shearwater, Mediterranean Shearwater *Puffinus yelkouan* and European Storm Petrel *Hydrobates pelagicus*), only one (the European Storm Petrel) weighs less than a Black Rat. Its distribution is largely limited to rat-free islands or caves in cliffs inaccessible to rats (Malta and Sicily: Massa & Sultana 1990-91; Balearics: Aguilar 1991;

TABLE 3

NUMBERS OF CORY'S SHEARWATERS ON ISLETS OFF CORSICA WITH RATS (X) AND WITHOUT RATS (-)

Islands	Surface area (ha)	Numbers of Cory's Shearwaters (expressed in pairs)	Presence of Black Rats
Grain-de-sable	0.2	10-20	-
Vacca	0.5	33	-
Toro piccolo	0.5	13	-
Fazzio	1.3	1-5	X
Toro grande	1.6	26	-
Pietricaggiosa	4.6	1-5	X
Ratino	4.9	1	X
Giraglia	9.4	30	-
Forana	15.5	3-12	X
Gargalo	16.7	20	X
Piana	18.5	3-10	X

From Guyot *et al.* (1992) and unpublished data.
Difference comparing density between the two groups of islets is significant (Kolmogorov-Smirnov test, $D=1$, $P<0.05$).
Mean number was used for Cory's Shearwaters.

TABLE 4

DATA ON LARGER MEDITERRANEAN ISLANDS WITH BLACK RATS AND BREEDING COLONIES OF CORY'S SHEARWATERS

Islands	Surface area (ha)	Number of Cory's Shearwaters (expressed in pairs)
Lavezzi (Corsica)	66	255-400
Riou (France)	90	110-130
Cavallo (Corsica)	120	5
Zembra (Tunisia)	340	20-25000
Linosa (Sicily)	500	>10000
Port-Cros (France)	640	40-50
Porquerolles (France)	1254	110-130
Gozo (Malta)	7000	1000-2000

No relationship exists between size of islands and size of colonies (Spearman rank correlation, N.S.). Data from Thibault (1993b).
Mean number was used for Cory's Shearwaters.

Corsica: Bretagnolle & Thibault 1990). On some islets, small colonies of European Storm Petrels do coexist with rats, but their numbers are very small and the populations are on the verge of extinction (e.g. Plane Island near Marseille, Walmsley 1986). For the Mediterranean Shearwater, Vidal (1985) noticed cases of egg and chick predation by the Black Rat on Porquerolles Island, near Hyères, and Mayol (1986) considered that its decrease on some islets in the Balearics was caused by rats. But the two species coexist on many islands and it seems that the intensity of predation is related to rat density and to island size. Alcover (1989) put forward three hypotheses to explain the drastic decline of the Mediterranean Shearwater in the Balearic Islands since the Upper Pleistocene: (i) introduction of rats; (ii) scarcity of marine resources; and (iii) traditional human capture for food. For the Manx Shearwater *P. puffinus* in the United Kingdom, long-term monitoring on Canna Island has shown that breeding success may be seriously affected by predation by Brown Rats *Rattus norvegicus* (Swann & Ramsay 1984), but rat density seemed to be too variable to threaten the shearwater population. This was not the case on a small island, the Calf of Man, where Manx Shearwater numbers have decreased drastically (Brooke 1990).

In conclusion, on medium-sized islands where the numbers of rats fluctuate, predation on Cory's Shearwater does not present a threat for the survival of breeding colonies. But, on small islets, permanently high rat density constitutes a threat to Cory's Shearwater colonies, as well as to other Mediterranean Procellariiformes. Priority must therefore be given to eradicating rats from the smaller islands.

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